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Diplomarbeit

GROW
Horticulture for urban wastelands

ausgeführt zum Zwecke der Erlangung des akademischen Grades eines Diplom-Ingenieurs / Diplom-Ingenieurin
unter der Leitung von

Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Christian Kühn
Univ.Ass. Dipl.-Ing. Harald Trapp
E 253 1 Abteilung für Gebäudelehre und Entwerfen

eingereicht an der Technischen Universität Wien
Fakultät für Architektur und Raumplanung von

Wolfgang Werschnig
0440424

Wiedner Hauptstraße 85/11
1050 Wien

Wien, am

“Ein solcher Bau verändert den Menschen, der ihn baut, in der Weise, wie der Mensch, der ihn baut, ihn vorantreibt, vollendet. Ich bin frei gewesen für alles, bevor ich die Idee (den Kegel zu bauen) gehabt habe, jetzt bin ich nur Opfer dessen, der den Kegel baut.”

Thomas Bernhard, Korrektur

für Megi

GROW

Horticulture for urban wastelands

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Spektrum der Wissenschaft, Issue April 2010 Photo: Kenn Brown, Monolithic Studios

Introduction

In the year 2009 I got in touch with the topic of urban farming during my time in Australia as an exchange student. Participating in the design elective *Footprint* with Russell Hughes and Graham Crist at the Royal Melbourne Institute of Technology, I was first confronted with the problem of urban growth in connection with food supply.

I was curious about the topic and started to investigate to get a deeper insight. Harald Trapp, lecturer at the Vienna University of Technology, encouraged me to use my ambition for my diploma thesis. It was a hard time, but finally I found my personal access to urban farming.

This scheme is an experiment and has the aim to provide a realistic proposal. It is recommended to compare my design to all those futuristic examples appearing since the topic became came into vogue. They are attractive at the first sight but some of them turn out to be useless because they don’t provide any additional benefit to the urban situation and the population. Or even worse, the design makes plants impossible to grow within...

Amber Beernink - The Vertical Greenhouse
I.3
www.verticalfarm.com 2012.3.11 11:26 AM

Benet Dalmau, Saida Dalmau, Ana Julibert - Spiral Garden, iida Awards 2010
I.4
www.designboom.com 2012.3.11 11:23 AM

Benet Dalmau, Saida Dalmau, Ana Julibert - Spiral Garden, iida Awards 2010
I.5
www.designboom.com 2012.3.8 2:05 PM

Honourable designs

"...a public sustainable place like a green heart, easy to maintain and self-sufficient, created by a joint population that will stimulate social interaction among neighbours. a light, spiral structure protected by a transparent and suggestive mesh, the project encourages the city to create sustainable exchange spaces in different ways. this spiral contains an ascending garden where native vegetation can coexist with urban orchards, shared and planted for the neighbours for easy maintenance and serving also as a green outdoor walk."

Benet Dalmau, Saida Dalmau, Ana Julibert 1

Some proposals are trustable examples of urban farming and demonstrate how to deal with a sensitive topic. They provide more than just food. The designers of *Spiral Garden* know that farming in an urban environment has to cooperate with the local population and interact with the built up neighbourhood.

Beside technical requirements, architecture has another ambition. This exercise can't be handled like an ordinary building. People have to identify this type of architecture. Therefore new aesthetic needs have to be fulfilled. It's not an ordinary designing exercise for dwellings or office use on a human scale. Designers have to consider special requirements of plants. Plants can be more sensitive to their environment than humans.
It is a challenge to adjust all design issues and economic facts for establishing urban farming.

1 http://www.designboom.com/weblog/cat/8/view/11759/spiral-garden-by-benet-saida-dalmau-anna-julibert-carmen-vilar-iida-awards-2010.html 2012.3.8 2:05 PM

Page 8: Barlindhaag Consult AS - Global Seed Vault, Longyearbyen, Svalbard, Norway 2007-2008
I.6
Philip Jodidio: Green, Architecture Now!, Taschen Köln 2009 Photo: Mari Tefre/Global Crop Diversity Trust

Lacaton & Vassal - House in Coutras, Gironde, France 2000
I.7
Nexus, Issue 21, Photo: Philippe Ruault

Paolo Soleri - Arcosanti, Arizona, USA 2011
I.8
Photo: Walter Werschnig

Architecture trends & urban interventions

"We believe that architecture is more than simply shelter. It is intimately connected with the creation of identity and self-confidence. And this is the basis of sustainable development."
Anna Heringer and Eike Roswag, 1

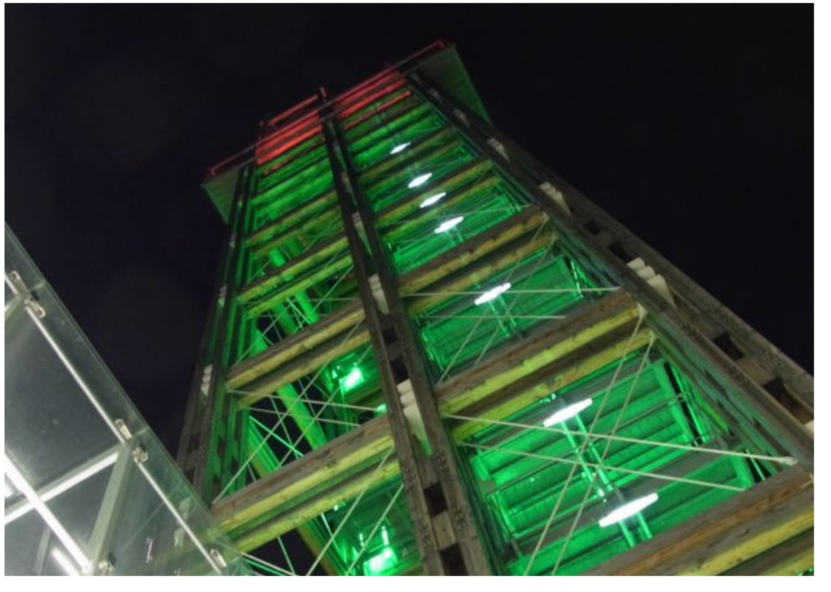
Cognate disciplines of architecture show the current understanding of sustainability and how we can deal with environmental issues. Beside climate change and other natural disasters, economic crises force us to rethink our architecture. There is no immediate connection to urban farming. But strategies of exemplary projects show us how to handle that new topic.

"Rapid population growth and expanding suburbs have made many cities unsustainable. Architect Paolo Soleri proposes a new kind of city - the arcology - that uses design principles taken from nature to enhance human life while minimizing ecological impacts."
David S. Mayne about Arcosanti, DVD booklet description, 2

Responsible designers have to collaborate by reinventing architecture and deliberate on the current issues. Paolo Soleri is a representative of an idealistic architecture. In the year of 1970 he started his urban laboratory in the desert of Arizona, named Arcosanti. It is still under construction because of economic reasons, and its grassroots based concept. But maybe Arcosanti will last longer than *Foster and Partners'* giant urban vision of *Masdar City* in the Arabic Emirates, a well-meant project but fragile in existence. Future will show if the large amount of investments turn out to be well-invested.

1 Philip Jodidio: Green, Architecture Now!, Taschen Köln 2009
2 David S. Mayne: Blueprint for the future: The Architecture of Paolo Soleri, Very Sirius Productions, 2009

Anna Heringer and Eike Roswag - Handmade School, Rudrapur, Dinajpur, Bangladesh 2005
I.9
Philip Jodidio: Green, Architecture Now!, Taschen Köln 2009 Photo: Kurt Hörbst



Rahm architekten - Bahnorama, Vienna, Austria
I.10

“The seed vault is part of an unprecedented effort to protect the plant’s rapidly diminishing biodiversity. The diversity of our crops is essential for food production, yet it is being lost”
Norwegian government’s declaration on the occasion of the opening in February 2008, 3

The *Global Seed Vault* is an outstanding example of future architecture challenges. In contrast to digital data or other valuables, such a vault could host highly controversial nuclear waste as well. But in the end, this approach brings up more problems, rather than providing any solution.

Another option is to go back to handmade construction methods. The domain of vernacular architecture can teach us how to resolve ventilation and other building physics issues by proven low-tech strategies.

“... Its innovation lies in the adaptation of traditional methods and materials of construction to create light-filled celebratory spaces, as well as informal spaces for children. Earthbound materials, such as loam and straw, are combined with lighter elements like bamboo sticks and nylon lashing to shape a built form that addresses sustainability in construction in an exemplary manner.”
Aga Khan Award jury for Architecture, 2

1, 2 Philip Jodidio: Green, Architecture Now!, Taschen Köln 2009

Ecosistema Urbano - Ecoboulevard of Vallecas, Madrid, Spain, 2006
I.11
Philip Jodidio: Green, Architecture Now!, Taschen Köln 2009 Photo: Emilio P. Doitzua

OK, Höhenrausch 2, Linz, Austria
I.12
www.ok-centrum.at, 2012.3.3 5:42 PM, Photo: Hermann Wakolbinger

Considering economic, social and political issues, urban development is a multi layer discipline. Individual motorized traffic has been dominating the post industrial city for decades. Mobility still has a huge impact on urban development. But the treatment of the topic is changing dramatically. Exemplary the city highway of the South Korean capital Seoul was deconstructed to make room for a landscape park. 1 Fears that traffic system would collapse turned out to be completely wrong. Politicians have to accept the fact, that in many situations less traffic options will cause less traffic.
Recreation is in a close relationship with mobility demands of the urban population. Landscape parks and their performance have been redefined. Green spaces are closer to fulfill activity needs than having representative functions.

“The proposal for the Ecoboulevard of Vallacas can be defined as an operation of urban recycling that consists of the installation of three socially revitalizing air trees placed in the existing urban pattern, the densification of trees within their existing concourse, the reduction and asymmetric disposition of the traffic routes...”

Belinda Tato and Jose Luis Vallejo

The *Ecoboulevard* project in Madrid demonstrates a new understanding of the conception of time in connection to public spaces. Artificial trees named *temporary protheses* will be dismantled, *leaving remaining spaces that resemble forest clearings*. 3
There is a trend towards low-key interventions with a temporary character. *Höhenrausch, a project of the European Capital of Culture* is established, in Linz since 2009. It is an example that shows us how to experience urbanity from a new perspective and how to collaborate with event culture.

1 http://inhabitat.com/seoul-recovers-a-lost-stream-transforms-it-into-an-urban-park/ 2012.3.12 11:32 AM
2, 3 Philip Jodidio: Green, Architecture Now!, Taschen Köln 2009

Page 12: www.gruenwand.at - Fassade 48er Amtsgebäude, Vienna, Austria
I.13

Paperopoli - Linzergarten, St. Pölten, Austria 2010
I.14
Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011 Photo: Alexi Pelekanos

Oliver Bishop-Young - Skip Conversations since 2008
I.15
Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011

Human desire & grassroots movements

"Accompanied by community cookouts and parties, the garden installation made of plastic planter tubs became a meeting place, hangout, and showplace for social and inter-ethnic encounters... Since people were able to plant the installation on their own, they had some room to maneuver, and the experience of acting upon their own initiative strengthened their confidence in dealing with public space."
Susanne Witzgall about "Linzergarten" by Paperopoli 1

Cities are loosing their human scale. Pollution, high real estate prices and social segregation, as a consequence, are degrading the quality of life. Green spaces are not only for recreation. They have social duties and a education mission to their environment.

"In Skip Conversions by English designer Oliver Bishop-Young, such things as a lawn, a flower bed, a mini-pond with plants, or a tree and bench are set inside the abdominal cavity of various construction trailers and, in the guise of mobile, temporary visitors, they stimulate the grey surface of urban sidewalks and parking lots."
Susanne Witzgall about Skip Conversations by Oliver Bishop-Young 2

A high number of bottom-up initiatives and art projects came up to highlight the absence of basic green infrastructure. Grassroots movements strive for a symbiosis with their urban surrounding and have therapeutic potential.

"Guerrilla gardening also pursues a parasitical strategy. It has been increasingly practiced in recent years by more and more private gardeners, working illegally and in secret, and has become a worldwide movement in the meanwhile. Armed with seed bombs, hoes, shovels, and plants, the gardening guerrillas carry on a selective, wearisome battle,..."
Susanne Witzgall about guerrilla gardening 3

Guerrilla gardening is not only a simple violation of the law. In context to the graffiti art movement, it is important to provide tolerance for a healthy urban development. It's a kind of support to the administration, to point out potentials and the right of participation.

1, 2, 3 Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011

Britta Riley - The Windowfarms Project, USA
I.16
www.windowfarms.org 2012.3.8 2:34 PM

Prinzessinnengarten, Moritzplatz, Berlin 2010
I.17
Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011 Photo: Marco Clausen

“... pleasure in good food and good company, the search for environmentally friendly, socially oriented urban lifestyles; the desire to be aesthetically and creatively active; poverty and unemployment, ...”
Susanne Witzgall about reasons for urban gardening 1

Urban gardening is a general term and a big issue. The movement is characterized by the fact that there is no central authority or organisation. The diversity of social groups specify the community. New York’s trendsetter or Detroit’s working poor may participate in the current issue of urban gardening. The interaction with neighbourhoods ensures the movement’s survival.

“The Windowfarms Project is a fast-growing web platform that helps city dwellers grow food in their apartments year-round and channels their innovations into an open research framework for the future of urban agriculture.”
about the Windowfarms Project by Britta Riley 2

The *Prinzessinnengarten* in Berlin, Kreuzberg is a well known and successful example.
The concept is based upon the work of volunteers and the mobility of plants. Containers and bags are flexible in use and easy to move. There are speculations about franchise based branches in other German cities. But the founders are not interested in this growth. They don’t believe in a *patent medicine* and a missionary incidence. [3]

It is not sure that the landlord, the municipal administration of Berlin will continue to lease that area next season. The occupation of urban waste lands is a big issue in connection with urban farming. Political authorities are famous for their missing courage.
In general landlords are fearful about leasing land to someones use.

1 Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011
2 Repair the environment, Ars Electronica Festival, Linz 2010
3 http://www.zeit.de/lebensart/2011-04/prinzessinnengarten-neu/komplettansicht 2011.5.3 11:30 AM

Stephen Mushin - Aquaponics 'Food Hub' silverbeet harvest, Melbourne, Australia 2011
I.18
www.stephenmushin.com 2012.3.8 1:54 PM

Bohn & Viljoen Architects - The Urban Agriculture Curtain, London, Great Britain 2009
I.19
Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz, Ostfildern 2011

"The 120m greenhouse based system will grow 4000 leafy greens (herbs/lettuces) and has been designed as a community scale commercial system. It is solar powered, collects all of its water from its roof and we hope to eventually grow our own fish feed. The larger vision is to create a network of similar Food Hubs in the community as training centers."

Stephen Mushin about his Food Hubs Project 1

Many urban farming projects broach the issue of new growing systems. Stephen Mushin's *Food Hubs* vision is a aquaponic based concept. It is a soilless cultivation method combining a fish farm with hydroponics. By using the water from fish ponds as a natural enriched nutrient solution, it is possible to omit artificial mixed components. It's an alternative to common hydroponic cultivation methods with the aim to provide organic food.

The *Urban Agricultural Curtain,* is a step further to vertical farming. Optimizing space management is a big issue to urban farming. The project is similar to *The Windowfarms Project.*

"They discovered that many office windows could be used for food production, and suggested that they be outfitted with a curtain made of planter bowls, which is hooked up to an automatic watering system. A pleasant side effect of these curtains is that they moderate light and even improve the climate."

Susanne Witzgall about "The Urban Agriculture Curtain" by Bohn & Viljoen Architects 2

1 http://stephenmushin.com/photo_display.php?id=157&library_id=23 2012.3.8 1:54 PM
2 Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011

NY Sun Works - Science Barge, New York, USA
I.20
www.nysunworks.org 2012.3.5 2:44 PM

NY Sun Works - The Greenhouse Project, New York, USA
I.21
www.nysunworks.org 2012.3.8 2:26 PM Photo: Burling

The *Science Barge and The Greenhouse Project* in New York are urban laboratories with the aim to teach children how to grow food, and about water management, nutrition and efficient land use. The projects are in cooperation with schools. Pupils get knowledge about climate change, biodiversity, contamination, pollution and waste management. [1]

"To facilitate this hands-on learning environment, the Greenhouse Project laboratory will also include solar panels, hydroponic growing systems, a rainwater catchment system, a weather station and a vermi composting station.
The laboratory operates as an integrated part of the school's curricula and prepares children to exceed NYC's science standards."

New York Sun Works about The Greenhouse Project 2

Compared to an average American tomato, the *Science Barge* tomato is carbon neutral, needs only a quarter of fresh water, no pesticides and the seventh part of space demand. [3] Testing new technologies is a big issue on the current progress. With the help of solar panels greenhouses can be operated in a carbon neutral way. Considering the large amount of energy consumed by the greenhouse industry, it is important to investigate in eco-friendly energy concepts.

1, 2, 3 http://nysunworks.org.s46880.gridserver.com/?s=thesciencebarge
2012.3.5 2:50 PM

Detroit Industries - Urban Agriculture 2003
I.22
Susanne Witzgall, Florian Matzner, Iris Meder: (re)design nature, Hatje Cantz Verlag, Ostfildern 2011

Liz Christy, Community Gardens, New York 1973
I.23
Carolin Mees: Urban Agriculture, Arch+ 196/197, Issue January 2010

Urban crisis

In the year 2030 more the 60% of the world population will live in cities. Today about 70% of CO_2-emissions are caused by transport and food supply of cities. 1 It is a challenge for the urban development to improve the situation and make urban dwelling more sustainable.

The issue of urban farming is not completely new. There is a strong relationship to rare green spaces in urban areas and the effect of economic crisis to cities. The impact is enormous. Compared to rural regions urban agglomerations are more fragile. Social consequences come out earlier and more intensive.

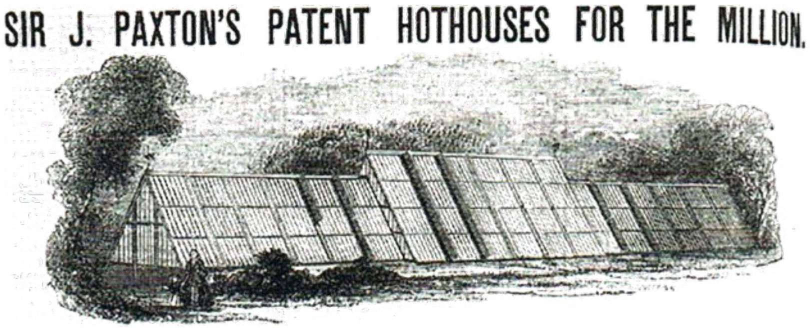
In the last decades most industrial structures were closed down. Today many grassroots movements in the USA are using the situation for their benefit. Detroit is a perfect example. Car industry has closed down and people are forced to leave the town. Left over inhabitants use abandoned land for growing their food.

As a result of the oil crises in the 70s, *Community Gardens* were established in New York. In 1974 the city was bankrupt. As a consequence communal institutions were closed down. Financially strong inhabitants moved to the suburbs and urban poor were left. 1975 one quarter of the Bronx were fallow lands. 2

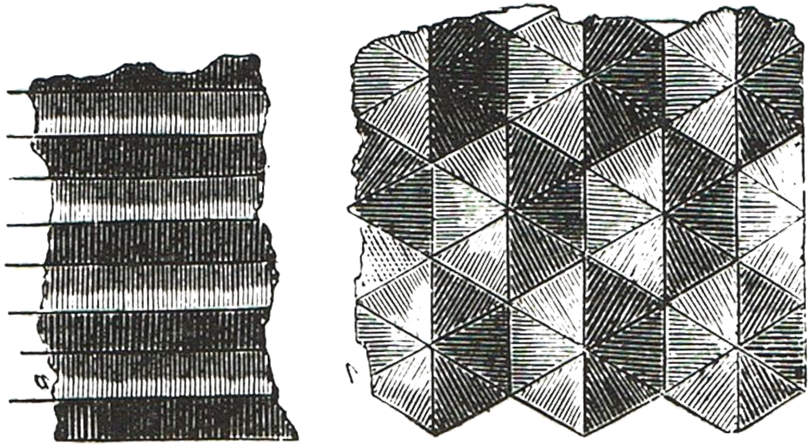
Economic crises also come along with war times. The *Relief, Victory or War Gardens* were supported by government during world wars in the USA. Domestic farming in courtyards and public parks discharged the budget and were important for social freedom. 3
In the times of economic recovery individual motor car traffic was supported by government. People moved to the suburbs and became addicted to frozen foods and fast food restaurants.

History demonstrates how cities are effected by economic crises and inhabitants are forced to reactivate parks and courtyards for their self supply. Since 2008 a new crisis brings up the topic of urban farming again.

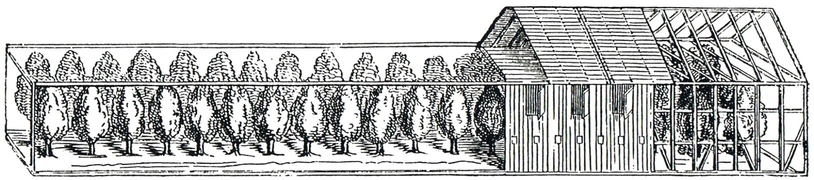
1, 2, 3 Carolin Mees “Urban Agriculture, Nahrungsmittelproduktion und Stadt” Arch+ 196/197 Zeitschrift für Architektur und Städtebau, January 2010



Paxton's patent "Hothouses for the Million", 1858
I.24
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988



"Ridge-and-furrow-roof" John C. Loudon Bayswater 1815-18
I.25
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988



Salomon De Caus, Pomeranzenhaus im Heidelberger Schlossgarten vor 1620
I.26
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988

Conservatory architecture

Early discoveries at the ruins of Pompeii prove the existence of trivial constructions in the ancient world, similar to greenhouses. There are speculations that they were covered with translucent stones.[1]

The first recorded systematic cultivation of crops started in the medieval monastery gardens. In the age of Renaissance exotic fruits were brought to Europe. It was a challenge to cultivate these plants and protect them from the cold climate. Simple moveable timber structures were built. [2] These structures were further developed to orangeries and became representation buildings of Europe's emperors.

The greenhouse in the garden of Otto von Münchhausen was the first notable greenhouse construction. It was built in 1714 and is similar to common greenhouses used nowadays. [3]
The typical dutch greenhouse was oriented from east to west. A brick wall facing north was housing a wood stove.The development of the elongate greenhouse was made possible by the invention of steam heating.

The continuous steel casting method and the industrial steel production of *Bessemerbirne* in 1856 allowed larger constructions. [4] The *ridge-and-furrow-roof* is an exemplary design to enhance solar radiation. It was invented by the Scottish landscape architect John Loudon, a pioneer in creating new solar heated greenhouses.

A highlight for the architecture of greenhouses was built in London, to host the Great Exhibition in 1851. [5] The Crystal Palace at the Hyde Park was a great success. Visitors were fascinated by the new sense of space. In those days greenhouses were called *bright-rooms* and served as public places. The Industrial Revolution initiated a big socio-economic change. People were disconnected from nature. Winter gardens were housing exotic plants for the satisfaction of green needs.

In 1858 the first mass-produced greenhouse *Hothouses for the Million* was brought on markets by Joseph Paxton. [6] It was a prototype. Common greenhouse constructions haven't changed dramatically for decades.

1, 2, 3, 4, 5, 6 Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988

Korea's first "vertical farm"
I.27
Fabian Kretschmer: Ackerbau im Hochhaus, Der Standard Print 2011.5.26 Photo: Insung Tec

The Victory Gardens - propaganda poster during World War II
I.28
Dickson Despommier: The Vertical Farm, Thomas Dunne Books 2010 Photo: Minnesota Historical Society

Crystal Palace, London 1851
I.29
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988

2009 first "vertical farm" in Europe at Paignton Zoo, England

2000

2001 largest greenhouse the Eden Project, Cornwall, England

1994 idea of "ecological footprint"

1991 Biosphere 2 at Arizona, USA

1978 "Hydroponic Food Production" by Howard Rehs

1972 release of the report "The Limits if Growth"

1970 first community garden project in the USA

1962 geodesic dome project in Manhattan by Richard Buckminster Fuller

1954 photovoltaic cells by Gerald Pearson, Calvin Fuller and Daryl Chapin

1929 first hydroponic grown plants by William Frederick Gericke

1923 ecological Agriculture guide "Edaphon" published by Raul France

1900

1914 first victory gardens during wartime in the USA, Canada and Great Britain

1902 first air condition by Willis Haviland Carrier

1898 "The Garden City" by Ebenezer Howard

1858 first common greenhouse "Hothouses for the Million" by Joseph Paxton

1865 first allotment gardens ("Schrebergärten")

1856 first industrial steel production, Bessemerbirne

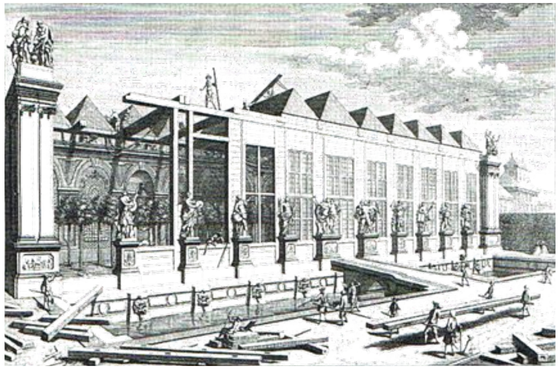
1851 the Crystal Palace by Joseph Paxton at the international industry exhibition, London, UK

1822 greenhouse effect discovered by Jean Baptiste Josephine Fourier

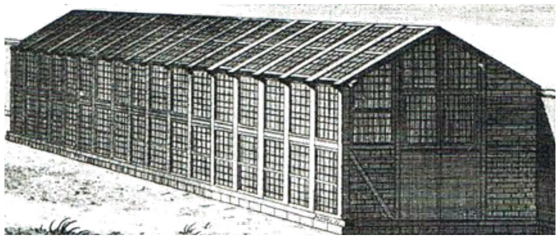
1813 greenhouses with "solar heating" by John Loudon

1800

1800 invention of hot-water heating systems



Pomeranzenhaus Unteres Belvedere, Vienna 1715
I.30
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988



Greenhouse in the garden of Otto von Münchhausen
I.31
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988

Hanging Gardens of Babylon by Dutch artist Martin Heemskerck
I.32
http://en.wikipedia.org/wiki/Hanging_Gardens_of_Babylon 2012.3.12 8:22 PM

1785 first gas lamp in the Netherlands
by Petrus Minckeleers

1714 greenhouse in the garden of Otto von Münchhausen

1700

1700 development of the elongate greenhouse

1688 invention of the continuous steel casting

1627 first idea of hydroponics in “Sylva Sylvarum”
by Sir Francis Bacon

1626 “Pomeranzenhaus” in Heidelberg

1600

Age of Renaissance: first exotic fruits arriving in Europe

1000

500 development of medieval monastery gardens

0

79 AD ruins of “greenhouses” in Pompeji

600 BC the Hanging Gardens of Babylon

Timeline, history of urban farming
data origin: Arch+ 196/197 Zeitschrift für Architektur und Städtebau, Issue January 2010
Jürgen Mayer H. Neeraj Bhatia : -arium, Wheather + Architecture, Hatje Cantz Verlag Ostfildern 2010
Stefan Koppelkamm: Künstliche Paradiese, Verlag Ernst & Sohn, Berlin 1988

Challenges to urban farming

“Vertical farms can offer the perfect solution to the main crises the world faces today such as deforestation, population increases, climate change, pollution, depleting resources, dwindling ecology, decreasing food supplies urban heat island effect, and more.”

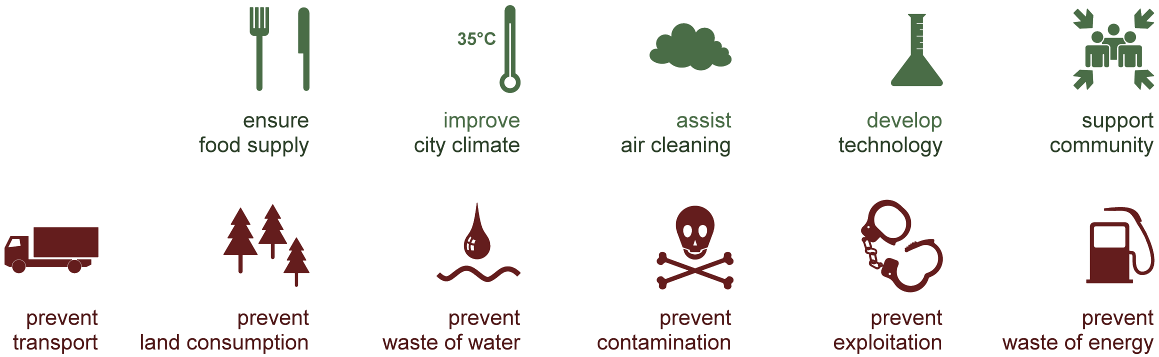
Dickson Despommier about advantages of vertical farms 1

Will urban farming guarantee food supply? How do we act in urban surroundings and how do we provide a public benefit? Can we grow only tomatoes and cucumbers, what about apples and wheat in urban greenhouses?

Agriculture is a system, transforming itself since thousands of years and according to society. Urban farming has the demand to complement common agriculture. We can’t make the city self-sustaining. Light exposure, soil quality and traffic emissions are problems for urban farming. If we want to grow food in cities we can’t build ordinary skyscrapers like we use to build for office use. Skyscrapers affect the micro climate and cause wind turbulences. The light situation within an urban surrounding is very delicate.

There is a missing link between small initiatives and large scale visions of vertical farming. If we want to establish horticulture in an urban context, we have to consider hidden potentials. Some projects combine vegetable cultivation with extensive apiculture 2 (honey production) and aquaponics (intensive fish farming). 3 There is an enormous amount of lost heat from supermarkets, office buildings or industry. Schools, universities and other social infrastructure can provide knowledge. Communities and social solidarity can be encouraged. Urban wastelands have a great potential for interventions. It is important to consider these issues and develop new strategies.

Challenges to urban farming
I.33



Advantages of urban farming
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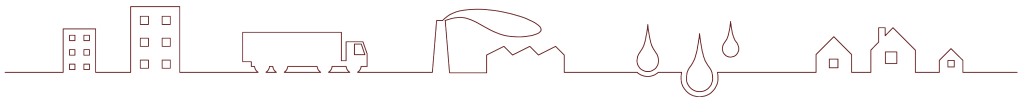

Urban contaminations
I.35

1 Dickson Despommier: The Vertical Farm, Feeding The World in the 21st Century, Thomas Dunne Books 2010
2 Bees in the City? New York May Let the Hives Come Out of Hiding http://www.nytimes.com/2010/03/15/science/earth/15bees.html 2012.3.18 4:27 PM
3 Stephen Mushin: The Food Hubs Project http://stephenmushin.com/photo_display.php?id=157&library_id=23 2012.3.8 1:54 PM

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http://maps.google.com 2010.10.26 3:49 PM

Orange harvest: the hidden cost of Italy's soft drinks trade
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www.independent.co.uk 2012.3.3 1:35 PM

Nikolaus Geyrhalter - Our Daily Bread 2005
I.38
www.unsertaeglichbrot.at 2012.3.3 2:21 PM Photo: Nikolaus Geyrhalter

Almeria, a greenhouse nightmare

"... farm runoff despoils vast amounts of surface water and groundwater. Some 70 percent of all the available freshwater on earth is used for irrigation, and the resulting runoff, typically laden with leftover salts, herbicides, fungicides, pesticides, and fertilizers leached from the nutrient-depleted farmed soil, is returned to countless rivers and streams."

Dickson Despommier about soil contamination [1]

Almeria is covered by 40.000 ha of greenhouses, made out of cheap plastic foil. [2] Most of the greenhouses are low capital investments and family-owned. Each farm is about 1-1.5 ha large. Water supply is insecure and growers tend to use a lot of pesticides, especially against whiteflies and thrips which both spread various viral diseases. [3]
One tomato needs 13 litres of fresh water (180l/kg) to grow. Ground water level is dropping. To ensure future production desalting plants will be built. Artificial lakes of used water cover wide areas. The water has to be decontaminated of pesticides before it is ending up in the sea.

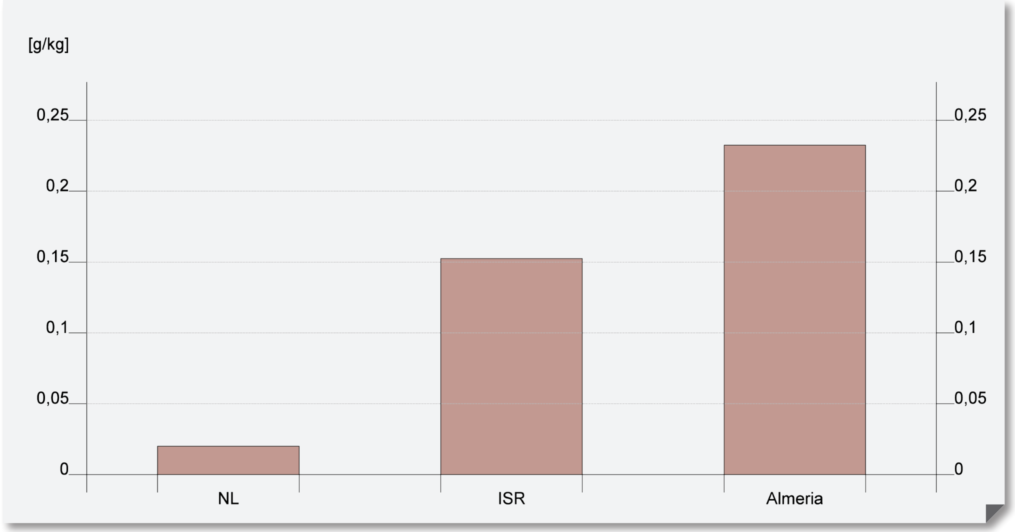
It is a fact that about 20.000 illegal workers, by a majority from Africa, are engaged to service Europe's largest vegetable garden. The average income is less than 400€ per month. Most of the salary is spent for maintenance and living costs. [4] Workers are exploited, because of their hopeless situation. At first they believe that Europe will provide a good future for them. But they are forced to work under hot greenhouse roofs and are exposed to poisonous pesticides.

"Coca-Cola is facing questions about its links to orange harvesting in southern Italy, which campaigners say relies on the cheap labour of African migrants living in squalid conditions."

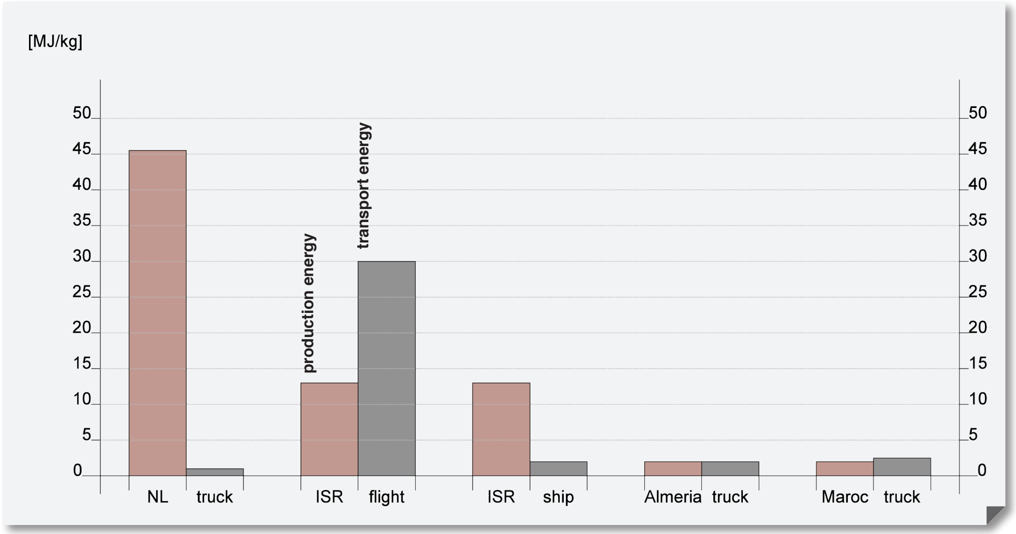
Cahal Milmo and Andrew Wasley: The hard labour behind soft drinks [5]

The labour situation in Italy is similar to Spain. Coca-Cola is the first international company rethinking their business strategy about orange supply and production methods.

1 Dickson Despommier: The Vertical Farm, Feeding The World in the 21st Century, Thomas Dunne Books 2010
2 Mirko Tomic: Betrifft, Hauptsache billig, Wie werden die kleinen Preise gemacht? SWR Fernsehen 2010 2011.11.23 20:15
3 Daniel Cantliffe and John Vansickle: Competitiveness of Spanish and Dutch Greenhouse Industries with the Florida Fresh Vegetable Industry 2009
4 Volker Heise: Betrifft, Hilfe! Was essen wir?, SWR Fernsehen 2011.2.23 20:15
5 http://www.independent.co.uk/life-style/food-and-drink/features/the-hard-labour-behind-soft-drinks-7440046.html 2012.3.3 1:20 PM



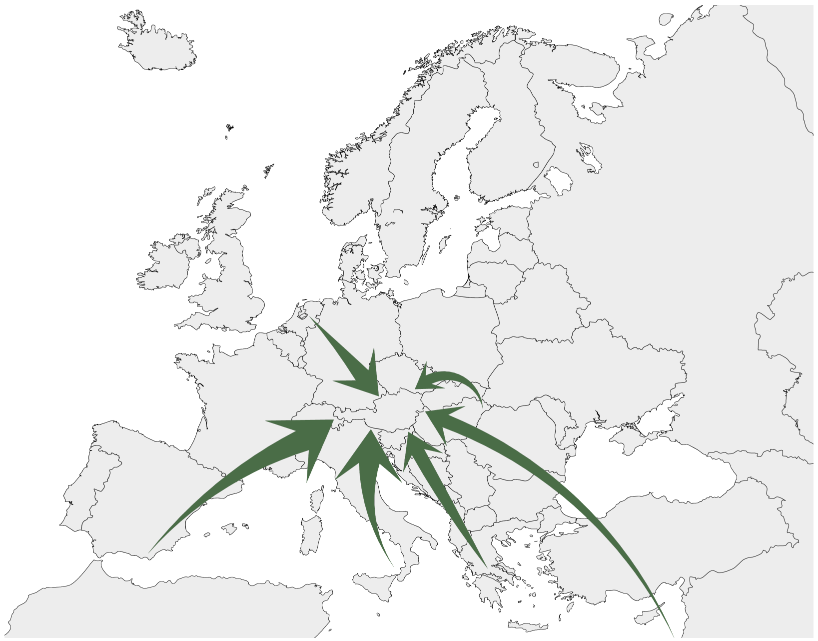
Active ingredients (pesticides, ...) for production of tomatoes
D.1
Christian von Zabeltitz: Integrated Greenhouse Systems for Mild Climates, Springer 2011



Consumption of energy for production and transport of tomatoes
D.2
Christian von Zabeltitz: Integrated Greenhouse Systems for Mild Climates, Springer 2011

Page 25: Capsicums - Mathy Großmarkt, Linz, Austria
I.39

Tomato consumption, Austria
I.40



Vegetable import Austria
M.1

[kg/capita/year]	tomatoes	cucumber	capsicum	lettuce	strawberry	zucchini	eggplant
1	25,30	6,40	4,90	9,70	4,10	1,40	
2							0,30

Consumption values, Austria
T.1
data origin: 1 www.statistik.at 2012.3.2 1:50 PM
2 www.lfl.bayern.de 2011.4.5 11:50 AM

Vegetable import & supply

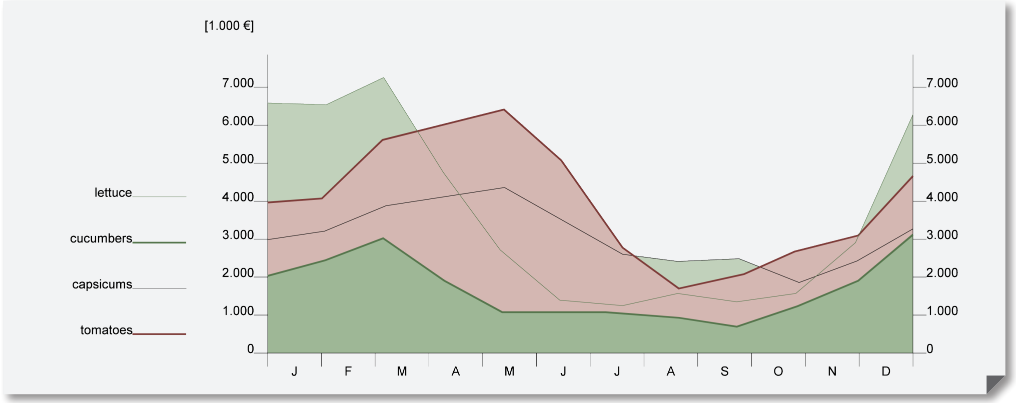
More than three billions of people are living in cities worldwide. We are used to consume what we want, any time we want. We are dependent from seasonable fruits and vegetables, provided all over the year. [1]

Most vegetables in our supermarkets have their origin in Spain, Italy, Greece, The Netherlands, Hungary or Israel. Transported by trucks or by plane hundreds of kilometres, across the continent.
During winter time vegetable supply is ensured by production overseas. People expect to be served fresh vegetables all year round without considering consequences. Growing crops in arid climate zones causes many environmental problems.

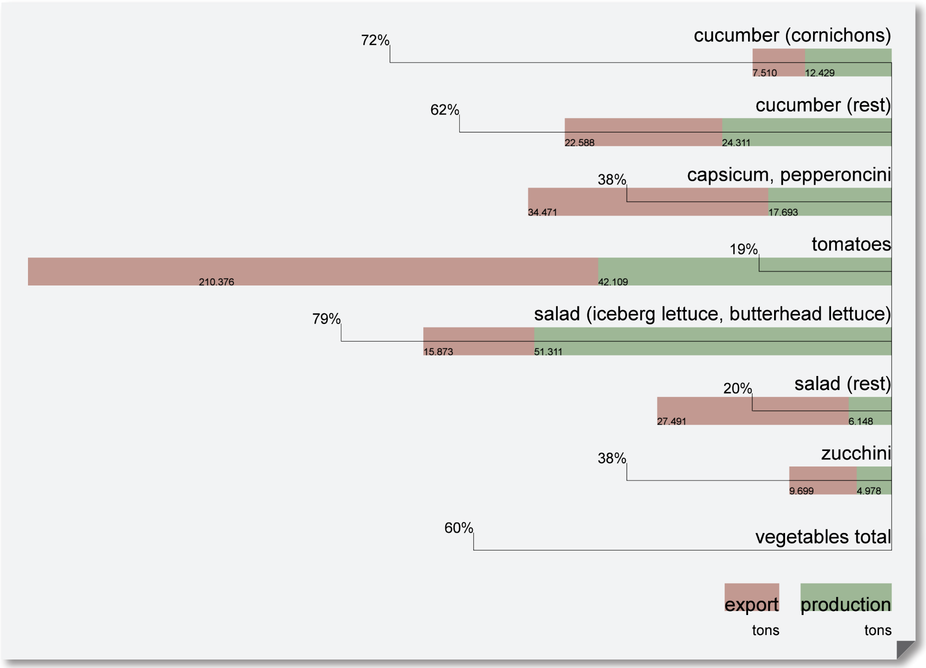
In Austria each person consumes about 24 kg tomatoes each year (25,3 kg in 2009). In 2009 210.376 tons tomatoes were imported from abroad. [2] Most tomatoes come from Italy, Spain and The Netherlands. The Situation in the rest of Europe is comparable: In Germany 1.9 million tons of tomatoes are consumed each year. 80% are from Spain and The Netherlands. [3]

But people want to know where their food is grown. A number of TV reports and documentary movies approach the issues of food production preconditions. [4]
Considering the Austrian food survey by GfK in 2010 the most important criteria for foodstuffs are freshness and good taste. Beside that, consumers are interested in contaminations, a short distance transport and local production. 35% of the consumers feel up to spend 10% more on local food. That demonstrates the awakening consumers sensibility and the willingness to change buying behaviour.

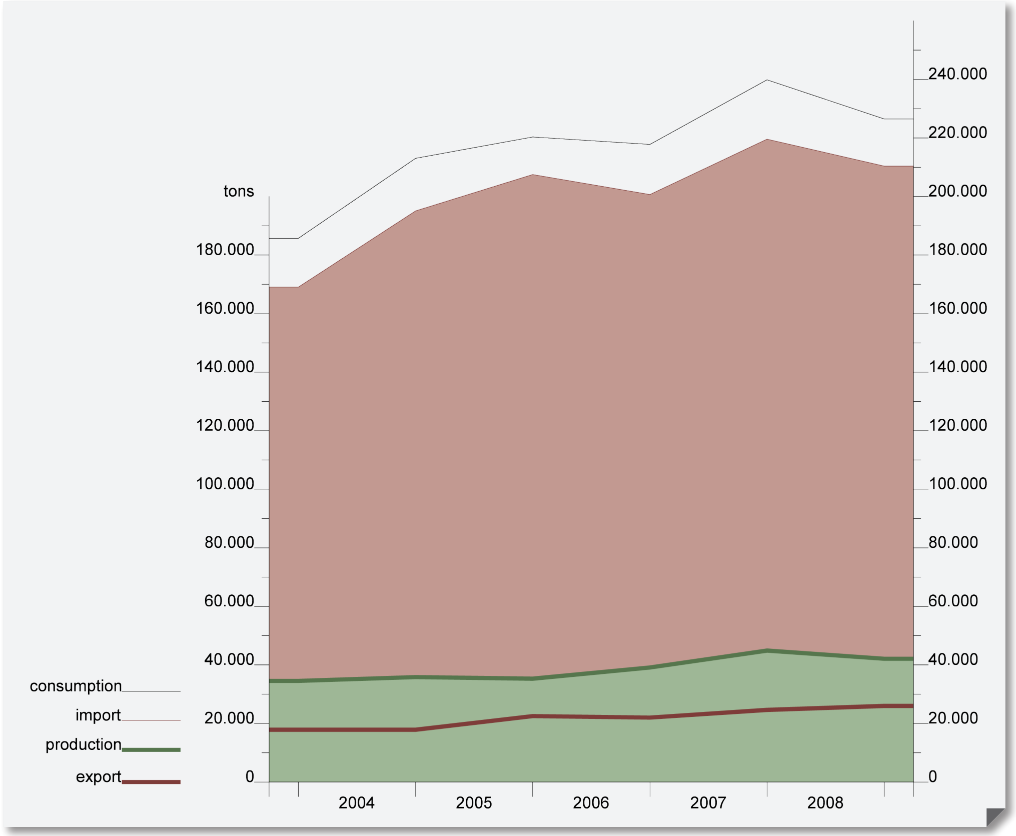
1 Human Planet - Leben in der Stadt ZDFneo http://www.zdf.de/ZDFmediathek/beitrag/video/1563596/Human-Planet---Leben-in-der-Stadt 2012.3.3 11:34 AM
2 Statistik Austria , ISIS-Auswertung 1995-2009
3 Volker Heise: Betrifft, Hilfe! Was essen wir?, SWR Fernsehen 2011.2.23 20:15
4 Michael Pollan, Eric Schlosser and Richard Lobb: Food, Inc. USA 2008, Nikolaus Geyrhalter: Our Daily Bread, Austria 2005



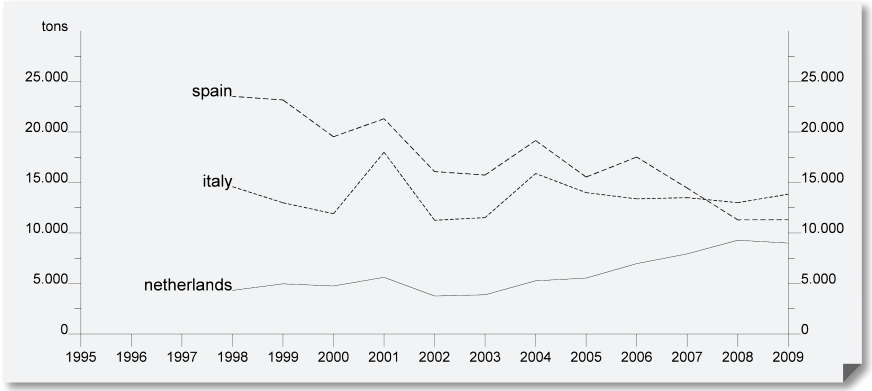
Vegetable import average, Austria 2002-2006
D.3
data origin: www.statistik.at 2011.3.3 4:56 PM



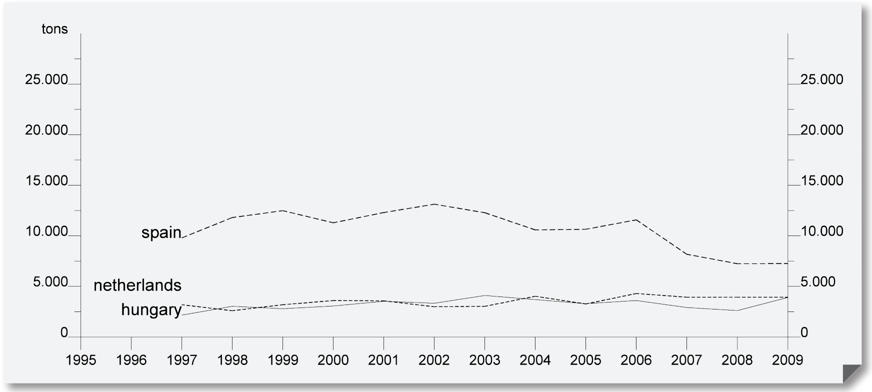
Supply balance vegetables (self-sufficiency in %), Austria 2008/09
D.4
data origin: www.statistik.at 2011.4.5 12:07 PM



Supply balance tomatoes, Austria 2003-2009
D.5
data origin: www.statistik.at 2011.3.1 12:06 AM



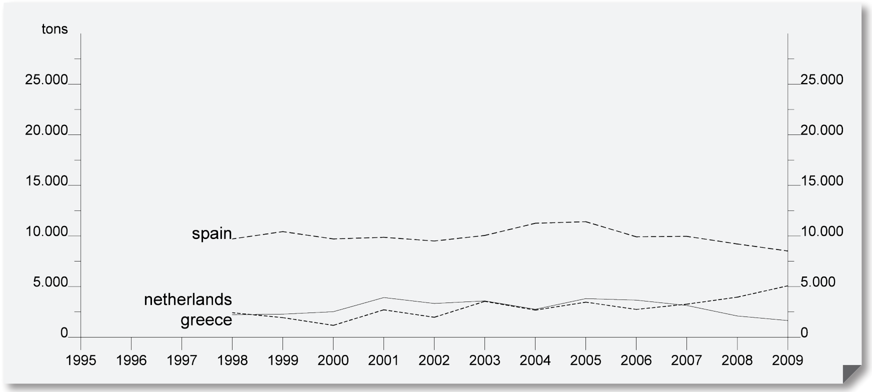
Tomato import, Austria 1998-2009
D.6
data origin: Statistik Austria , ISIS-Auswertung 1995-2009



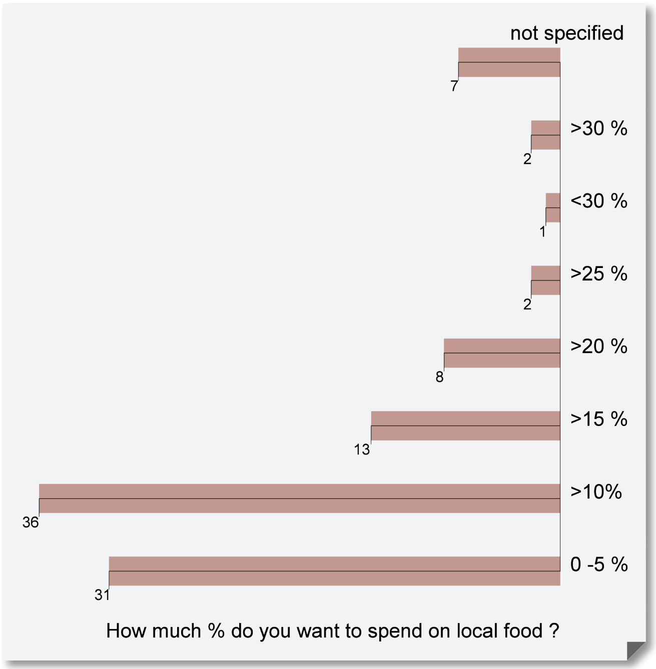
Capsicum import, Austria 1997-2009
D.7
data origin: Statistik Austria , ISIS-Auswertung 1995-2009

tomatoes		cucumbers		capsicums		zucchinis		eggplants	
13.841,9	Italy	8.518,0	Spain	7.257,4	Spain	4.784,9	Spain	1.427,2	Spain
11.313,9	Spain	5.080,6	Netherlands	3.927,3	Netherlands	4.110,8	Italy	636,6	Netherlands
8.992,0	Netherlands	3.842,2	Germany	3.913,2	Hungary	914,8	Germany	483,9	Turkey
2.396,7	Germany	1.651,7	Greece	3.212,4	Israel	182,8	Turkey	125,3	Italy
1.867,1	Marocco	1.224,7	Hungary	2.816,1	Greece	102,0	Netherlands	70,0	Germany
775,5	Israel	1.028,0	Italy	1.770,5	Turkey	87,7	Marocco		
771,9	Turkey	903,2	Turkey	1.480,4	Germany	33,0	Hungary		
139,2	Hungary	174,4	Israel	1.1751	Italy	14,9	France		

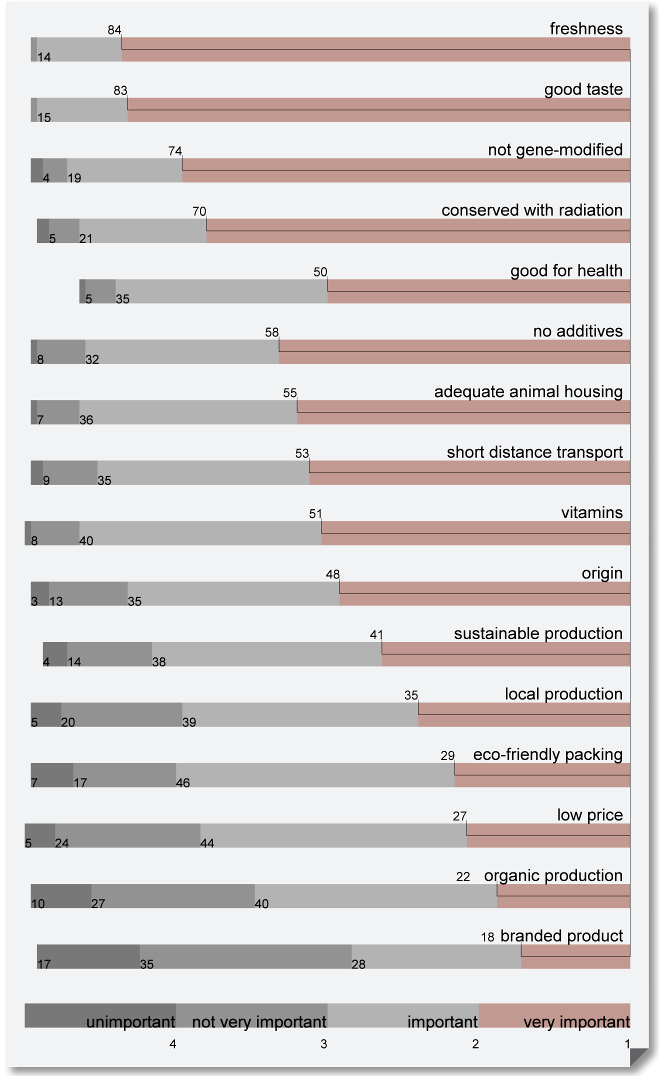
Vegetable import (tons), Austria 2009
D.9
data origin: Statistik Austria , ISIS-Auswertung 1995-2009



Cucumber import, Austria 1998-2009
D.8
data origin: Statistik Austria , ISIS-Auswertung 1995-2009

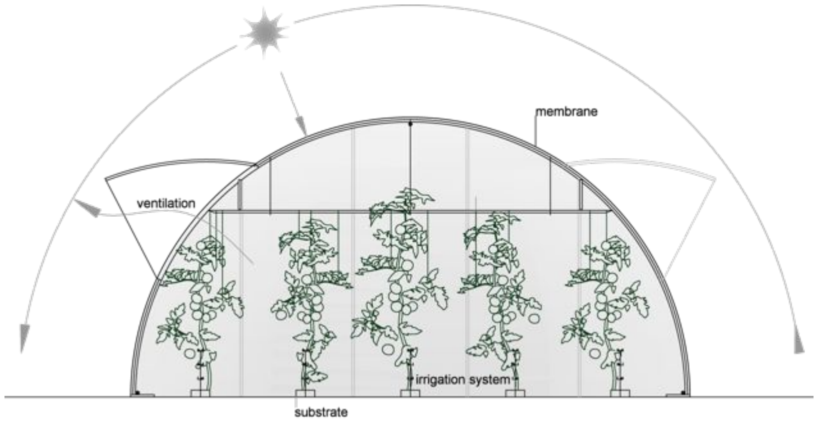


Willingness to pay, Austrian food survey, GfK 2010
D.10
www.lebensministerium.at 2011.3.17 6:49 PM

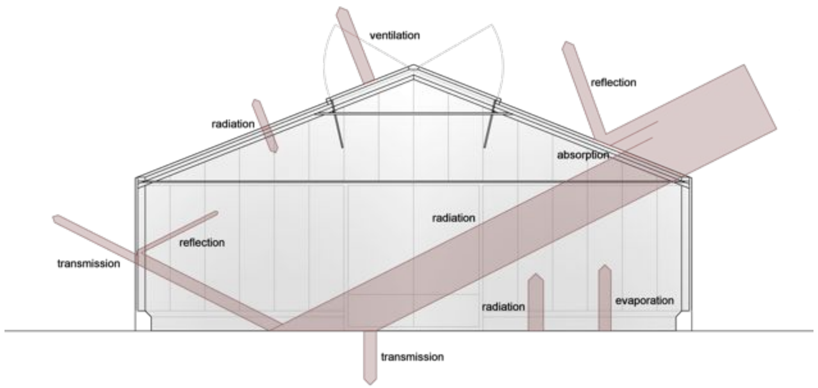


Food quality, Austrian food survey, GfK 2010
D.11
www.lebensministerium.at 2011.3.17 6:49 PM

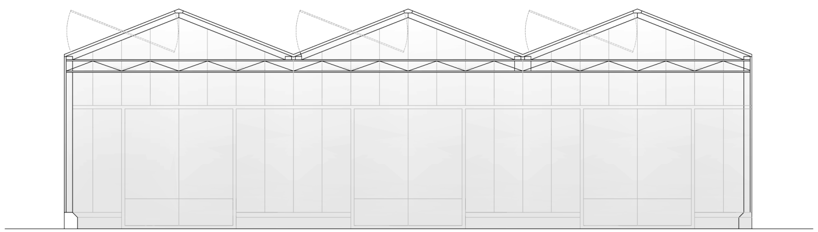
Page 30: Cucumber greenhouse after harvest, Vienna, Austria
I.41



Round arched tunnel
I.42



Greenhouse energy balance
I.43
Christian von Zabeltitz: Gewächshäuser, Ulmer Verlag, Stuttgart 1978



Venlo greenhouse
I.44

Greenhouse industry & principles

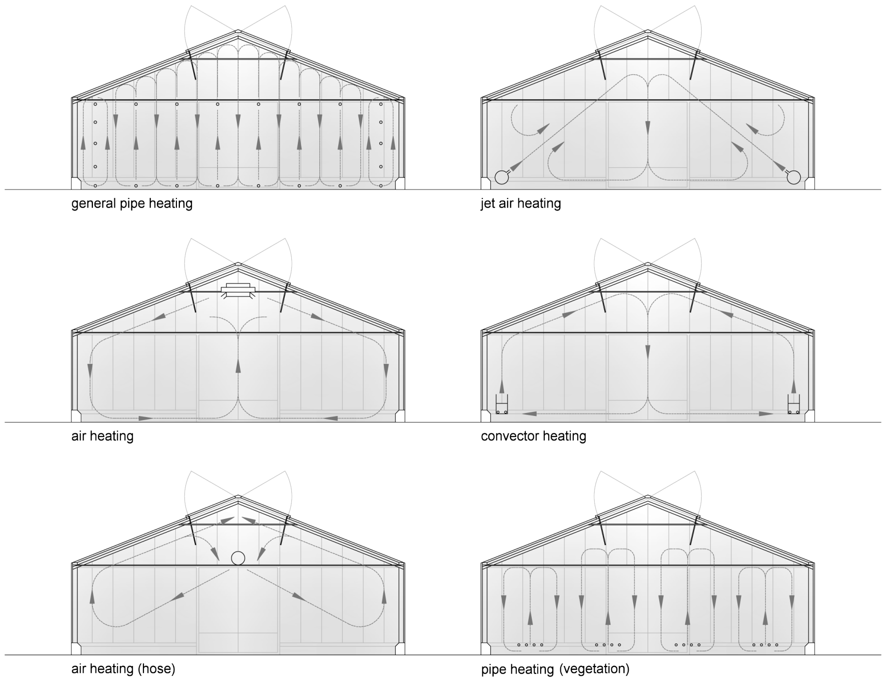
Greenhouses are structures made to provide perfect conditions for plant cultivation. They are flexible in use and it is common to use cheap construction materials.
Greenhouses are used to extend growing seasons by controlling light conditions, humidity, temperature and air consistence. Horticulture can help saving water consumption. It is possible to disclaim the use of pesticides and to save acreage by a higher crop rate.

There is a wide variety of greenhouse structures depending on light conditions, cover materials, expected snow loads, ventilation and growing systems. Common greenhouse frames are made of aluminum or galvanized steel. 1 Claddings are usual made of plastic film (Parral-type greenhouse in Almeria). The Dutch Venlo-type is covered with glass and established in many countries above 50°N latitude. Shading, heating and ventilation systems require an operating hight up to 6 meters (tomato cultivation).

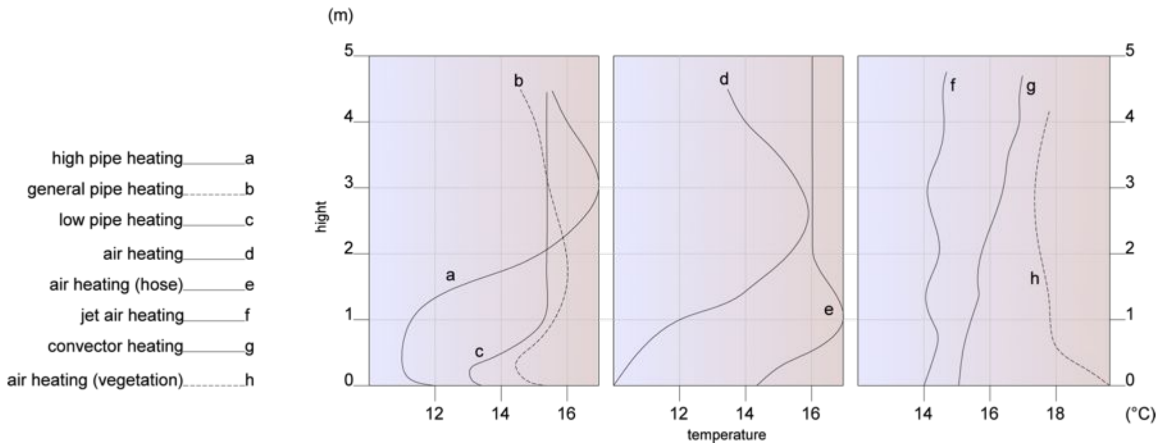
Compared to open field grown vegetables, greenhouse production is more expensive. Beside structure and labour costs, energy consumption, substrate and fertilizer increase the production costs. A modern greenhouse is operated by computerized environmental control, heating and irrigation systems. Today investments into high-tech greenhouse operations are increasing worldwide.

Greenhouse costs including climate control, transport and fertilization are about US$ 75/m^2 (Woerden and Bakker, 2000). 2 Dutch greenhouse manufacturers improved construction methods and operating efficiency enormously. Beside technical improvements, labour figures are about 5-8 workers/ha in The Netherlands (Woerden and Bakker, 2000) 3 compared to 7-12 workers/ha in North America (Jensen and Malter, 1995) 4 Low-cost-structures like plastic film tunnels are common in Spain and Italy. Construction costs are from 7,8 €/m^2 to 15,6€/m^2 (Costilla et al. 2005). 5

1, 5 Christian von Zabeltitz: Integrated Greenhouse Systems for Mild Climates, Springer, Heidelberg 2011
2, 3, 4 E. Heuvelink: Tomatoes, Crop Production in Horticulture, CABI Publishing Oxfordshire, UK 2005



Greenhouse heating systems and air circulation
I.45
data origin: Christian von Zabeltitz: Gewächshäuser, Ulmer Verlag, Stuttgart 1978



Temperature profiles
D.12
Christian von Zabeltitz: Gewächshäuser, Ulmer Verlag, Stuttgart 1978

In The Netherlands glasshouses are covering large areas of about 10,500 ha. Italy reports some 61,900 ha (mostly large plastic film tunnels) and is followed by Spain with a total area of 46,852 ha (Costa et al., 2004). [1]

Membrane structures are more flexible, easy to handle and can be used temporary. Plastic film has a short life cycle of about 4-6 years. [2]
Glass constructions are not as cheap and adaptable as membrane structures. But glass takes more advantage of natural sunlight and can be heated during cold seasons.

Greenhouse design rules are very simple. It is important to consider a low surface-to-base-area ratio for an energy efficient construction. [3]
The orientation has a respectable impact to the solar profit and yield values. Compared to an east-west oriented greenhouse light transmission is higher in winter and lower in summer than in a north-south oriented greenhouse. In general it is important to consider roof angular and shape, growing season, and location. For example, cucumber yield in Almeria (Spain) can increase up to 25-50% in an asymmetrical east-west-oriented greenhouse with a roof slope of 45° to south and 27° to the north compared to 11° and 24° respectively (Castilla et al. 2001). Diffuse or scattered light can penetrate deeper into a plant canopy than direct light. Production can be increased by 5-6% per year. [4]

Greenhouse architecture has not been changed for many decades. It seems that there is a perfect system for the requirements of nowadays. To adapt the principles of greenhouses for future high profit farming it is important to understand building physics and standards for plant breeding.

1 E. Heuvelink: Tomatoes, Crop Production in Horticulture, CABI Publishing Oxfordshire, UK 2005
2, 4 Christian von Zabeltitz: Integrated Greenhouse Systems for Mild Climates, Springer, Heidelberg 2011
3 Henning Bredenbeck: Technik im Gartenbau unter Glas, Energieeinsparung durch Wärmedämmung an der Gewächshaushülle, KTBL Arbeitsblatt 2001

Banana cultivation, Hveragerdi, Iceland
I.46
http://en.wikipedia.org/wiki/Banana_production_in_Iceland 2012.3.17 12:24 PM

LED supported vertical farming, Plant Lab, The Netherlands
I.47
www.croppings.nl 2012.3.17 12:14 PM

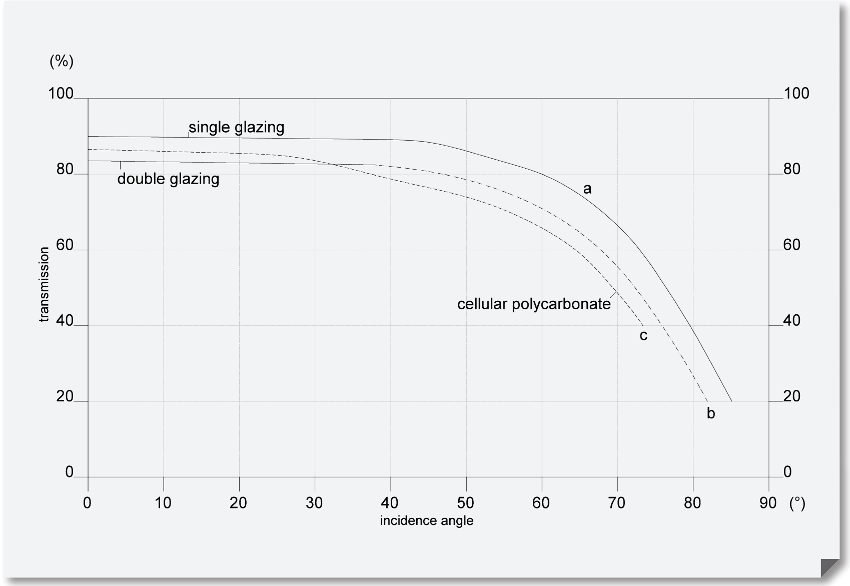
Local climate conditions are regulating the growing season. Plants grown under protected cultivation are adapted to average temperatures from 17°C to 27°C. Optimal operating temperatures range from 22°C to 28°C during daytime and 15°C to 20°C during night. A minimum sunshine of 500-550 hours during winter months in the Northern Hemisphere is recommended. 1
Ventilation is important for the exchange of carbon dioxide, oxygen, temperature and humidity differences. The ratio of air inlets to greenhouse floor area should be about 20-25%. 2

In The Netherlands, operating costs are considerably higher because of the poor conditions of light and temperature during the winter. Heating systems are necessary to ensure a constant climate in winter times or to balance different temperatures from day to night. While Almeria has a total amount of 3.000 annual sunshine hours, growing conditions in Iceland are on the limit. 3
In Hveragerdi an area of about 20 ha is covered with greenhouses. The growing season is up to nine months. It's nearly unbelievable that 2.000 tons of tomatoes, cucumbers, capsicums and eggplants are produced annually. Also during summer, the light conditions are very poor and cultivation has to be supported by artificial illumination with the help of neon and mercury arc lamps. 4 Considering a four hour day during wintertime from November to February, it wouldn't be possible to grow vegetables on iceland without the benefit of geothermal heating.

Artificial illumination is used for intensive production, to push plant growth by extending the day to the night or to support growing during the day. There are different methods for artificial illumination: photoperiodic illumination (50-500 lux), assimilative in combination with daylight (1000-5000 lux), assimilative for artificial illumination (2000-10000 lux). 5 New technologies have to be explored to ensure artificial illumination. Light-emitting diodes (LED) are an up-coming technology. They can be powered by photovoltaics and are used by research facilities in The Netherlands.

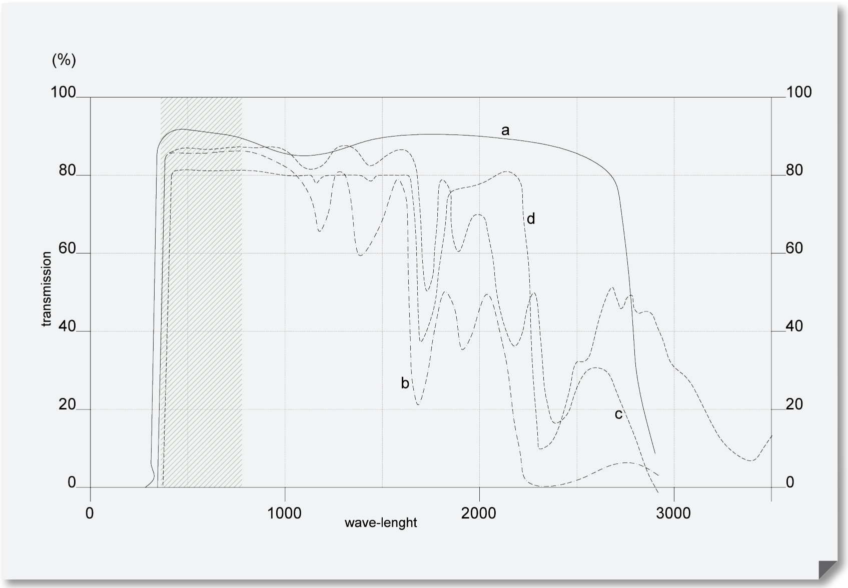
1, 2 Christian von Zabeltitz: Integrated Greenhouse Systems for Mild Climates, Springer, Heidelberg 2011
3 Daniel Cantliffe and John Vansickle: Competitiveness of Spanish and Dutch Greenhouse Industries with the Florida Fresh Vegetable Industry 2009
4 E. Michael Salzer: In den Tropen des Nordatlantik, Merian Issue 8/42
5 Christian von Zabeltitz: Gewächshäuser, Ulmer Verlag, Stuttgart 1978

single glazing .... a
double glazing .... b
cellular polycarbonate c

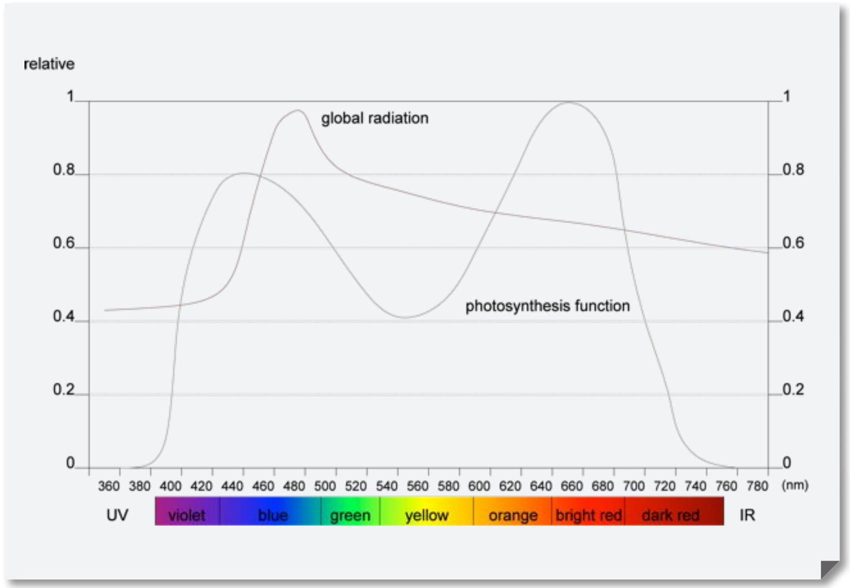


Light transmission and incidence angle
D.13
Christian von Zabeltitz: Gewächshäuser, Ulmer Verlag, Stuttgart 1978

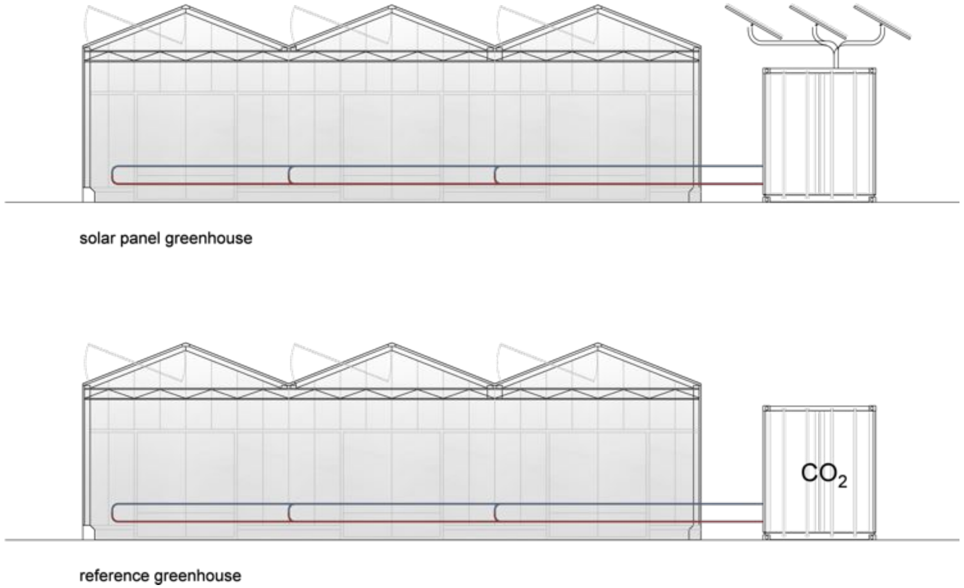
single glazing .... a
cellular polycarbonate .... b
polyester c
PVC ... d



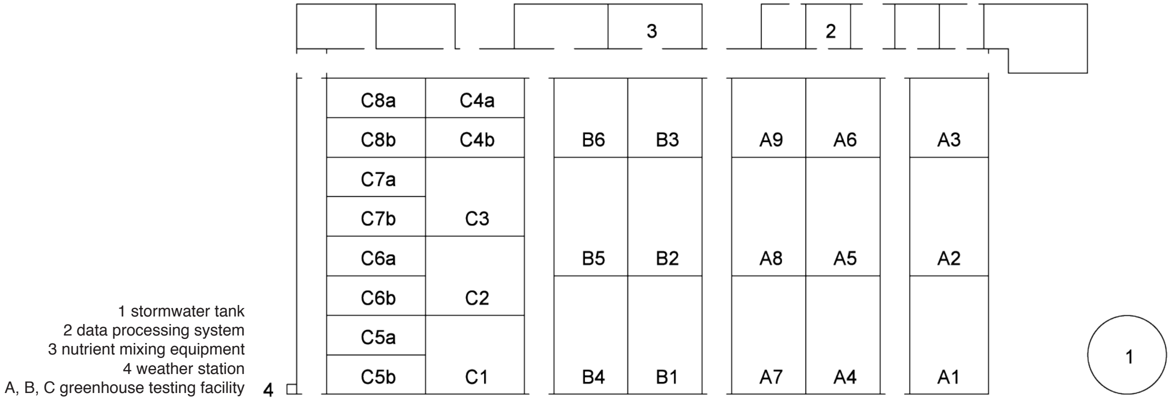
Spectral transmission of different materials
D.14
Christian von Zabeltitz: Gewächshäuser, Ulmer Verlag, Stuttgart 1978



Spectrum global radiation, considering artificial illumination
D.15
www.ktbl.de 2011.11.3 4:25 PM



Solar panel greenhouse - common heated greenhouse, HU Berlin
I.48
data origin: www.agrosnet.de 2011.3.23 9:40 AM



Research facility, HU Berlin
I.49
data origin: www.agrosnet.de 2011.3.23 9:40 AM

The low energy greenhouse

"The main objective of the project is to reduce the consumption of fossil energy and hence the (fossil) CO_2-emission for crop production in greenhouses to zero. This ambitious goal can be achieved by using a system-oriented approach which consists of a cooperation of technical innovation and technical arrangements in cultivation."
ZINEG - The Low Energy Greenhouse 1

To operate a greenhouse sustainably, energy can be supplied by solar panels. It is also important to provide a closed system with single glazing and multi-layer thermal screen. Process controlling software is in use to optimize energy storage and the potential re-use of solar energy.
Research conclusions help to identify saving potentials and to determine the boundaries of that technology. Simultaneous horticulture studies are important to adapt climate management, irrigation and nutrient supply. With phytomonitoring technology it is possible to investigate in crop responses to various climate conditions. 2

Beside testing new technologies, there is a wide range of research topics. Following bullet points are inspired by the research project *Low Energy Greenhouse* at the *Humboldt Universität zu Berlin*.

Breeding of test plants:
- cultivating of asian leafy vegetables and spices

Testing substrates for cultivation and crops:
- hydroponic cultivation systems for eggplants

Production of seeds:
- using aeroponics for potato reproduction

Phytomonitoring and phytocontrol:
- testing new strategies for ventilation, fog systems and CO_2 accumulation for optimization of micro climates

Acclimatization of plants to climate change:
- focusing on drought stress

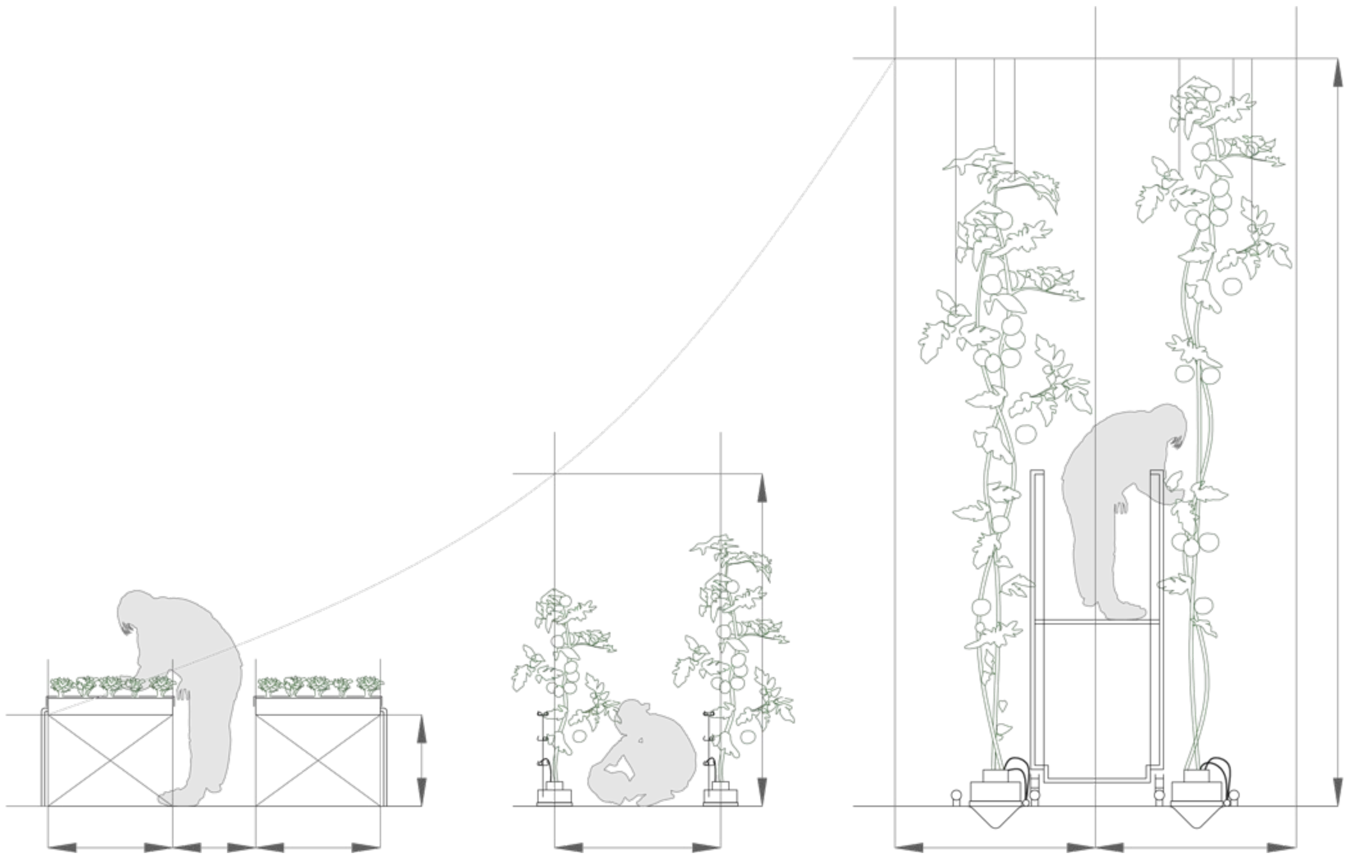
New strategies for virus-free plants:
- focusing on virus transfer with vegetative multiplication
- using silicates and algae as nontoxic insecticides
- cultivating corn with nutrient solution for biomass production

3

1, 2 http://www.zineg.de/?q=en/node/50 2012.3.19 12:27 PM
2 http://www.agrosnet.de/gwh/greenhouse.html 2011.3.23 9:40 AM


Fortaplant.

Page 36: Cucumber culture after harvest, Vienna, Austria
I.50



Common hydroponic cultivation systems
I.51

Cultivation systems & yields

"Numerous commercially viable crops such as strawberries, tomatoes, peppers, cucumbers, herbs, and a wide variety of spices have seen their way from commercial greenhouses to the world's supermarkets in ever-increasing amounts over the last fifteen years."

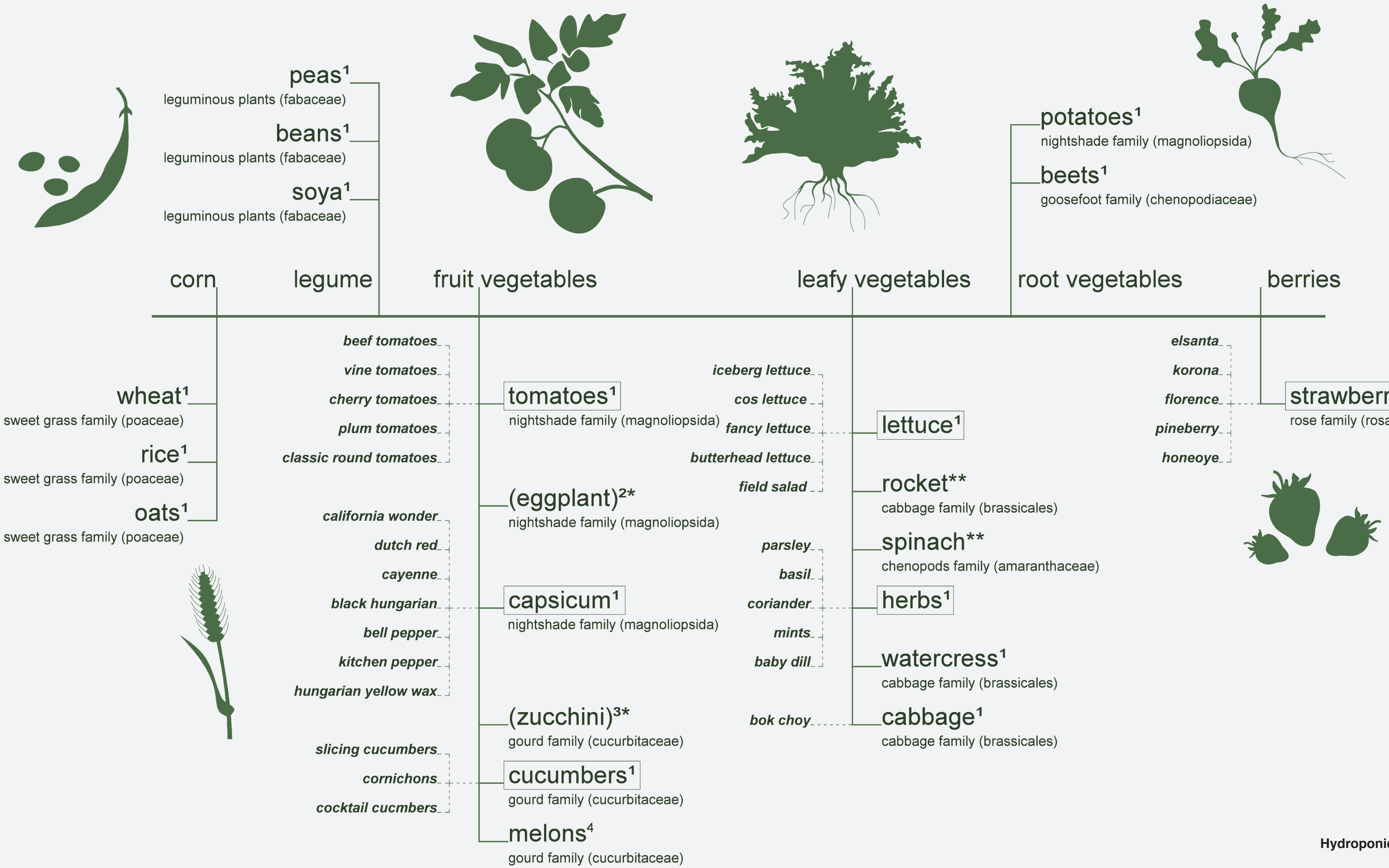
Dickson Despommier about hydroponic crops 1

Lots of vegetables and herbs are common to be grown in greenhouses. In Almeria winter crops, such as tomatoes, peppers, cucumbers and squashes differ from summer crops, such as various muskmelons, watermelons, and green beans. Production peaks are from December to January and from May to June. Approximately 90% of common cultivation in Almeria is produced on artificial soil. It's a special soil mixture partly of clay and sandy gravel and is called *Enarenado*. Dutch producers prefer hydroponic systems which use rock wool for a media and some producers do well with the soilless nutrient film technique. 2

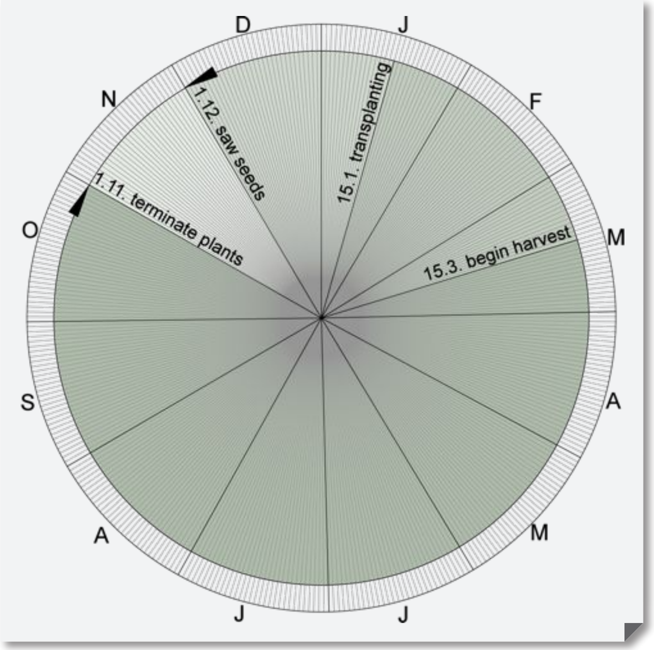
The increased production of tomatoes grown hydroponically is usually 20-25 % higher. Special cucumbers and tomatoes have been developed for greenhouse culture. Those crops are trained to grow vertically and not to spread along the ground. They are harvested throughout the entire season (one-year crop period). 3

Yield values are very different. They depend on climate and growing system. With full controlled hydroponic systems high crops are possible. For example, average tomato yields in high-light area (Almeria, Spain: 3000 hours sunshine per year) are lower (28 kg/m^2) than in The Netherlands or Canada (60 kg/m^2) even though light intensity per day is five times higher in Spain during winter compared to The Netherlands (Costa and Heuvelink, 2000). 4

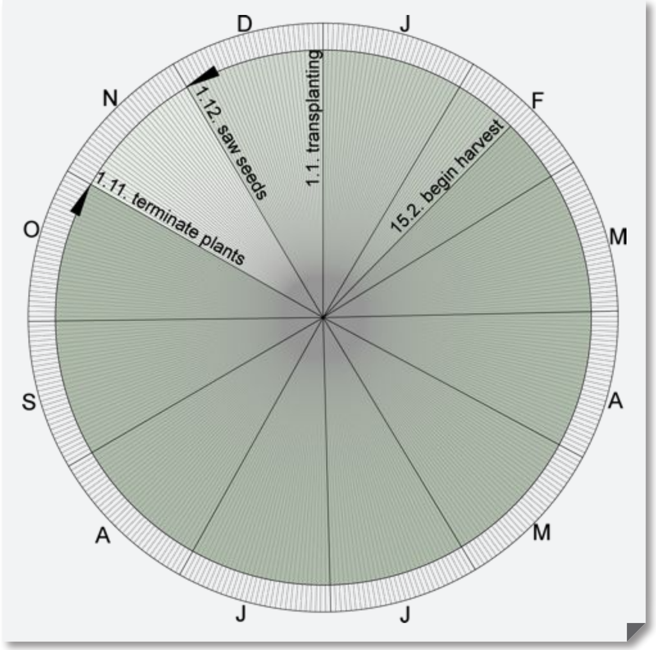
1 Dickson Despommier: The Vertical Farm, Feeding The World in the 21st Century, Thomas Dunne Books 2010
2 Daniel Cantliffe and John Vansickle: Competitiveness of Spanish and Dutch Greenhouse Industries with the Florida Fresh Vegetable Industry 2009
3 Howard M. Resh: Hydroponic Food Production, Routledge 2004
4 E. Heuvelink: Tomatoes, Crop Production in Horticulture, CABI Publishing Oxfordshire, UK 2005



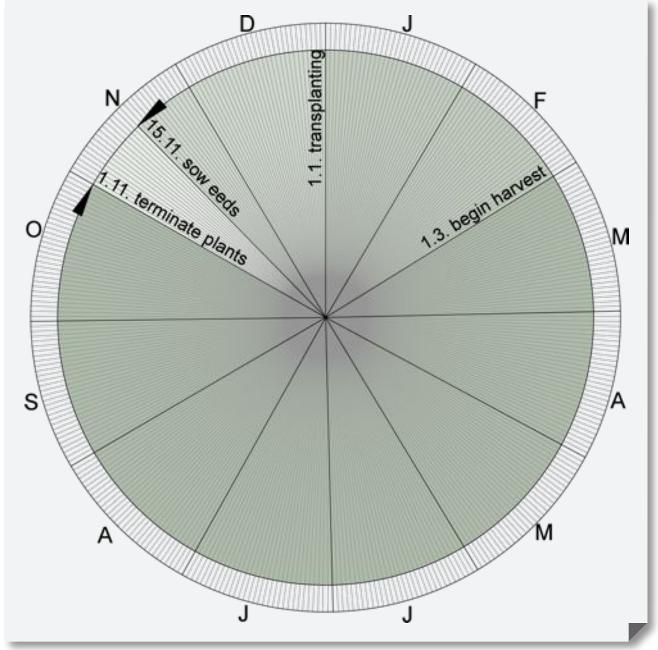
Hydroponic crops
I.52
data origin: 1 Howard M. Resh: Hydroponic Food Production, Routledge, New York-London, 2004
2 http://www.agrosnet.de/gwh/greenhouse 2011.3.23 9:40 AM
3 http://nwrec.hort.oregonstate.edu/zuc.html 2012.3.2 1:07 PM
4 http://www.abhydroponics.com.au/page/rotating_system.html 2011.4.4 9:37 PM



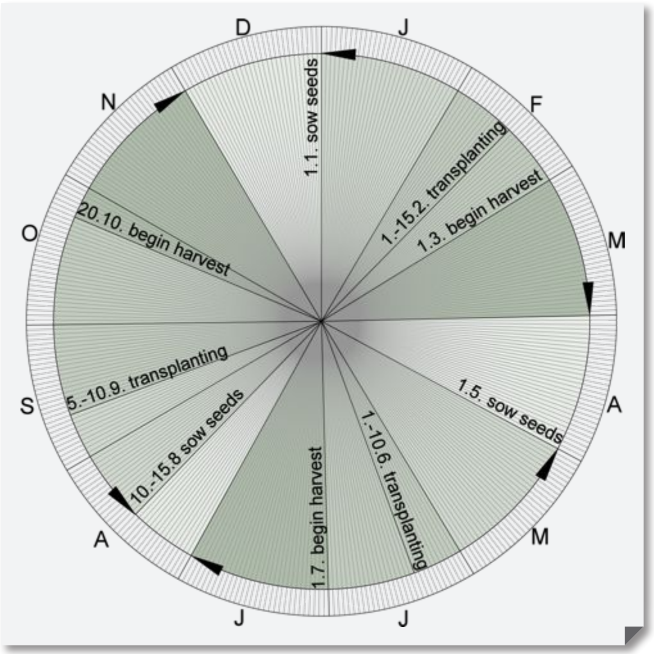
Capsicum plant schedule (single crop annually)
D.16



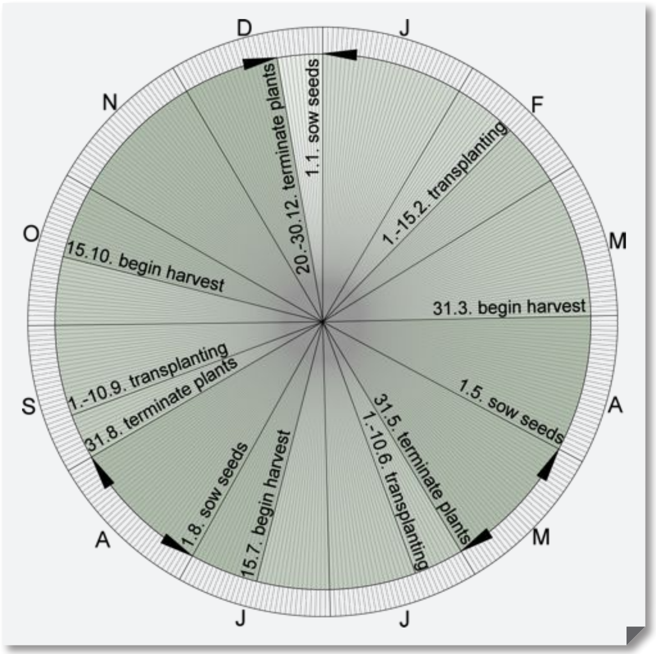
Cucumber plant schedule (single crop annually)
D.17



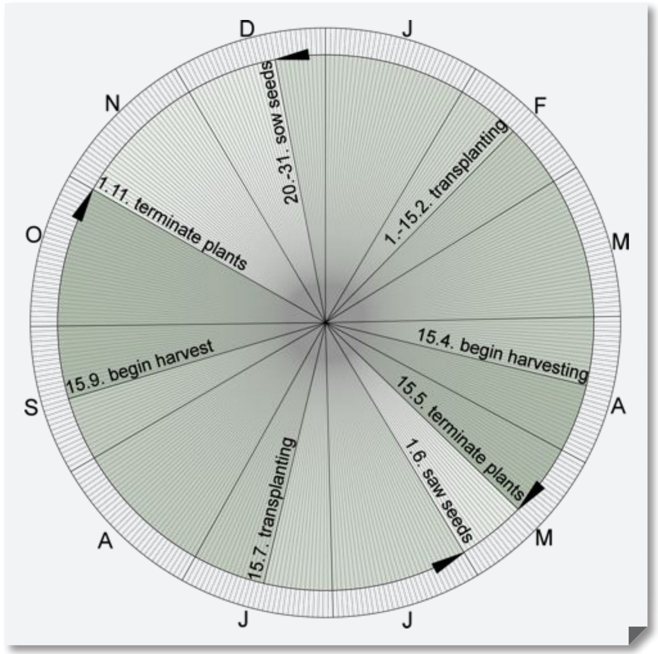
Tomato plant schedule (single crop annually)
D.18



Lettuce plant schedule (three crops annually)
D.19



Cucumber plant schedule (three crops annually)
D.20



Tomato plant schedule (two crops annually)
D.21

data origin: Howard M. Resh: Hydroponic Food Production, Routledge 2004

Yield values, Austria
T.2
data origin: www.statistik.at 2011.4.6 10:59 PM

[kg/m²/year]	tomatoes	cucumber	capsicum	lettuce	strawberry*	zucchini	eggplant
1	39,37	19,89	6,68	3,28	1,31	4,05	4,95

* field crop

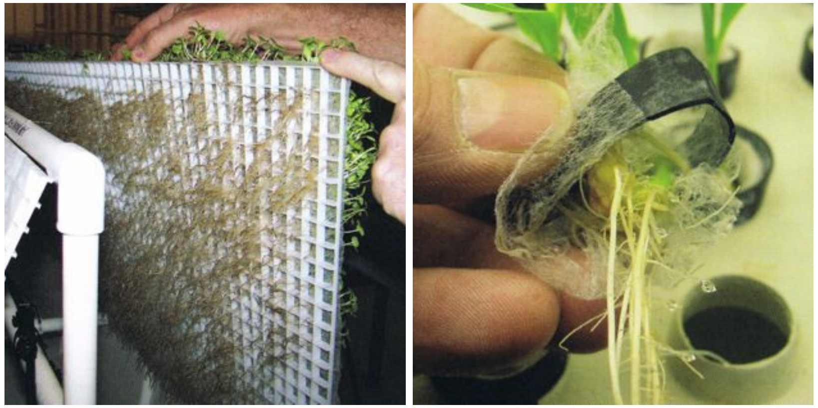
Yield values worldwide
T.3
data origin: 1 North America Howard M. Resh: Hydroponic Food Production, Routledge 2004
2 Australia http://www.abhydroponics.com.au/page/rotating_system.html 2011.4.4 9:37 PM
3 USA http://nwrec.hort.oregonstate.edu/zuc.html 2012.3.2 1:07 PM
4 Netherlands Christian von Zabeltitz: Integrated Greenhouse Systems for Mild Climates, Springer 2011
5 Netherlands E. Heuvelink: Tomatoes, CABI Publishing 2005
6 Netherlands http://www.actahort.org/members/showpdf?booknrarnr=711_1 2012.3.2 1:09 PM
7 Netherlands http://edis.ifas.ufl.edu/cv284#TABLE_3 2011.4.5 1:05 PM
8 Netherlands http://www.lei.dlo.nl/leichina/files/7be847e6d728182373ff92fe7e61ef13.pdf 2011.4.5 1:22 PM
9 Canada http://www.agf.gov.bc.ca/ghvegetable/publications/documents/industry_profile.pdf 2011.4.5 1:32 PM
10 http://www.povrce.com/?P=gen&A=FAO&HTM=10081 2012.3.2 1:12 PM

[kg/m²/year]	tomatoes	cucumber	capsicum	lettuce	strawberry	zucchini	eggplant
1	13,45	3,14	21,00	2,35	11,41		
	67,25				54,75		
2	168,00	126,00	75,00	277,00	54,00		32,00
3						4,48	
4	50,00	70,00	26,00				
5	50,00						
6	110,00	168,00	64,00				
7	42,00	58,00	26,00				
8	15,00	22,50	9,00				7,50
9	73,00	160,00	27,00	50,00			
10				4,50			
average	65,41	86,81	35,43	83,46	40,05	4,48	19,75

Weighted yield values
T.4

[kg/m²/year]	tomatoes	cucumber	capsicum	lettuce	strawberry	zucchini	eggplant
weighted value	**55,83**	**34,71**	**31,84**	**19,26**	**22,49**	**4,27**	**6,23**

Variety of hydroponic grown tomatoes
I.53



Aeroponics by Richard Stoner, NASA
I.54
Dickson Despommier: The Vertical Farm, Thomas Dunne Books 2010 Photo: Richard Stoner / AgriHouse

Strawberry column culture: Hydrostackers
I.55
Dickson Despommier: The Vertical Farm, Feeding The World in the 21st Century, Thomas Dunne Books 2010 Photo: Dieter Tamson

Beside water, oxygen and carbon dioxide plants need basic elements to grow. All hydroponics are in common to be supplied with a nutrient solution. To make up a nutrient solution fertilizer salts are dissolved in water. An optimal formulation depends on the following variables: Plant species and variety, stage of plant growth, season of year, day length, weather conditions. Fertilizer injector systems work well in combination with computer monitoring. Stock solutions are concentrated nutrient solutions. They are prepared as 50, 100 or 200 times normal strength for mixing up with the irrigation. [1] There are open and closed hydroponic systems. In Spain nutrient solutions mostly won´t be recycled and contaminate the environment.

Most essential elements within the plants:
Nitrogen, Phosphorus, Potassium, Sulfur, Magnesium, Calcium, Iron, Chlorine, Manganese, Baron, Zinc, Copper, Molybdenum, Carbon, Hydrogen, Oxygen; [2]

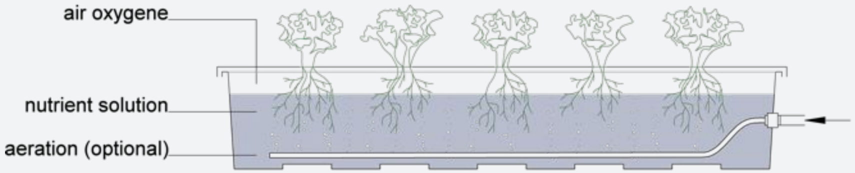
A soilless medium must provide oxygen, water, nutrients and support for the plant roots. The choice of the medium will be determined by availability, cost, quality and the type of the cultivation method. It is important to be aware of containing toxic contaminants and that growing media should be sterilized before use.

Common growing media:
Expanded clay, rock wool, coir (coco peat), perlite, pumice, vermiculite, sand, gravel, brick shards, polystyrene packing, peanut hulls, wood fiber, foam, sawdust, ... [3]

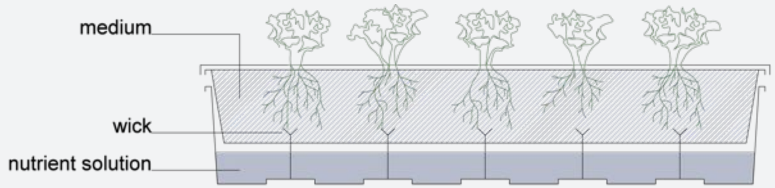
The water culture is a true hydroponic system without the use of any growing medium. This includes aeroponics. Plant roots are suspended into a closed dark chamber in which jets of nutrient solution are periodically sprayed. The Nutrient Film Technique is a water-cultural technique in which plant roots are contained in a small channel through which a thin film of nutrient solution is continuously circulating.

Common hydroponic techniques:
Static solution culture, continuous-flow solution culture, aeroponics, passive sub-irrigation, ebb and flow culture, run to waste, deep water culture, bubbleponics, ...

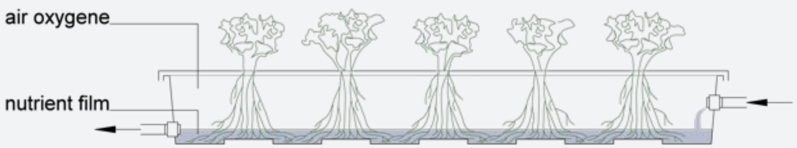
1, 2, 3 Howard M. Resh: Hydroponic Food Production, Routledge 2004



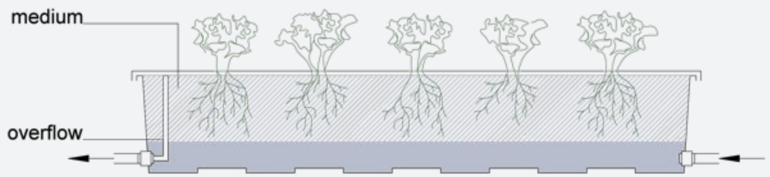
static solution or deep water culture



passive subirrigation: wick system

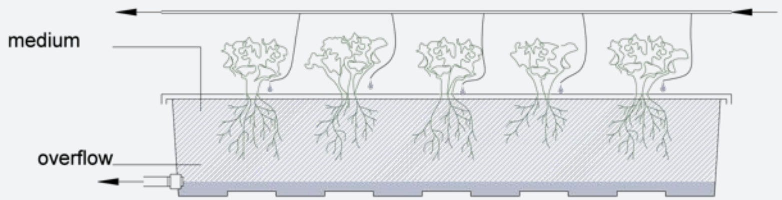


nutrient film technique or continuous-flow solution culture



ebb and flow system

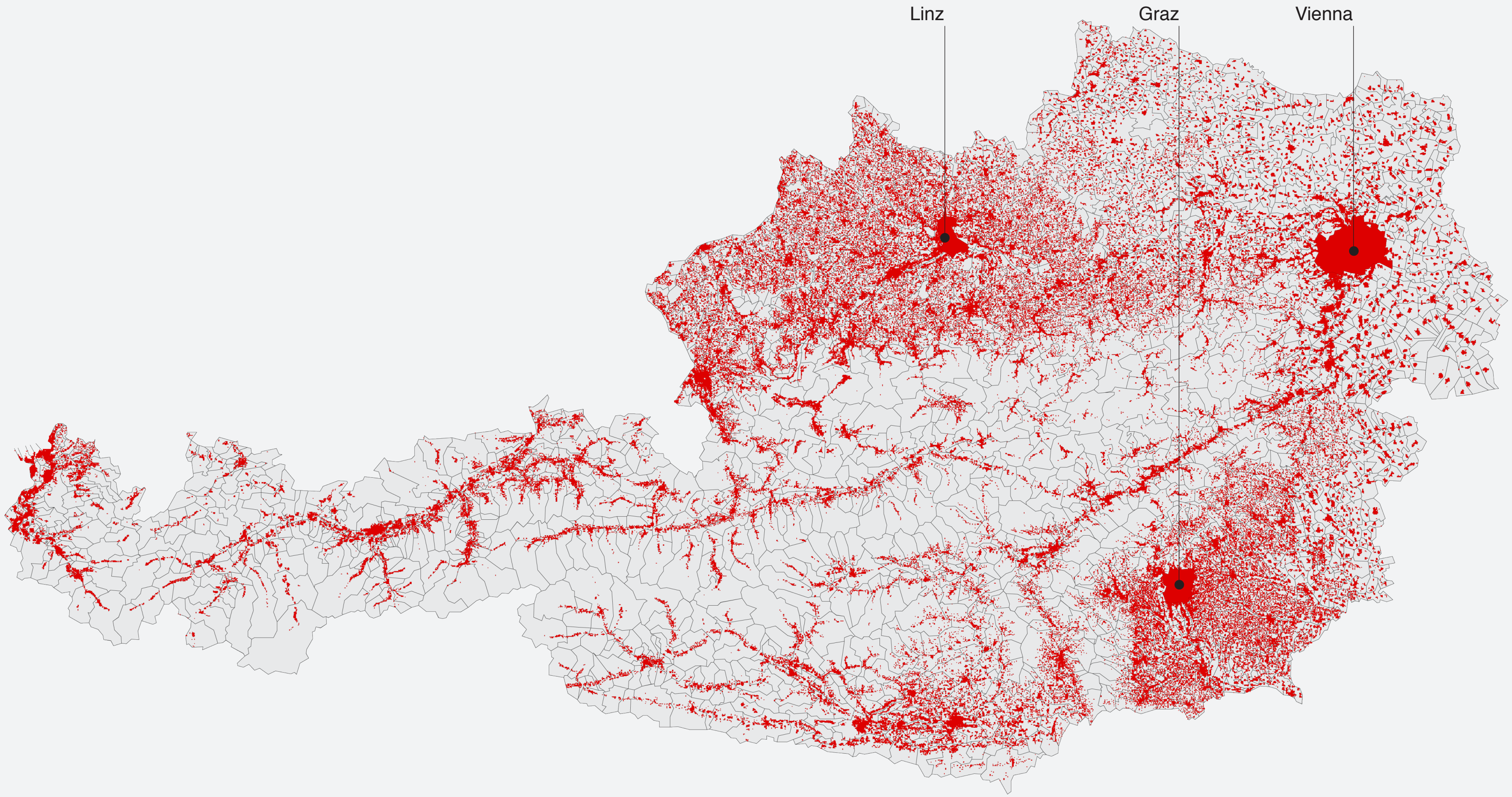
aeroponics



run to waste or drip system

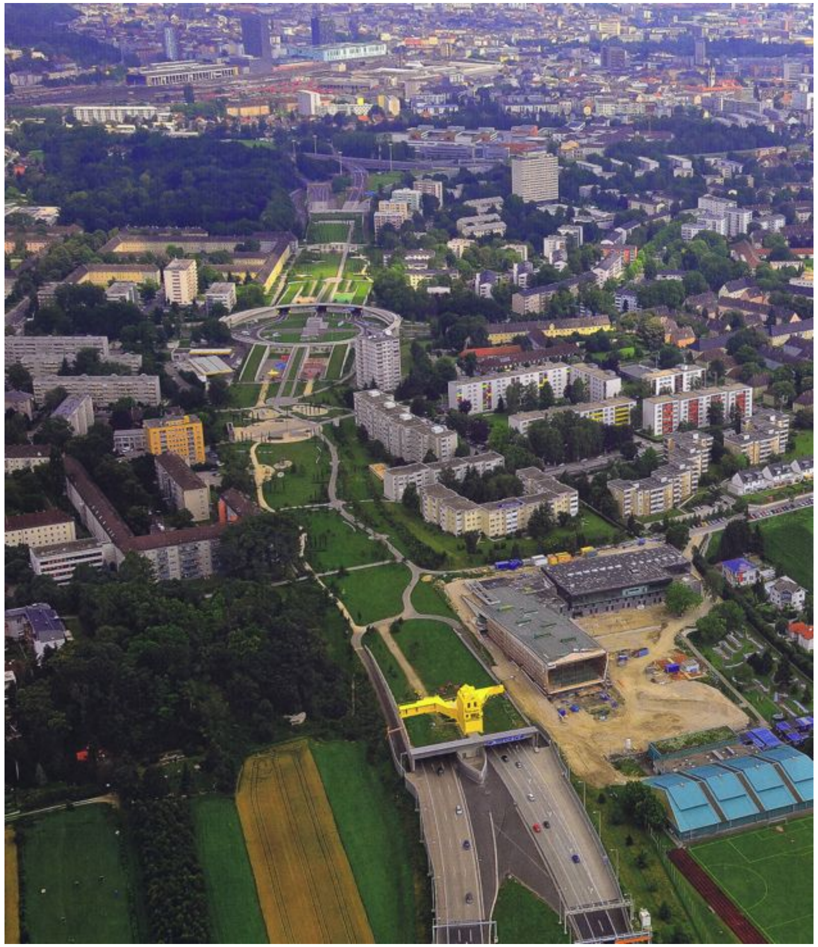
Movable hydroponic units
I.56
data origin: http://www.simplyhydro.com/system.htm 2012.3.2 1:21 PM
Howard M. Resh: Hydroponic Food Production, Routledge New York-London, 2004
George F. Van Patten: Hydroponic Basics, Van Patten Publishing 2004

Voest area, Linz, Austria
I.57



Regional conurbations, population density, Statistik Austria 2008
M.2
www.statistik.at 2011.3.23 1:57 PM

Voest area, Linz, Austria
I.58



Landscape park, highway A7, Linz, Austria
I.59
Bauwelt Issue 43 10. November 2010, Heimo Pertlwieser, Stadtplanung Linz

Location & building site

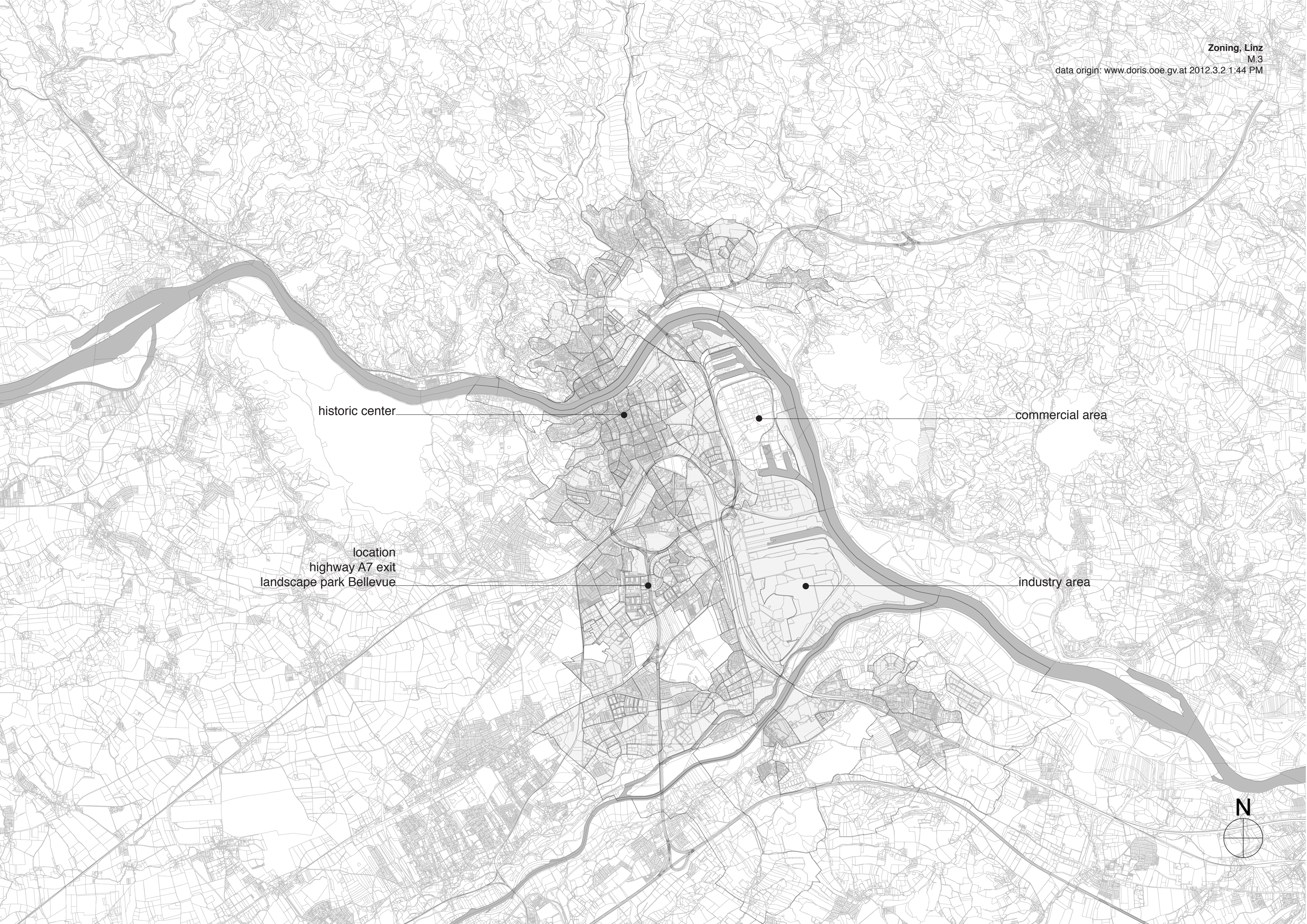
"In its role as European Capital of Culture, Linz can be the avant-garde of a new culture of interaction with nature. Especially as an industrial city that knows many of the problems typical as well for other cities can it do exemplary work for our further urban development. We need to realize that with the environmental problems we experience today we are just at the beginning. The world population will prospectively double again and this enormous demographic increase will according to all surveys happen all but exclusively in cities"
Helga Fassbinder interviewed by Elisabeth Wertmann 1

In 2009 Linz was the *European Capital of Culture*. Therefore many projects were realised to improve the attractiveness. Beside museums and a theatre a new railway station including an administration and business district was built. Even so Linz got a total refurbishment in the last decade, the image of the town is still dominated by industry. Linz is continuously changing its attitude and there is a potential awareness of culture and ecology. Since steel production isn't as dominant as in the last century, know-how is exported all over the world. Knowledge became a natural resource.

There are perfect conditions to establish an *urban farming* project in Linz. It is part of the Upper Austrian agglomeration (Linz-Wels-Steyr) with a population of about 460.000. Compared to other Austrian cities in, the town has got a small historic centre and the city structure is not as fragile. The urban situation is similar to other industry-dominated cities. Urban wastelands are generated by urban sprawl and traffic infrastructure.

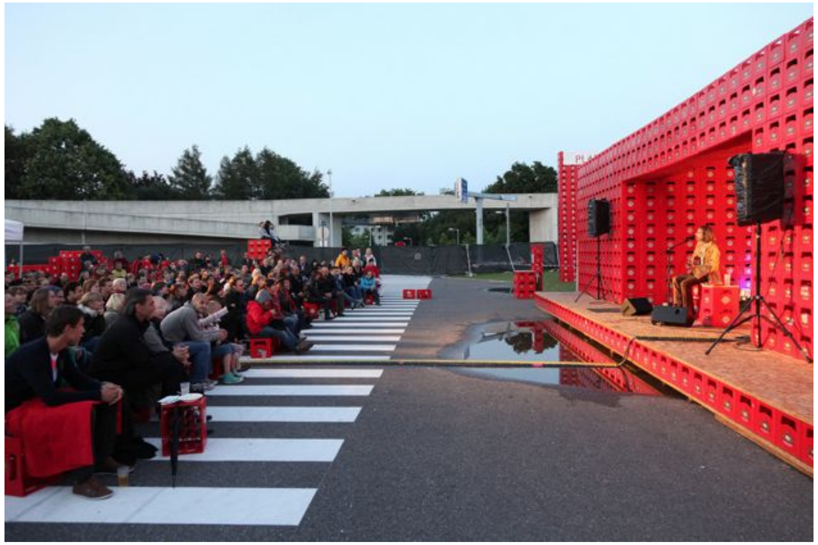
1 Helga Fassbinder interviewed by Elisabeth Wertmann, Österreichisches Wirtschaftsblatt 10.4.2009 http:/www.biotope-city.net/artikelen%20editie1/english/Fassbinder-Wertmann.engl.html 2010.12.3 2:44 PM

Highway A7, Linz, Austria
I.60



Zoning, Linz
M.3
data origin: www.doris.ooe.gv.at 2012.3.2 1:44 PM
historic center
commercial area
location
highway A7 exit
landscape park Bellevue
industry area
N

Fattinger, Orso, Rieper: Bellevue - Das gelbe Haus, Linz, Austria 2009
I.61
www.bellevue-linz.at 2012.3.3 6:51 PM Photo: Peter Fattinger



Fattinger, Orso: Deja-vue - Eine temporäre Bühne für den Alltag, Linz 2011
I.62
www.dejavu-linz.at 2012.3.3 6:54 PM Photo: eSeL.at

Urban growth is dominated by merging suburbs and vanishing city boundaries. The geometric town center has moved away from the historic district aside the Danube riverbank.
Employees are commuting to their work daily "discovering" the city by car. In the North-South direction highway A7 serves the region as its most important traffic arteria.

Because of noise exposure and air pollution it has been covered to enhance quality of living conditions of about 40.000 inhabitants. A new landscape park links Bindermichl and Spallerhof, two urban districts, which were separated for decades. But it is still a disappointing situation: A motorway exit in form of a traffic circle is cutting off the park abruptly. It's a *monolithic* barrier and *designed without any sense of humour.* [1]

The situation was soon discovered by cultural initiatives. A project by *Peter Fattinger* and friends named *Bellevue* was housing a temporary culture event at the southern end of the park. [2] It was part of the *Linz 09 European Capital of Culture* with a budget of 150.000 Euros. [3] For three months the yellow painted outlook platform and stage was highlighting an alternative image of Linz.
It was an acclaimed attraction, primarily serving the local population. After a break, *Peter Fattinger* came up with another project in summer 2011. [4] *Dejavue* was located in the center of the motorway exit, pointing out the precarious traffic situation.

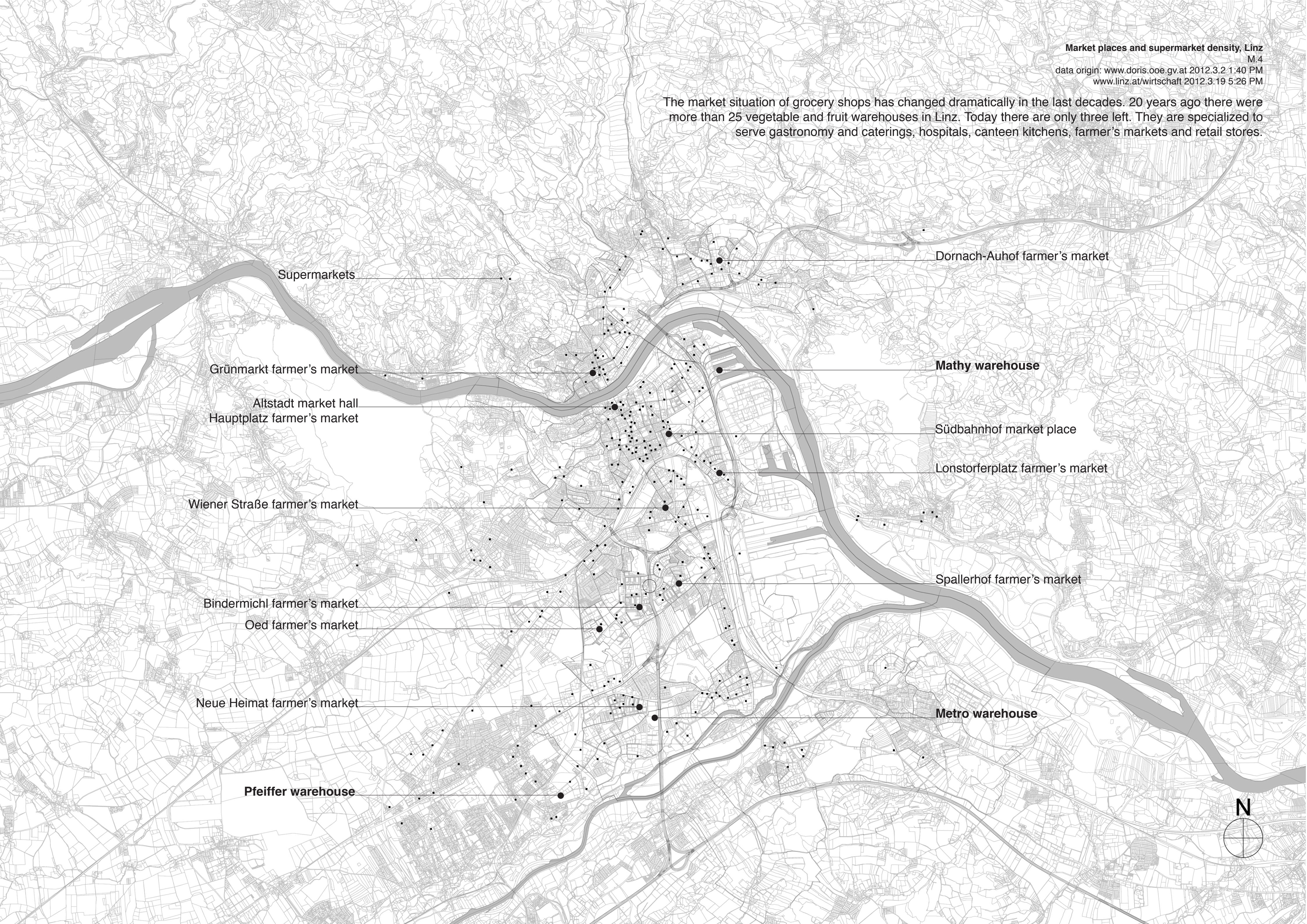
The center of the roundabout is an exemplary urban wasteland caused by traffic infrastructure. Meanwhile it is serving as a maintenance area for police operations and the highway service crew.
A project at this place can pick up elements from temporary cultural events to establish a long-term installation. It could provide access and serve as a local attractor, or operate like a sculpture, including some potential of ironic statement to the issue of roundabout decoration. It should meet the demand of a unique local solution but keep open the option to adapt similar urban situations.

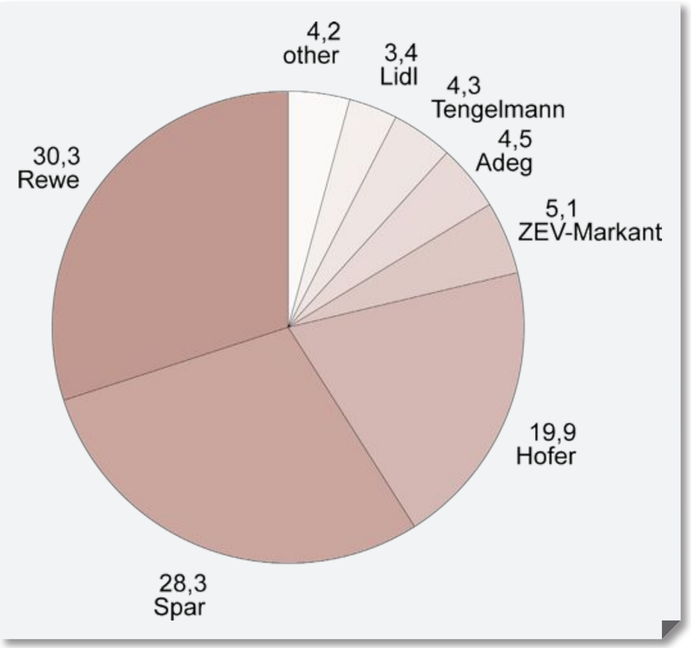
1, 3 Christian Kühn : Wo schlägt das Herz der Stadt?, Die Presse Print 11.Juli 2009
2 http://www.bellevue-linz.at 2012.3.3 6:51 PM
4 http://www.dejavu-linz.at 2012.3.3 6:54 PM

Highway exit at Bellevuepark, Linz, Austria
I.63

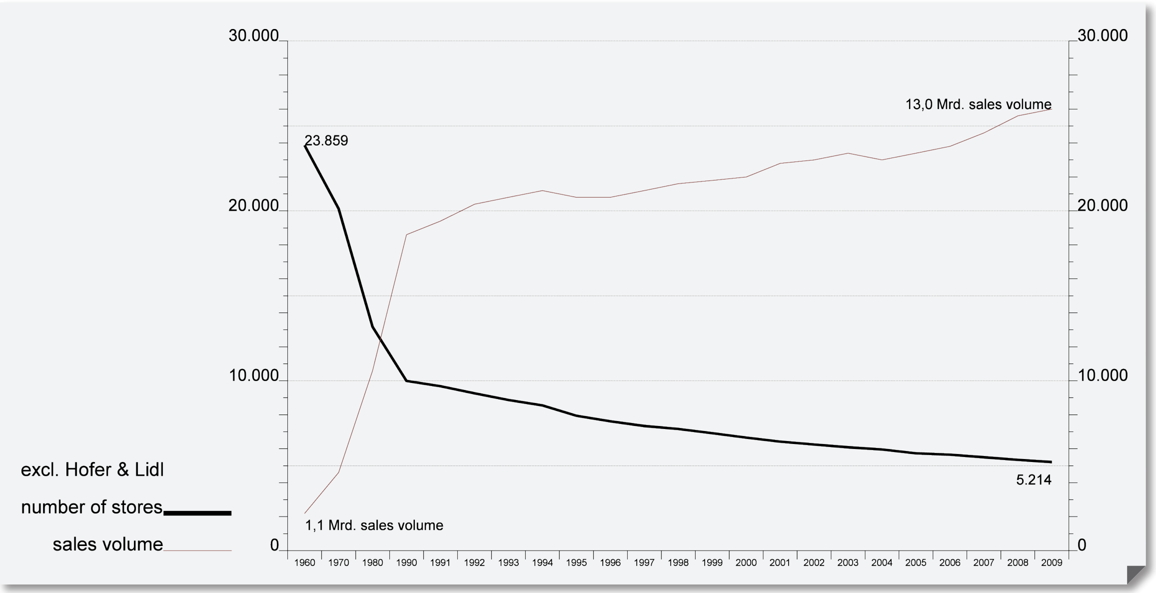
Market places and supermarket density, Linz
M.4
data origin: www.doris.ooe.gv.at 2012.3.2 1:40 PM
www.linz.at/wirtschaft 2012.3.19 5:26 PM

The market situation of grocery shops has changed dramatically in the last decades. 20 years ago there were more than 25 vegetable and fruit warehouses in Linz. Today there are only three left. They are specialized to serve gastronomy and caterings, hospitals, canteen kitchens, farmer's markets and retail stores.



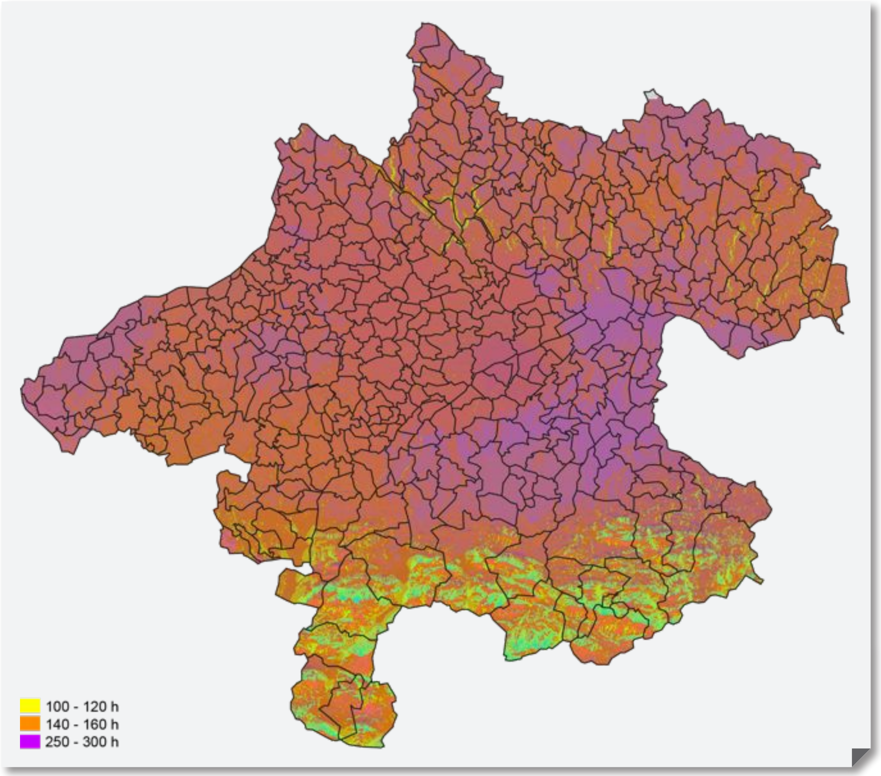


Food trade marked share, Austria Nielsen 2008
D.22
www.nielsen.com 2011.3.17 7:47 PM

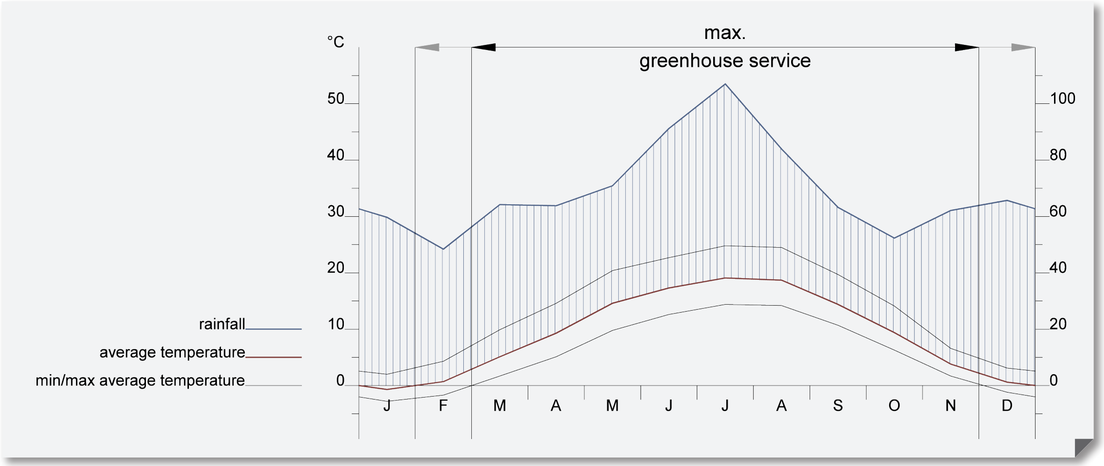


Food marked development, Austria Nielsen 2010
D.23
www.nielsen.com 2011.3.17 7:47 PM

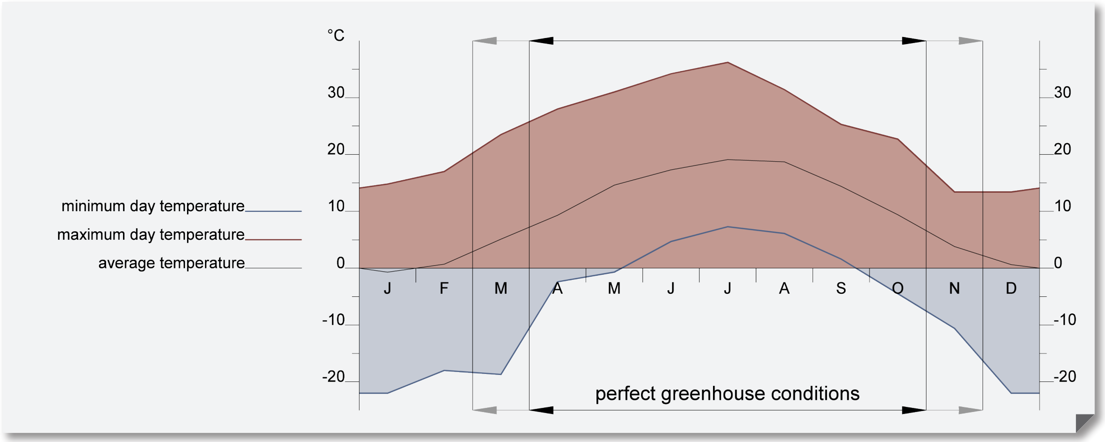
Linz, Austria: 1632 sun hours/year



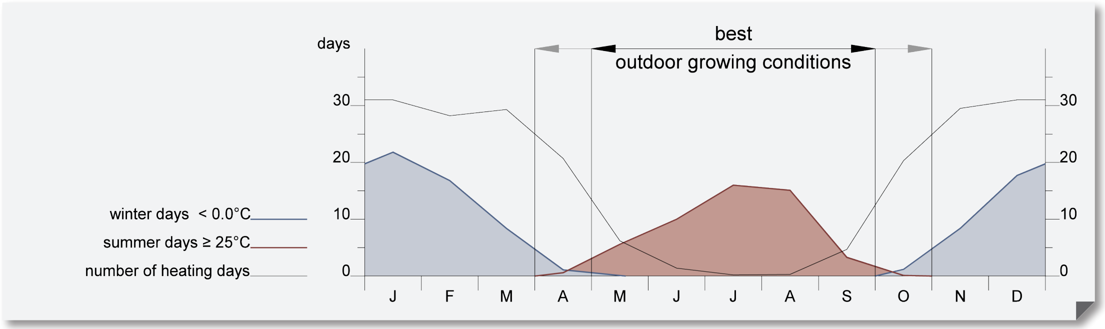
Sun hours per month, Upper Austria
M.5
www.doris.ooe.gv.at 2011.3.19 5:16 PM



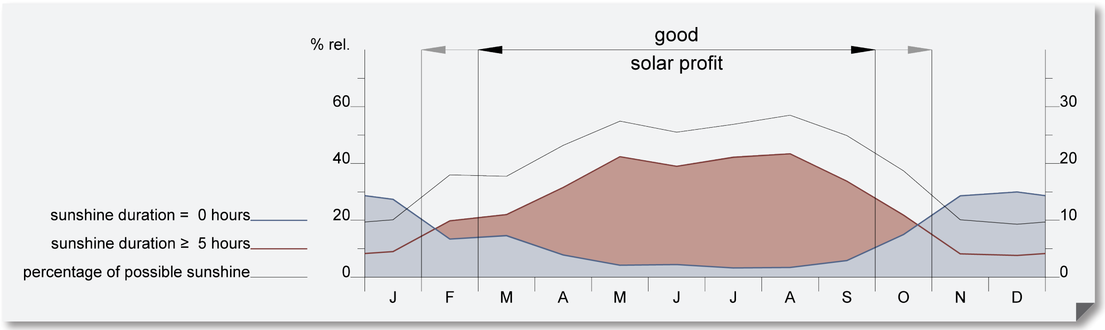
Climate chart, Linz
D.24
data origin: www.zamg.ac.at 2011.1.16 1:24 PM



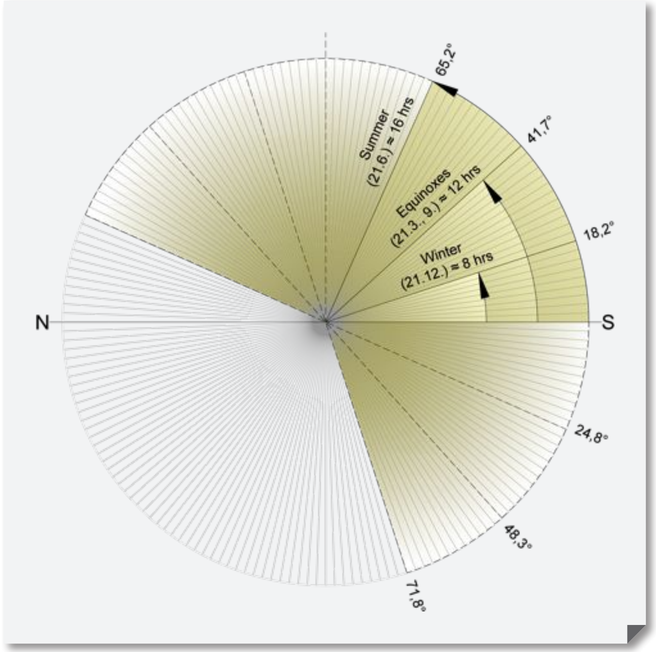
Extreme temperatures
D.25
data origin: www.zamg.ac.at 2011.1.16 1:24 PM



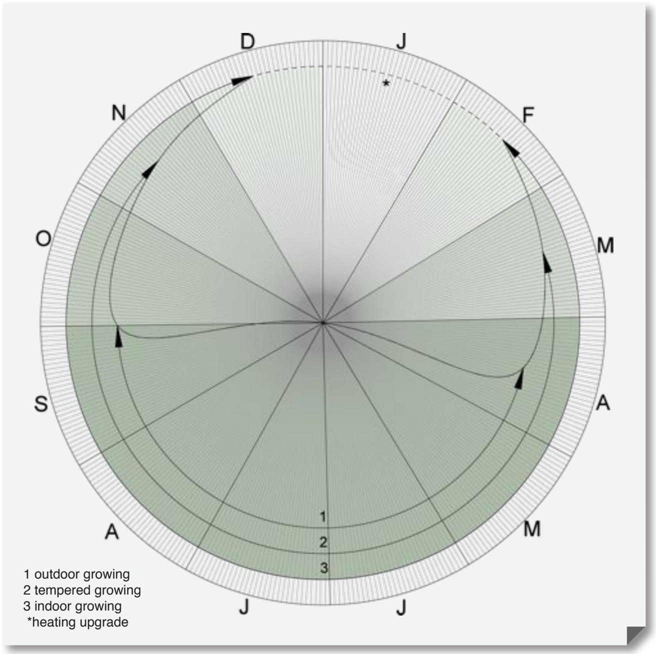
Heating days
D.26
data origin: www.zamg.ac.at 2011.1.16 1:24 PM



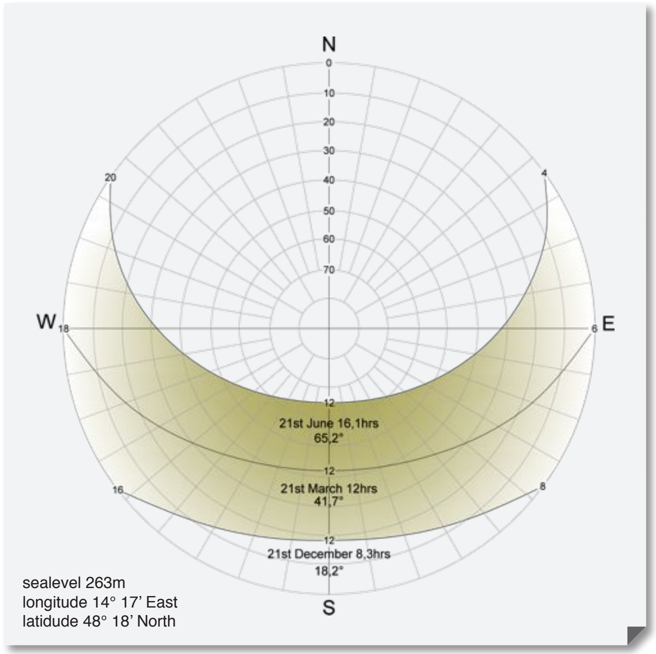
Sunshine
D.27
data origin: www.zamg.ac.at 2011.1.16 1:24 PM



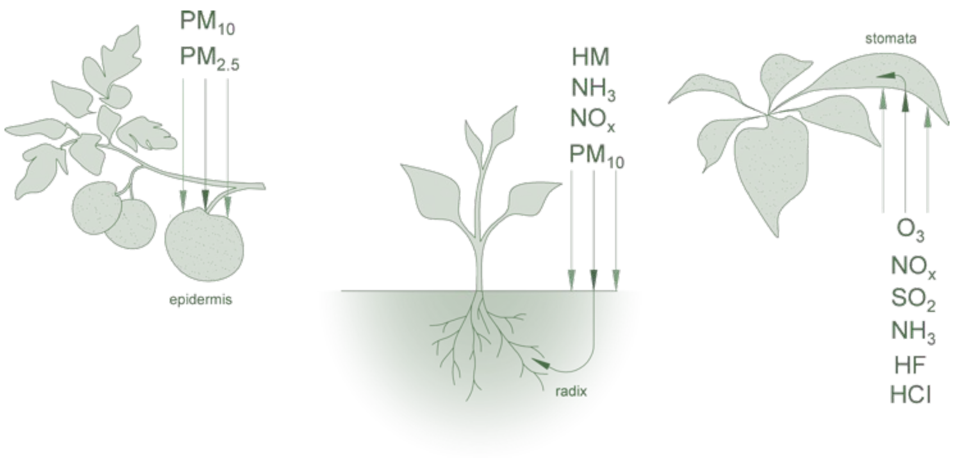
Perfect glass angle
D.30



Growing period
D.31



Sun diagram, Linz
D.32
data origin: www.stadtklima-stuttgart.de 2011.1.16 7:17 PM



Toxic air pollutants, impact on plants
I.64

		PAH	HM	PM_{10}	C_6H_6	CO	C_2H_4	HCl	NH_3	HF	C_mH_n	NO_x	O_3	SO_2
origin	industry	X	X	X		X	X	X		X		X		X
	households	X		X		X								
	traffic	X		X	X	X	X				X	X	X	
	agriculture			X					X		X			
toxic	human	X	X	X	X	X					X	X	X	X
	vegetation		(X)	(X)			X	X	X	X		X	X	X

Toxic air pollutants
T.5
data origin: www.land-oberösterreich.gv.at 2011.8.2 2:38 PM

Pollution & air quality monitoring

There is a large number of toxic emissions in urban regions. Most are caused by industry and traffic. In the last years target values have been regulated by laws, in the first instance to ensure human health conditions and to protect vegetation and ecosystems.

Particulate matter (PM10, PM2.5) consists mostly of traffic exhaust and tire particles and is spread widely far from point of origin. 1 It is an aim to analyze the impact on urban farming and how residues contaminate crops. Gases like ozone (O_3) and sulphur dioxide (SO_2) are inhaled through leaves and harm the growing process or make plants losing their leaves. 2 Nitrogen oxides (NO_x) can contaminate soil and are toxic if inhaled by plants. 3 Heavy metals can be absorbed by the plant. Even though lead in fuel has been prohibited for years and industry now has to clean emissions by converters, foodstuff have still to be observed by regulations and controls.

Toxic soil contaminants (heavy metals) 4

- Pb lead
- Cr chrome
- Ni nickel
- Zn zinc
- Cd cadmium
- Cu copper
- Hg mercury

Contaminants in foodstuffs (heavy metals) 5

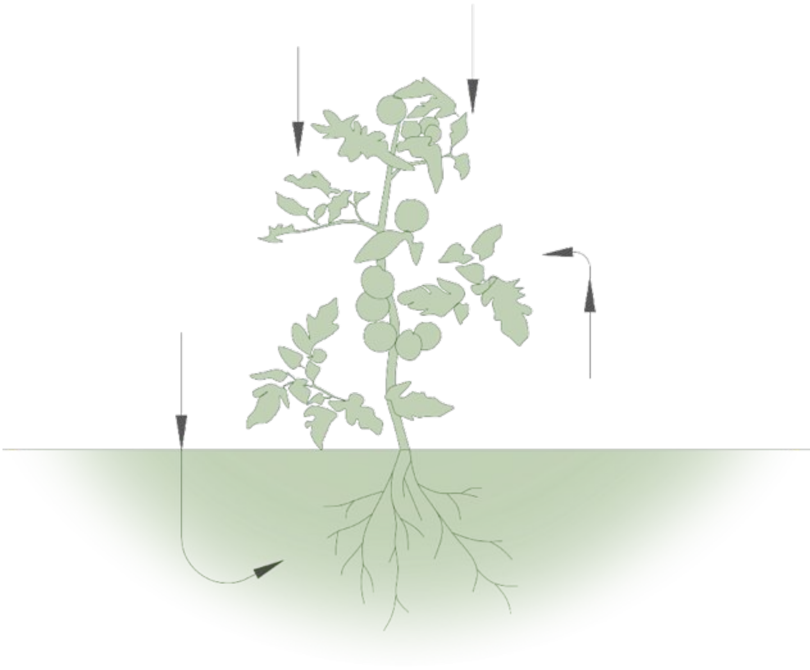
Pb Lead:
Cereals, legumes and pulses, vegetables, potatoes, brassica vegetables, leaf vegetables and cultivated fungi, fruit, berries and small fruit

Cd Cadmium:
Cereals, bran, germ, wheat and rice, soybeans, vegetables and fruit, leaf vegetables, fresh herbs, cultivated fungi and celeriac, stem vegetables, root vegetables and potatoes

1, 2, 3 Dr. Igor Roblek: Verkehr und Mobilität in den Alpen, Ständiges Sekretariat der Alpenkonvention, Innsbruck, Austria 2007

4 Oö. Bodengrenzwertverordnung 2006: Toxic soil contaminants (heavy metals) http://www.ris.bka.gv.at/Dokumente/Lgbl/LGBL_OB_20060529_50/LGBL_OB_20060529_50.pdf 2011.10.2 1:48 PM

5 Commission regulation (EC) No 1881/2006: setting maximum levels for certain contaminants in foodstuffs
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:364:0005:0024:EN:PDF 2011.10.2 2:56 PM



Air and soil pollutants, impact on plants
I.65

Council directive 1999/30/EC
relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:163:0041:0060:EN:PDF 2011.9.2 1:55 PM

Directive 2000/69/EC of the European parliament and of the council
relating to limit values for benzene and carbon monoxide in ambient air
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:313:0012:0021:EN:PDF 2011.9.2 2:23 PM

Directive 2004/107/EC of the European parliament and of the council
relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:023:0003:0016:EN:PDF 2011.9.2 3:12 PM

Directive 2002/3/EC of the European parliament and of the council
relating to ozone in ambient air
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:023:0003:0016:EN:PDF 2011.9.2 4:52 PM

List of important air pollutants:

SO_2 sulphur dioxide (Schwefeldioxid)
origin: carbon and oil combustion, industry
toxic: human, vegetation
- limit values for human health and the protection of ecosystems (directive 1999/30/EC)

O_3 ozone (Ozon)
origin: traffic (sunlight + NOx + hydrocarbon)
toxic: human, vegetation
- target values for human health and the protection of vegetation (directive 2002/3/EC)

NO_X (NO, NO_2)nitrogen oxides (Stickoxide) > ozone
origin: power plant, traffic
toxic: human, vegetation
- limit values for human health and the protection of vegetation (directive 1999/30/EC)

C_mH_n hydrocarbon (Kohlenwasserstoffe) > ozone
origin: agriculture, traffic
toxic: human

HF hydrofluoric acid (Fluorwasserstoff)
origin: industry
toxic: vegetation

NH_3 ammonia (Ammoniak)
origin: agriculture
toxic: vegetation

C_2H_4 ethene (Ethen)
origin: industry, traffic
toxic: vegetation

HCI hydrogen chloride (Chlorwasserstoff)
origin: industry
toxic: vegetation

CO carbon monoxide (Kohlenmonoxid)
origin: households, traffic (tunnels garages), industry toxic: human
- limit values for human health (directive 2000/69/EC)

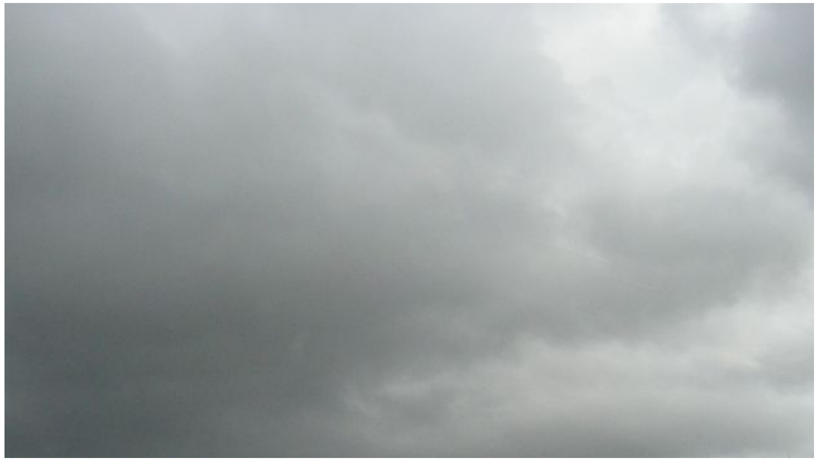
C_6H_6 benzene (Benzol)
origin: traffic
toxic: human
- limit values for human health (directive 2000/69/EC)

PM10 PM2,5 particulate matter (Feinstaub)
origin: industry, traffic, households, agriculture
toxic: human
- limit values for human health (directive 1999/30/EC)

Heavy metals (Schwermetalle) > PM10
origin: industry
toxic: human
- limit values for human health (lead) (directive 1999/30/EC)
- target values (arsenic, cadmium, nickel, benzo(a)pyrene) (directive 2004/107/EC)

PAH polycyclic aromatic hydrocarbons (Polyzyklische aromatische Kohlenwasserstoffe) > PM10
origin: households, power plants, traffic, industry,…
toxic: human

Were these tomatoes treated with CO_2 enrichment?
I.66



Is air pollution a big issue on horticulture?
I.67

Air quality is monitored by the government. There is a high number of stations next to highways, in urban regions and on countryside. The measuring data implicates that air quality in urban agglomerations is not as good as in rural regions. But airflow (wind exposure) may cause circulations all over urban space. Air pollutants can't be located exactly to their point of origin. Sometimes there is less air pollution next to a frequented traffic route than in the rest of the city.

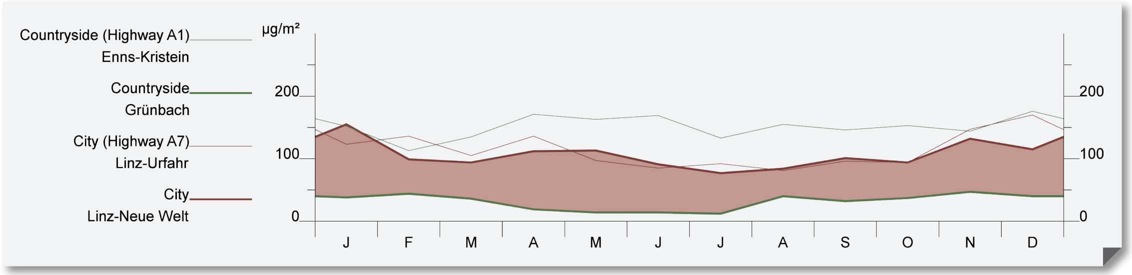
Nevertheless, during my research I was not able to find any law, regulating air emissions caused by traffic or industry in connection with contaminating vegetables. Therefor I got in touch with the Austrian Agency for Health and Food Safety (AGES), the University of Natural Resources and Life Sciences Vienna (BOKU), and the office of Rudi Anschober of the provincial government of Upper Austria concerning environment and consumerism issues.

My personal summary is, that meat industry seems to be by far more regulated than vegetable production. Food safety monitoring is a wide subject, concentrating on the prevention and control of diseases in plants, animals, and humans. [1] It is not prohibited to grow foodstuff along highly frequented highways. Nevertheless carbon dioxide emissions can be a benefit for plant cultivation, considering that some greenhouses are extra enriched with carbon dioxide by gas or fuel burners. Vegetables imported from abroad are largely uncontrollable. It is desirable to point out that sensitive topic.

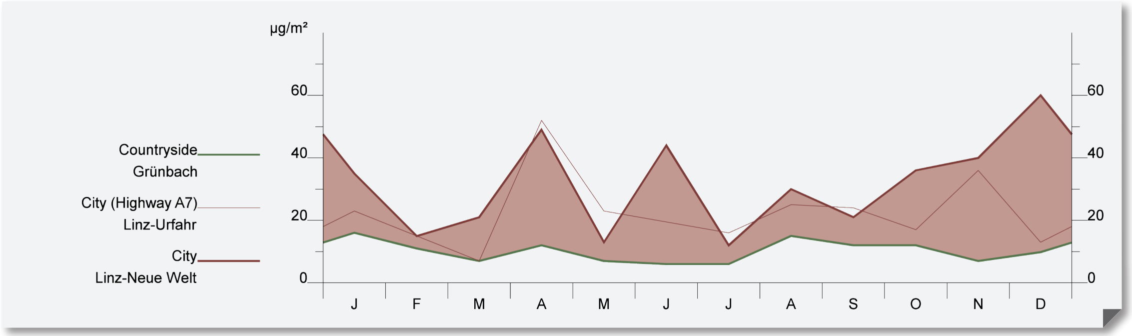
"CO_2 enrichment to 750-800 µmol/mol increases yields by 30% compared with standard outside conditions (about 340 µmol/mol)." [2]

1 http://www.ages.at/ages/en/ages-austrian-agency-for-health-and-food-safety/ 2012.3.13 10:53 AM
2 E. Heuvelink: Tomatoes, Crop Production in Horticulture, CABI Publishing Oxfordshire, UK 2005

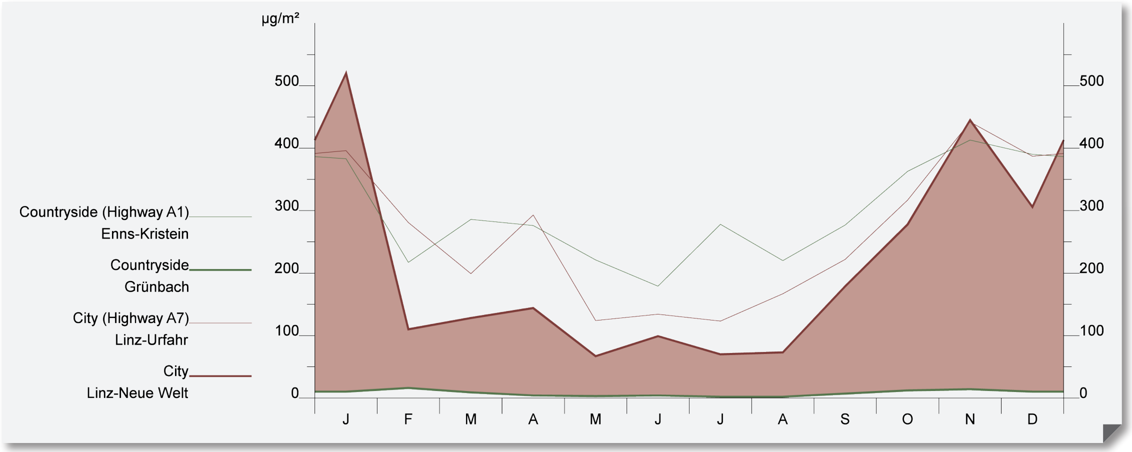

Grünbach (countryside)
Selection of air control points, Linz
M.6
data origin: www.doris.ooe.gv.at 2012.3.2 1:32 PM
Linz-Urfahr (city-highway A7)
Linz-Neue Welt (city)
N
Enns-Kristein (countryside, highway A1)



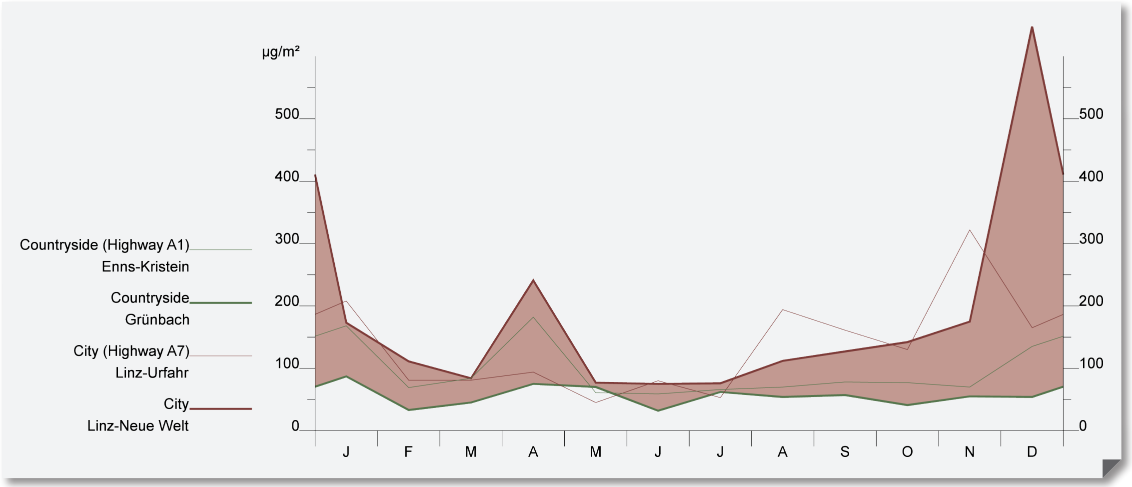
NO_2 nitrogen dioxide, max. monthly average
D.33
data origin: www.land-oberoesterreich.gv.at 2011.2.17 11:26 AM



SO_2 sulphur dioxide, max. monthly average
D.34
data origin: www.land-oberoesterreich.gv.at 2011.2.17 11:26 AM

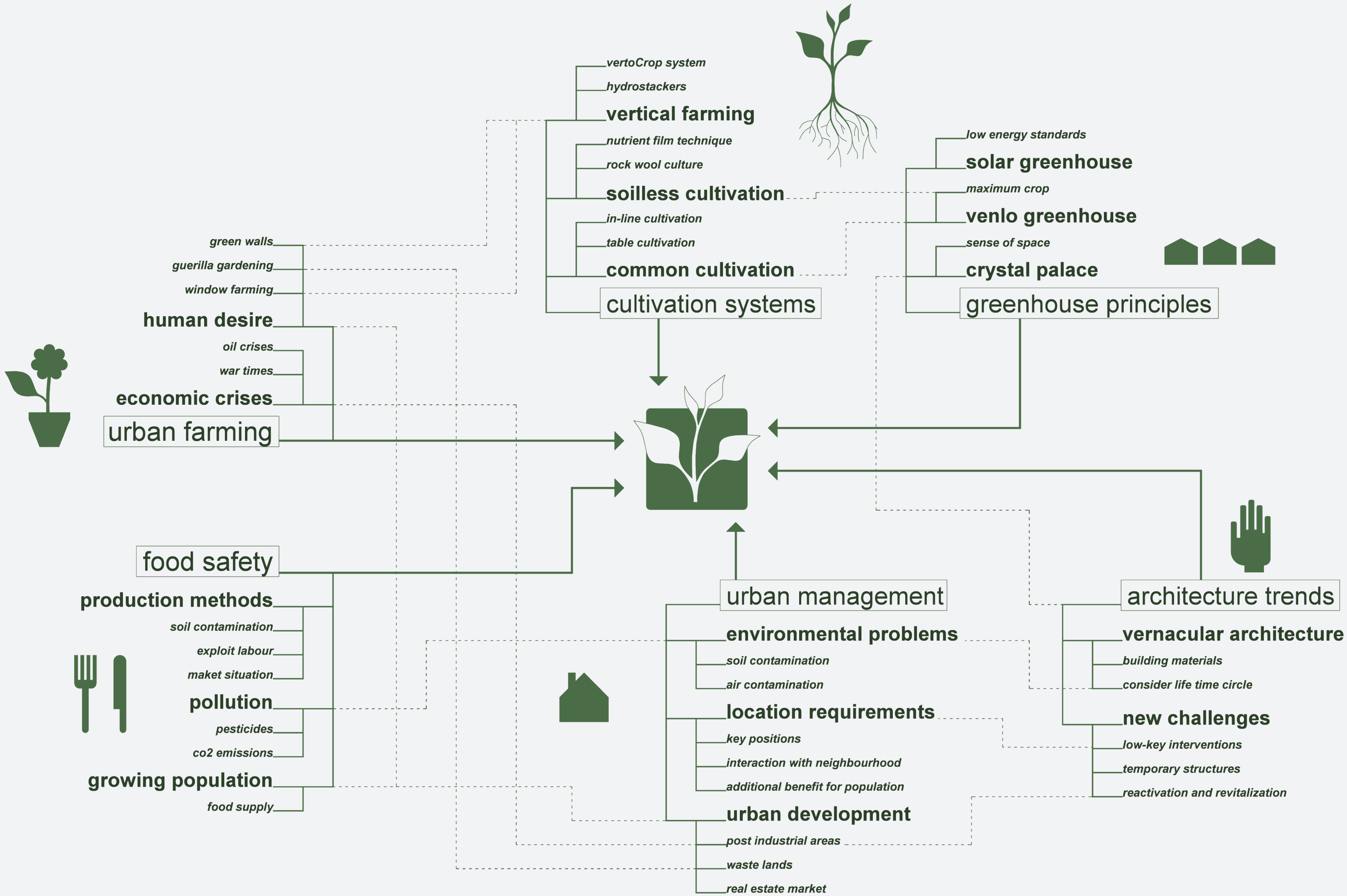


NO nitrogen monoxide, max. monthly average
D.35
data origin: www.land-oberoesterreich.gv.at 2011.2.17 11:26 AM



PM10 particular matter, max. monthly average
D.36
data origin: www.land-oberoesterreich.gv.at 2011.2.17 11:26 AM

O_3 ozone, max. monthly average
D.37
data origin: www.land-oberoesterreich.gv.at 2011.2.17 11:26 AM



Influences on design process

Design strategies

"Ideally, vertical farms should be cheap to build, modular, durable, easily maintained, and safe to operate. They should also be independent of economic subsidies and outside support once they are up and running, which means they should also generate income for the owners."

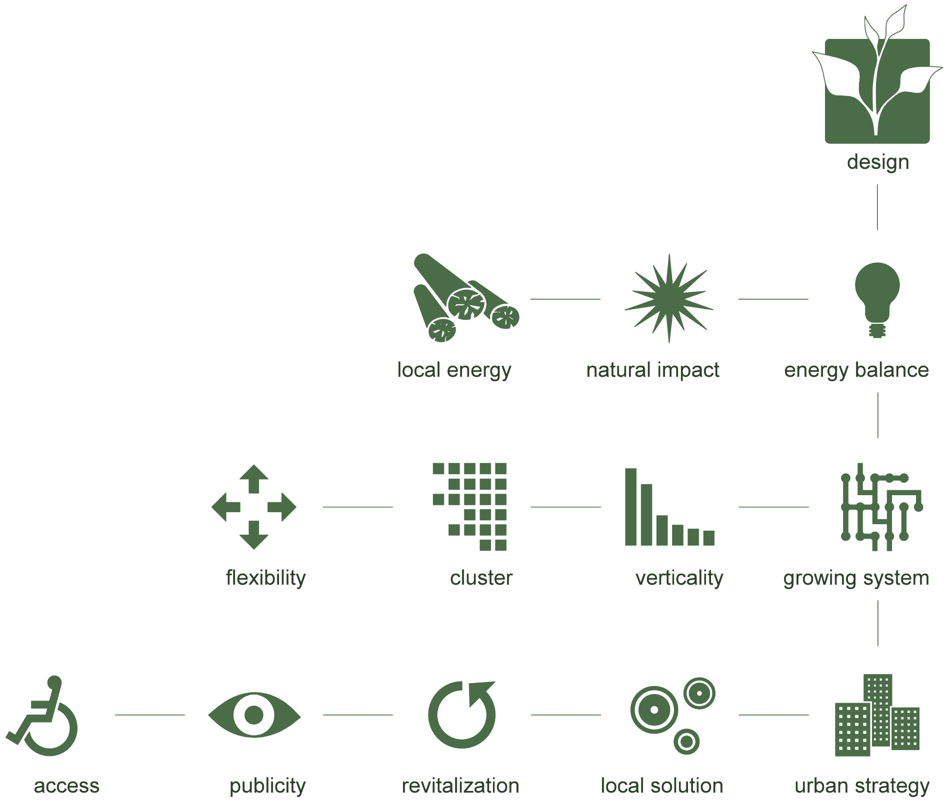
Dickson Despommier about desirable attributes to vertical farming 1

This scheme has the ambition to develop its own aesthetics without any "fashionable" demand. It should help to establish farming in an urban context. It is a link between small initiatives and large scale visions of vertical farming. Therefore area-based common agriculture has to be transformed to vertical by considering greenhouse principles and the impact of urban soil contamination. Beside developing technology and serving fresh vegetables, the design broaches the issue of land consumption caused by traffic, using existing infrastructure and revitalizing urban wastelands.

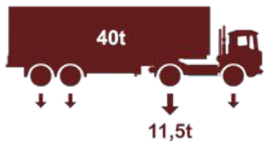
My ambition is to create architecture which will deal with the local urban situation, the requirements of human needs, and the requirements of growing plants by maintaining the traffic situation and providing access. Focusing the process from breeding to harvesting, the building has to act like a machine. It is desirable to provide an efficient and flexible growing system and to adapt existing hydroponic technologies for soilless growing, bearing in mind different growing heights of plants and their demands.

It is important to consider plant schedules, to house different climate zones for breeding and cultivation and to include the vacancy of building parts during winter months for an energetic efficient building shape. A year-round service is possible reverting to the natural impact of solar radiation and local energy sources. Beside using the principles of natural ventilation it is my ambition to adapt the building to the environment without any special modifications. As a consequence a trackless deconstruction should be possible.

The sensitive building site is characterized by a tricky bearing structure because of the highway tunnel in the underground. Loads should be equally spread around the site and dimensioned for truck loads as a maximum.

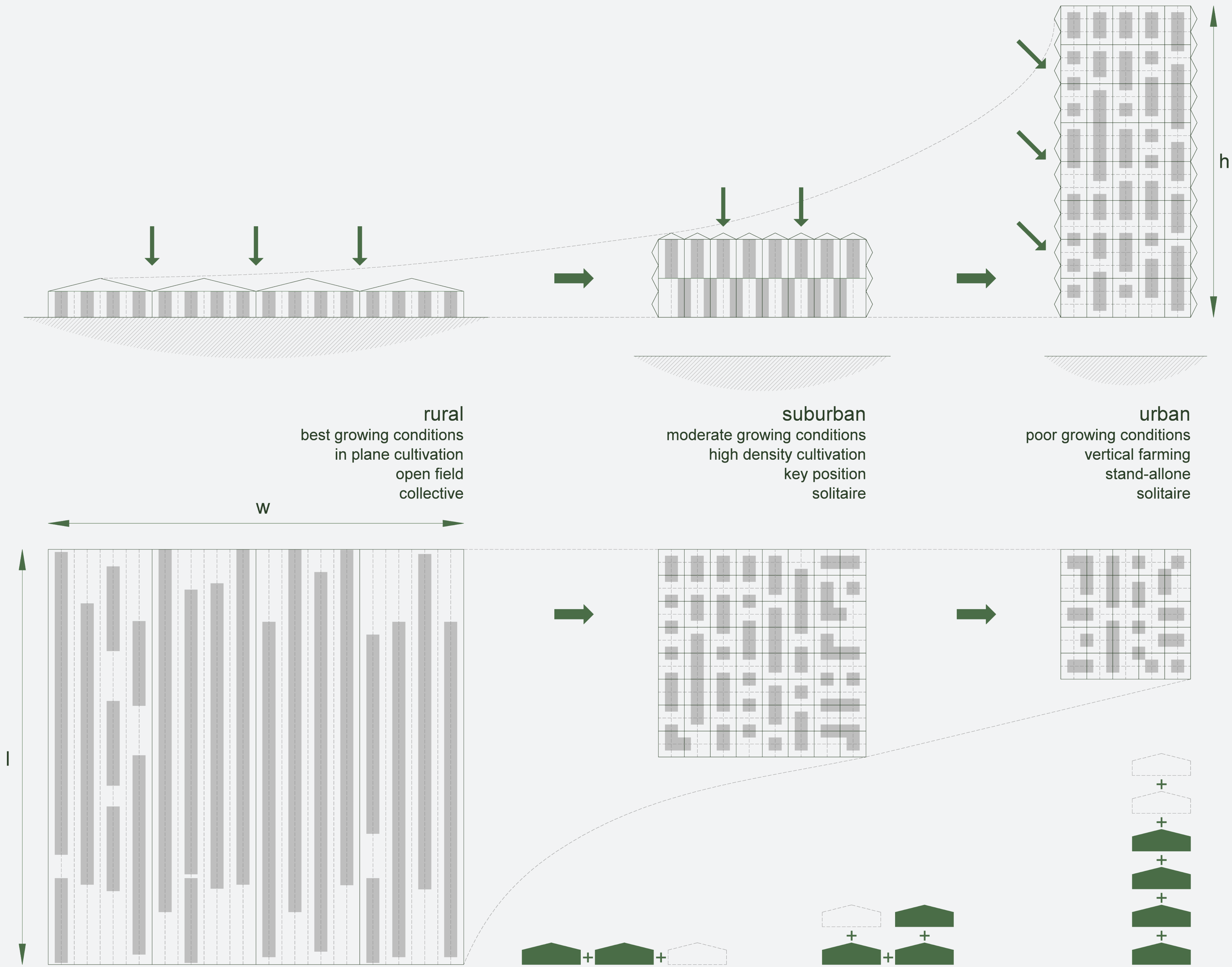


Design strategies
I.69



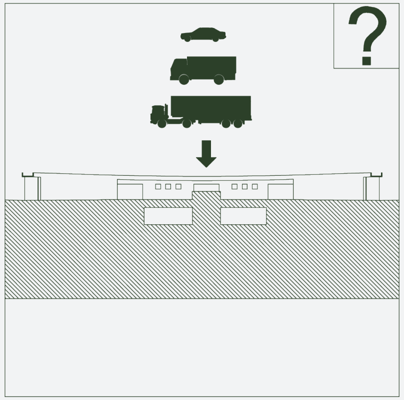
Truck loads
I.70

1 Dickson Despommier: The Vertical Farm, Feeding The World in the 21st Century, Thomas Dunne Books 2010

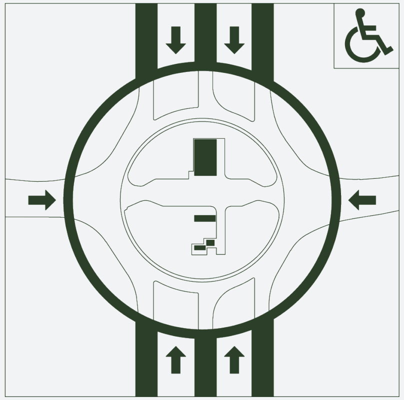


Urban transformation of greenhouse architecture

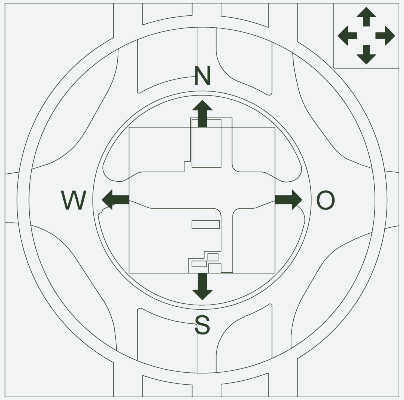
Bellevuepark, Linz
P.1



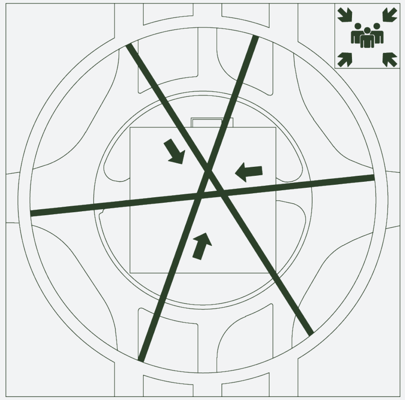
0.1 maintain traffic situation



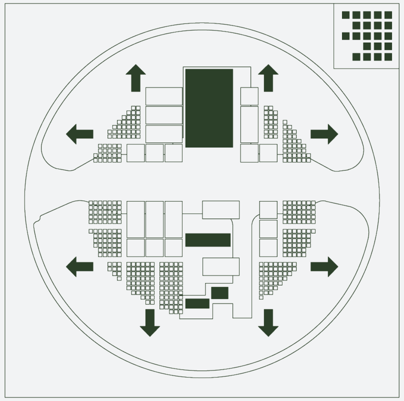
0.2 provide access



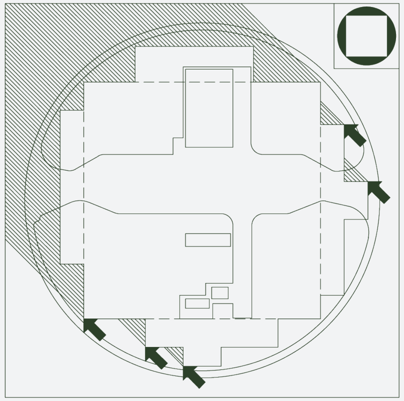
0.3 adjust orientation



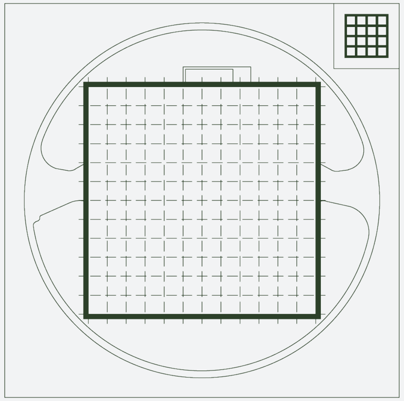
0.4 create attractor



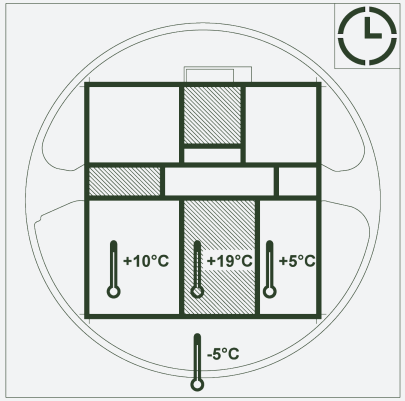
1.1 flexible utility level



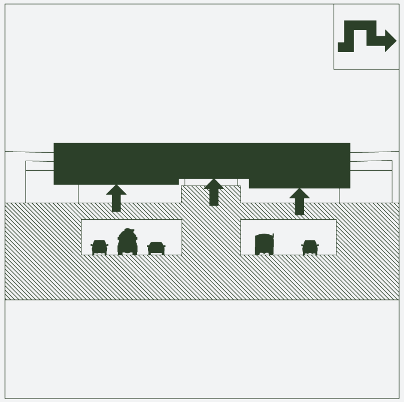
1.2 finding energetic shape



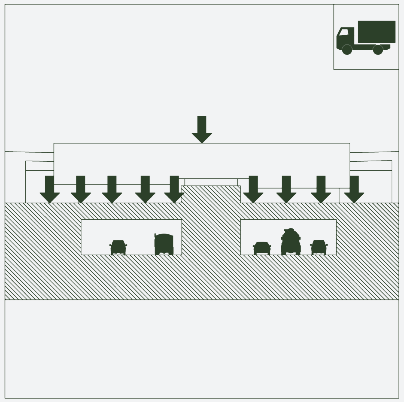
1.3 efficient separation grid



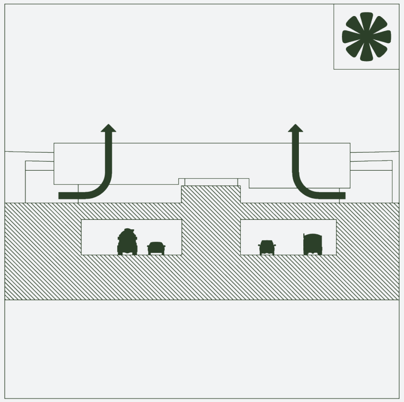
1.4 different greenhouse service



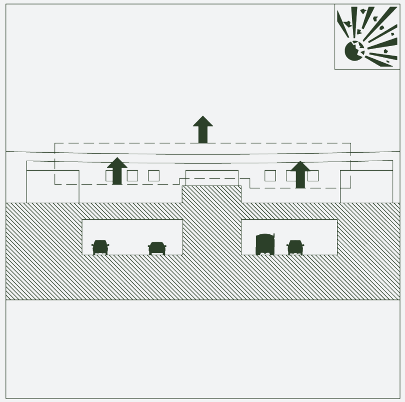
2.1 adaptation to environment



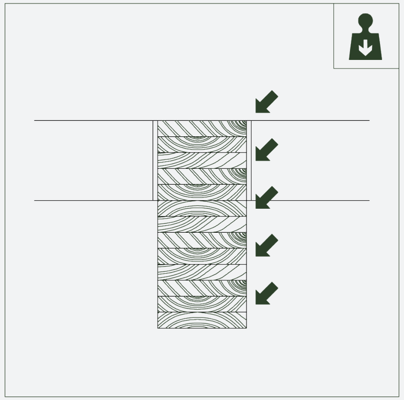
2.2 constant load distribution



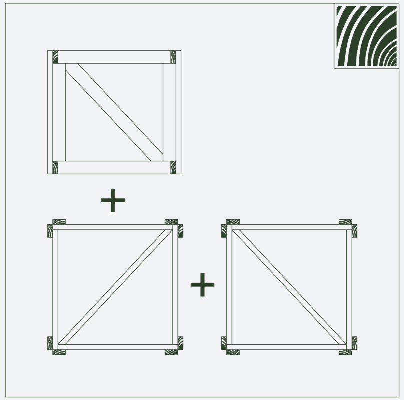
2.3 natural ventilation



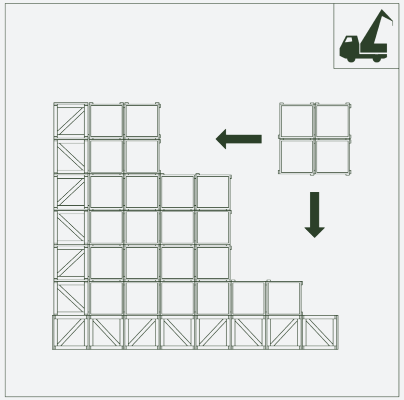
3.4 trackless deconstruction



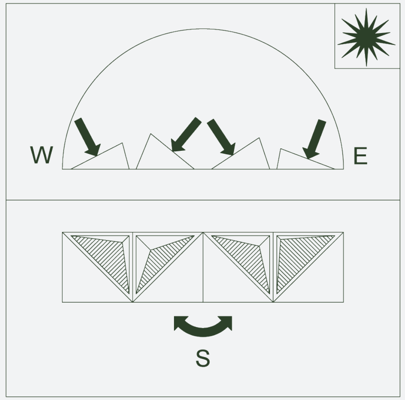
4.1 lightproof gluelam trusses



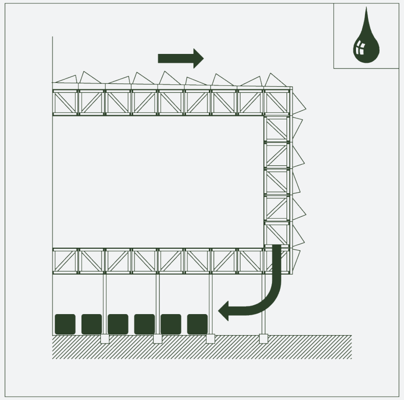
4.2 ordinary timber framing



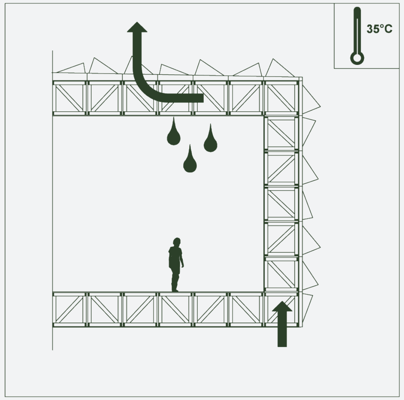
4.3 prefabrication



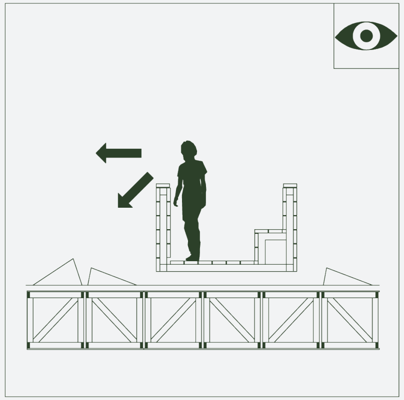
4.4 maximum solar radiation



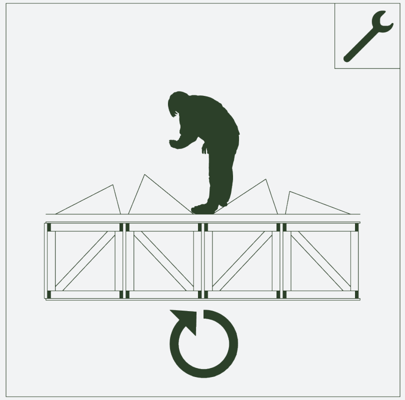
5.1 rainwater management



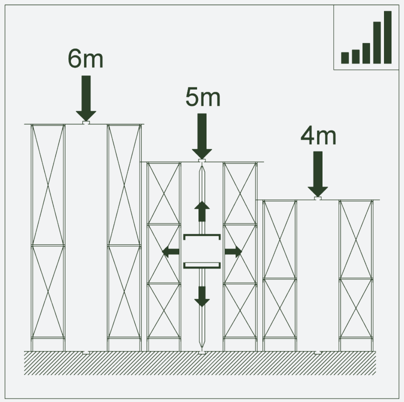
5.2 double-walled construction



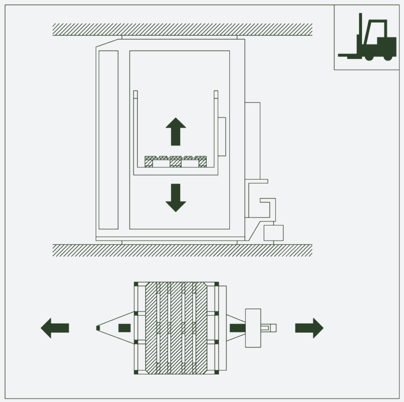
5.3 public roof access



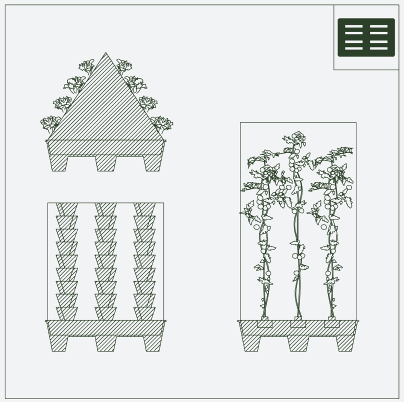
5.4 removeable gladding elements



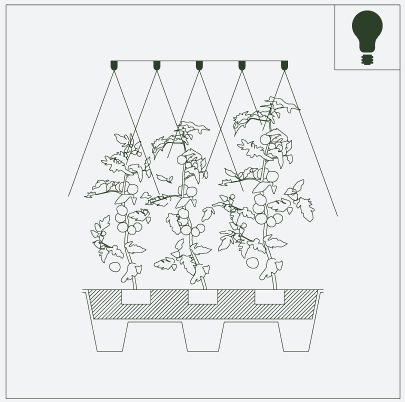
6.1 high-bay rack system



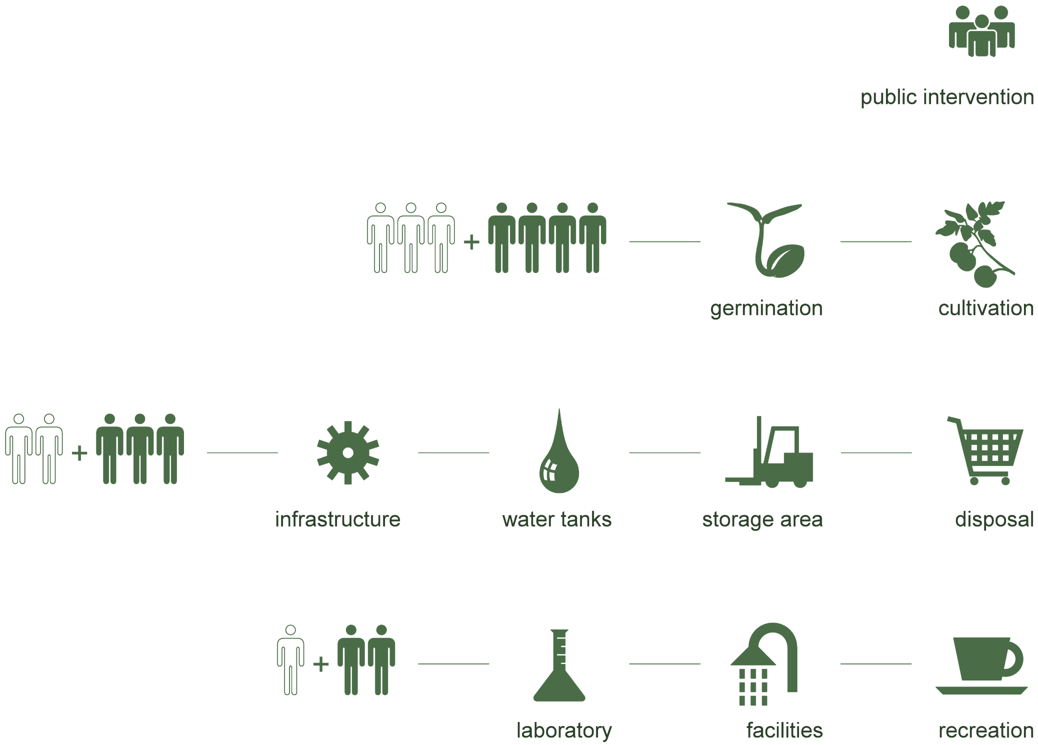
6.2 automated forklift



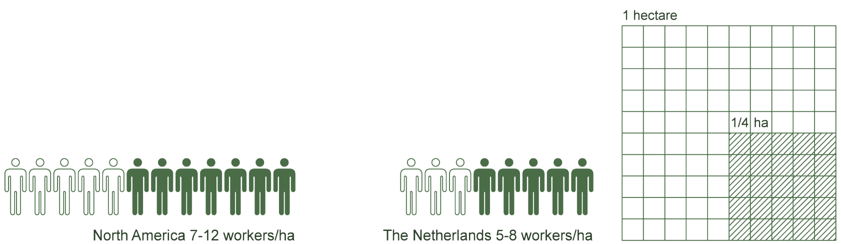
6.3 moveable growing units



6.4 LED-supported illumination



Building performance and employees
I.72



Workers per ha greenhouse cultivation
I.73
data origin: E. Heuvelink: Tomatoes, Crop Production in Horticulture, CABI Publishing Oxfordshire, UK 2005

Design & building performance

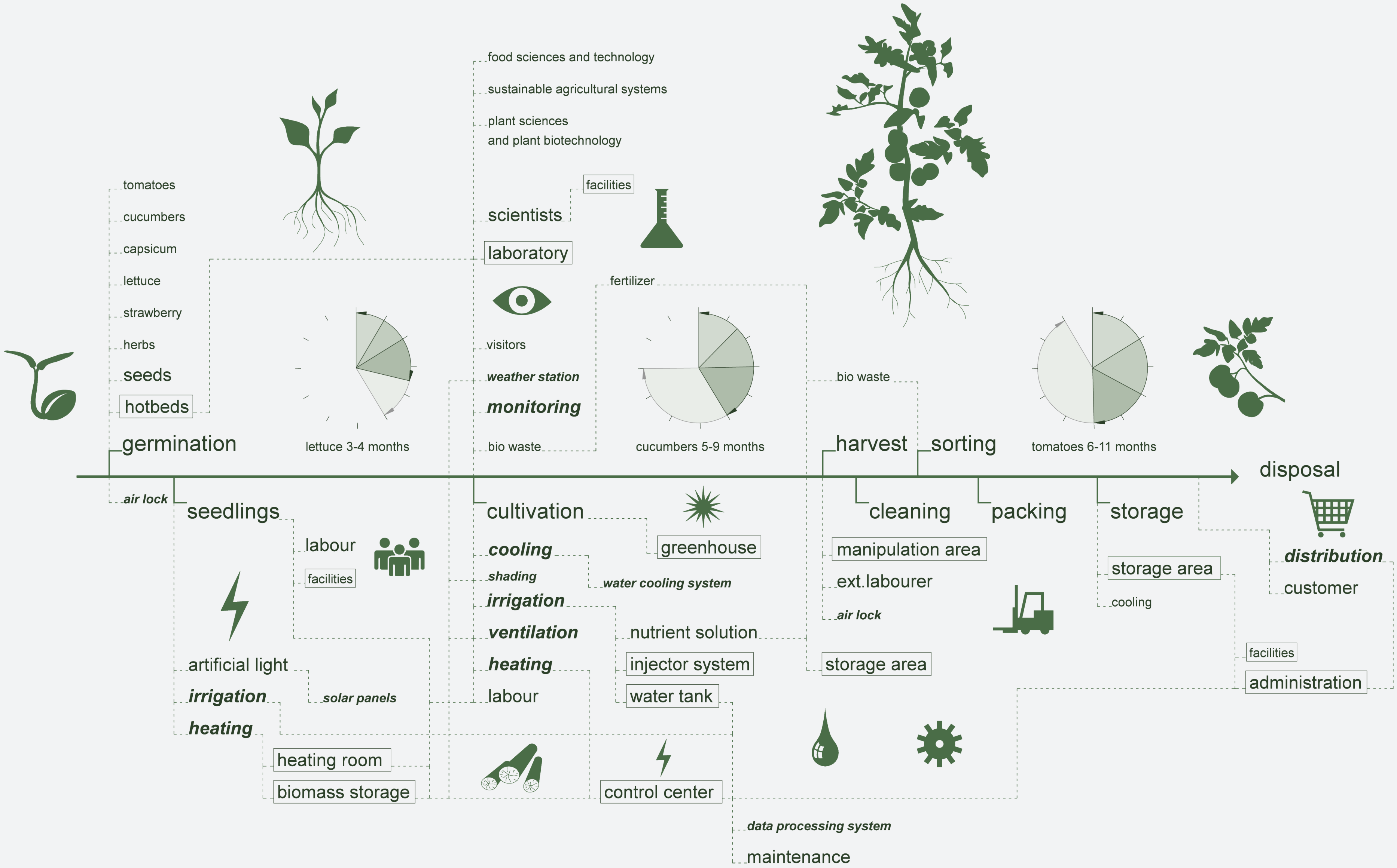
The building is housing two basic functions, coexisting in a symbiosis. A lifted greenhouse and a catwalk system.
There is a flexible and extendable utility level on the ground-floor, surrounded by the roundabout and covered by an adapted greenhouse. The catwalks are serving as a local attractor. They look simple at the first sight. But they offer public access to the roof and make it discoverable. Crossing the roundabout visitors can monitor cultivation on footpaths, or they just take a shortcut. The catwalks interact with greenhouse circulation and consolidate the connection to the surrounding. Without causing any damage, the timber structure is using the concrete balustrade in a parasitic way.

Considering light efficiency, gluelam trusses are unprofitable. A modular rigid timber framework is transparent, can be prefabricated and used for wall, floor and ceiling constructions. It serves as well as a host for infrastructure (heating, irrigation and rainwater pipes). Rainwater is collected and goes down to a modularly expandable water tank system on the ground level.

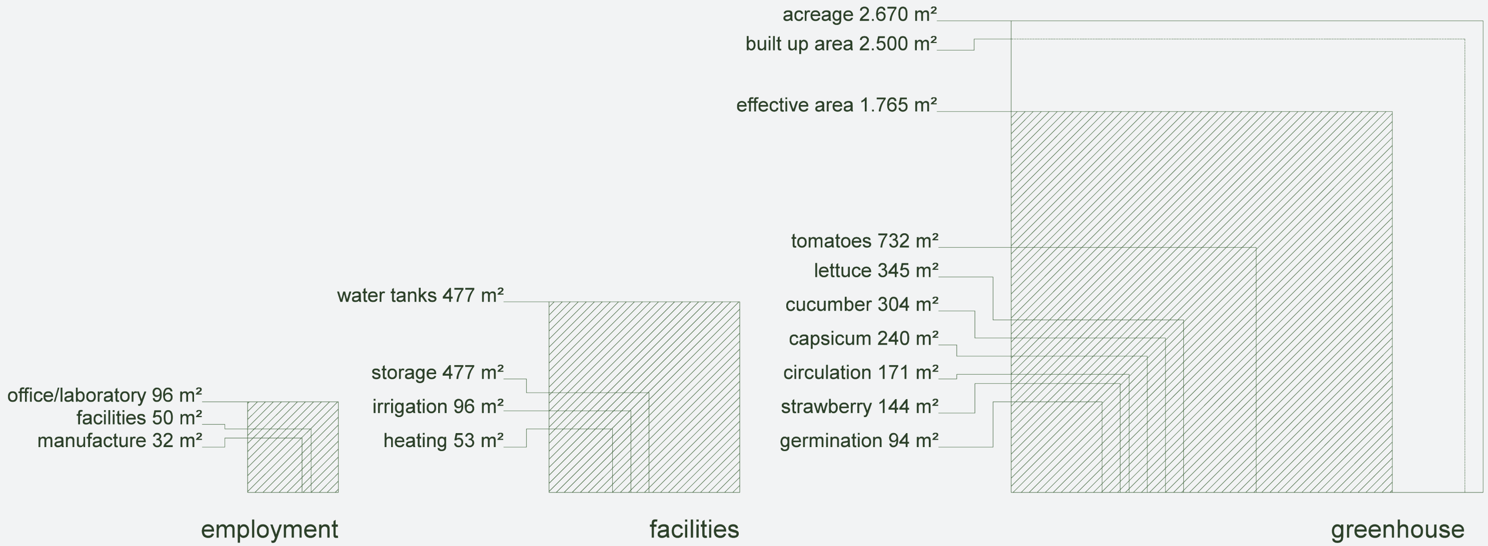
A solar skin with removable cladding elements covers the construction. Materials and technologies (solar panels) can be replaced. The basic pattern consists of a variety of slopes for year-round and all-day-long sun penetration. The elements are housing a mirror system and louvres. The double walled skin with an air space in between is ventilated to protect the framework from condensation and moisture.

The cultivation system is an adapted high bay storage rack system and fits to the different greenhouse heights for cultivating well-known and popular crops. Growing units relate to euro-pallets, which are moveable, multifunctional, and space-saving. Tomatoes, cucumbers and capsicums are cultivated in rock wool culture, lettuce with nutrient film technique and strawberries in column culture. Growing units are supported by artificial illumination to enable growing on a multi-level based cultivation.

My ambition is to serve about 1% of the population of the city (1.893). All space program calculations base on yield and consumption values to cover a built-up area of about 2.500m² (50m x 50m).



Building performance diagram: germination to disposal
I.74



(built up area x corridor x crop factor x yield) / consumption ~ 1.893

calculation example tomato supply: (732 m² x 0,55 x 2 x 56 kg/m²) / 25,3 kg/y = 1.782

built up area > 8%
crop factor 4
acreage 12 %
consumption 4,1 kg/y
yield 22 kg/m²
strawberry

built up area > 14%
crop factor 2
acreage 10 %
consumption 4,9 kg/y
yield 32 kg/m²
capsicum

built up area > 17%
crop factor 2
acreage 13%
consumption 6,4 kg/y
yield 35 kg/m²
cucumber

built up area > 20%
crop factor 5
acreage 36 %
consumption 9,7 kg/y
yield 19 kg/m²
lettuce

built up area > 41%
crop factor 2
acreage 30 %
consumption 25,3 kg/y
yield 56 kg/m²
tomatoes

(consumption*population) / yield = acreage

(acreage / crop factor) + 45%(corridor) = built up area

assumed supply ~ 1% population
(~1.893)

A B C stock	built up area	greenhouse	heating	
	[m²]	[m²]	[m²]	
	area [m²]		Area [%]	
	16		3	
2	32	732	22	tomatoes
1	16	304	9	cucumbers
1	16	240	7	capsicums
1	16	345	10	lettuce*
1	16	144	4	strawberry
	96	(5 %)	**53**	(3 %)

Utility area
T.6

consumption	yield	area	supply		
[kg/capita/year]	[kg/m²/year]	[m²]	[%]	[%]	
			inhabitants		
			189311		
25,30	56,00	805	0,9	30	tomatoes
6,40	35,00	334	1,0	13	cucumbers
4,90	32,00	264	0,9	10	capsicums
9,70	19,00	949	1,0	36	lettuce*
4,10	22,00	317	0,9	12	strawberry
		2.669	(151 %)		* approximated

Acreage
T.7

crate	yield	harvest	volume	shelf area	built up area	
[kg]	[kg/year]	[crops/year]	[m³]	[m²]	[m²]	
			crate [m³]	hight [m]	Corridor [%]	
			0,02	2	55	
6,0	45.091	2	75	38	58	tomatoes
5,5	11.704	2	21	11	16	cucumbers
5,0	8.448	2	17	8	13	capsicums
2,0	18.026	6	30	15	23	lettuce*
3,0	6.970	4	12	6	9	strawberry
					120	(7 %)

Storage area
T.9

shelf hight	crop factor	hight	built up area		
[m]		[m]	[m²]	[%]	
			Corridor [%]		
			45		
6	2	3,0	732	41	tomatoes
5	2	2,5	304	17	cucumbers
5	2	2,5	240	14	capsicums
5	5	1,0	345	20	lettuce*
4	4	1,0	144	8	strawberry
			1.765	(100 %)	

Built-up area greenhouse
T.10

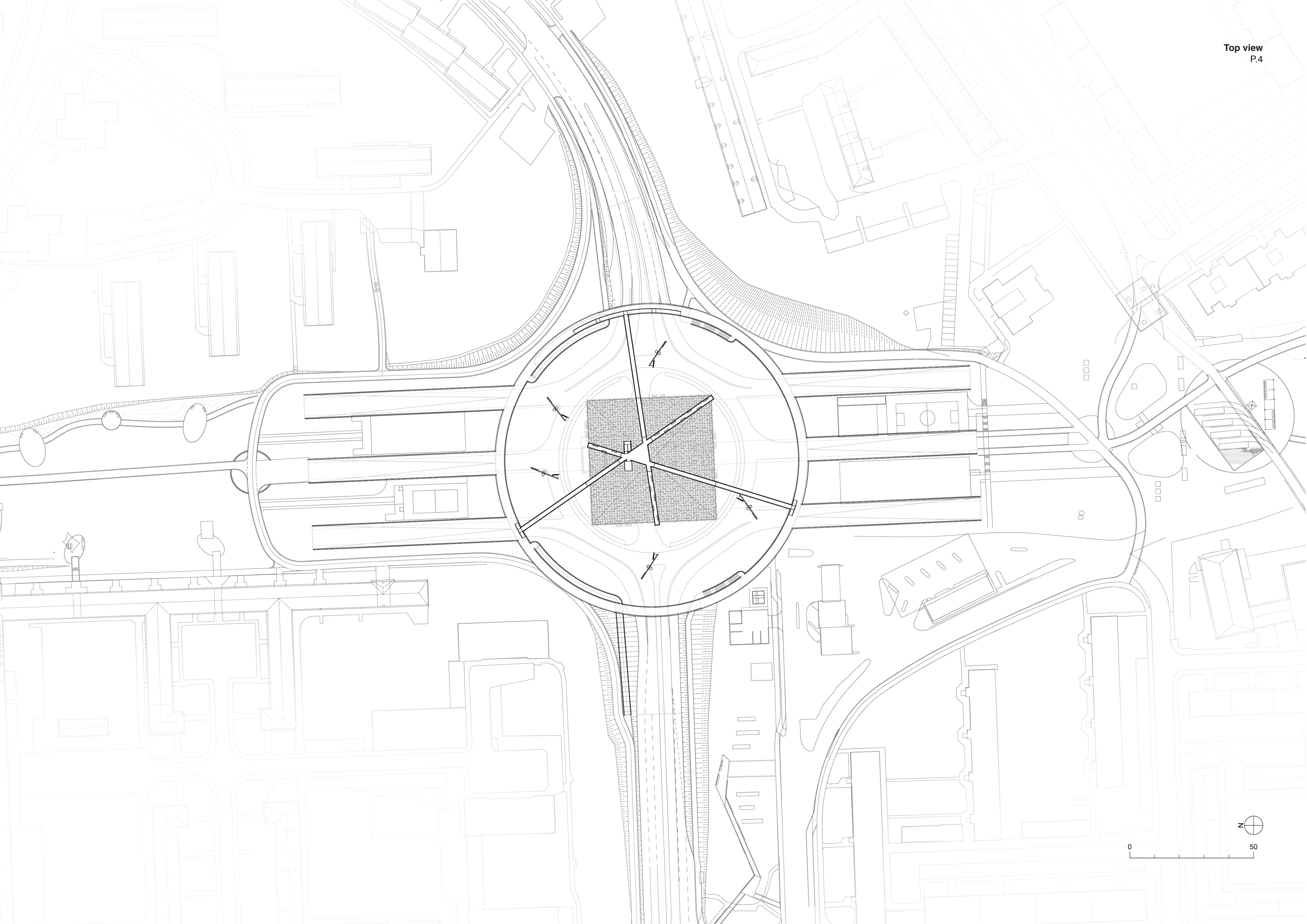
volume	area	built up area	volume	area	built up area	
[m³]	[m²]	[m²]	[m³]	[m²]	[m²]	
use [l/m²/month]	hight [m]	volume [m³]	rain [l/m²/month]	hight [m]	volume [m³]	
75	0,75	0,42	70	0,75	0,42	
60	81	144	56	75	134	tomatoes
25	33	60	23	31	56	cucumbers
20	26	47	18	25	44	capsicums
71	95	169	66	89	158	lettuce*
24	32	57	22	30	53	strawberry
		477	(27 %)		**445**	(25 %)

Water storage
T.11

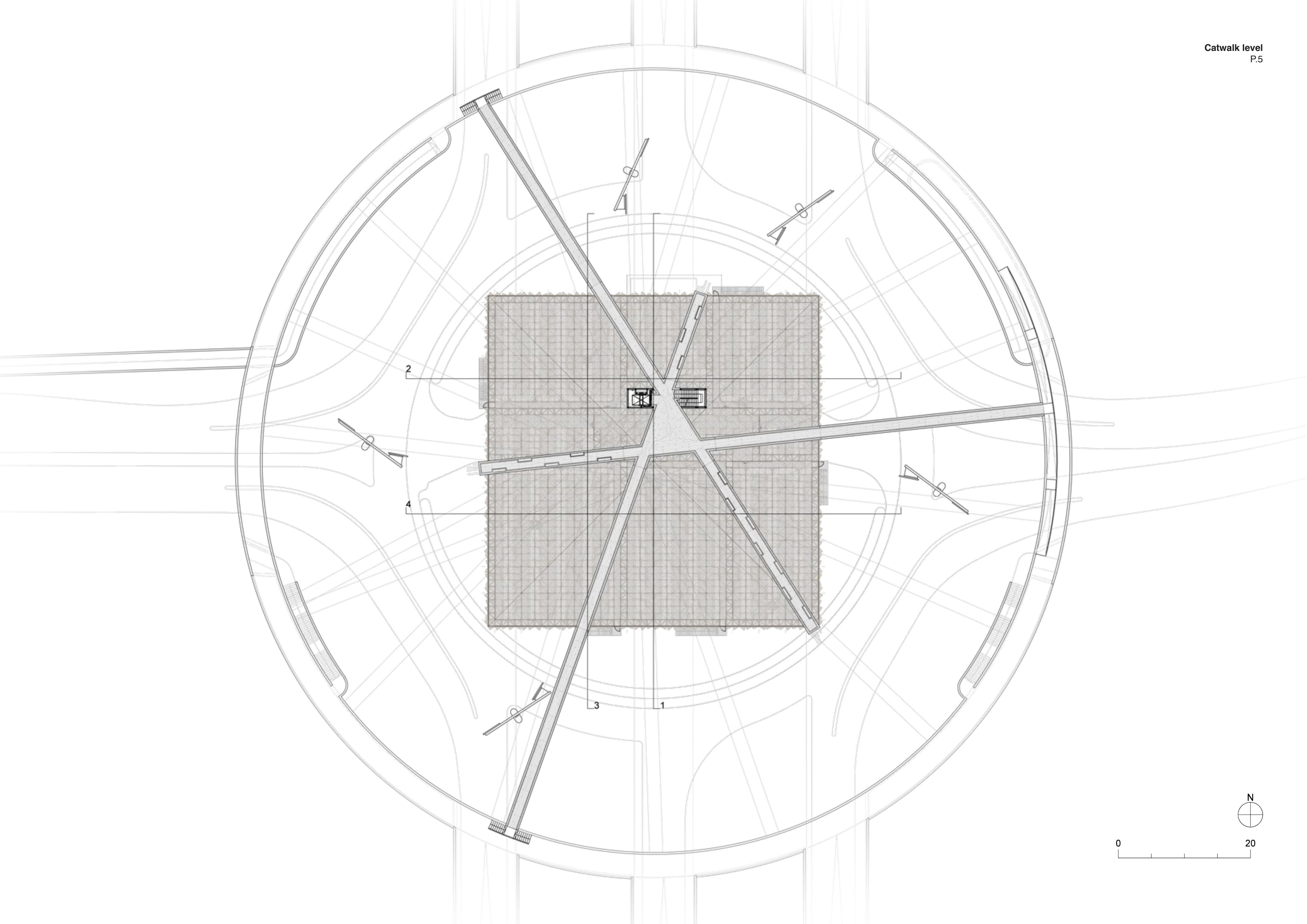
spacing	plants	area	shelf area	built up area	
[m²/plant]	[pl/year]	[m²]	[m²]	[m²]	
		block [cm²]	hight [m]	Corridor [%]	
		16	3	45	
2,50	2.013	161	40	58	tomatoes
1,50	502	40	10	15	cucumbers
2,00	528	42	11	15	capsicums
0,40	380	10	3	4	lettuce*
0,40	127	5	1	2	strawberry
				94	(5 %)

Germination area
T.12

Top view
P.4

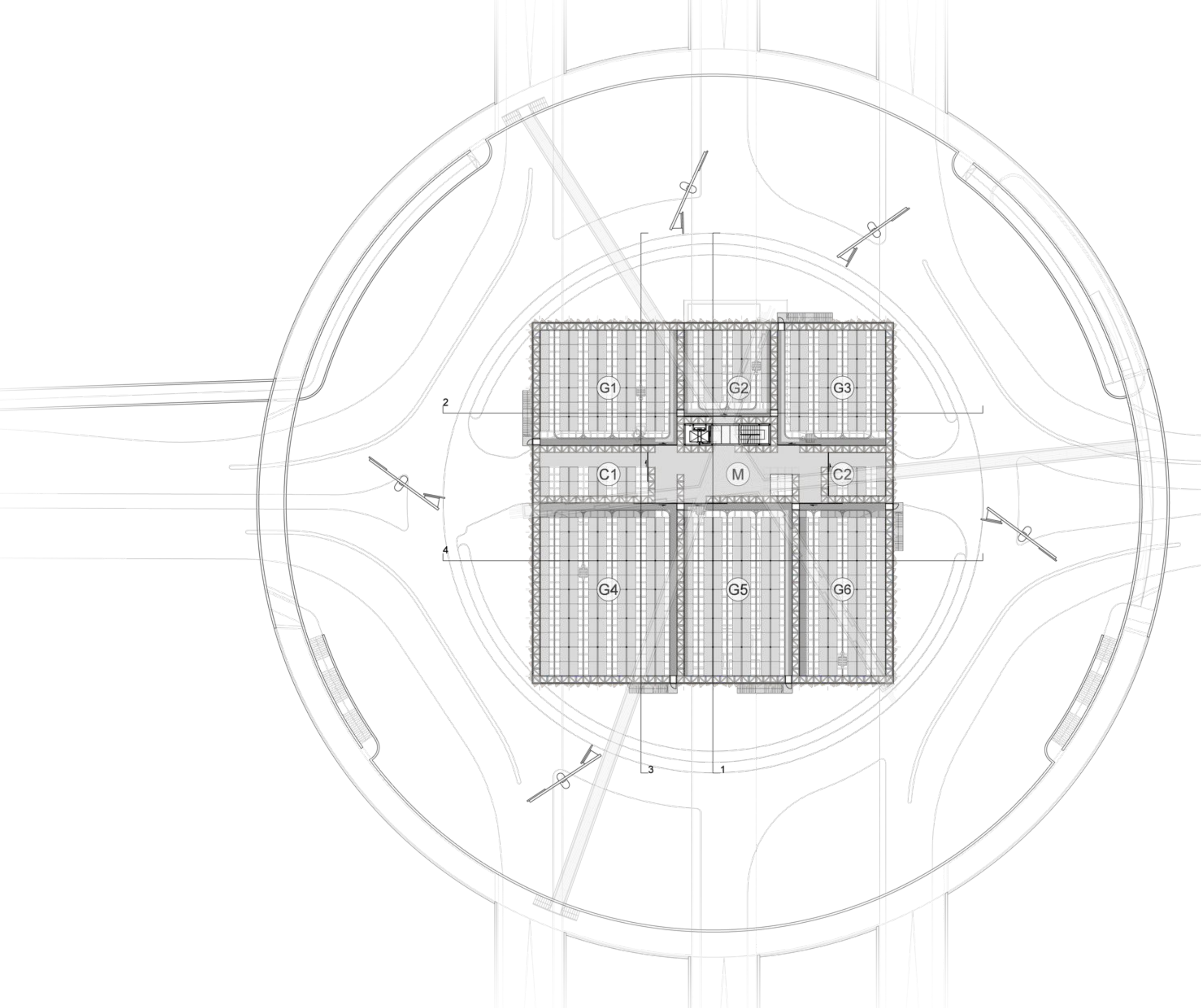


Catwalk level
P.5



Greenhouse level
P.6

G1	Cucumbers 17%
G2	Strawberry 8%
G3	Capsicum 14%
G4, G6	Tomatoes 41%
G5	Lettuce 20%
M	Manipulation area
C1, C2	Germination

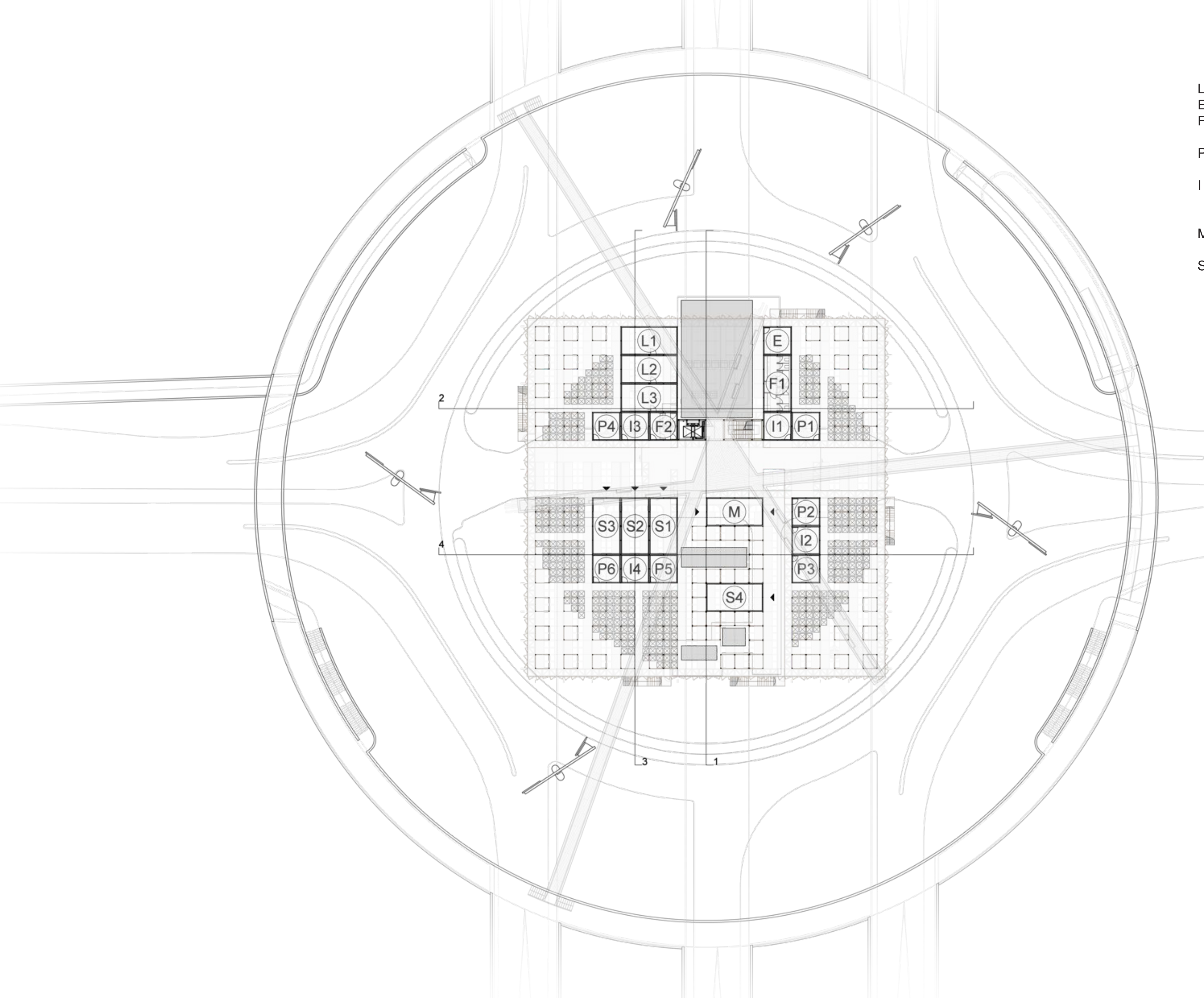


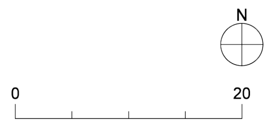
N

0 20

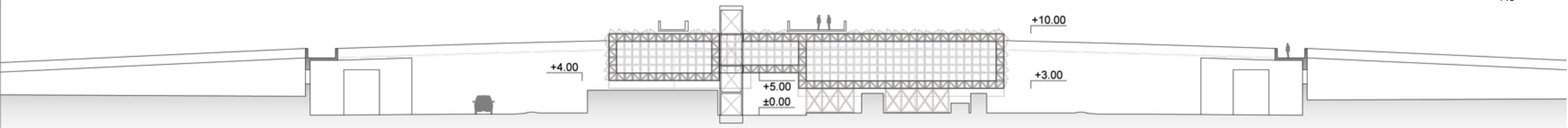
Utility level
P.7

L	Laboratories
E	Recreation room
F	Facilities
P	Water pump ABC stock
I	Heating Control panel
M	Manufacturing area
S	Storage Cold storage house

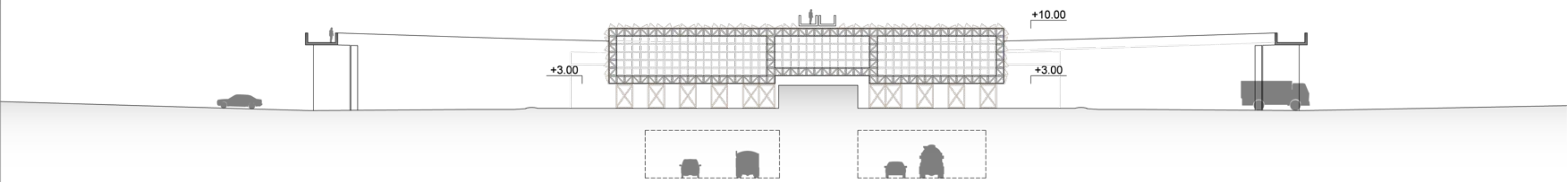




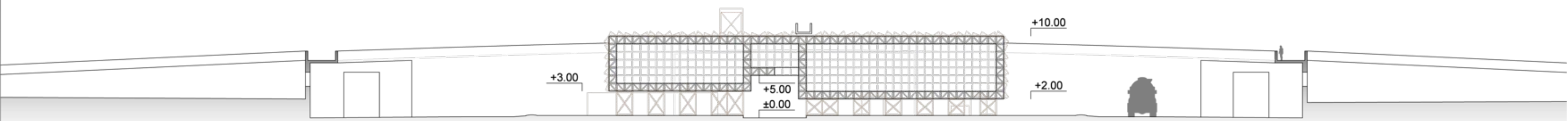
Longitudinal section 1
P.8



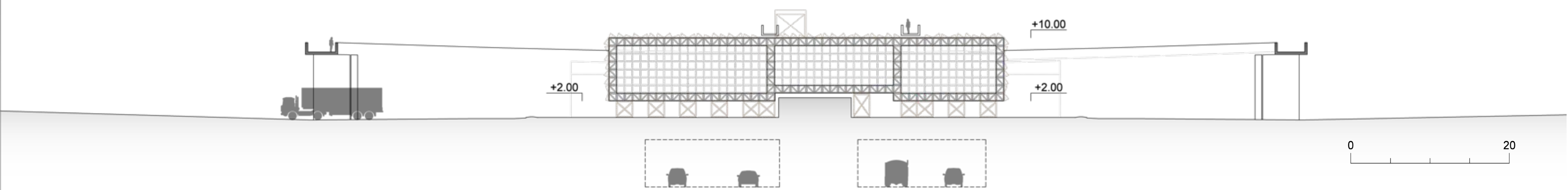
Cross section 2
P.9



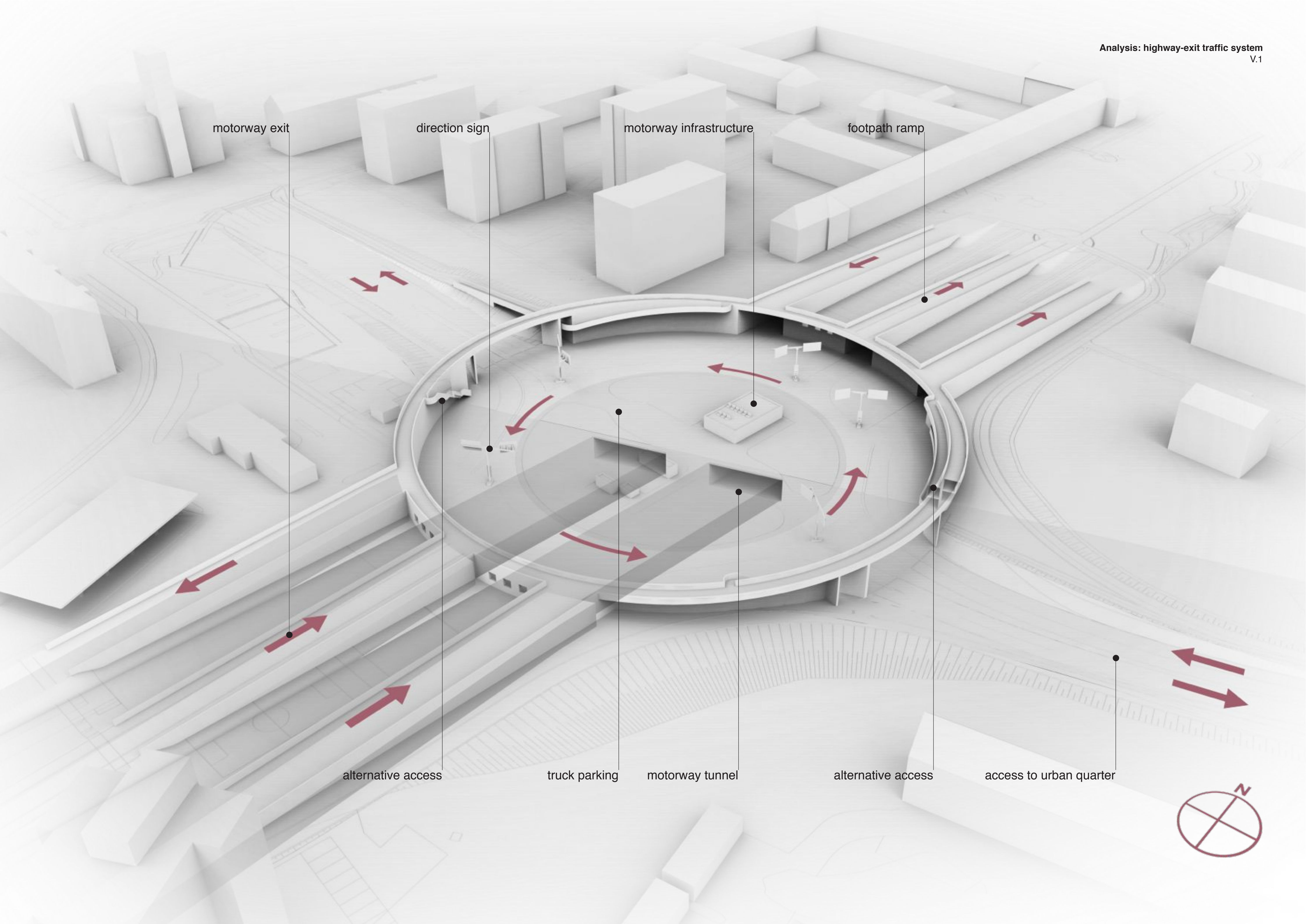
Longitudinal section 3
P.10



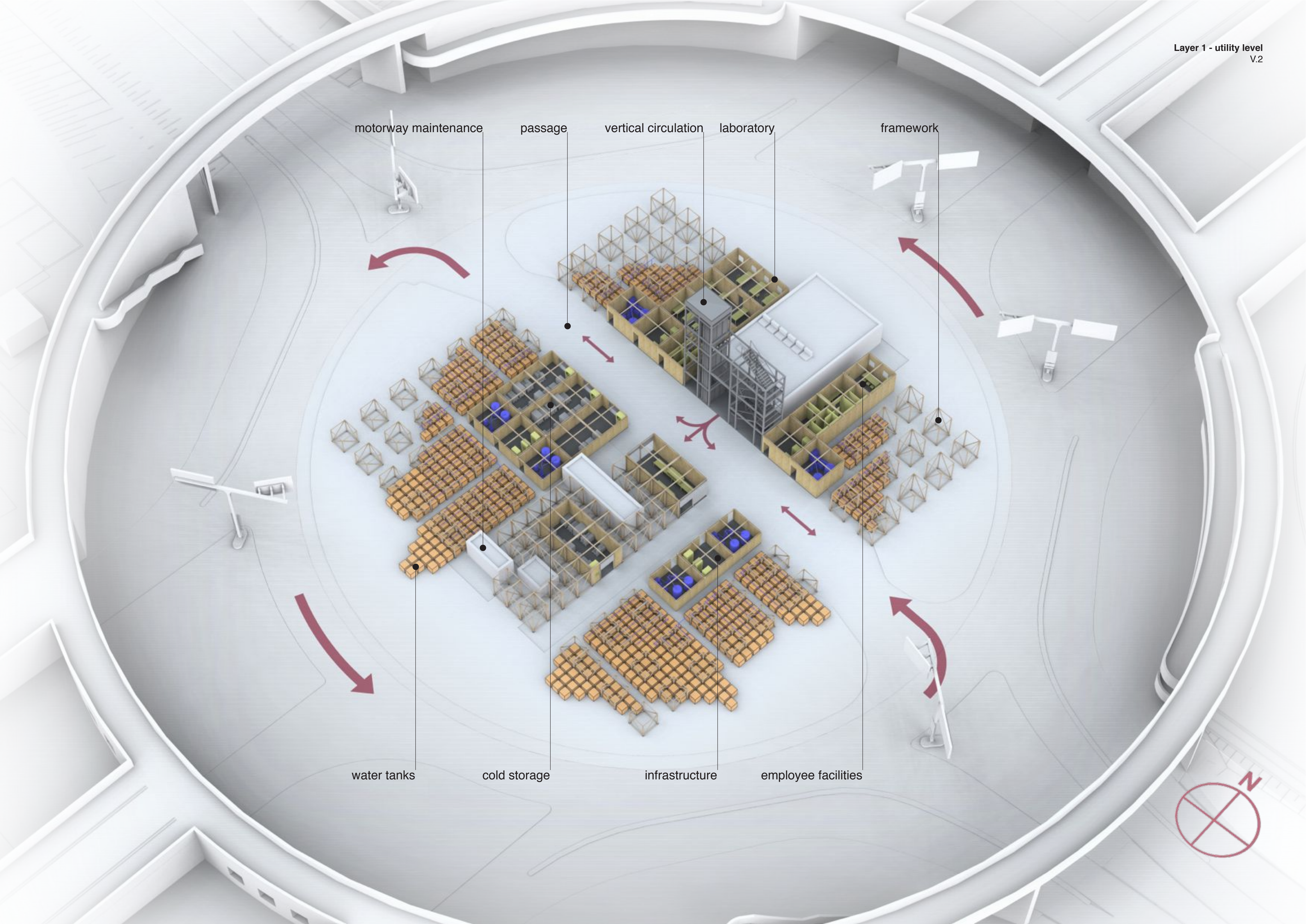
Cross section 4
P.11



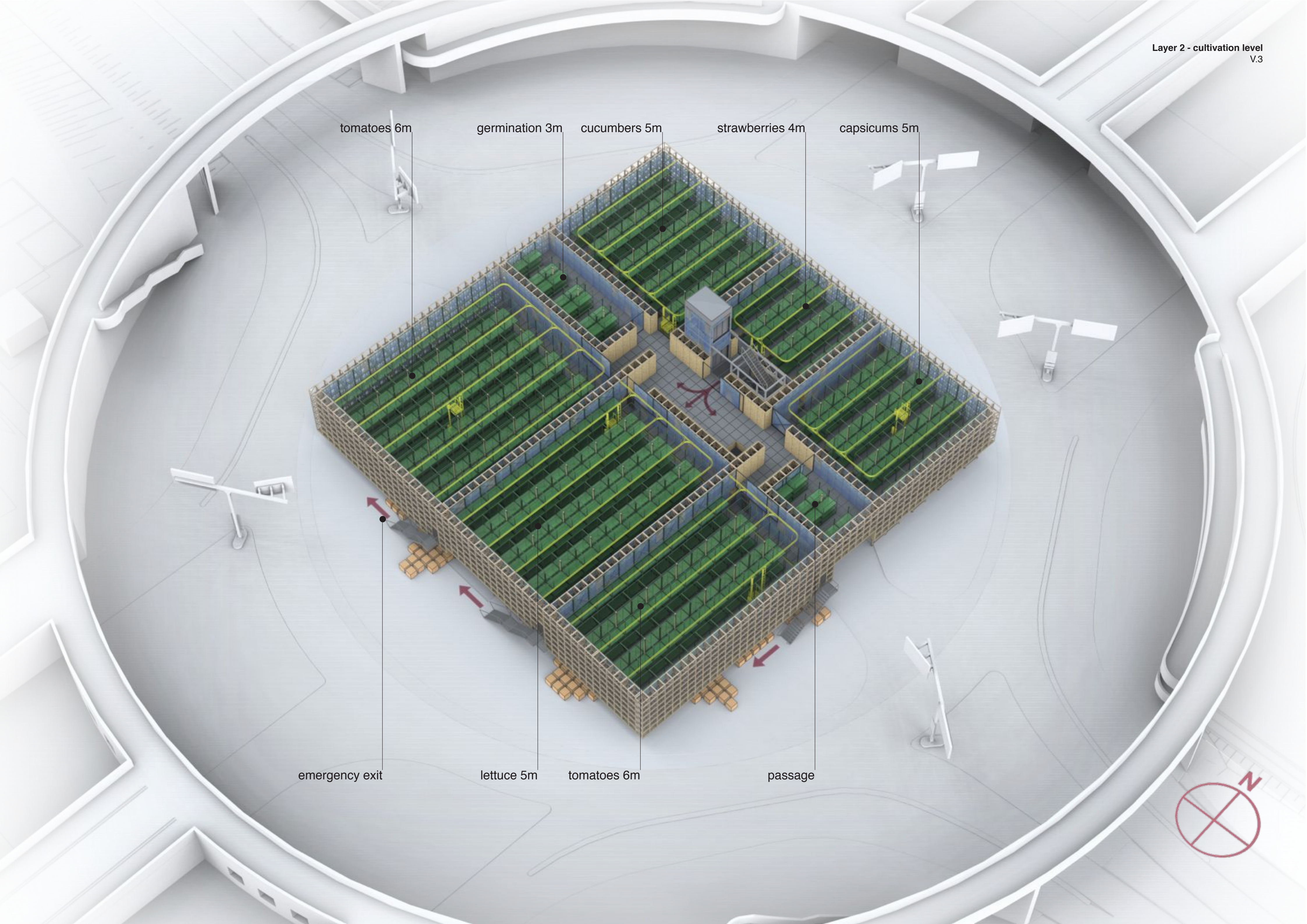
Analysis: highway-exit traffic system
V.1



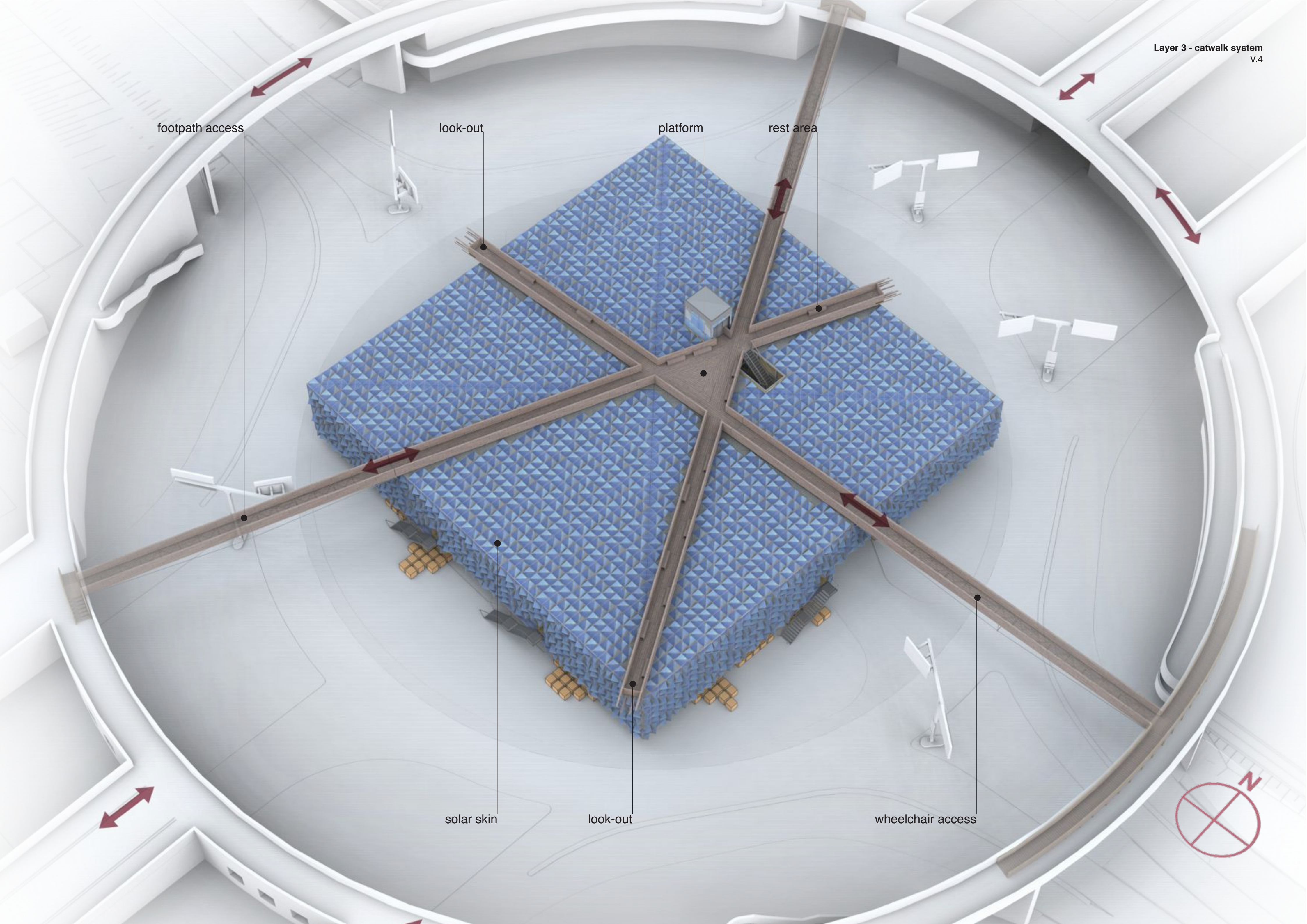
Layer 1 - utility level
V.2



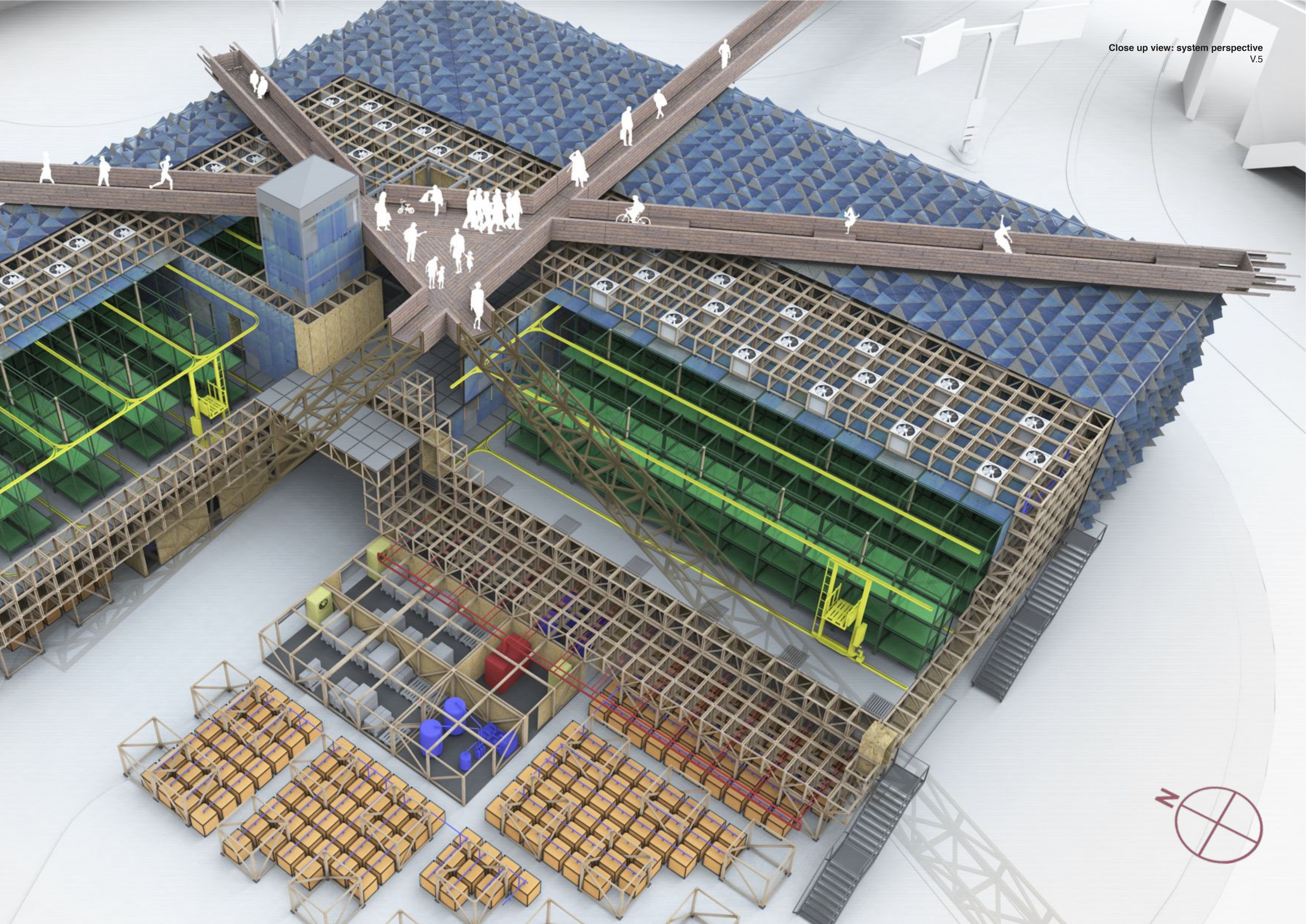
Layer 2 - cultivation level
V.3



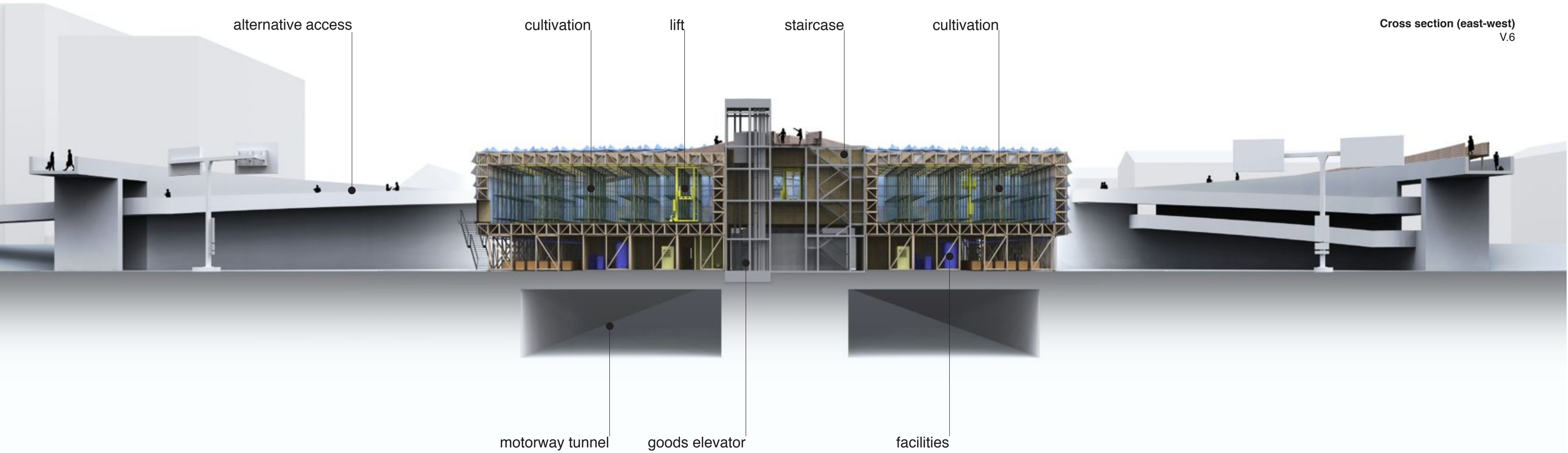
Layer 3 - catwalk system
V.4



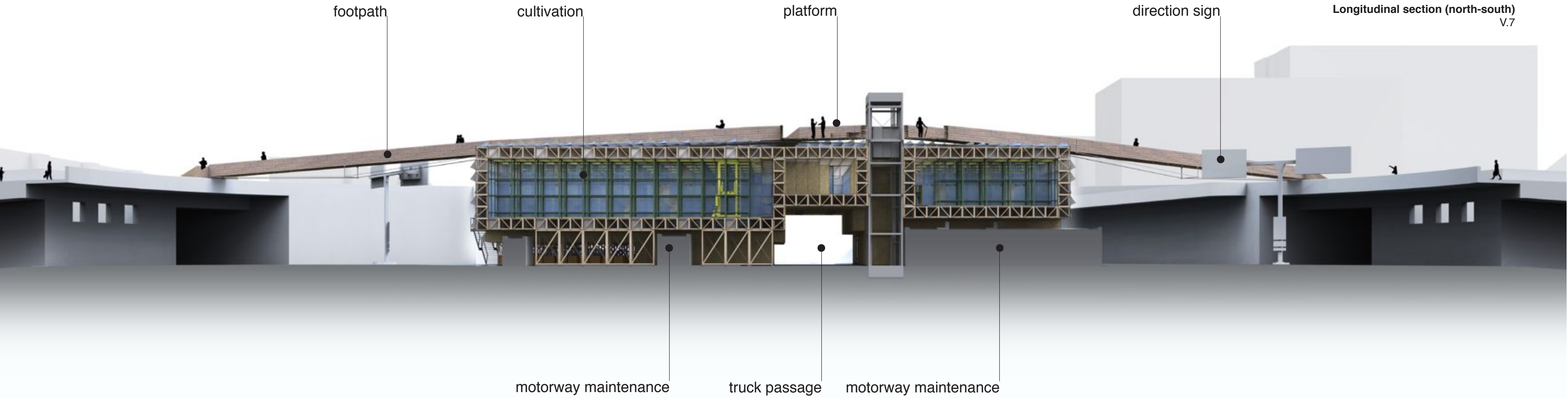
Close up view: system perspective
V.5

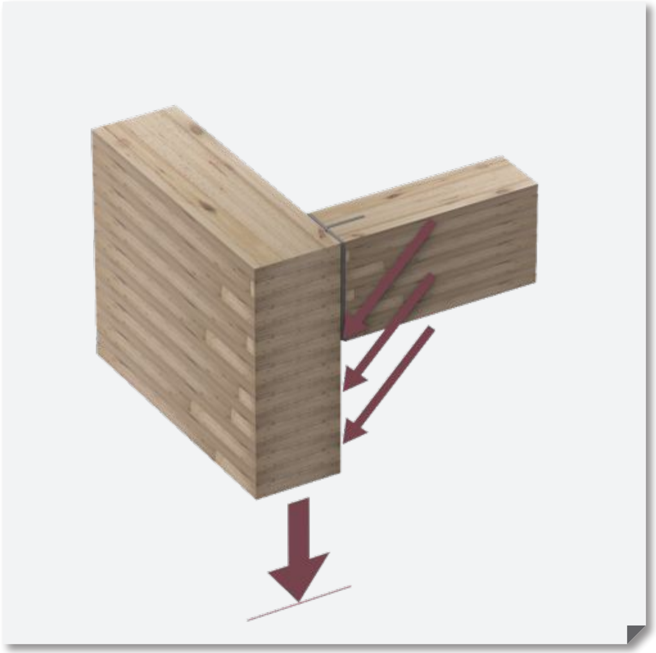


Cross section (east-west)
V.6

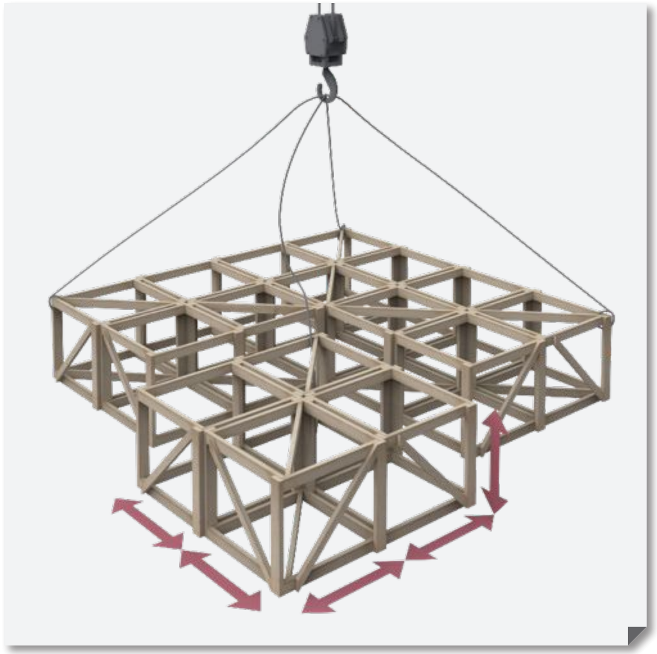


Longitudinal section (north-south)
V.7



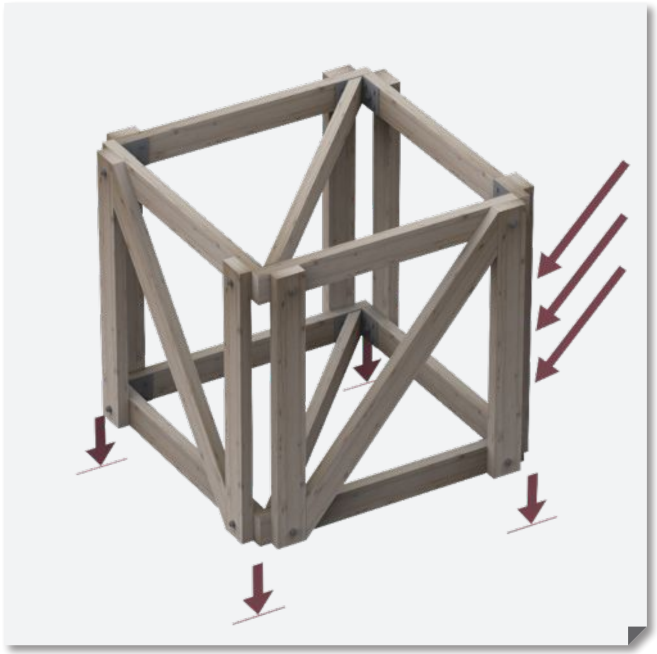


Gluelam truss: poor light conditions
V.8

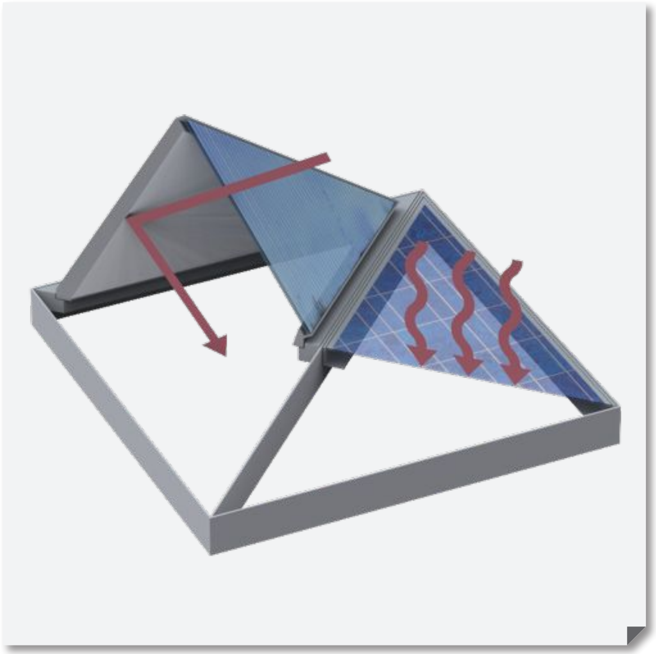


Framework: modular combination
V.9

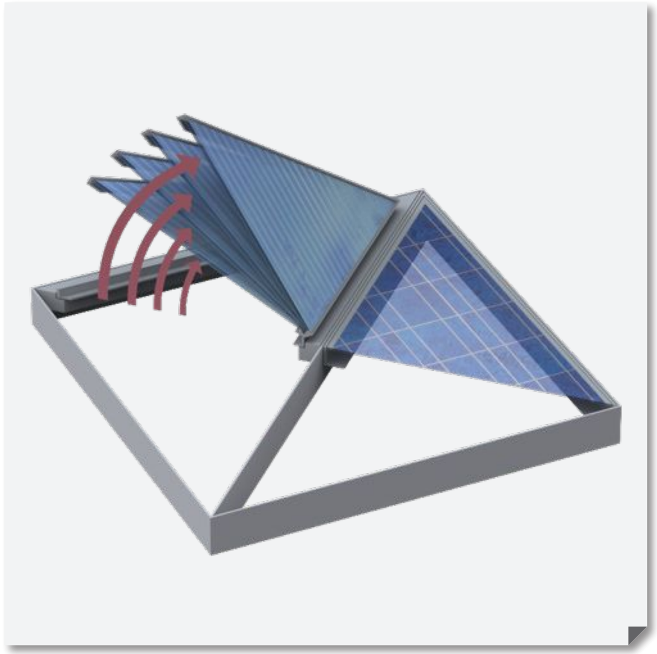
Bolted connection
V.10



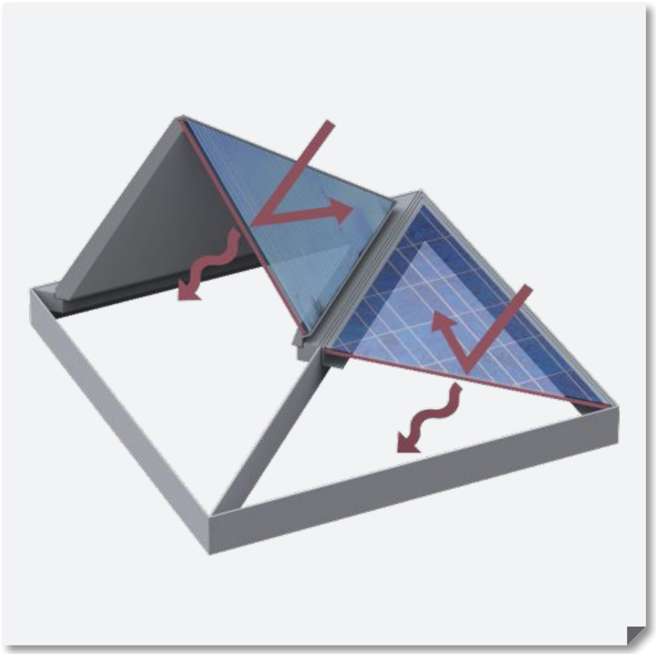
Framework construction
V.11



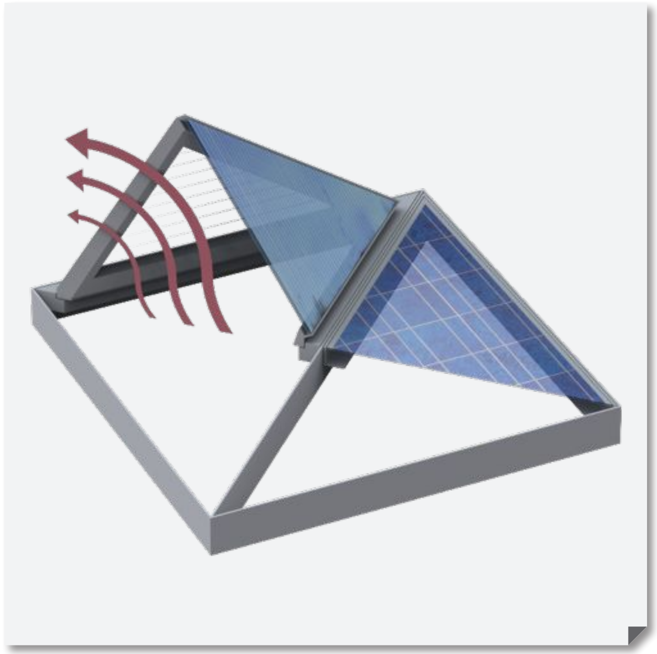
Light reflection and diffused light
V.12



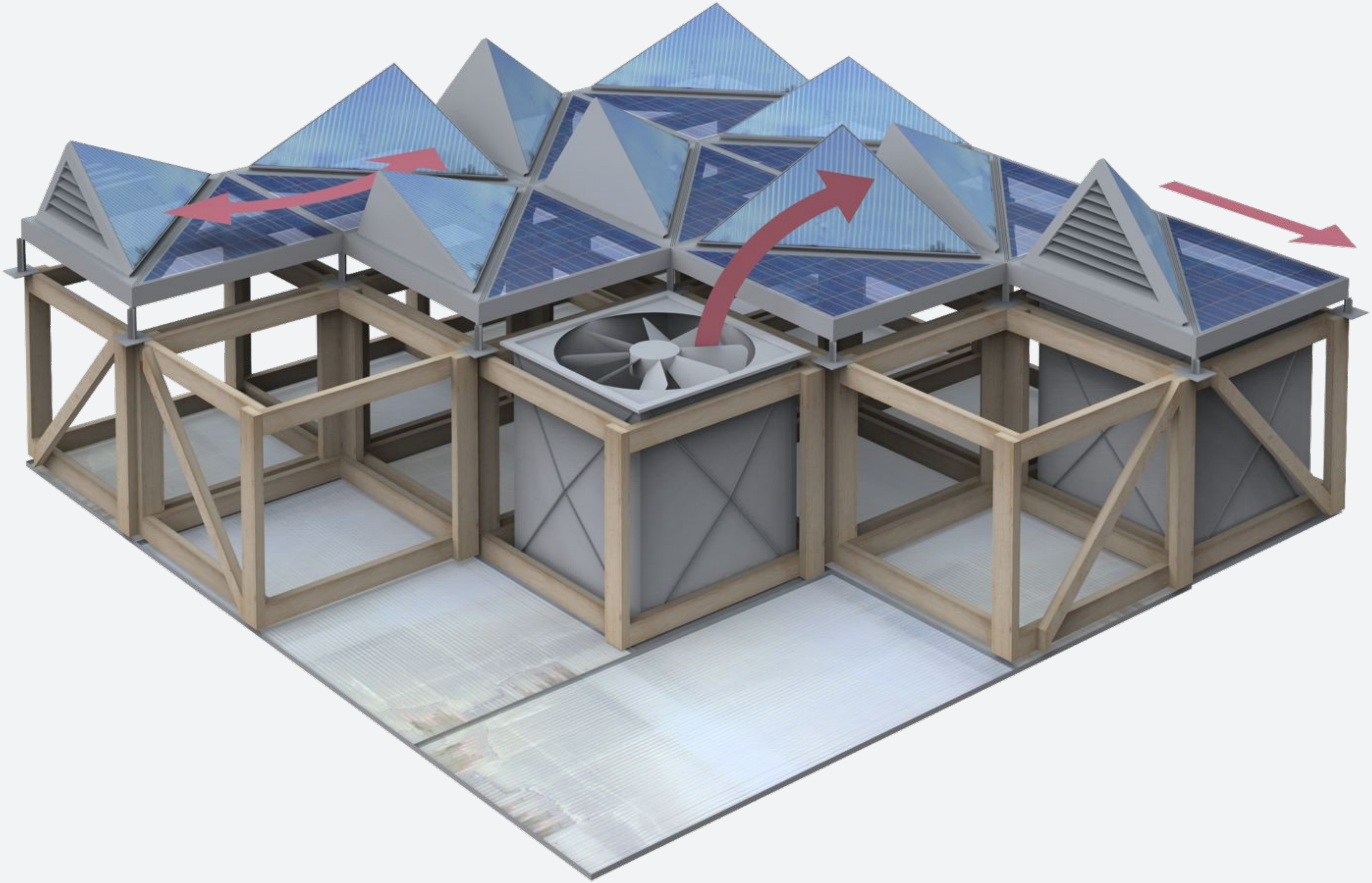
Variety collector slopes
V.13



Shading effect and glass coating
V.14

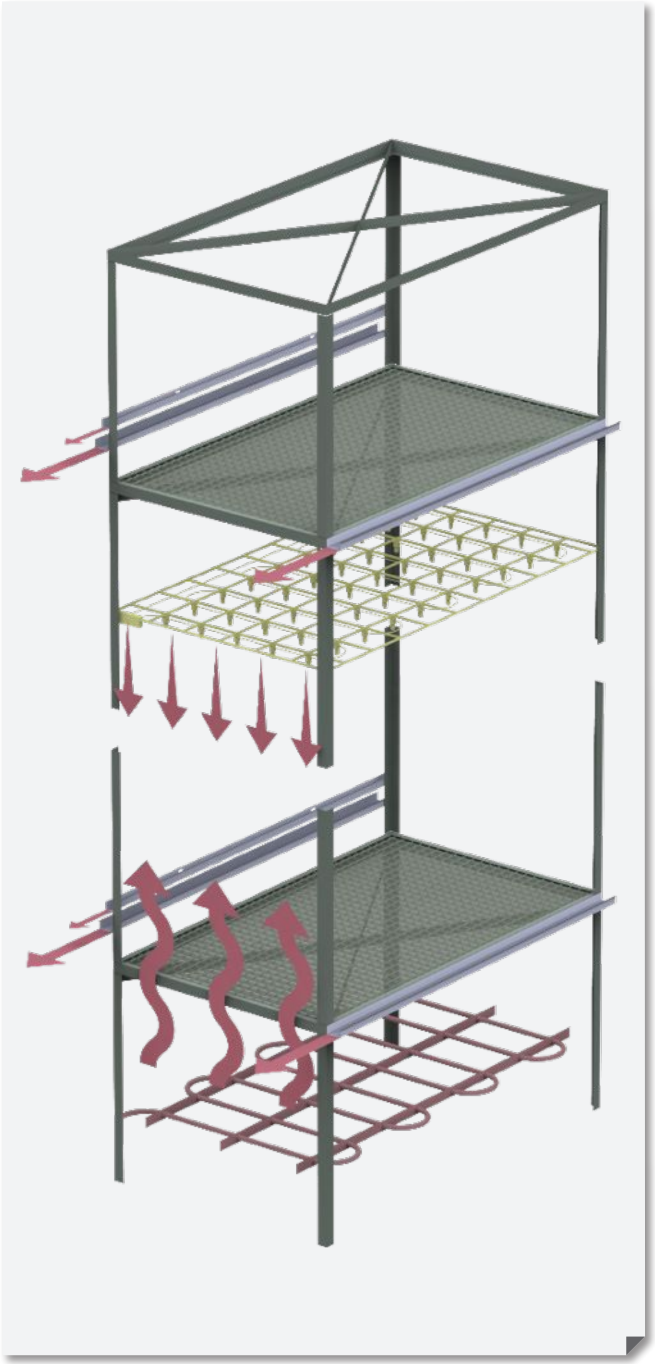


Natural ventilation and louvres
V.15

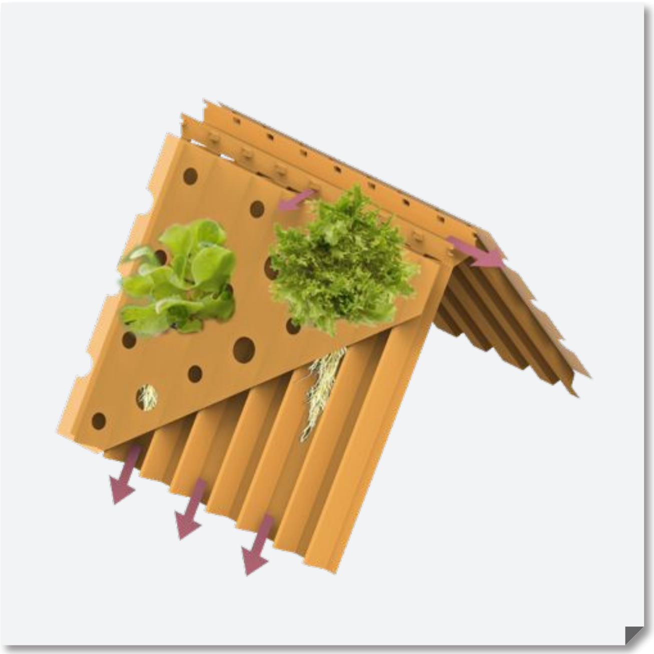


Framework construction with solar skin
V.16

Hydroponic rock wool culture
V.17



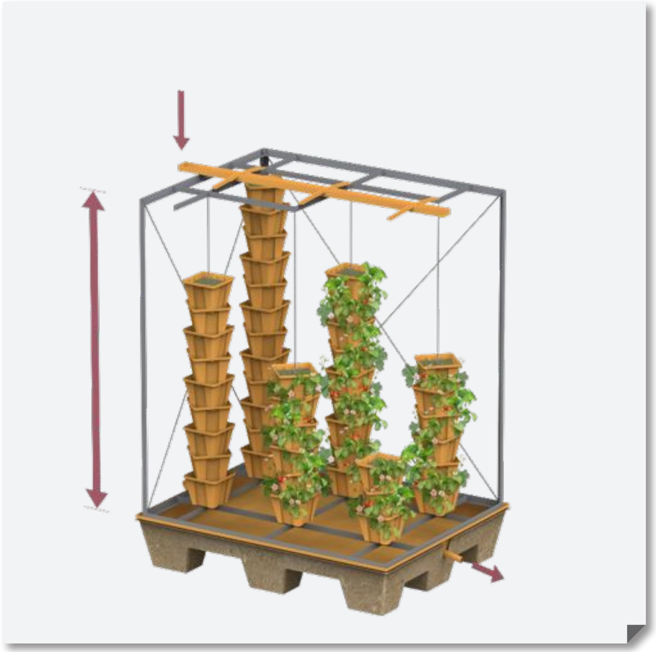
Hydroponic column culture
V.18



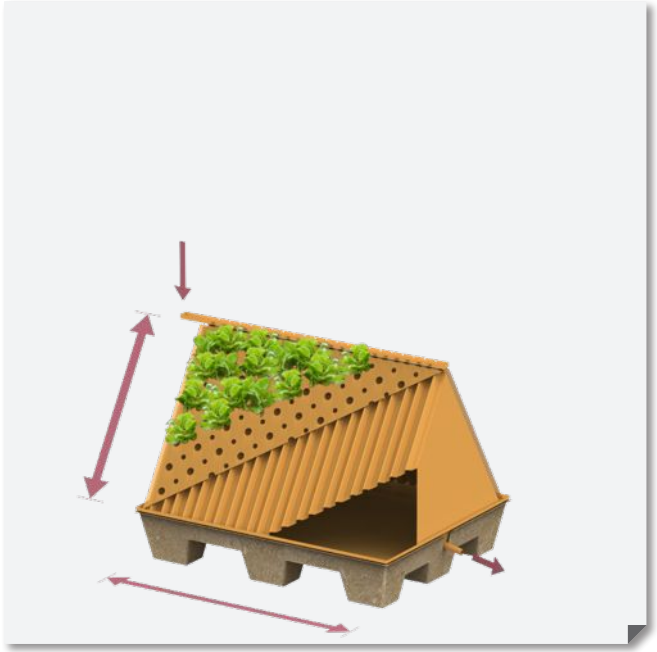
A-frame culture, nutrient film technique
V.19

Rack system: heating, irrigation and LED-panels
V.20

Forklift and moveable pallet system
V.21



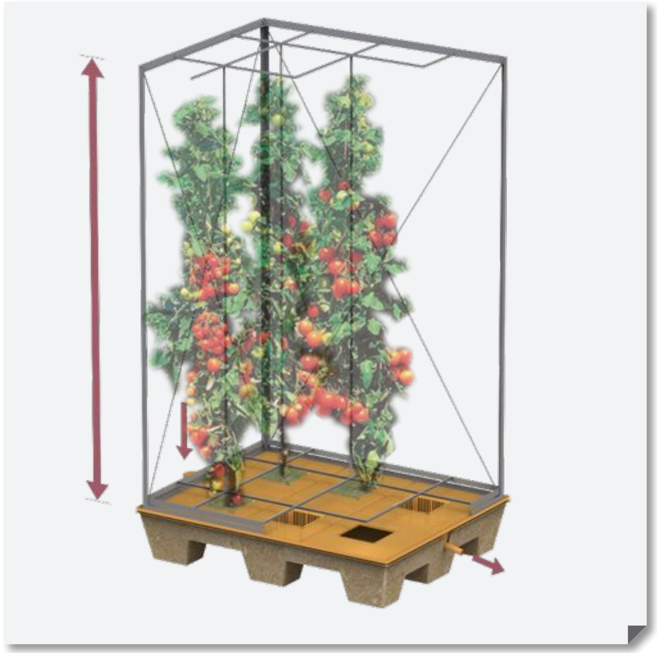
Strawberry column culture unit
V.22



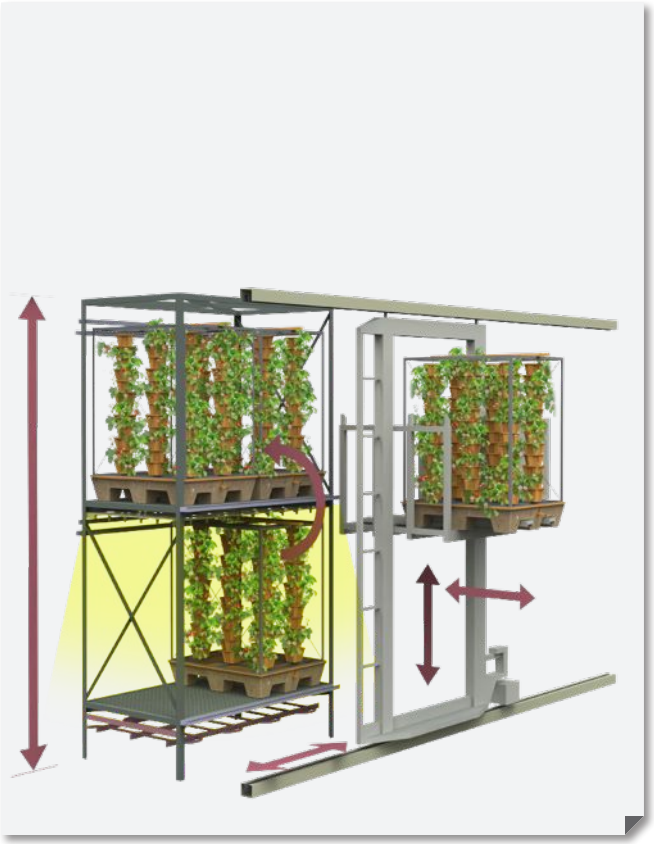
Lettuce A-frame nutrient film technique unit
V.23

Capsicum rock wool culture unit
V.24

Cucumber rock wool culture unit
V.25



Tomato rock wool culture unit
V.26

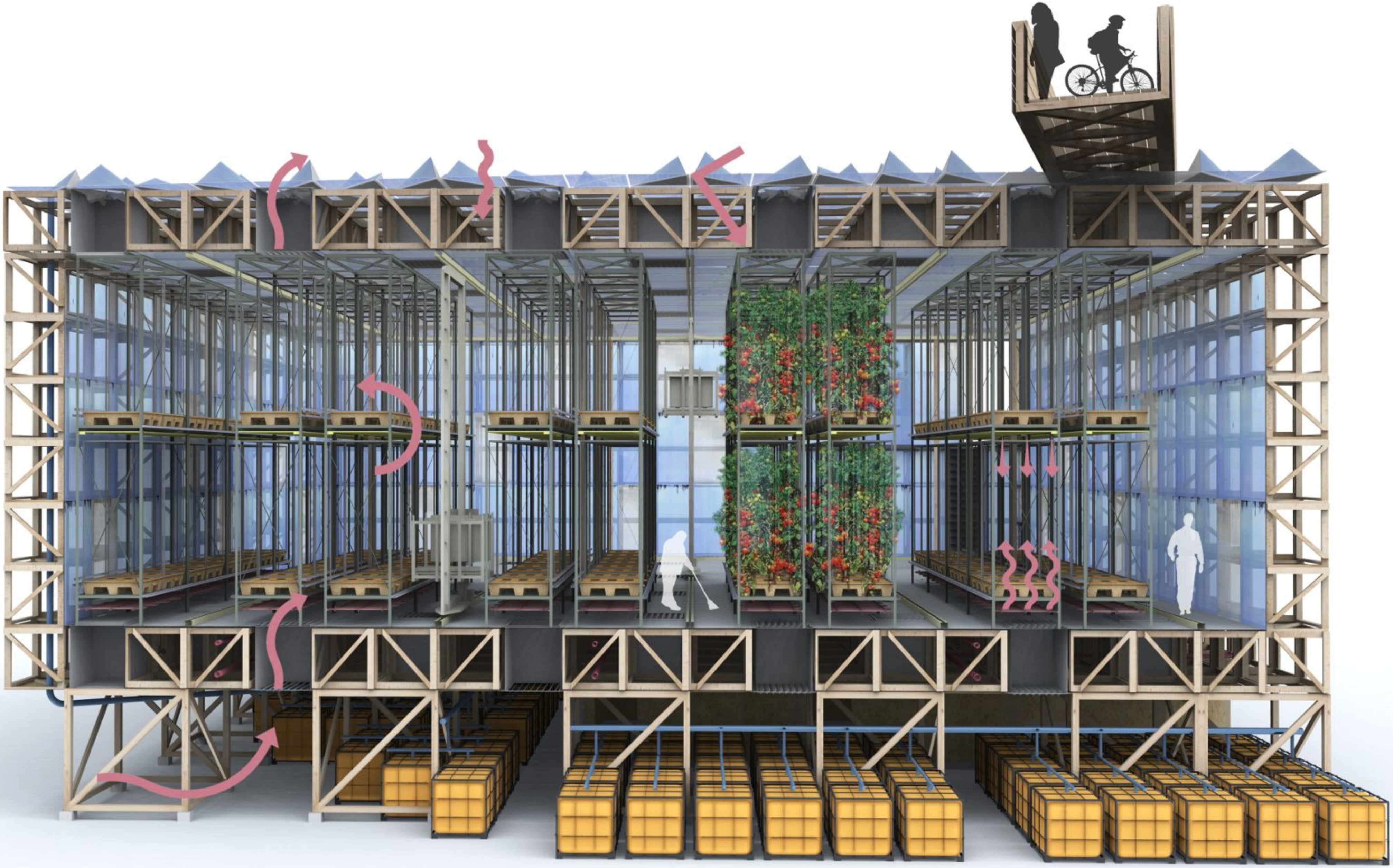


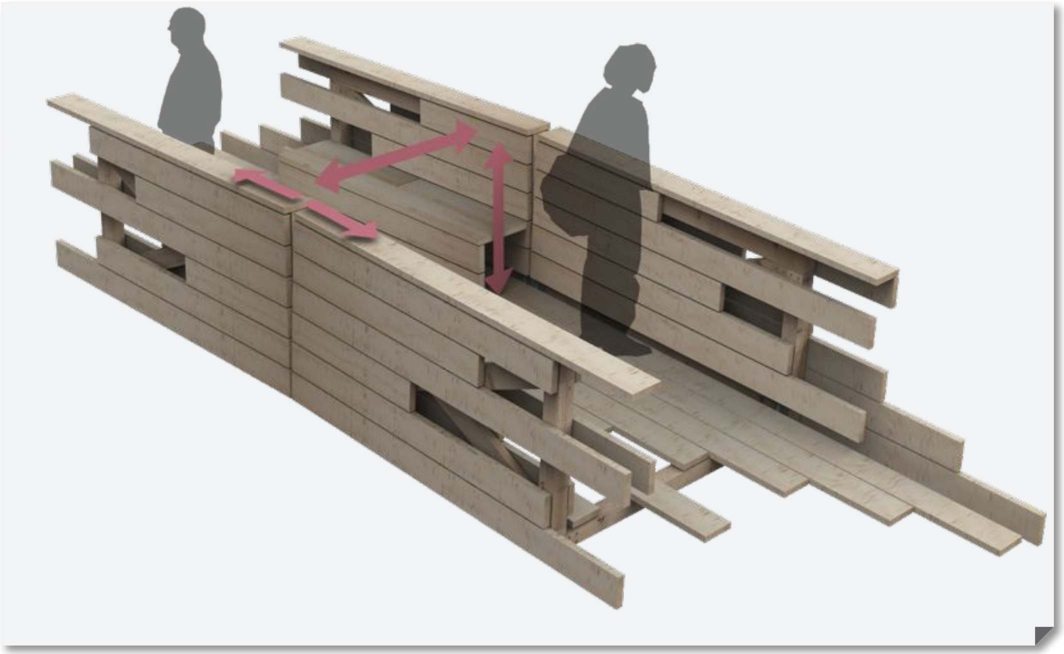
Strawberry shelf system and lift, hight: 4m
V.27

Lettuce shelf system and lift, hight: 5m
V.28

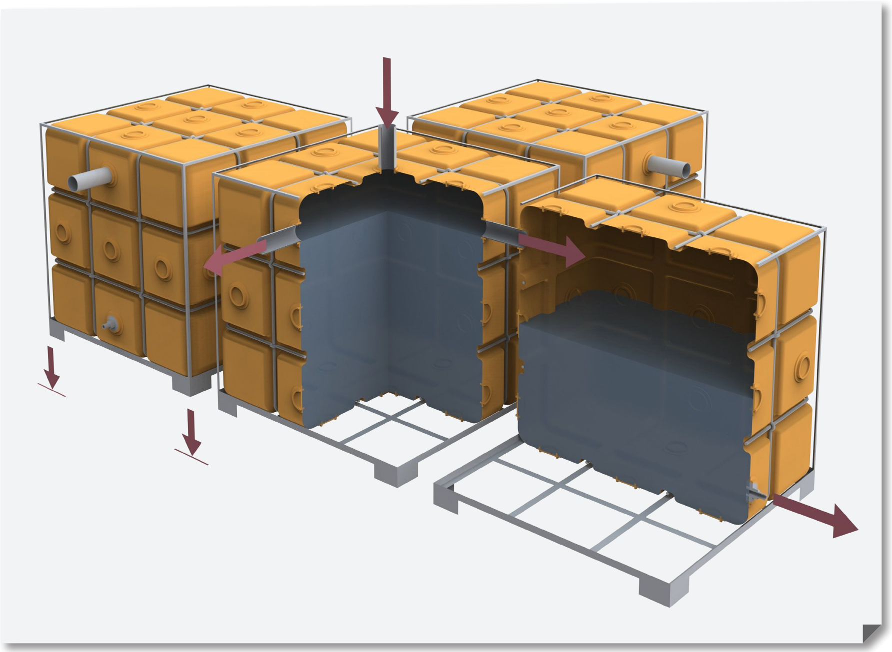
Tomato shelf system and lift, hight 6m
V.29

Tomato greenhouse system section
V.30

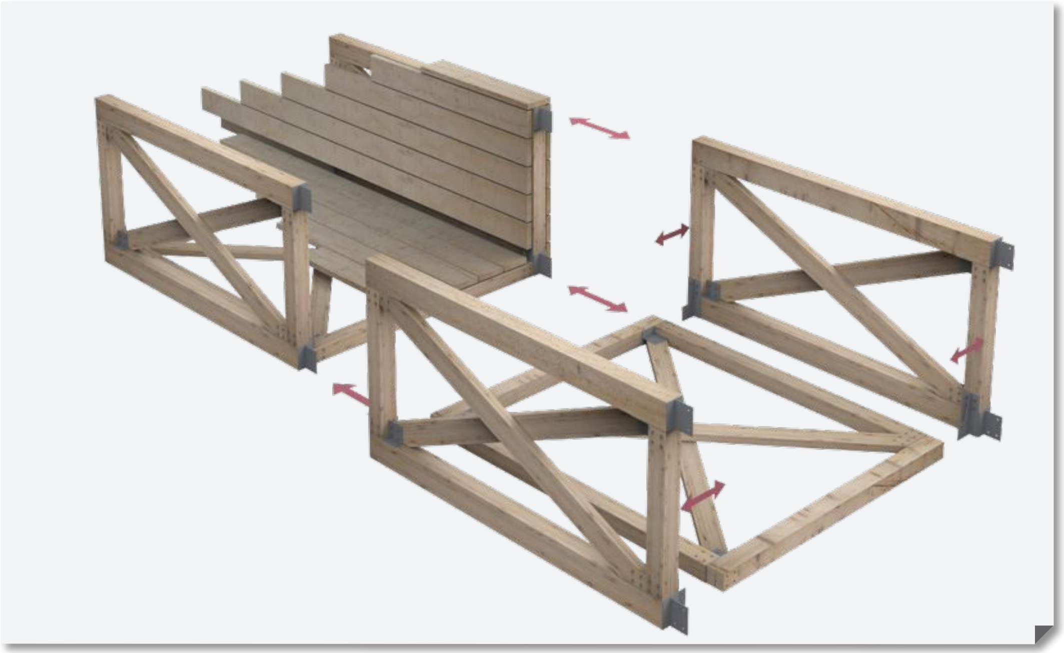




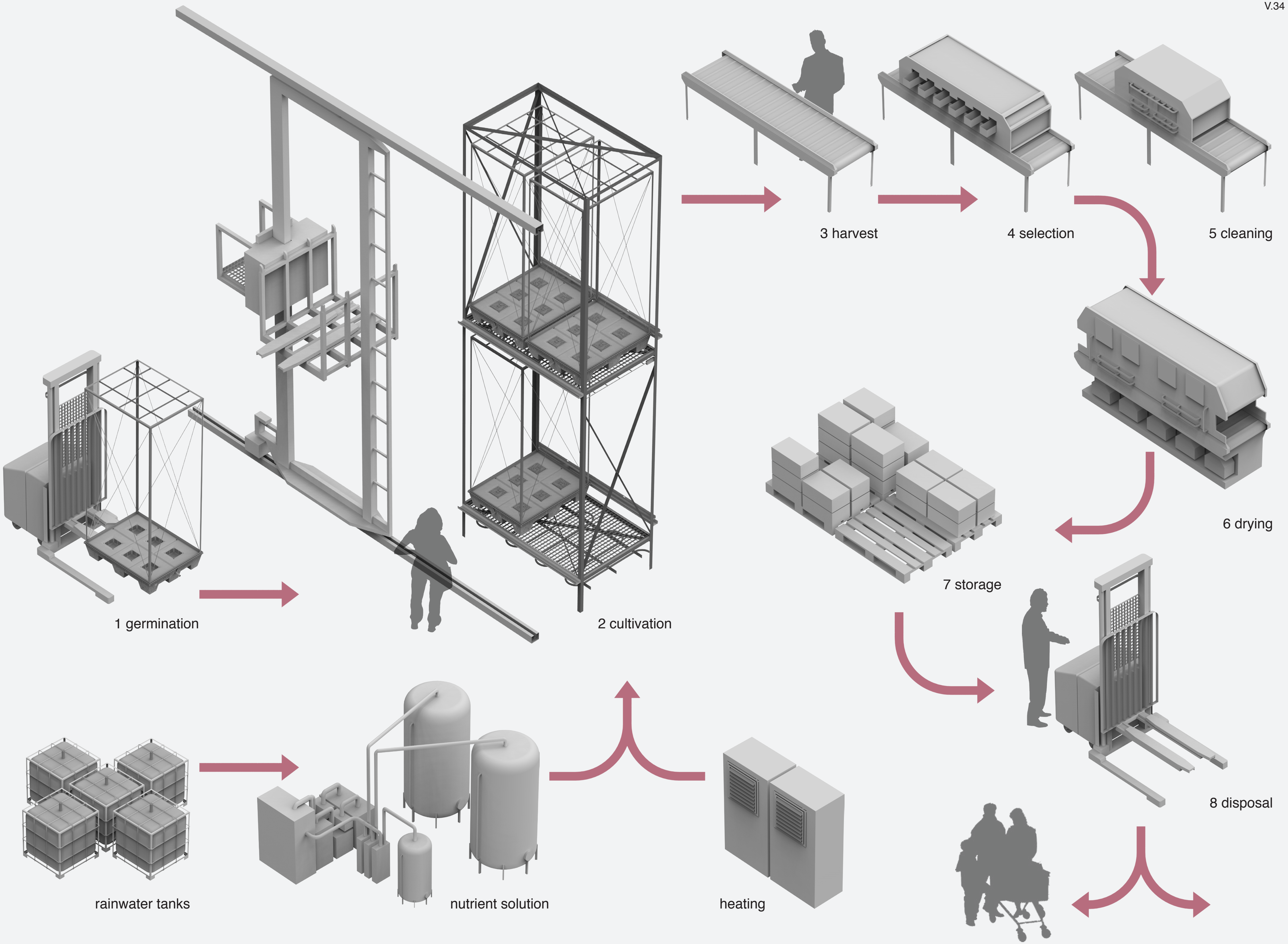
Catwalk system with bench
V.31

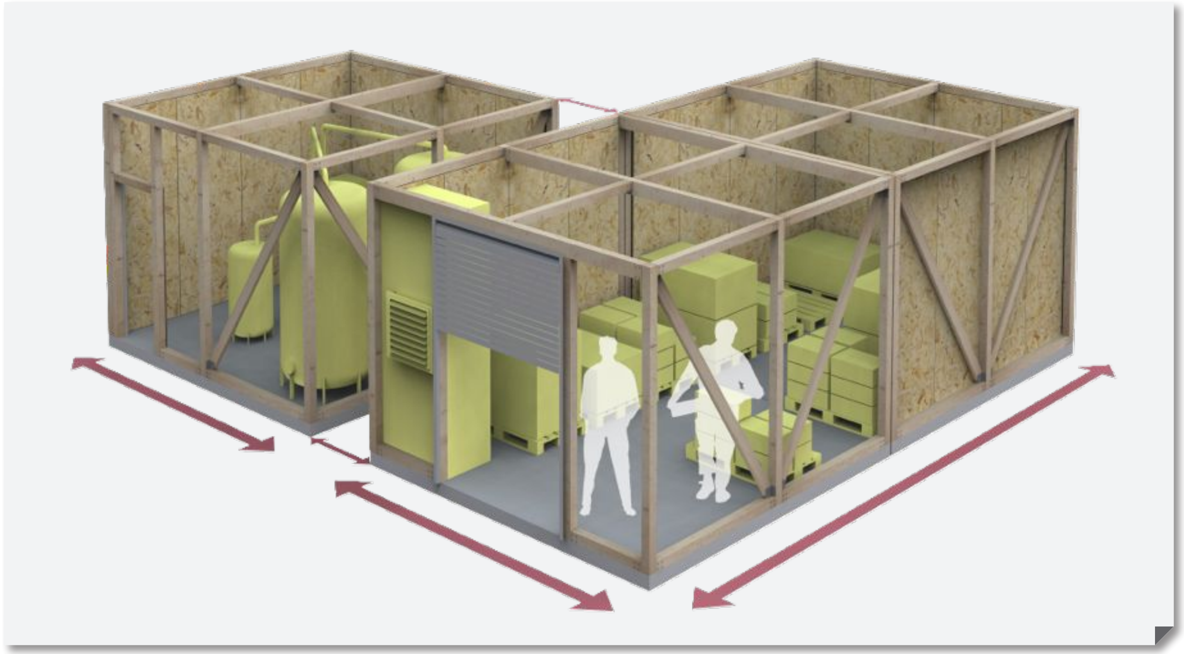


Modularly expandable water tank system
V.32

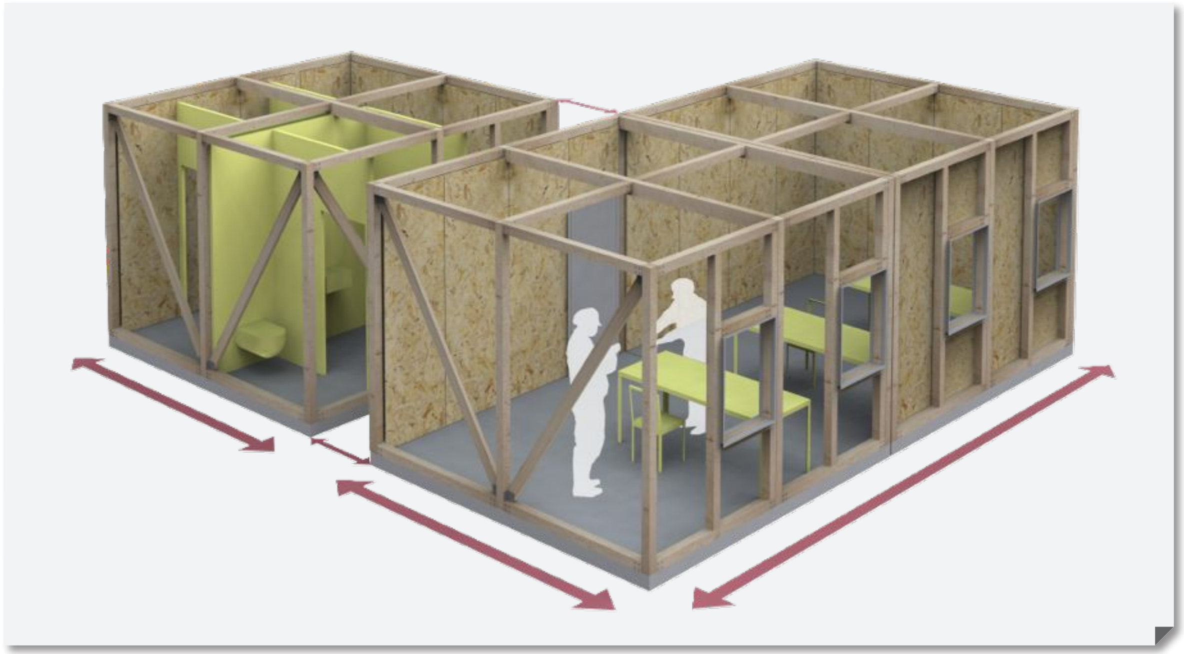


Catwalk construction detail
V.33

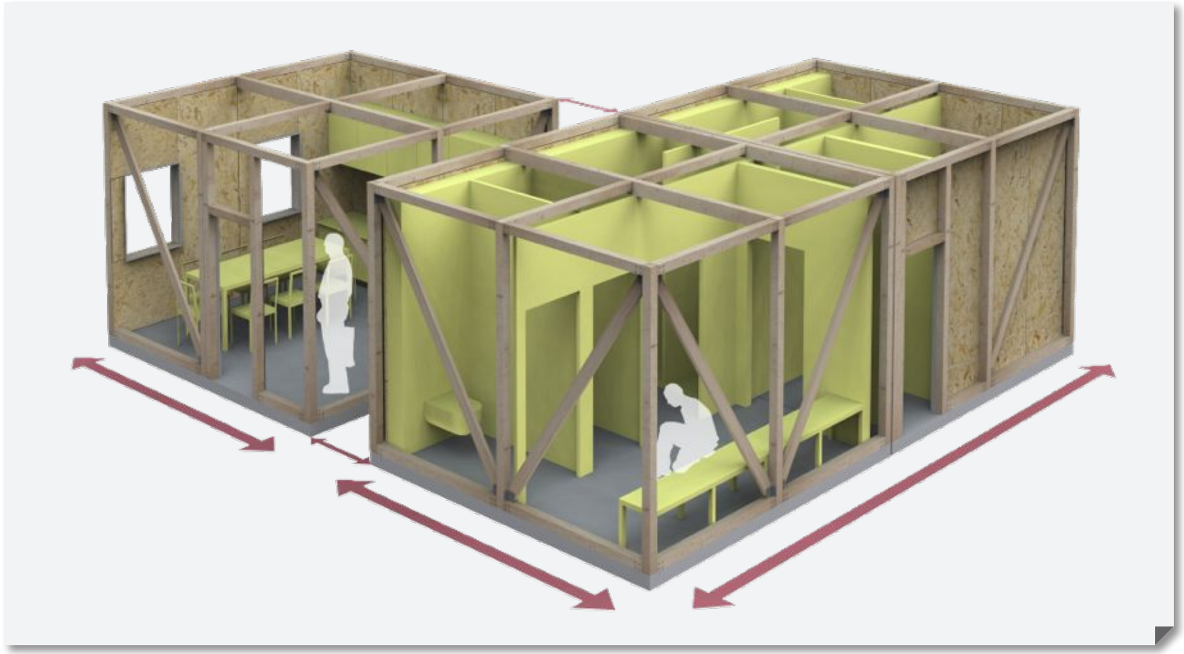

Simplified production cycle
V.34
1 germination
2 cultivation
3 harvest
4 selection
5 cleaning
6 drying
7 storage
8 disposal
rainwater tanks
nutrient solution
heating



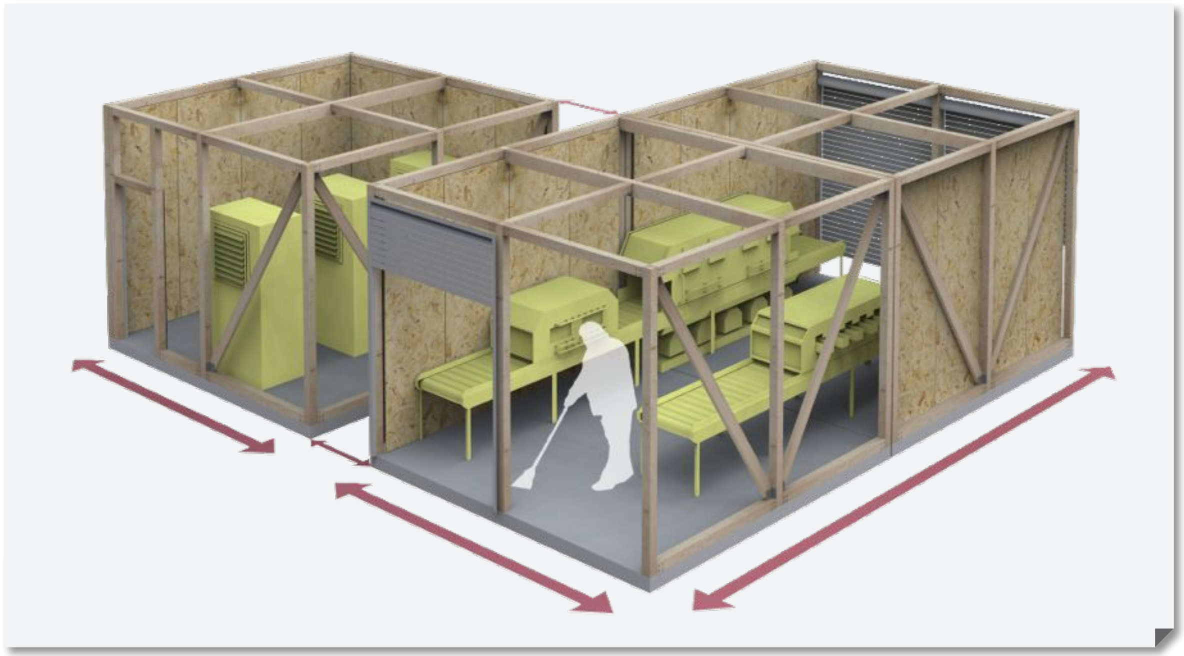
Utility level: storage unit (8x4m) and nutrient injector system unit (4x4m)
V.35



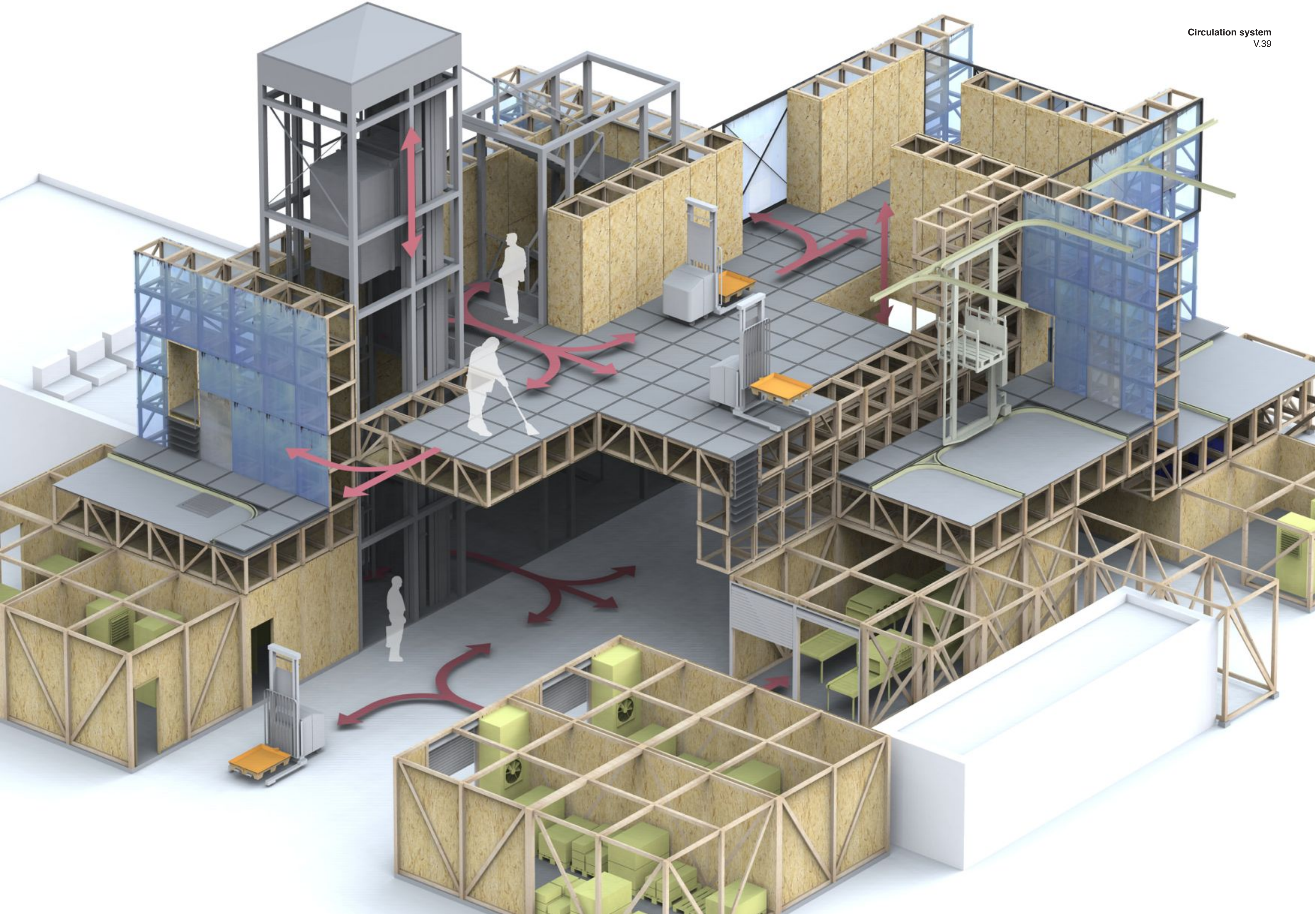
Utility Level: facility unit (4x4m) and laboratory unit (8x4m)
V.36



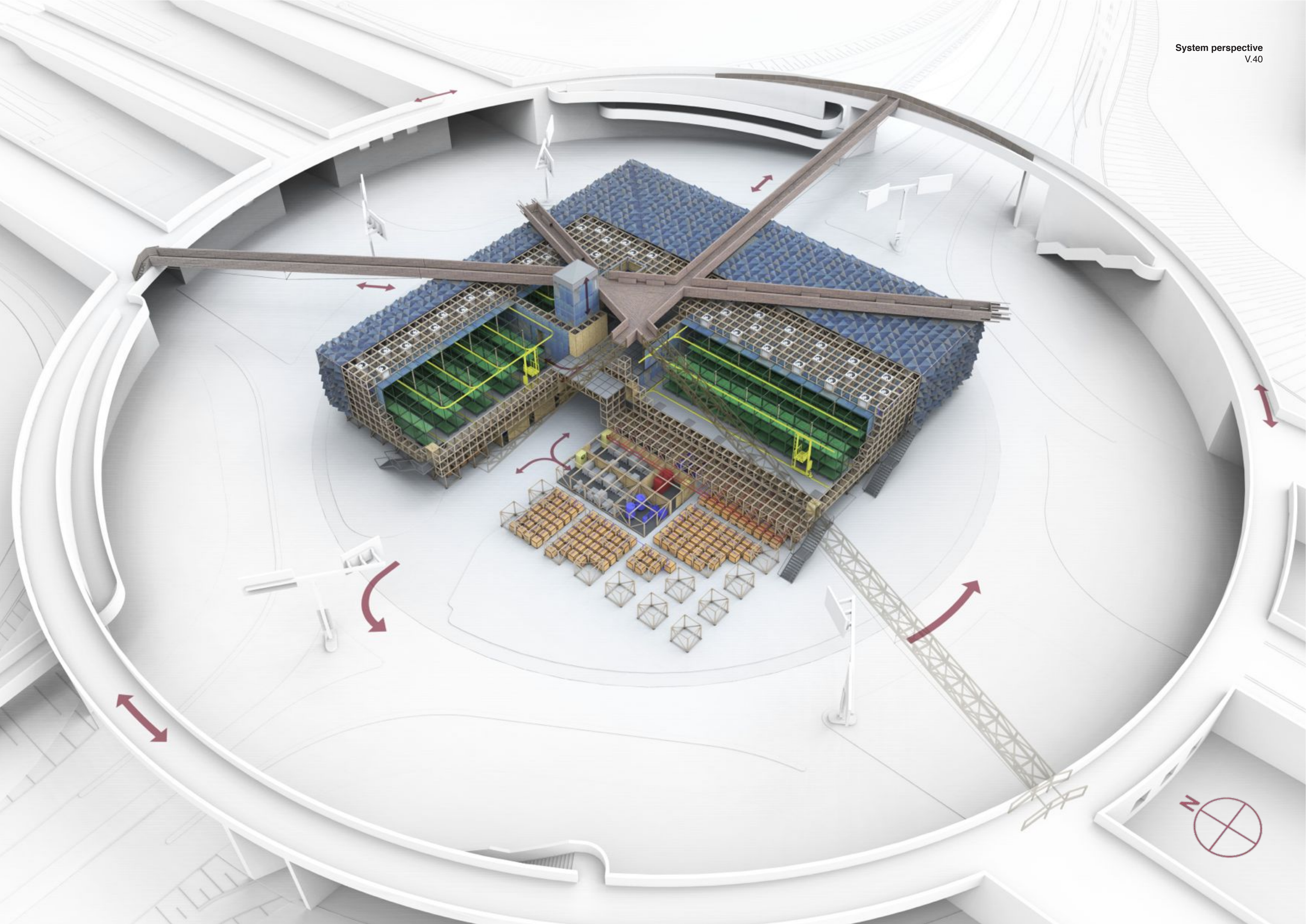
Utility level: recreation room (4x4m), showers and locker room (8x4m)
V.37



Utility level: heating unit (4x4m) and vegetable manufacturing unit (8x4m)
V.38



System perspective
V.40



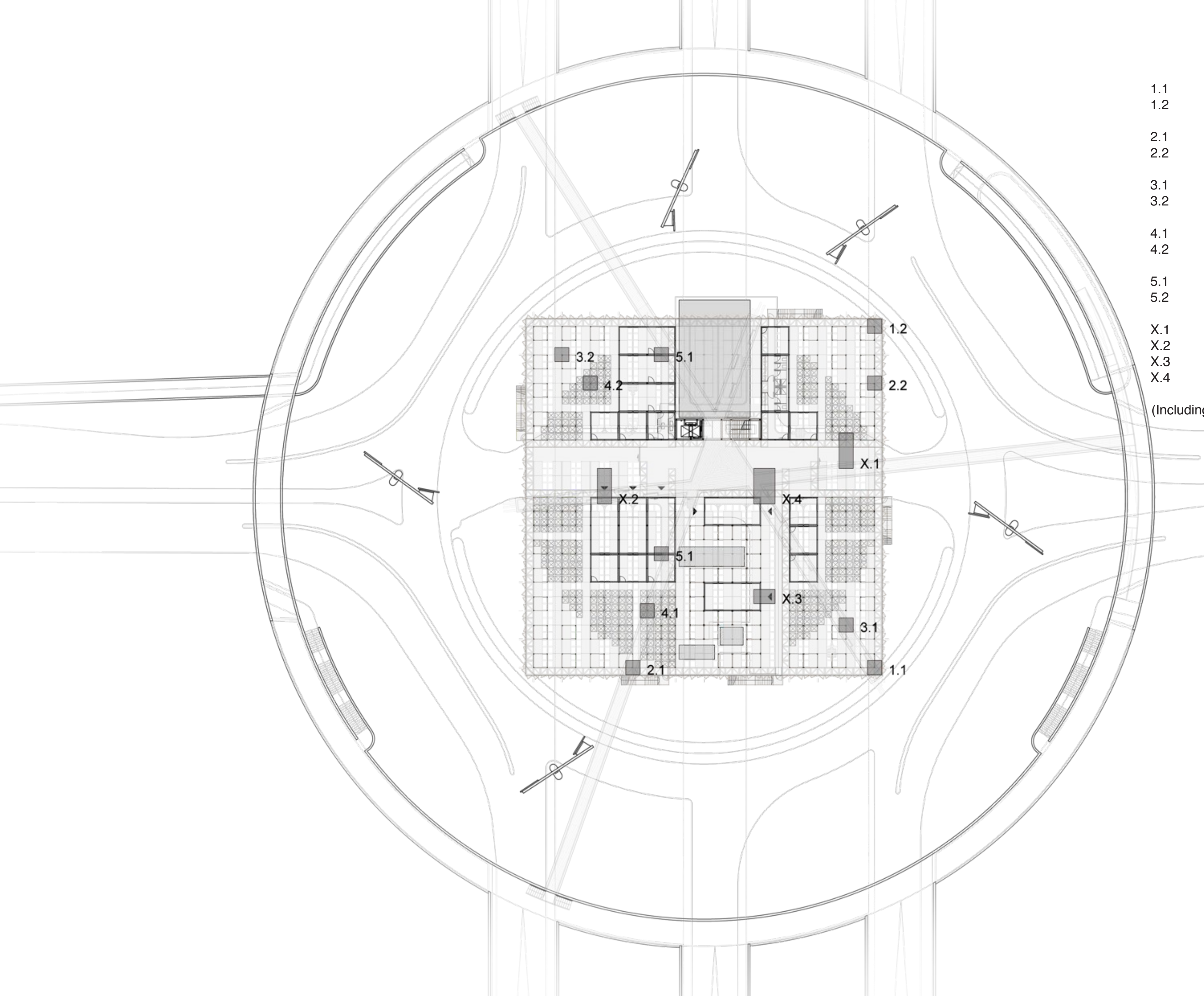
Street view
V.42

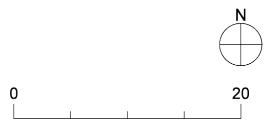
Interior view
V.43

Structural analysis
P.12

1.1	Corner situation (5,8t)
1.2	Corner situation (5,1t)
2.1	Wall situation (6,2t)
2.2	Wall situation (5,7t)
3.1	Rack situation (6,9t)
3.2	Rack situation (6,8t)
4.1	Rack + water tank (9,0t)
4.2	Rack + water tank (9,0t)
5.1	Rack + office box (7,2t)
5.2	Rack + storage box (7,9t)
X.1	Rack + water tank (10,6t)
X.2	Rack + storage box (9,2t)
X.3	Rack + storage box (7,3t)
X.4	Utility box (11,8t)

(Including snow and working loads)





[kN/m³]	Materials
6,00	Timber
78,50	Steel
25,00	Glass
10,00	Water
20,00	Concrete

Material loads
T.13
data origin: Robert Krapfenbauer: Bautabellen, Verlag Jugend und Volk Wien 1998

[m]	[kN/m³]	[kN/m²]	Ceiling
0,048	6,00	0,29	Framework
0,006	78,50	0,47	Construction
0,008	25,00	0,20	Gladding
		0,96	

[m]	[kN/m³]	[kN/m²]	Floor
0,048	6,00	0,29	Framework
0,040	20,00	0,80	Top-Gladding
0,020	6,00	0,12	Gladding
		1,21	

[m]	[kN/m³]	[kN/m²]	Walls
0,048	6,00	0,29	Framework
0,006	78,50	0,47	Construction
0,008	25,00	0,20	Gladding
		0,96	

[m]	[kN/m³]	[kN/m²]	Storage rack
0,010	78,50	**0,79**	Construction
		0,79	

Greenhouse loads
T.14

[m]	[kN/m³]	[kN/m²]	Water cubes
0,005	78,50	0,39	Frame
0,500	10,00	5,00	Water
		5,39	

[m]	[kN/m³]	[kN/m²]	Framework
0,040	6,00	0,24	Framework
0,100	20,00	2,00	Foundation
		2,24	

[m]	[kN/m³]	[kN/m²]	Boxes
0,020	6,00	0,12	Construction
0,040	6,00	0,24	Gladding
		0,36	

Utility loads
T.15

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	1	2	4,5	framework
1,21	2	2	-	4,8	floor
0,79	-	1	6	4,7	storage rack
0,96	-	3	6	17,3	walls
0,96	2	2	-	3,8	ceiling
					working loads
2,00	2	2	-	8,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				58	

1.1 Corner situation
T.16

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	1	3	6,7	framework
1,21	2	2	-	4,8	floor
0,79	-	1	5	3,9	storage rack
0,96	-	3	5	14,4	walls
0,96	2	2	-	3,8	ceiling
					working loads
0,50	2	2	-	2,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				51	

1.2 Corner situation
T.17

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	2	2	9,0	framework
1,21	2	2	-	4,8	floor
0,79	-	2	6	9,4	storage rack
0,96	-	2	6	11,5	wall
0,96	2	2	-	3,8	ceiling
					working loads
2,00	2	2	-	8,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				62	

2.1 Wall situation
T.18

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	2	3	13,4	framework
1,21	2	2	-	4,8	floor
0,79	-	2	5	7,9	storage rack
0,96	-	2	5	9,6	wall
0,96	2	2	-	3,8	ceiling
					working loads
0,50	2	2	-	2,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				57	

2.2 Wall situation
T.19

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	4	2	17,9	framework
1,21	2	2	-	4,8	floor
0,79	-	4	6	18,8	storage rack
0,96	2	2	-	3,8	ceiling
					working loads
2,00	2	2	-	8,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				69	

3.1 Rack situation
T.20

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	4	3	26,9	framework
1,21	2	2	-	4,8	floor
0,79	-	4	5	15,7	storage rack
0,96	2	2	-	3,8	ceiling
					working loads
0,50	2	2	-	2,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				68	

3.2 Rack situation
T.21

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	4	2	17,9	framework
5,39	2	2	-	21,6	water cube
1,21	2	2	-	4,8	floor
0,79	-	4	6	18,8	storage rack
0,96	2	2	-	3,8	ceiling
					working loads
2,00	2	2	-	8,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				90	

4.1 Rack + water tank situation
T.22

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	4	3	26,9	framework
5,39	2	2	-	21,6	water cube
1,21	2	2	-	4,8	floor
0,79	-	4	5	15,7	storage rack
0,96	2	2	-	3,8	ceiling
					working loads
0,50	2	2	-	2,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				90	

4.2 Rack + water tank situation
T.23

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	2	3	13,4	framework
5,39	1	2	-	10,8	water cube
1,21	5	2	-	12,1	floor
0,79	-	6	3	14,1	storage rack
0,96	5	2	-	9,6	ceiling
					working loads
2,00	5	2	-	20,0	roof
0,80	5	2	-	8,0	snow
3,00	3	2	-	18,0	service load
				106	

X.1 Rack + water tank situation
T.24

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	4	2	17,9	framework
0,36	-	4	2	2,9	storage box
1,21	2	2	-	4,8	floor
0,79	-	4	6	18,8	storage rack
0,96	2	2	-	3,8	ceiling
					working loads
2,00	2	2	-	8,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				72	

5.1 Rack + storage box situation
T.25

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	4	3	26,9	framework
0,36	-	4	3	4,3	office box
1,21	2	2	-	4,8	floor
0,79	-	4	5	15,7	storage rack
0,96	2	2	-	3,8	ceiling
					working loads
2,00	2	2	-	8,0	roof
0,80	2	2	-	3,2	snow
3,00	2	2	-	12,0	service load
				79	

5.2 Rack + office box situation
T.26

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	2	3	13,4	framework
0,36	-	2	3	2,2	storage box
1,21	3	2	-	7,2	floor
0,79	-	4	6	18,8	storage rack
0,96	3	2	-	5,8	ceiling
					working loads
0,50	3	2	-	3,0	roof
0,80	3	2	-	4,8	snow
3,00	3	2	-	18,0	service load
				73	

X.3 Rack + storage box situation
T.27

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	1	3	6,7	framework
0,36	-	1	3	1,1	storage box
1,21	5	3	-	18,1	floor
0,96	5	3	-	14,4	ceiling
					working loads
2,00	5	3	-	30,0	roof
0,80	5	3	-	12,0	snow
3,00	4	3	-	36,0	service load
				118	

X.4 Utility box situation
T.28

[kN/m²]	length [m]	width [m]	hight [m]	load [kN]	construction loads
2,24	-	2	2	9,0	framework
0,36	-	2	2	1,4	office box
1,21	5	2	-	12,1	floor
0,79	-	6	3	14,1	storage rack
0,96	5	2	-	9,6	ceiling
					working loads
2,00	5	2	-	20,0	roof
0,80	5	2	-	8,0	snow
3,00	3	2	-	18,0	service load
				92	

X.2 Rack + storage box situation
T.29

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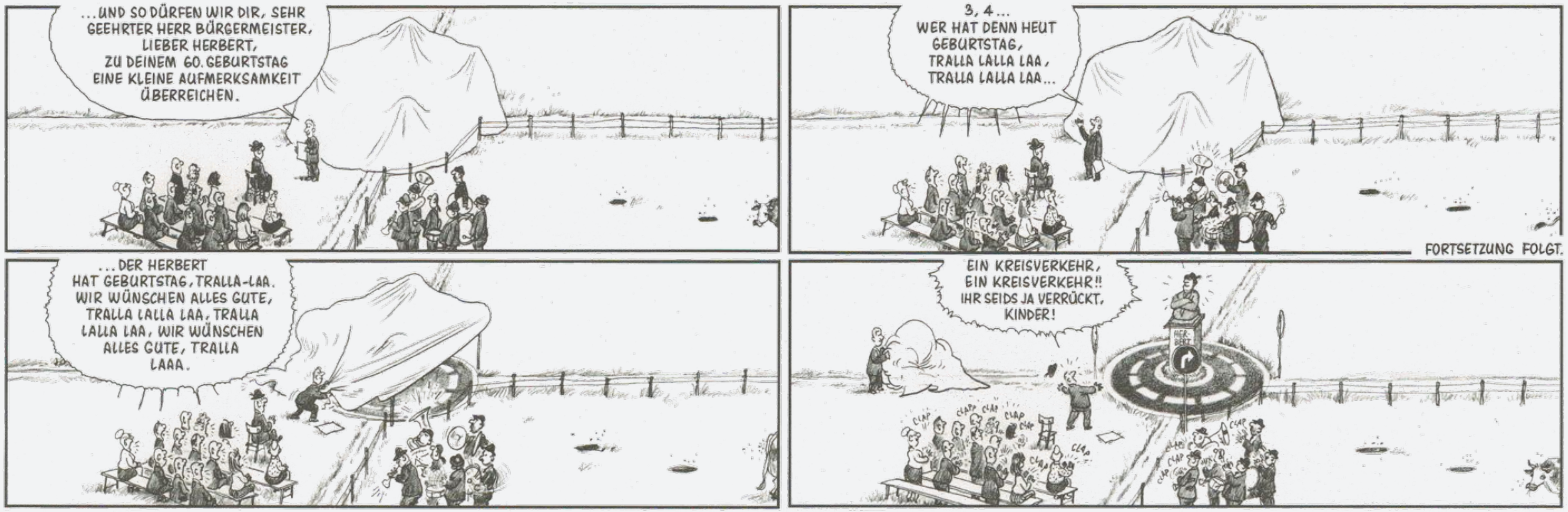

...characteristic Austrian roundabout decoration

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