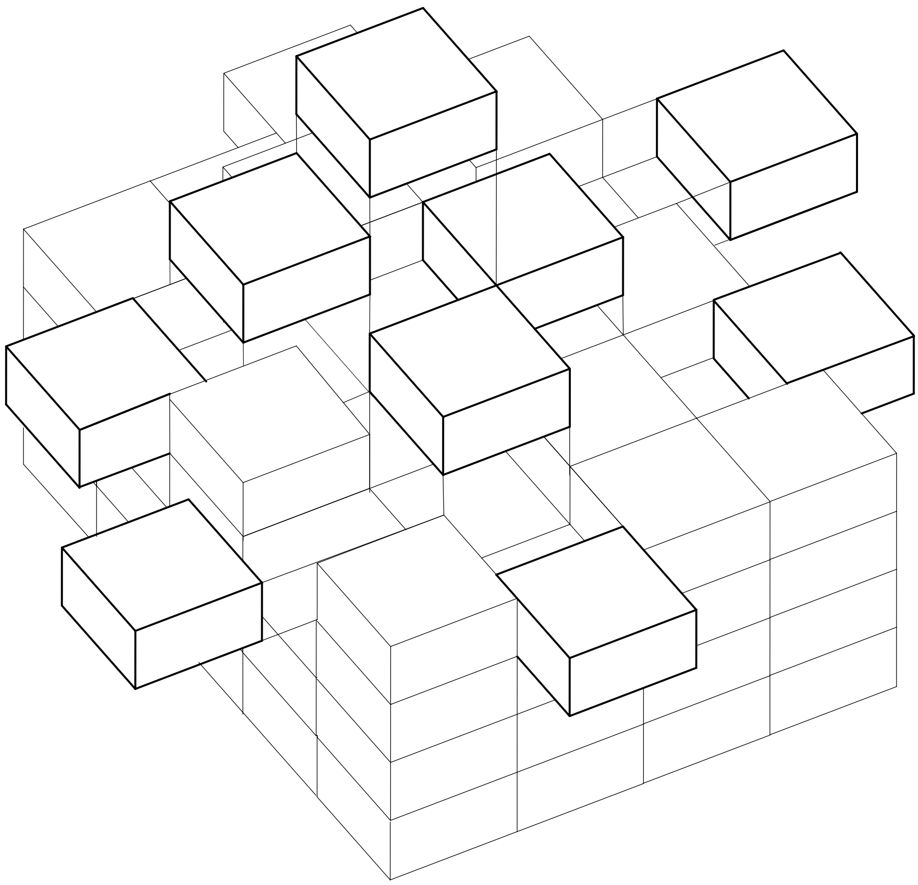
THE FOOD HUB
a Copenhagen's sustainable melting pot.

Aalborg university
A&D - MSc04 ARC - Master thesis
Group 23



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MOTIVATION

The initial motivation for the project was to design a future oriented building that addresses to sustainabiliy.

The primary aspect that affected the decision of the site in Refshaleøen, in Copenhagen was the uprising level of water, due to the Global Warming. The phenomenon of flooding is a burning issue, that affects Copenhagen and the specific site is proved to be in particular danger in the future, considering that it lays on the coast.

Moreover, the particular area according to the local plan is an area that is in development, therefore, this complies with the concept of designing a future oriented building.

The catalyst for deciding to design a food market was the ambition to create a building that represents a functional attraction and is able to improve the environment of the city. Alongside, with the future develepement of the Refshaleøen area, the food market will improve the users' well-being and will overwhelm the area with life.

ABSTRACT

This report presents the final result of the Master Thesis, part of the 4th semester in Architecture and Design, in Aalborg university.

The project will be developed through the integrated design process and by using the research and the evidence based design. The aim is to accomplish an integrated design for a future food market, throughout an holistic approach that combines a range of iterative processes.

Environmental and social sustainability are a major focus of attention within the project. Moreover, diverse topics, related to both the functions of a food market and the nature of the site will be developed. Some of them are: the phenomenon of flooding, that intimidates the city of Copenhagen , the senses related to architecture, the sustainable food production and consumption and the tourism.

An innovative proposal, with minimized energy consumption that meets the requirements of a zero energy building and adapts to the climate conditions will hopefully engage with the future development of the Refshaleøen area, to achieve a sustainable community.

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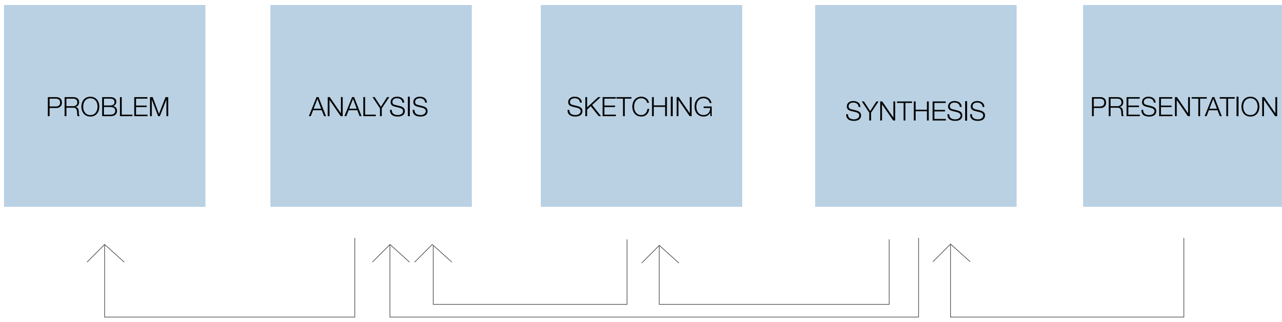
METHODOLOGY
Integrated Design Process (IDP)

Ill. 1 - Integrated design process (IDP)



The design of a sustainable market requires a holistic approach that focuses on the harmony between aesthetics, function and technical considerations. Moreover, architecture is challenged by different parties such as climate, sustainability, economic restrictions and unquestionably by the users' demands and needs. In a professional world, where the line between architects and engineers is blurred, it is vital that they use common tools and methods to ensure an optimal design. The integrated design process (IDP), developed by Mary Ann Knudstrup in Aalborg university is implemented as the methodology during the design process. It is an iterative process that comprises of five distinctive phases and requires going back and forward between them, to secure a holistic project where all the aspects of the design are considered and integrated from the early beginning. The five phases of the IDP are: the problem outline, the analysis phase, the sketching, the synthesis and finally the presentation. (Knudstrup, 2004)

PROBLEM PHASE

The initial phase is the problem configuration. A food market is designed in Copenhagen, in the Refshaleøen area optimized in terms of energy and climate demands, that scrutinizes the phenomenon of the uprising water level. An innovative holistic future- orientated project, considering the three aspects of sustainability, which is flexible and operative throughout the whole year. Finally, a market that intrigues diverse user groups and complies with their needs and expectations.

ANALYSIS PHASE

This phase consists of the investigation of different parties in relation with the site of the project and the project itself. Important premises are examined, such as:
Site conditions: The site and surroundings are analyzed to determine the potentials, limitations and qualities that they can offer to the architectural design.
Theme analysis: Various fields are researched including sustainable architecture, the fundamentals of energy consumption, the indoor environment of the building, essential for the users' health and well-being. Moreover, divergent user groups and their expectations are investigated and also the

phenomenon of floods, since the site is situated in the bank of the canal and the area is considered to be of high risk, in terms of the uprising water level. The analysis phase concludes with the building program.
Case studies: The case studies are part of the analysis phase. Different already existing architectural proposals are researched and investigated in terms of what qualities and aspects could be used and further developed in the final proposal.

SKETCHING PHASE

After the analysis the sketching phase kicks off, by integrating the architectural and technical considerations. Hand drawing sketches, 2D and 3D digital models, diagrams, as long as physical models are utilized to succeed an informed design. Programs such as LCA and LCC will be used to assess the materials' performance and Bsim and Be18 for the indoor climate and energy performance. Since the social aspect is quite important while designing such a project that deals with multiple users, tools, such as BSim are considered flexible enough to test the different temperature demands that may occur in the diverse functions of the project. Therefore, Be18 and Bsim will be guidelines during this phase. Important in the sketching phase is that every design proposal is evaluated according to the analysis phase, therefore it is imperative that steps back to the analysis phase are followed to gather the required information.

SYNTHESIS PHASE

This is the step where the chosen concept that conforms with all the parameters from the analysis and sketching is becoming more specific and concrete. The final technical calculations are prepared to ensure the optimal building performance. Concluding, the final proposal integrates the sufficient indoor climate, the required energy demands of 2020, the optimal selection of the materials considering the whole life cycle of the building, the users' needs and expectations and definitely the quality of the construction.

PRESENTATION PHASE

The last phase is the presentation phase, where the final project proposal is demonstrated in a report. The project is presented through plans, sections, elevations, visualizations and other illustrations that indicate whether the ambitions and objectives of the initial problem were accomplished.
(Knudstrup, 2004)

Research Informed / Evidence-Based Design

Ill. 2 - Reseach based- evidence based design

Research, reseach- informed and evidence based design are three definitions that are used interchangeably and are usually confused with each other. A clear understanding between these three terms is vital for avoiding the confusion in the design of the project.

RESEARCH

The aim of the research is to create new knowledge and scrutinize issues and questions in a precise and methodical process. (Stichler, 2016) The research comprehends of two distinct categories, the qualitative and quantitative, which are different to each other but both generate advanced knowledge. Quantitative research is utilizing the already existing physiological or organizing facts, published or randomised studies. Afterwards through statistical methods these data are analysed and used. On the other hand, the qualitative research is thrown in the cases that only a small knowledge about a topic exists or when there is the need to approach a topic in a different way. It consists of historical research, phenomenology, epistemology etc. (Stichler, 2016)

A common example of research are the case studies that will be also used as a guideline in this project.

RESEARCH-INFORMED DESIGN

Research informed design is a limited method, since it uses only published research as an informative resource. Particularly, published researched studies are used to instruct and guide the final design. (Stichler, 2016)

EVIDENCE- BASED DESIGN (EDP)

Evidence based design is the rational use of evidence to direct the decisions related to the design. The major difference between evidence based design and the research informed degisn is that the latter is using only published research studies, while the first benefits from multiple types of evidence to inform the design. Some examples of the EDP are the vendor's opinion, the advice, opinion of an expert related to such a design, the site visits or one's own experience. (Stichler, 2016)

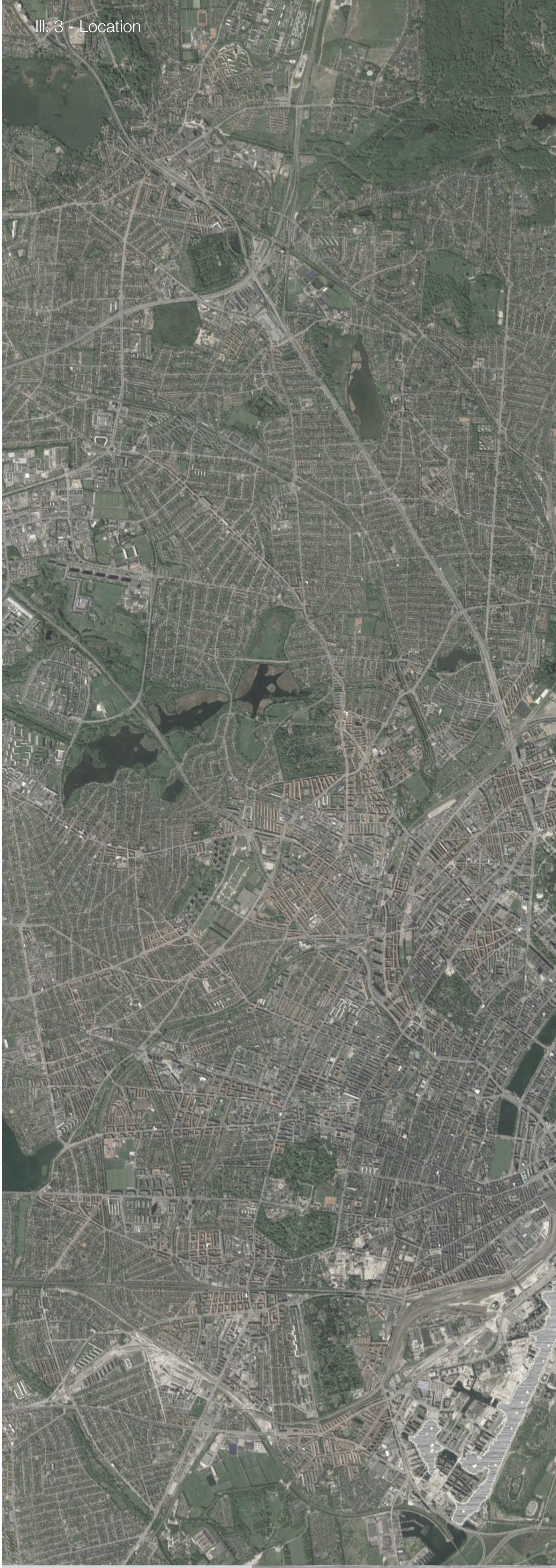
LOCATION

The site is situated in the area of Refshaleøen, which is part of the bigger island Amager in Copenhagen. It is in proximity of the city centre, and quite fast to reach both by public transportation and by bike.

Refshaleøen is an industrial region in the Copenhagen's harbor and for hundred years it accommodated the shipyard Burmeister and Wain, which employed 8000 people, therefore it is considered a figure for the Danish industrial history. Currently, the area experiences significant transformations. It mainly accommodates flea markets, small crafts, storage buildings, cultural and recreative activities. Most characteristic of them are the restaurant AMASS, the YARD art gallery, the Skabelonloftet community and so on. (Christianshavnernet.dk, 2019)

Currently, the area, which is almost 500.000m2 is owned by the company Ejendomsselskabet Refshaleøen A/S and in 2013 after cooperating with two other companies the SE Big Blue and the Energy Academy plan to redevelop it and transform it in a climate friendly neighborhood. Keeping in mind Refshaleøen as an old industrial area exceedingly polluted, they visualize it as the future sustainable place which will consist of sustainable businesses and housing. (Ue.dk, 2019)

Ill. 3 - Location

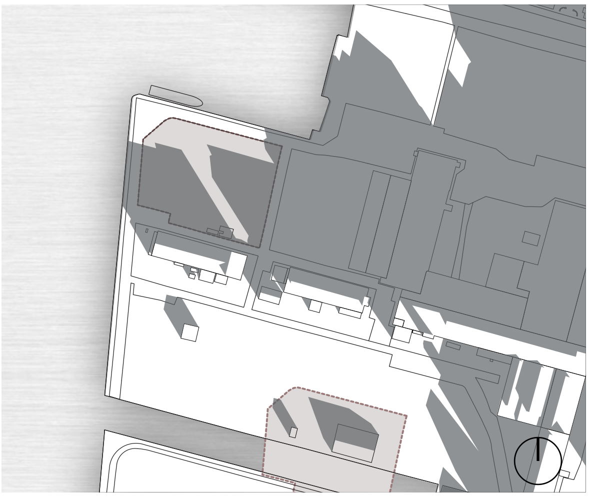


ANALYSIS

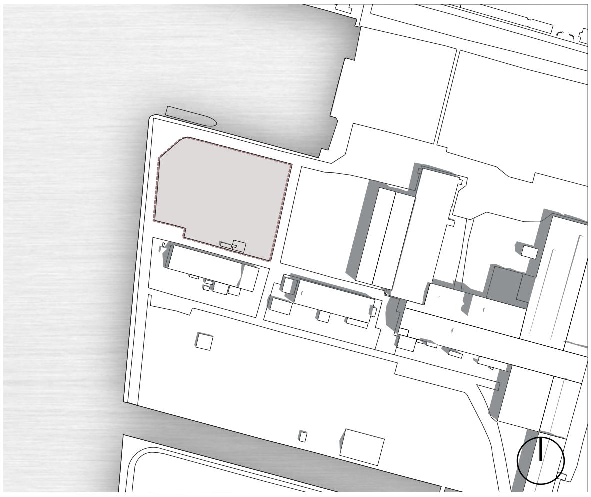
This chapter includes all the site and user analysis. The microclimate and urban analyses provide a full overview of the site's context. The users needs are outlined as well in the users analysis.

MICROCLIMATE ANALYSIS
Sun and shadows analysis

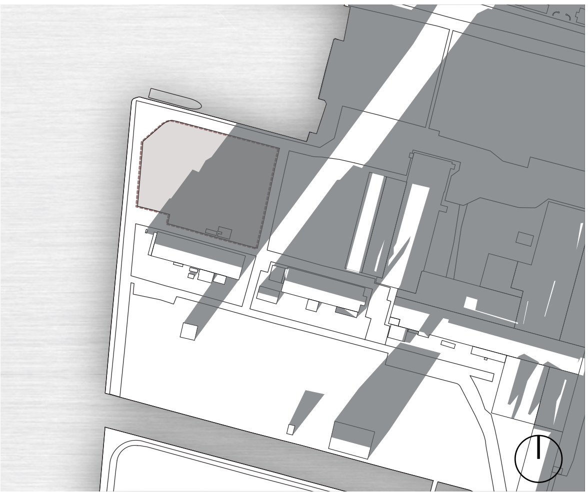
Ill. 4 - Site shadows in December at 10:00
Scale 1:5000



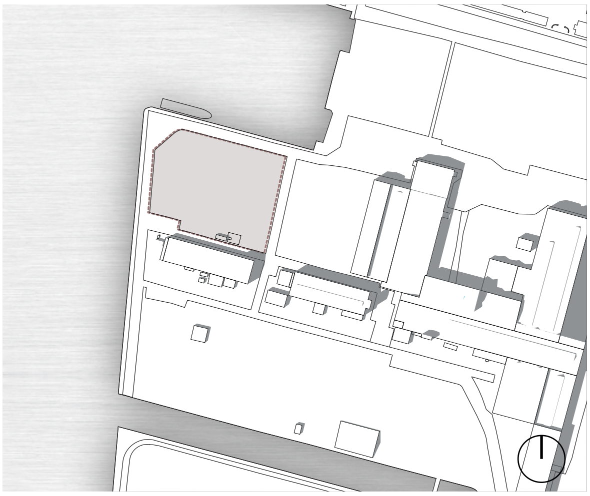
Ill. 5 - Site shadows in June at 10:00
Scale 1:5000



Ill. 6 - Site shadows in December at 15:00
Scale 1:5000



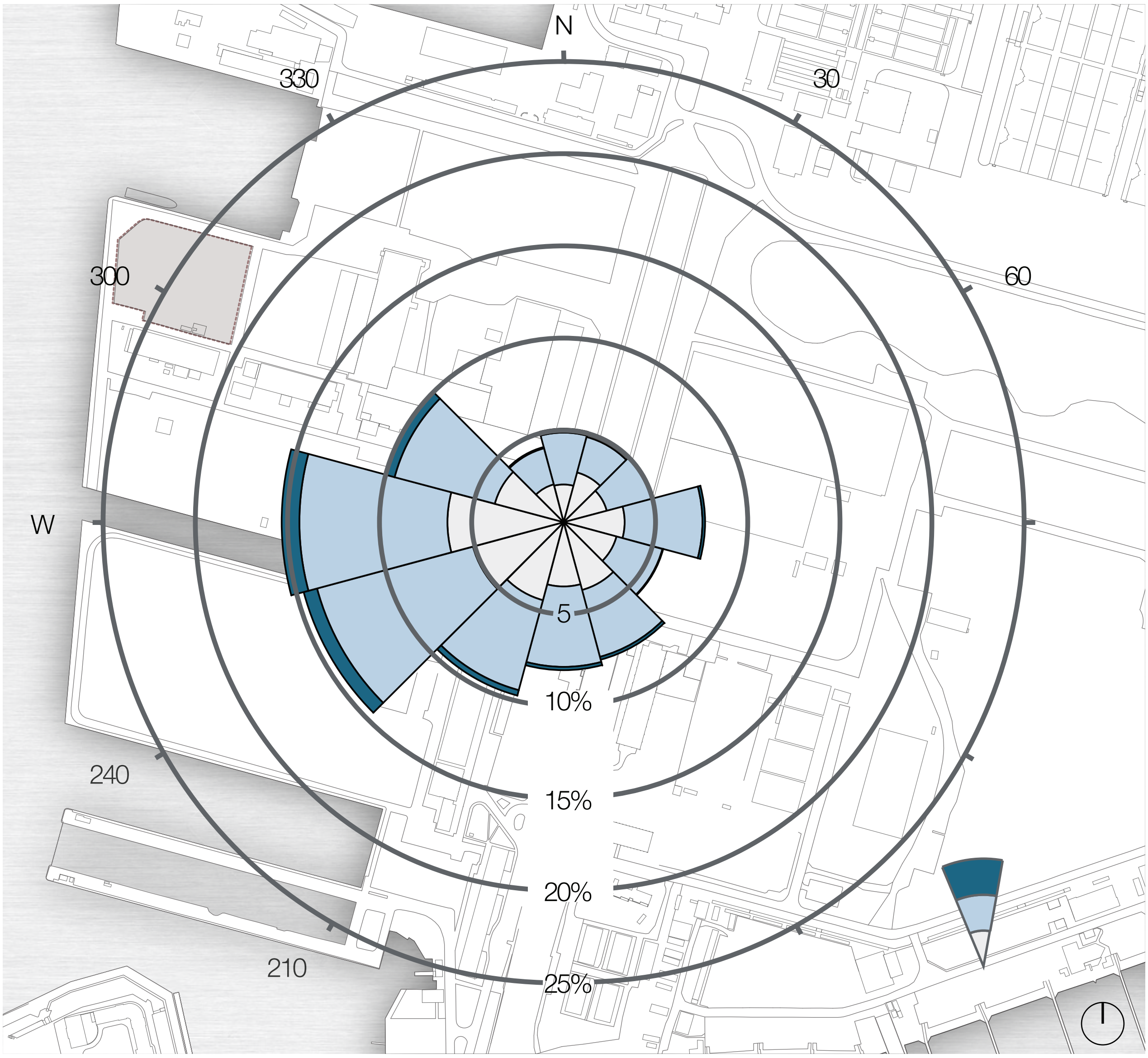
Ill. 7 - Site shadows in June at 15:00
Scale 1:5000



An analysis of the shadows has been carried out for two different days, the 21st of December and 21st of June, during the morning and the afternoon. The study aims to identify where overshadowing and sun exposure take place, in order to find the optimal placement of solar panels and to control those area that could be problematic for the indoor climate and the quality of the outdoor spaces.
Autumn and spring were also tested during March and September to get a better understanding how the context shadows the site and the diagrams are indicated in the appendix. In spring and autumn during the daily hours there is no overshading, allowing the solar panels to accomplish their peak performance. Moreover, in summer the shadows are minimized and there is no overshading, nevertheless the potential of overheatng should be taken into consideration. Finally, during winter the diagrams indicate that the area is particularly shaded therefore this will be considered for the placement of the solar cells. For the outdoor spaces, the diagrams that are relevant are those in June, since the users will use the out door area mostly during summer time.

Wind analysis

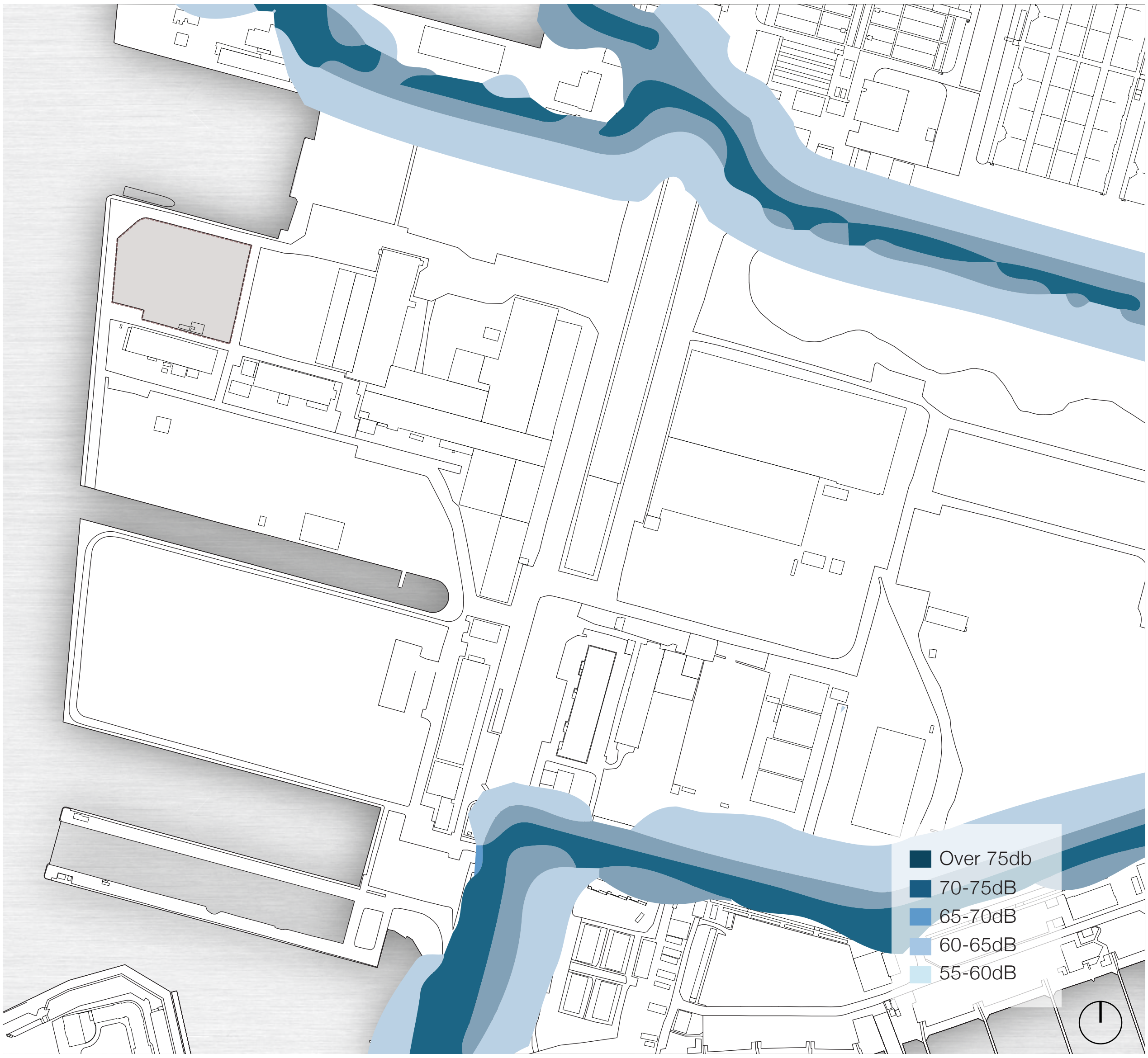
Ill. 8 - Wind analysis, scale 1:5000



The wind rose study was developed in Copenhagen airport between the 01-01-89 and the 31-12-98. (Dmi.dk, 2019) The predominant directions from south-west will be the same,and therfore the site may affect the local wind direction. As perceived from the area the main wind directions affect it, since it is not shielded by other buildings or vegetation. Moreover, also the wind that comes from north, even though it is not strong, is also affecting the site. The fact that the site lays in the canal of the sea creates a wind channel that will harm the future food market. Concluding, there is a requirement for shielding the building from southwest and north for securing a calm atmoshere and furthermore the wind direction will be considered for the design of the windows, so as to ensure adequate natural ventilation. (Dmi.dk, 2019)

Noise analysis

Ill. 9 - Noise analysis, scale 1:5000

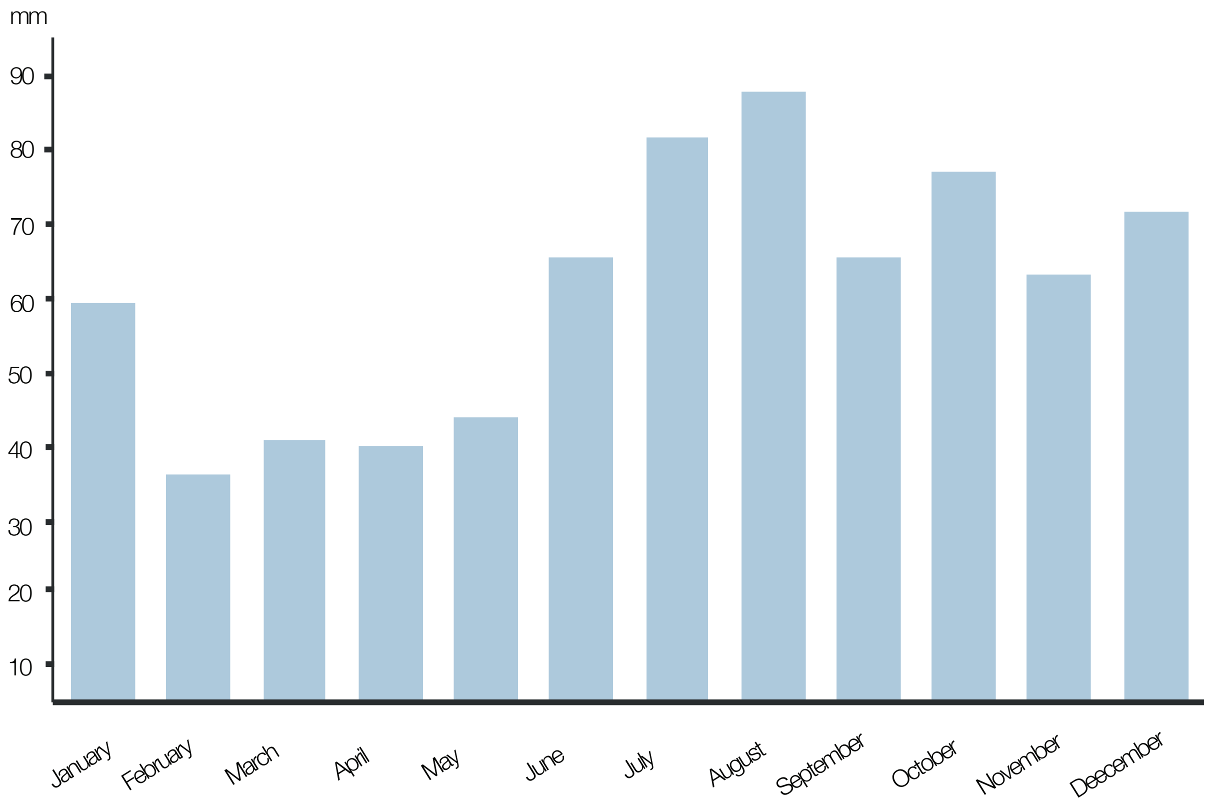


A noise analysis has been carried out according to the noise Denmark map, which demonstrates the noise load among the biggest roads and railways. The noise is determined according to the Danish Environmental Protection Agency's limit values. Particularly, the map indicates the noise produced by the roads, companies and railways during the day at a height of 1,5 m. (Miljøstyrelsen, 2012).

Generally, the site is located in a quiet area. The map shows that it is not affected by the noise caused by the largest street of the area, Refshalevej and the decibels are retained lower than 58, which is the recommended level. Therefore, there is no need for shielding, since the functions of a market, which will be crowded throughout the whole day, generally do not require protection of the high noise levels. An exception could be represented by those functions that may involve activities demanding concentration.

Precipitation

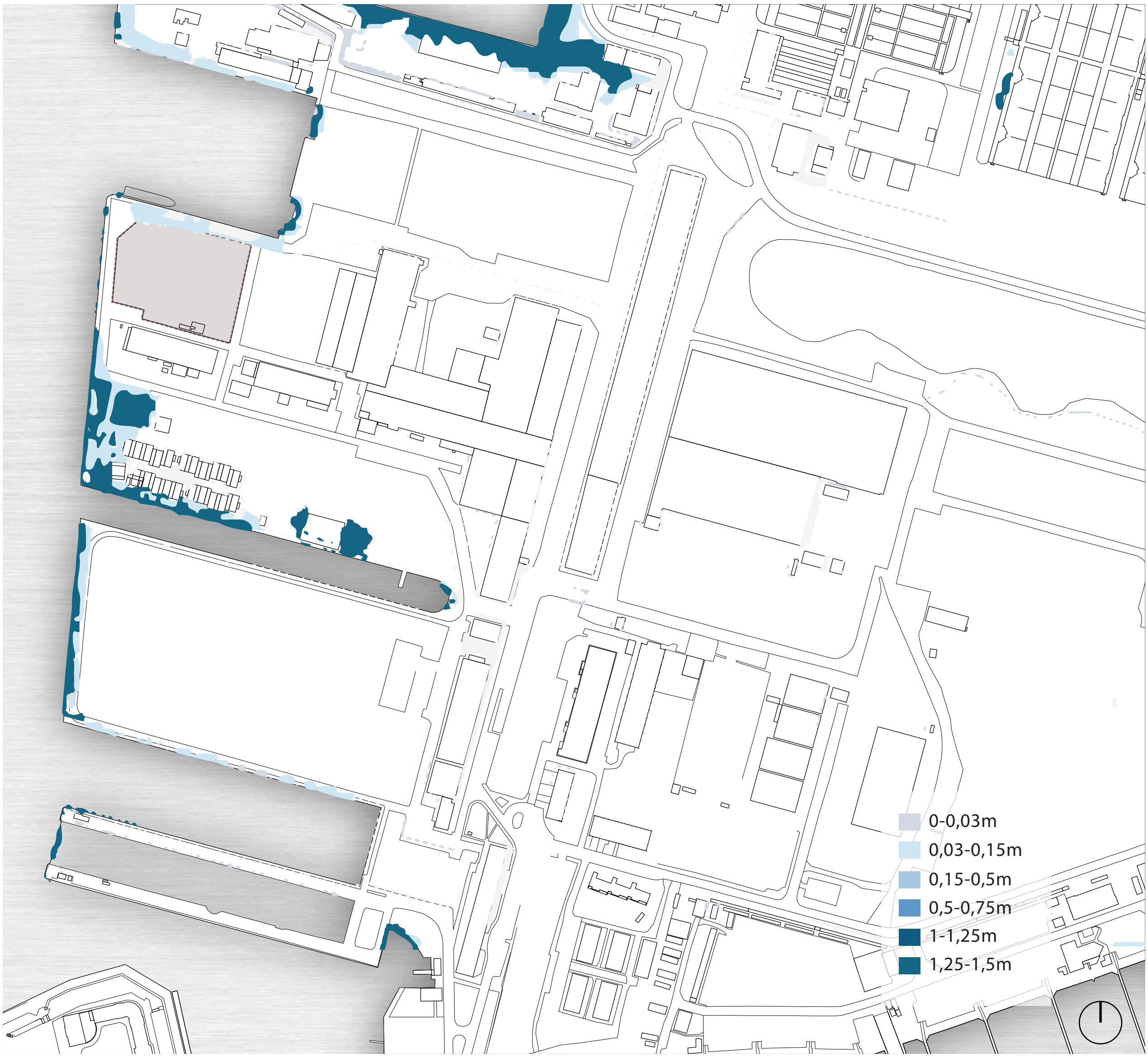
Ill. 10 Precipitation graph



Since the relationship with water and its possible rise is an important issue within the project, an analysis of rainfall has been carried out to understand the problems that rain could cause and the periods at risk.
The graph shows the average values of monthly rainfall in Copenhagen, in millimeters , in the period 2011-2018. (Danmarks Meteorologiske Institut, 2019), showing that most precipitations fell in July, August, and October.
Due to recent climate change, the number of extreme rains events is being increased and this means, for example, that rainfall will fall in larger quantities but in fewer days, causing more damage as a result.
Concerning the water rise in the area, the surge of storms, in the next 100 years, could cause an increase of water up to 1.5 m. (Kbhkort.kk.dk, 2019)
The solution that will be implemented in the project have to be able to face both, small seasonal floods, such as those expected in the near future and a possible final rise in water too.

Storm surge analysis

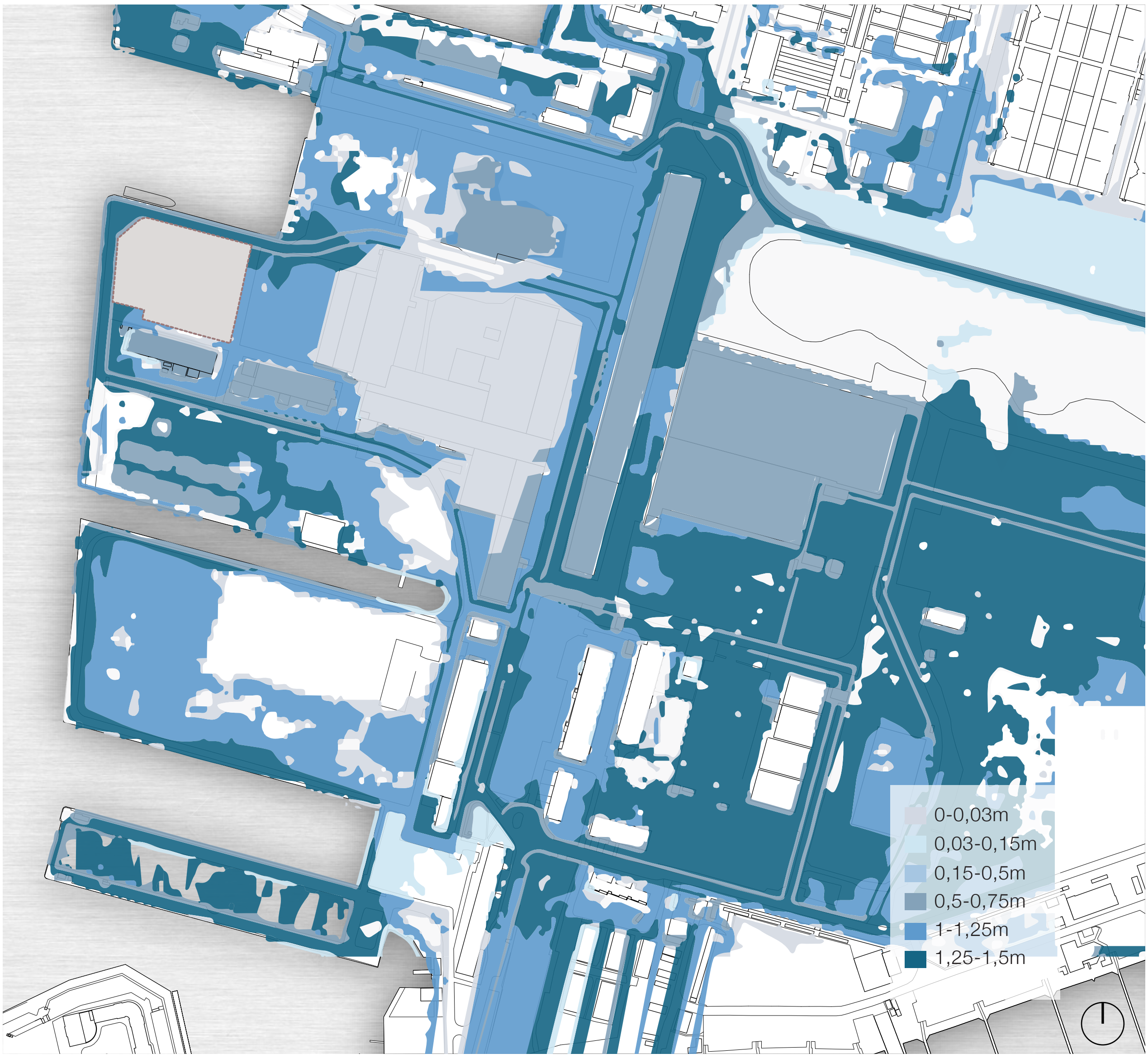
Ill. 11 - 100 year storm surge 2060, scale 1:5000



The map analysis indicates how much the area is flooded after respectively 40 and 100 years. As already mentioned in the flooding chapter, Copenhagen and particularly the area that the site is situated in, is of particular danger because of the upraising level of the water. Generally, the terrain is particularly flat and the area has not been shielded during the years. After 40 years, as shown in ill. 35 the site is not greatly flooded due to storm surge. Nevertheless, after 100 years the sea level will uprise at least 0,5 meters in most of the surroundings.

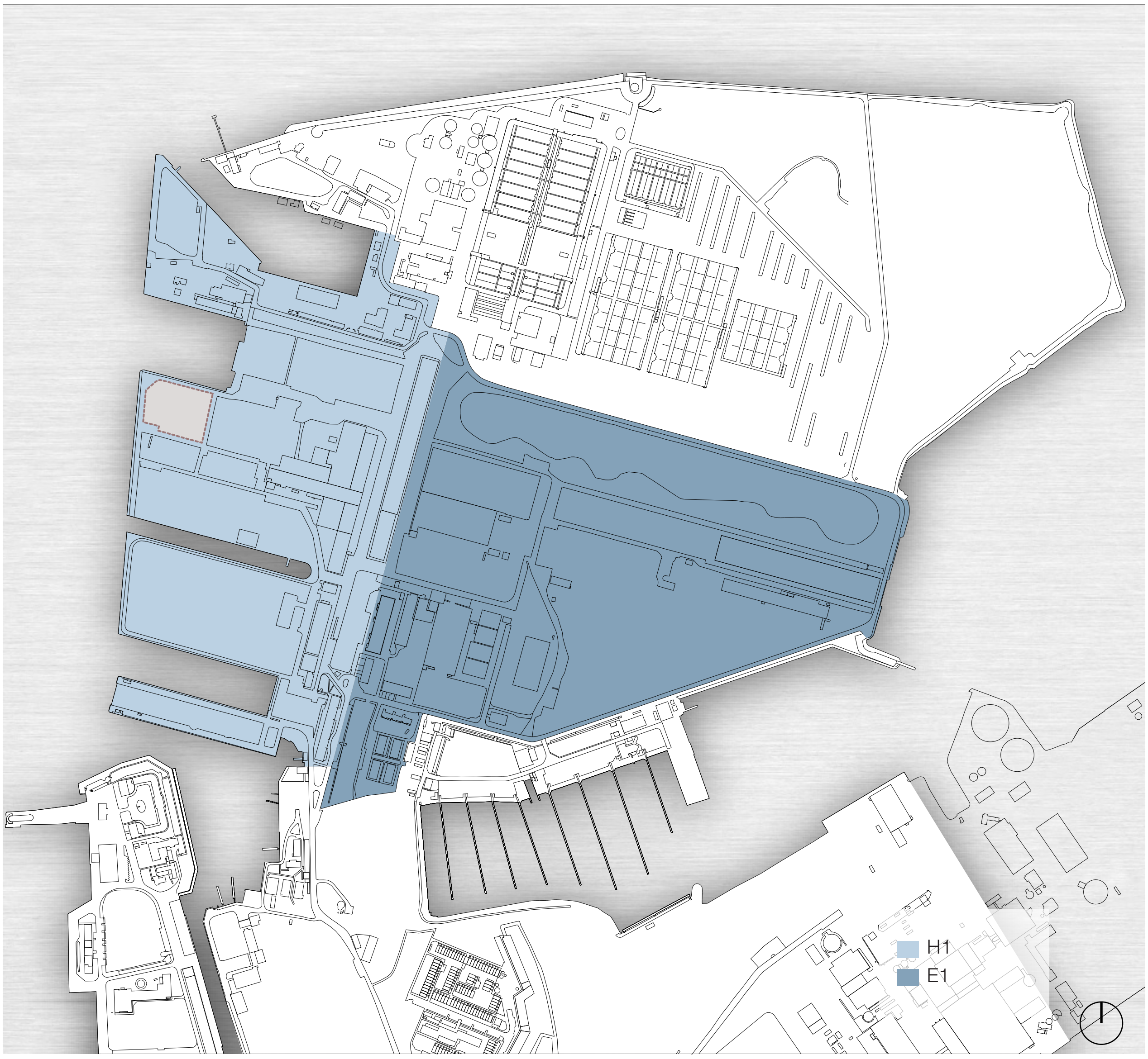
Since we are discussing about a future-oriented design and project this should be taken into consideration and strategies for dealing with the issue of flooding should be a focus for the design process, as already mentioned in the 'Flooding' chapter.

Ill. 12 - 100 year storm surge 2110, scale 1:5000



URBAN ANALYSIS
Local plan

Ill. 13 - Local plan n° 209 “Refshaleøen”, scale 1:10000



Refshaleøen, is considered a prospective area, which means that the urban development will start after 2023, when better traffic and improved environmental conditions will be available. In the meantime temporary activities are developing where the industry has left empty buildings, becoming thus part of the growth layer. Today, Refshaleøen is an area where people can go to work, to a concert, enjoy a gourmet meal, play beach volley, go to a gallery or enjoy the view of Langelinie and Frederiksstaden in industrial surroundings.

After Burmaister & Wain’s Shipyard closure in 1996, historical activity related to the area, a new local plan, in the form of supplement to the local plan n° 209 “Refshaleøen”, was required, due to the limited range of planning laws and exemptions provided.

The Local Plan 209 includes, a western area for mixed industries (E1) with a maximum settlement rate of 110 % and an eastern area for harbor purposes (H1) with a maximum settlement rate of 60 %.

Areas for mixed industries are generally used for lighter industries, workshops, craft, storage, wholesale and transportation with related administration, as well as for service industries, business, leisure, education and other companies that can be accommondated in the area. In addition, public enterprises can be admitted as technical structures, institutions and other social, educational and cultural service functions compatible with the application to mixed professions. Shops are allowed in accordance with retail provisions. Therefore, independent shops serving a local area may be created. The gross area of food shops should not exceed 500 m^2. In addition to a production company, a smaller shop may be granted for the sale of the company's products. The retail area may not exceed 20% of the total area of the holding and a maximum of 500 m^2.

Areas for port purposes are generally used for workshop and industrial enterprises with associated administration and similar, which have a particular connection to the port (need for sea transport) or which naturally belong to a port area. In addition, the public sector which is compatible with use for port purposes may be authorized.

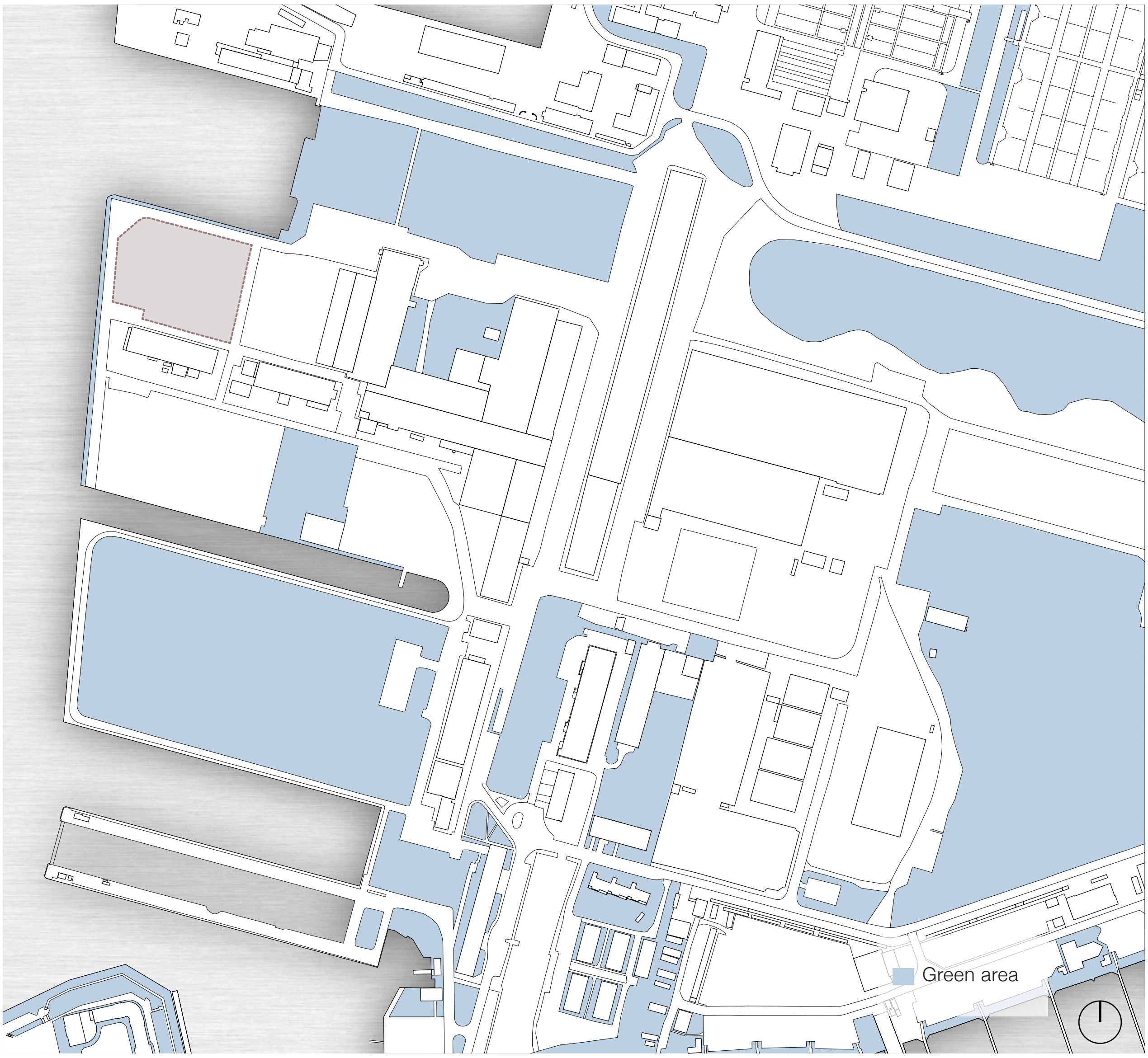
The purpose of the supplement local plan is to create the opportunity to promote diverse and flexible uses of the old shipyard area and to expand the use of an abandoned industrial area with new activities that support the distinctive character of the zone, based respectively on three core values for the development of Copenhagen: ”A good everyday life”, ”Knowledge and business” and ”Green growth”. The plan will lead to large uses, such as small manufacturing companies, as well as collective facilities, sports and recreational facilities, museums, theatres, galleries, concert halls and restaurants, that promote urban living. Offices and open spaces must be designed to meet the needs of people including individual urban spaces, that should be open to all and inviting to stay. Moreover, through the new plan basis, it is foreseen a strengthening of the relationship with the educational institutions at Holmen, as the Academy of Fine Arts' School of Architecture and Film School, which, besides, already have departments and workshops at Refshaleøen.

The Refshaleøen area is moreover recognised as a valuable cultural environment. B & W shipyard reflects an important part of Copenhagen's history as a portual and industrial city. In fact, B & W has been one of Denmark's largest shipyards for over 150 years. In the designated cultural environment, decisions on construction, demolition, application changes and similar must include the historical-cultural, architectural and/or landscape values of the area. The urban development planning should ensure that the values and historical-cultural contexts of the area are taken into consideration, so that the essential qualities can be used as a resource, which can make visible the benefit of the preservation, the experience of the city's history and the identity of the transformed urban areas.

Nowadays, the district has a very active cultural life, particularly strong in terms of musical experiences and galleries, which is another reason, according to the local board, to preserve and further strengthen the cultural power of the area.(Københavns Kommune, 2015)

MAPPING
Green and blue area

Ill. 14 - Mapping, Green and blu area, scale 1:5000

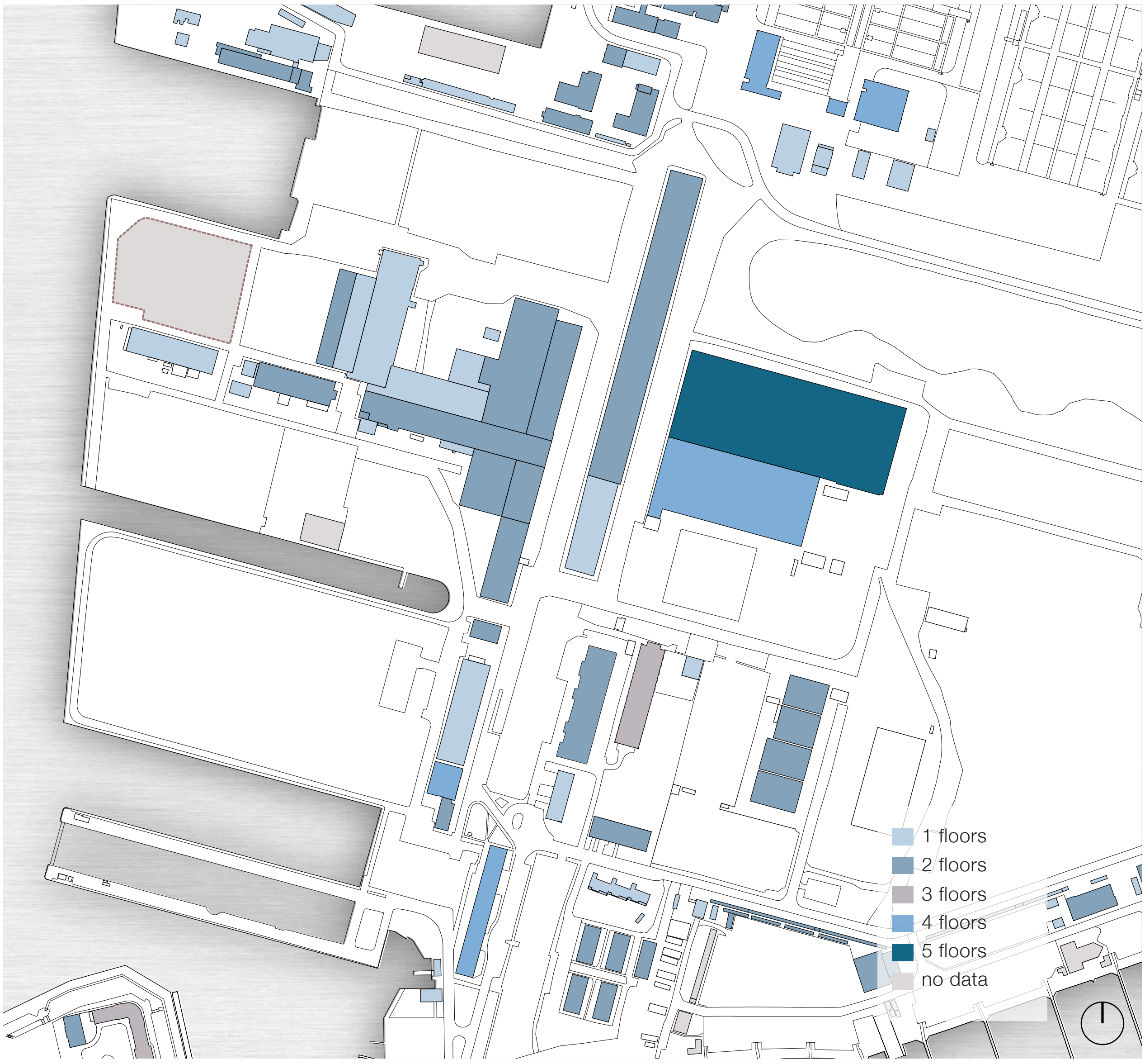


The Refshaleøen canals strongly characterize the whole area, also reminding of its ancient industrial-port function. The green areas are not particularly large today, however, the local plan involves the development of a green path from Stadsgraven until the end of Refshaleøen. The project supports the objectives of good cultural and recreational facilities for organized and self-organized sports and cultural life, which strengthens Copenhagen's opportunities to live a healthy and active daily life. In addition, it supports the objectives of green respiratory forums and green mobility. (Københavns Kommune, 2015)

The local plan also provides with the cultivation of urban gardens within the area (Københavns Kommune, 2015); a new trend in the development of modern cities, arising in relation to the environmental problems of the world and accelerated urbanization (Game and Primus, 2015).

Buildings height

Ill. 15 - Mapping, Buildings height, scale 1:5000



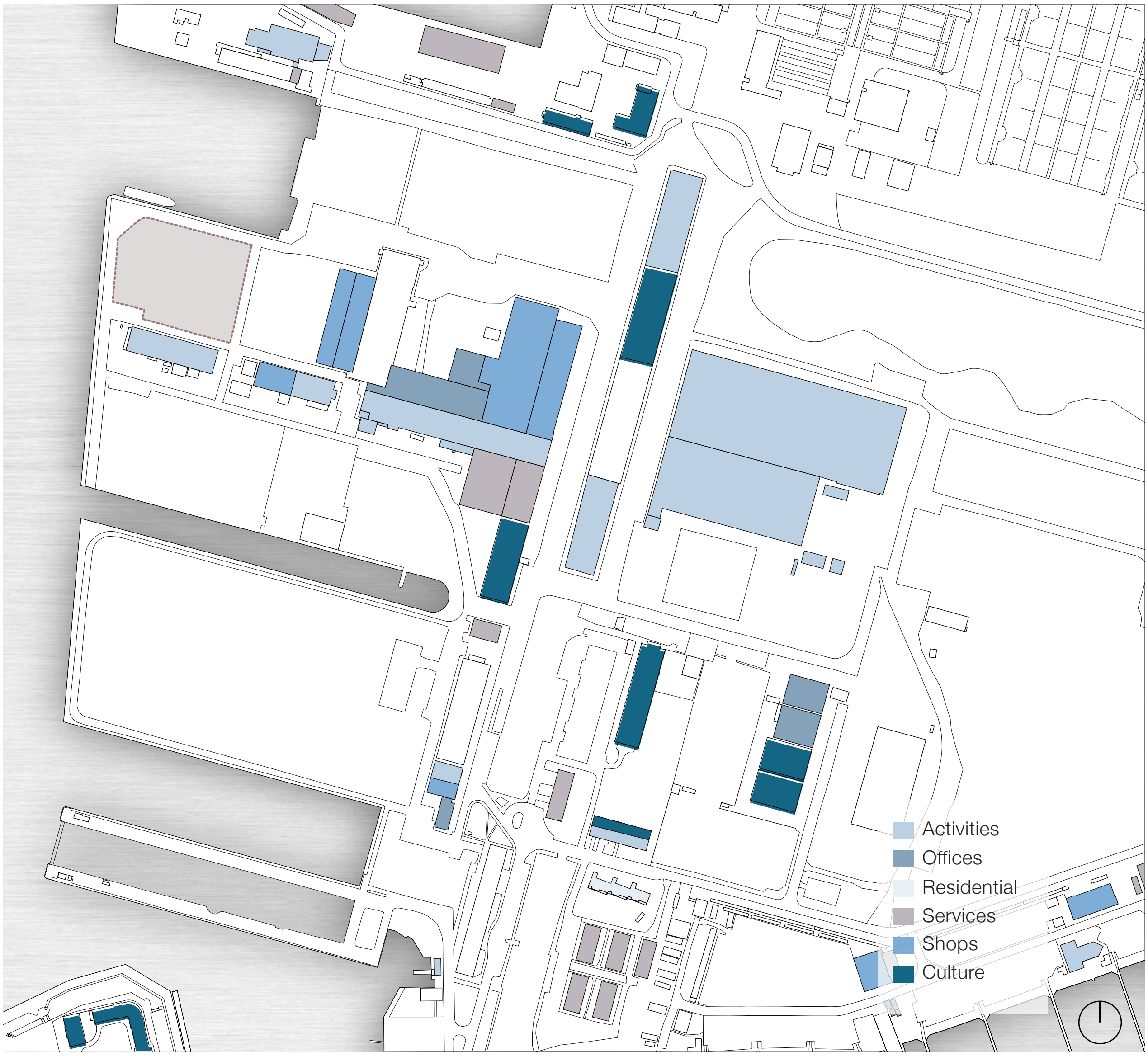
The buildings height analysis clearly shows that the local buildings do not exceed two-three-storey height. The four-storey buildings are very few and only new constructions. The tallest buildings in the area, which exceed five-storey height, are the ones belonging to the ex-B & W shipyard, buildings of historical value for the entire area.

In accordance with the supplement to local plan no. 209 "Refshaleøen", the maximum height of new buildings must not exceed 20 m height (Københavns Kommune, 2015).

As far as the height of the buildings around the project site is concerned, there should not be consistent overshadowing problems during the warmer seasons, when people are supposed to stay outdoors, thus allowing the design of open spaces.

Buildings functions

Ill. 16 - Mapping, Building functions, scale 1:5000



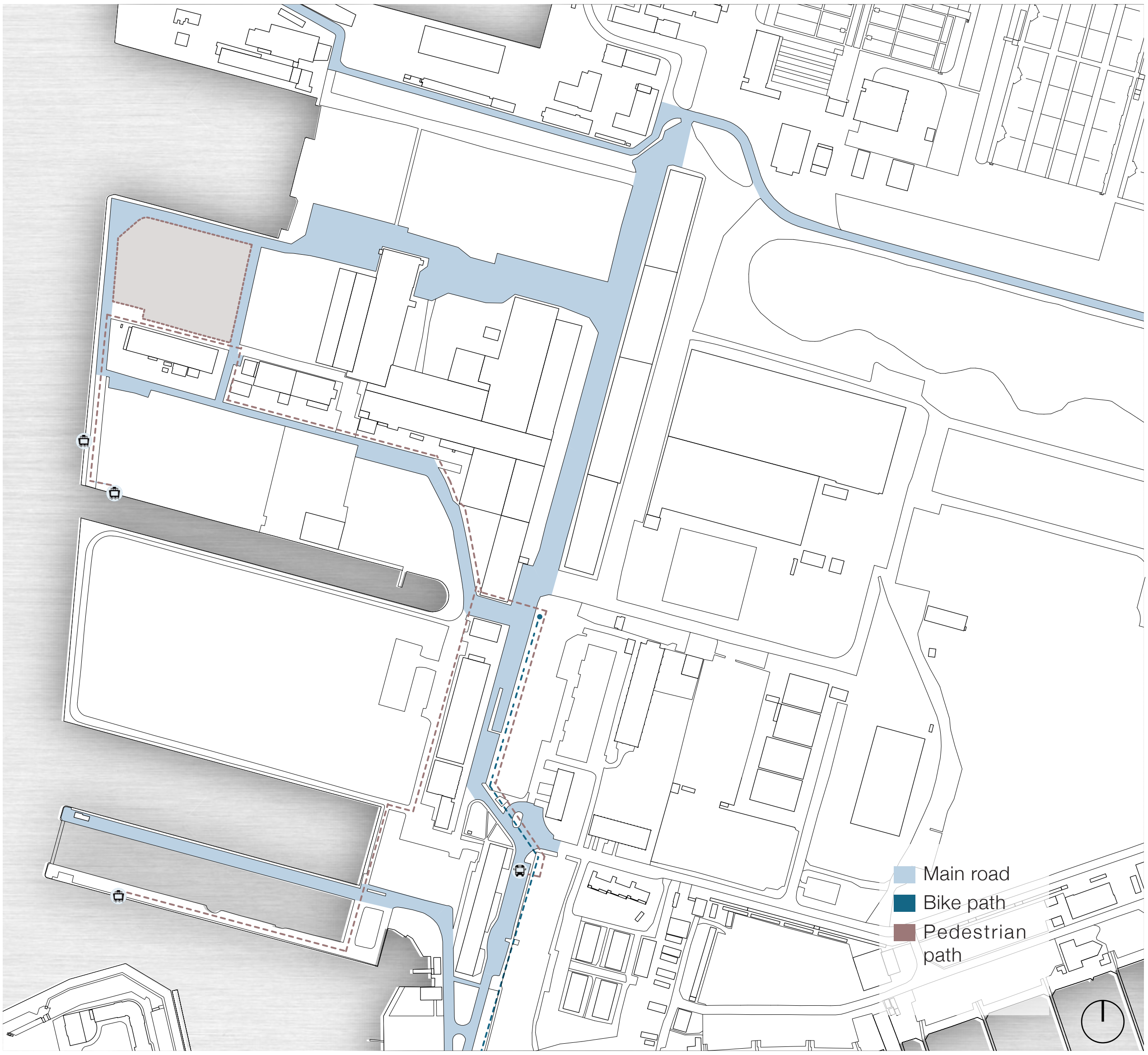
In order to understand with which kind of users the area is populated, and which direction the development of Refshaleøen from industrial to urban area has taken, an analysis of the functions has been made.

From the map it is evident that residential buildings are very few today, even if the local plan foresees them in the future. It is also clear that at Refshaleøen it is possible to find a real mix of functions: near the site there are offices, multifunctional spaces, shops, cultural centers, restaurants, gyms and sports centers. There is also a small accommodation facility and laboratories owned by the Academy of Fine Arts' School of Architecture.

The users who populate the area range between students, employees and tourists. Today the area is more populated by day than by night, an aspect that must be taken into account with regard to the safety of future users. (Gehl, 2010).

Infrastructures

Ill. 17 - Mapping, Infrastructures, scale 1:5000



Refshaleøen is connected with the rest of the city with only a few routes. Refshalevej is the main connection for the cars.

Until now, the cycle path only reaches a certain point in Refshalvej, as it is shown in the map. The local plan foresees for the area recreational cycle path and improved cycle connections. One of the project's goals is indeed to extend the bike track, alongside with the pedestrian route, all the way to the project area.

Public transport consists of line 9A and the Ferry, which was introduced in Refshaleøen in 2013. (Københavns Kommune, 2015).

Moreover, some touristic ferries have been recently added to the area. The guided tour Hop On Hop Off is availabe during the day and the CPH Water Shuttle sails between Langelinje and Reffen every 30 minutes. (Reffen.dk)

TOMOGRAPHIES
A phenomenological impression of the area

Thomographies in general is a method of exploring a phenomenon through a large number of examples or perspective. Urban tomography in particular is used to study the phenomenological impression of an area or a city by focusing on repetitive elements. (Krieger, 2011)

In order to give an instant view of the diversity of Refshaleøen, a sequence of pictures showing the different materials of the area has been collected. This pictures collage help to understand more specifically the composition of the area and can help to the correct implementation of the examined elements into the project.

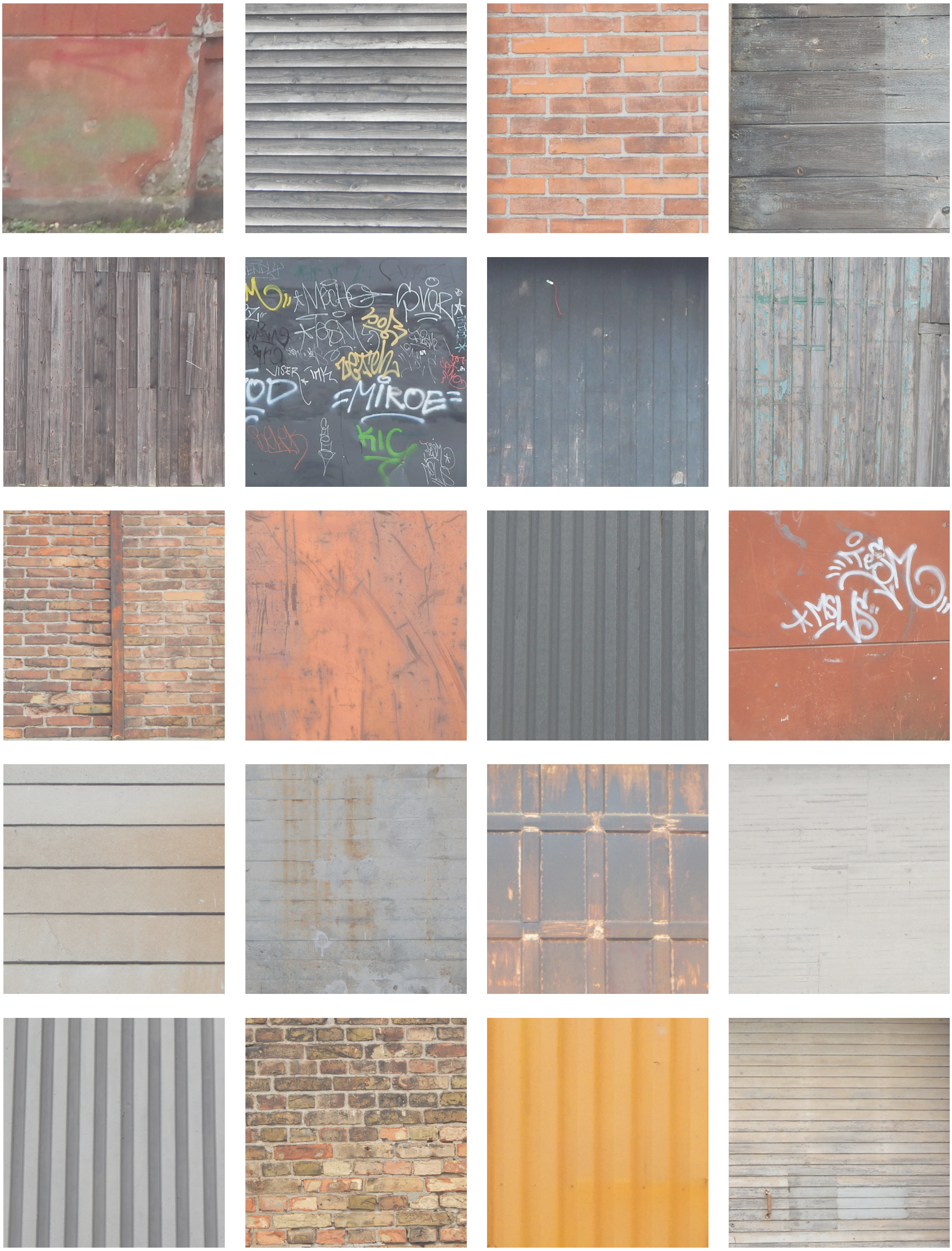
Observing the collage, it is evident that the diversity of materials is very high. It is difficult to find a main material, since they range from bricks of different sizes and colours, to different types of wood, from concrete with various types of textures, to steal and coloured containers.

Looking carefully at the textures, it can also be perceived Refshaleøen’s rugged and not yet fully urbanized character. In some photos it is possible to see patches of mould and humidity on the walls, in others it is possible to perceive that the wood has been aged and damaged by atmospheric agents and in others it is even possible that the facades of the buildings have been damaged by colored writings.

Although, at a first sight, this view may seem desolate, after have considered the architectural typologies of the food market and streetfood, the situation changes. These are places where diversity rules and where all this mixture could be tided up and become “part of a single and recognizable experience” (Norbeg-Schulz, 1984).

Materiality

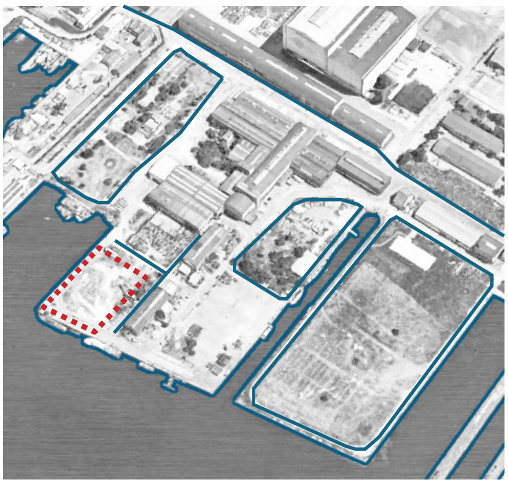
Ill. 18 - Site materials collage



LEGIBILITY
Kevin Lynch's urban analysis

Ill. 19 - Paths

Ill. 20 - Edges



Ill. 21 - Nodes

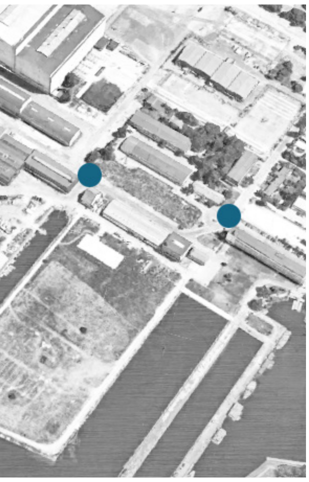
Kevin Lynch (1918-1984) was a professor of Urban Design at the Massachusetts Institute of Technology and he played an important role in the twentieth-century urban design. One of his most famous books is "The Image of the City", and it still represents one of the most widely readen urban design publications of all time. Lynch pioneered the concept of people drawing "mental maps" and underlined the importance of analyzing them to understand how people perceived their surroundings. In fact, he main focus of the urban analysis he illustrates, is on the people and on the users of the spaces. When people enter a building, they have some perceptions of the spaces. Therefore, the aim of Lynch investigation is to understand how people feel the urban environments, in order to understand in depth how a design can respond to the conscious and unconscious human needs. (Sethspielman.org, 2019)
According to Kevin Lynch theory, the city consists of some primary form elements. In particular, he defines five principal subdivisions: paths, nodes, edges, landmarks and districts. (Lynch, 1960)

PATHS

Paths are defined along where the people and goods flows are usually happening (Lynch, 1960). In particular, in the main paths placed close to the project site, the traffic of both people and cars and other vehicles is not consistent. The main street to reach the place is Refshalevej, and at the beginning it appears wide and easily walkable, but while approachinng the site the road spreads in more narrow side streets that make the access and the way finding to the area result in being difficult to understand and confusing. Furthermore, another path that must be considered, is the flow of boats that is happening close to the coast of the project site.

EDGES

The concept of the edges aims instead to differentiate one part of the urban fabric from another (Lynch, 1960). In the site area, the main boundary is the coast and the presence of the water itself, which defines a strict limitation. Moreover, the street



Ill. 22 - Landmarks

Ill. 23 - Districts

Refshalevej itself, when becomes wider determines a division of spaces, as well as the long and massive buildings placed along the site and the greenery presence on the south of the area.

NODES

The nodes are presented as where the activities, and often paths, meet (Lynch, 1960). A node that results to be particular interesting for the analysis of the area is the ending stop of the 9A bus, because it represents both a start and an end point of two different flows of pedestrians and the buses.
Other nodes that play an important role in the analysis of the spaces are the two street junctions that are supposed to lead to the site area.

LANDMARKS

The landmarks are those elements that stand out and help orient the people. (Lynch, 1960). Different landmarks can be spotted close to the area. In particular the most famous one is the famous "Amager Bakke", the Copenhagen incenеritor, opened in 2017, that is easily visible from great part of the city centre. A second landmark is the high old shipyard of Burmeister & Wain (B&W), which for over 100 years has been situated in the area. Finally, the floating student housing Urban Rigger of BIG is also to be considered as a landmark due to its popularity.

DISTRICTS

The districts determination implies a zoning analysis that can be perceived both physically or culturally. It is important to notice that some districts could be determined even if their boundaries are not strict. (Lynch, 1960). The different districts in the site can be defined according to the forms and the building types, but also the materials and the users. Therefore, the main cathegories will be the industrial, the business and the residential partitions.

SERIAL VISIONS
Refshalevej

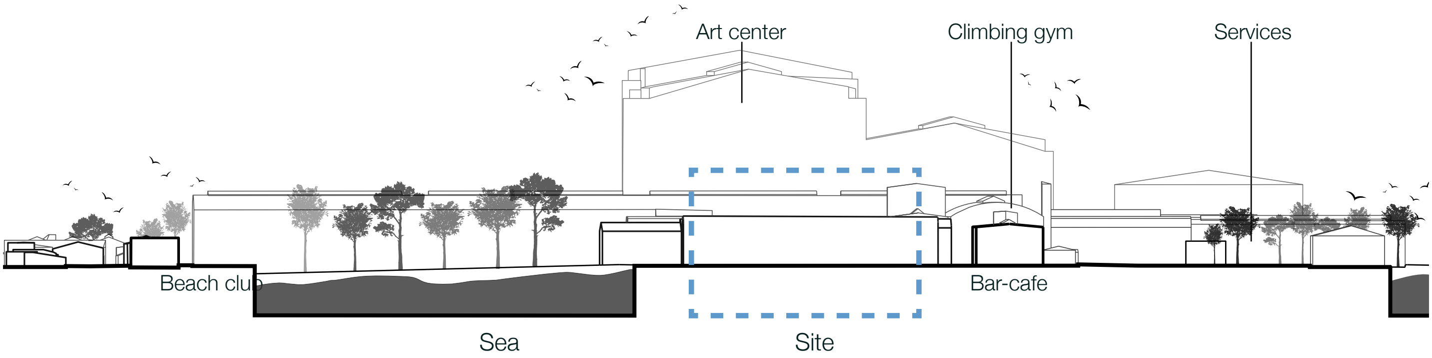
Ill. 24 - Serial vision Refshalevej, scale 1:5000

Serial views allow to explore a city from the perspective of a pedestrian observer (Farrelly, 2011). Therefore, they are an important tool to generate an understaning of the area.

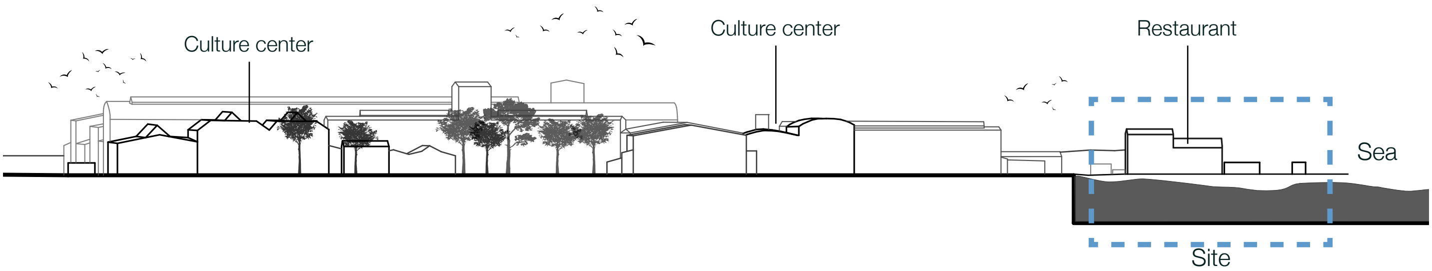
The route runs along Refshalvej, from the A9 stop to the Reffen's entrance. The impression is of a sloppy road without a clear division between road, cycle path and footpath. The area's port / industrial past is evident, and it is characterized by buildings which are very different from each other, both in terms of architecture feature and texture.

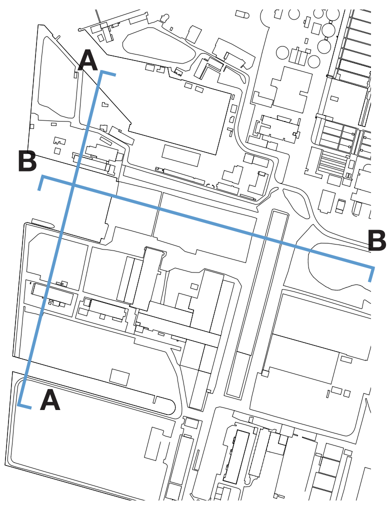
SITE SECTIONS

Ill. 25 - Section A-A
Scale 12000



Ill. 26 - Section B-B
Scale 12000





USERS ANALYSIS
User groups

The social aspect plays a fundamental role in a food market design. Considering the functional aspect, the project has to address to the people that are going to use the spaces, both workers and visitors. The people themselves, as future users, are going to determine the quality of the future built area.

A food market is supposed to provide a service to the community and therefore, a research upon what are the needs and the expectations of whom is going to benefit from this project must be the main focus to achieve a successful solution.

The future users can be defined according to the services that the market will provide. A food market usually addresses to a great variety of people who can be distinguished between workers and visitors, who themselves can be divided into locals and tourists. (Visitdenmark.dk, 2015) Following the plan that the Copenhagen district suggests for Refshaleøen, it comes natural to consider the implementation of different functions in order to attract the widest number of users. Since the area is supposed to develop through leisure and recreational activities (Københavns Kommune, 2015), the establishment of a gathering point that attracts a wide range of people will be beneficial. Moreover, the users could differ in age, gender, occupation and cultural background (Københavns Kommune, 2015). Also the reason for their stay and for benefitting of the market services could be different. Consequently the frequence with which they will use the spaces will differ too. Some could benefit from the service once in a while, however the project could represent a service to everyday users as well, for example, during the work break. Therefore, the project must be able to accomplish all these possibilities to maximize the outcomes.
Moreover, comprehending toustists in the user groups that it is going to be defined will certainly contribute not only to the vitality of the area, but also to its economic growth.

PEOPLE FLOWS ANALYSIS

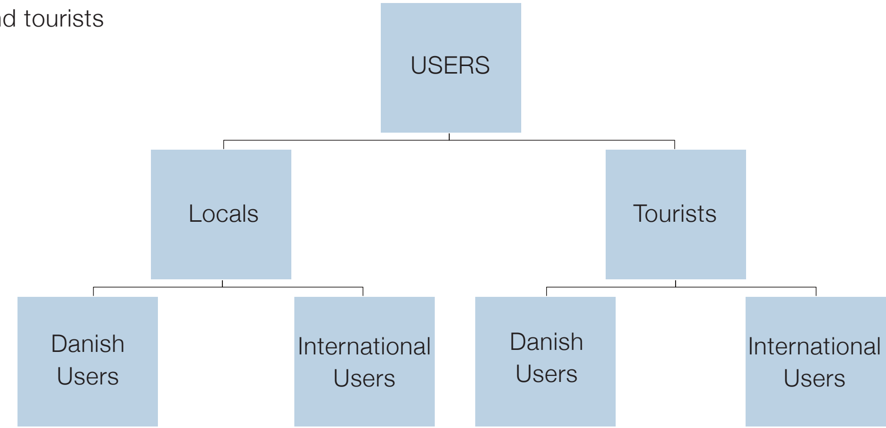
While defining the types of actor to whom the project aims to be addressed, it is important to analyse when and how these users are going to benefit from the offered services.

The ill. 52, aims to show in a typical day, during the opening time period (8.00 - 24.00), who is going to use the building.

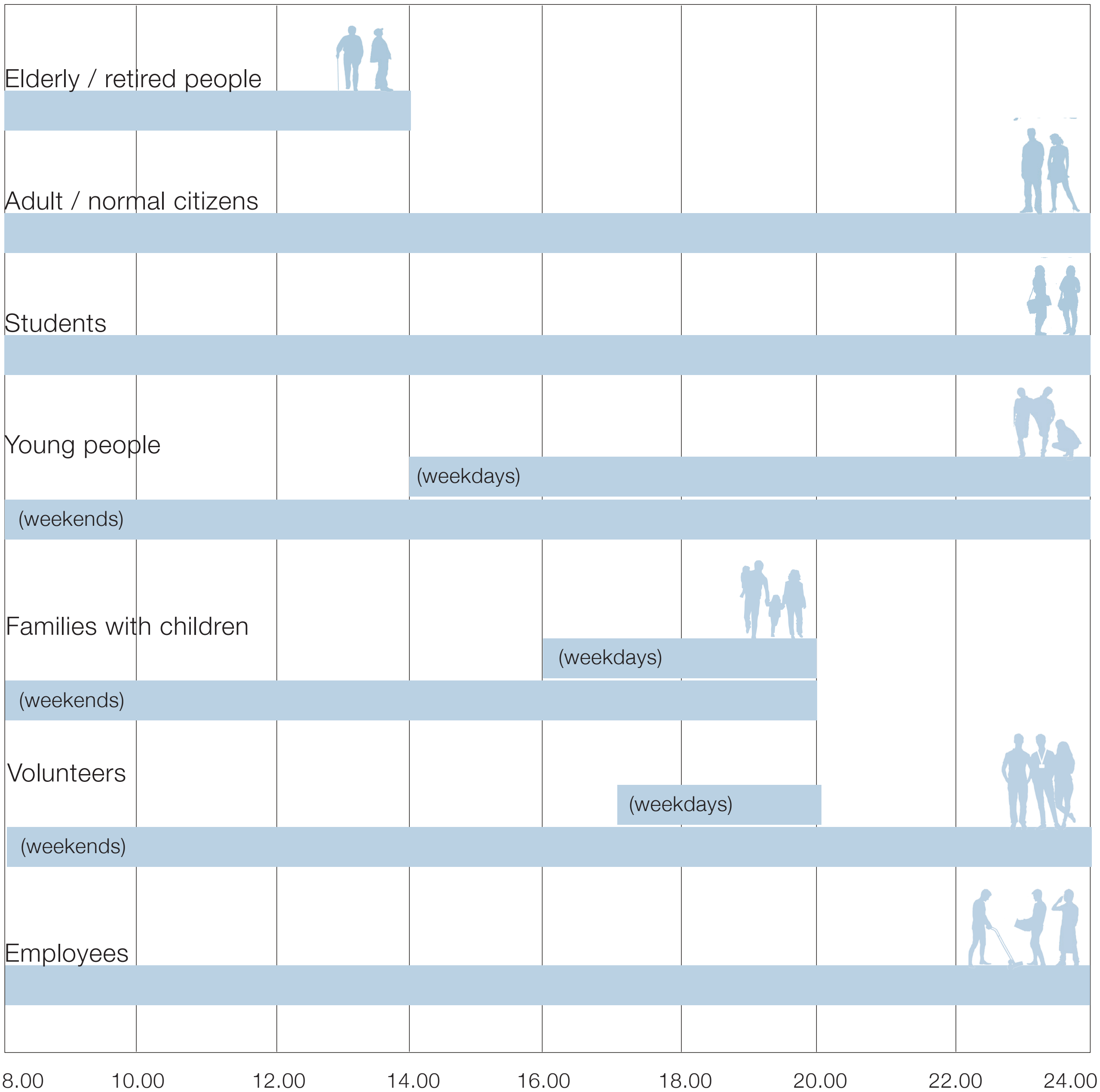
An important distinction could be about age and occupation. As examle elderly and retired people are supposed to use the place in the daytime and mostly in the morning hours, while, young people (14-18 year old) will benefit from the servicies in the evening after school or during the weekend. University students, as well as adults, could benefit from it during the whole day. Families with young children will probably use the services after school in the weekdays and more flexibly in the weekend period. Moreover, while the employees will cover the entire opening time, some volunteers could be invited, as well, for some educational classes or workshops.

The food-market's offer has therfore to be planned, keeping in mind, the range of people that are more likely to frequent it at the different times of the day, in order to make the place attractive during all the opening time. In this way, the market will become a melting pot where people can come in contact with different gastronomic and creative experiences. In fact, the more vital and populated a place is, the more it is considered safe and pleasant and therefore aims to attract new users and to create space for social interaction (Gehl, 2010).

Ill. 27 - Locals and tourists



Ill. 52 - Circadian rhythm analysis

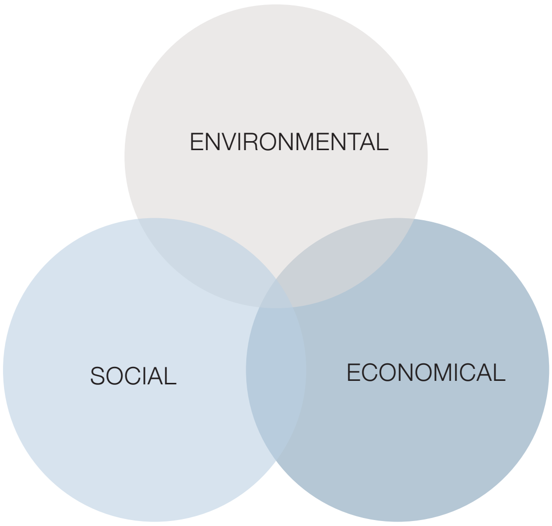


RESEARCH AND THEORY

This chapter includes all the research done, helps to gather an undestanding of the flooding phenomenon and provides a point of the parture for the design of the ”food hub”.

THE THREE PILLARS OF SUSTAINABILITY

Ill. 28 - The three pillars of sustainability



Denmark has set the goal to be independent from fossil fuels by 2050, and in this way aims to give contribution to global warming reduction. (Klima- og Energiministeriet, 2011). The building sector, as one of the main causes of carbon emissions, can contribute largely to a future without global warming. Therefore, during the design of a project a strong focus on sustainability is crucial. Sustaibility can be evalueted according to different aspects, and thus, its definition comprehends three different pillars: the environmental, the economical and the social. Therefore, in order to achieve a holistic and sustainable design solution, a combination of these three different aspects is needed (Green Building Council Denmark DGNB System Denmark, 2016).

Nowadays, the term "sustainability" is related to environmental considerations and how modern living, in terms of production and consumption, is contributing negatively to climate changes. Therefore, environmental sustainability refers to the reduction of the negative impact that a building can have on our planet, and in this scenario, also further reflections on energy efficiency are an important parameter (Green Building Council Denmark DGNB System Denmark, 2016).

Addressing to the environmental aspect of sustainability implies a deep understanding of how the different solutions and choices, within a project, may affect the environment. Different locations, orientations, and technical solutions can affect the future energy consumption and emissions of the building and therefore, they will determine the building's impact on the surroundings. (Olweny, 2019)
Also the choice of different constructions and materials should always be made with the awareness of their environmental impact. Taking as example an office building with a lifespan of 80 years, the energy consumption during its usage phase, is approximately 28% of the buildings contributions to global warming. The larger remaining 72% is caused by materials used to construct and maintain the building. (Birgisdóttir and Madsen, 2017).

Sustainable buildings provide indirect economic benefits to both the owner of the building as well as the society (Building Green Inc., 1999). To comply with the economic sustainability of a project, it is important to consider not only the optimization of the construction and operation costs, but also to consider the future benefits that will result to a higher productivity of the future users (Green Building Council Denmark DGNB System Denmark, 2016).

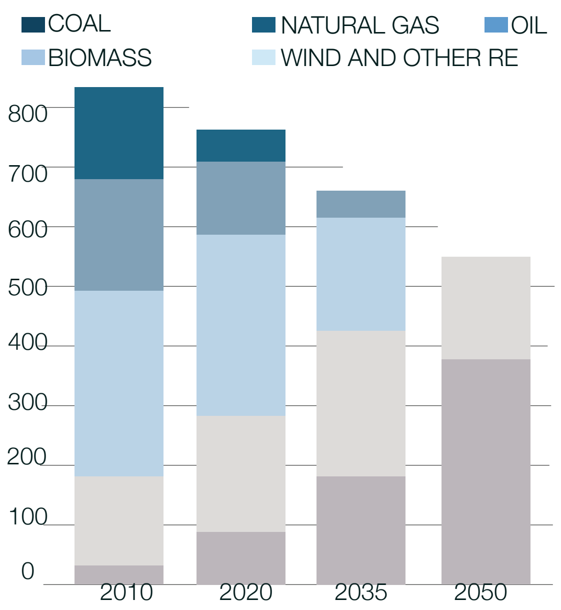
Social sustainable architecture is related to the interaction between the built and the social environment. A socially sustainable building implies that the design can address to the social challenges and contribute to the promotion of a positive development for the society (ArchitectureAU, 2013). Social sustainability takes into consideration the users, the indoor climate and all the parametres that refer to flexibility, accessibility and security (Green Building Council Denmark DGNB System Denmark, 2016). One of the problems regarding with the implementation of social sustainability in the project is the difficulty in measuring. In fact, differently from the environmental and economic aspects, a quantitative approach of measuring can not be used to indicate whether the project is or is not sustainable. (Marshall, 2017).

SUSTAINABILITY IN THE PROJECT

The project aims to fulfill all the three aspects that a sustainable solution requires. In particular, the goal of the project is to design a sustainable market that faces the future climate challenges that the city of Copenhagen is going to experience in the next decades. The project pursues to keep an active approach towards the challanges that our planet is facing nowadays, and aims to become a catalyst for the future development of the area. The project should be a future oriented architecture, aware of the impact that it will have in a long period prospect and able to perform when challenged from the environment. Therefore, the environmental aspect is one of the driving forces that will widely determine the quality of the project itself.
Moreover, the main function of the project will be the food market. Consequently, the project implies the creation of a melting pot. The building should represent a functional attraction, able to gather people and improve the city's environment and the users' well-being. At the same time, the project should sensitize and raise awareness on the importance of taking some measures on these climate challenges that are taking place.
Meanwhile, the reflections on the economy of the project will benefit the achievement of a sustainable solution. In fact, the economical considerations will grant a practical point of view and will enrich the project with a pragmatical and functional approach.

ZERO ENERGY BUILDING (ZEB)

Ill. 29 - Consumption of fossil fuels and renewable energy



ENERGY FRAMES

The building sector has a considerable effect on the energy use and undoubtedly on the environment. Particularly, 40% of the total energy use is caused by the building sector and this number is going to be decreased, considering that in the new buildings the energy performance and efficiency is a parameter taken into account during the design process. (Torcellini, Pless and Deru, 2006) The goal of the Danish government according to their Future strategy is the total reduction of consumption of fossil fuels, the share of renewable energy resources and at least 50% reduction of the gross energy use by 2050. All the energy should be produced by renewable sources such as solar, wind and biomass (Our future energy, 2011)

In order for a new building to accomplish the building regulations of 2020 it can consume up to 20kWh/m^2 per year. This energy is for heating, cooling, ventilation and domestic hot water, while the appliances and lighting are not taken into consideration for houses. A highly insulated envelope, with low transmission losses and adequately air tight are requirements, as long as a maximun infiltration of 0,5 l/sec per m^2 at 50Pa pressure.

ZEB AND THE DIFFERENT DEFINITIONS

There are multiple definitions about what a Zero energy building is, nevertheless the general understanding is that ZEB is a building that consumes as much energy as it produces through renewable resources. (Marszal et al., 2011) It is at the same time of high architectural quality, with a good indoor environment, that respects the users and the surroundings. Moreover, the renewable energy sources could be connected to the grid (net- ZEB) or be off- grid. Particularly, the off-site ZEB is accomplished by purchasing renewable energy from outside the site sources. It is advocated that a connection to the grid is positive due to the scarce of energy storage technologies. (Torcellini, Pless and Deru, 2006)

The different definitions of ZEB are:

- Net Zero Site Energy is a zero energy building that 'produces as much energy as it consumes in a year, when accounted for at the site'
- Net Zero Source Energy is a zero energy building that 'produces at least as much energy as it consumes in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site.'
- Net Zero Energy Costs is a zero energy building, where ' he amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.'
- Net Zero Energy Emissions is a zero energy building that' produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

(Torcellini, Pless and Deru, 2006)

ZEB IN THE PROJECT

The goal for the future food market is to achieve a Net Zero Source Energy building, since it considers the energy that is used for transportation to the site and also the generation.

Firstly, the connection to the grid is important, since as already mentioned the storage technologies are limited. In this way, whenever the building has a deficit of energy will take from the grid, while when it produces more than it needs, it will give back to it. Firstly, passive strategies will be implemented, to minimize the energy consumption. In the case of the food market the first considerations are to heat some rooms in the project with lower temperatures, therefore less energy is required during the process of the passive strategies implementation.

Later on, active strategies, such as on-site photovoltaics will be implemented to reach the zero energy buildings' demands.

The photovoltaics use the direct solar energy to produce electricity. Their main disadvantage is that solar energy is unpredictable and particularly, in Denmark, where the solar radiation is low they would not be as efficient as possible. (Huld and Amillo, 2015) Therefore, the optimal orientation, inclination and placement of the PVs should be a priority for achieving their peak performance. Different types of solar cells exist and every type appears with each one properties.

The most common used are the monocrystalline, the polycrystalline and the thin films. Comparing the monocrystalline and polycrystalline solar cells, the most efficient are the monocrystalline, therefore they are more expensive. The first ones are black, while the latter ones have a blue-ish hue. (Energysage.com, 2019) Thin films are the newest technology and advancements are expected in the next ten years. The main advantages that they encompass are their easy production, their flexibility, since they are produced in different shapes, they are less affected by the environment, the shades and high temperatures. (RGS Energy, 2019)

All of these options of solar cells will be taken into consideration through the design process, each one with each advantages and disadvantages.

INDOOR CLIMATE
Regulations and Danish standards

As afore-mentioned sustainability is a main focus while designing the food market. Particularly, social sustainability is a significant aspect to be considered since the users of the project are the focal interest, therefore a good level of indoor climate should be ensured. The indoor climate engages with four distinct parameters, the thermal, atmospheric and visual comfort and acoustics.

THERMAL COMFORT

The thermal comfort encompasses different temperature ranges according to four distinct classes/ categories. The first class is the strictest one, has the highest demands and is suggested for spaces populated with sensitive users, thus it is not suitable for the project, while the second one is less strict with a normal level of expectation. Therefore the second category fits better to the food market. In general, it is important to control the temperatures inside the enclosed spaces of the market constantly, so as not to exceed the 25 C^o and not dowturn the 16 C^o during winter. (Danish Standards DS/EN 15251, 2007).
The thermal sensation is decided based on two indicators, the Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD). In PMV the variables used are the clothing level, the air velocity, the indoor air temperature, the metabolic rate and the relative humidity. For the second class, the PPD has to be lower than 10% and the PMV between -0,5 and +0,5.
(Danish Standards DS/EN 15251, 2007).

In this project both the Danish standarts and the personal experiences will be considered when deciding the different temperatures in the distinct rooms- functions. More specific explanations for the thermal comfort related to the project are explained in the next pages.

ATMOSPHERIC COMFORT

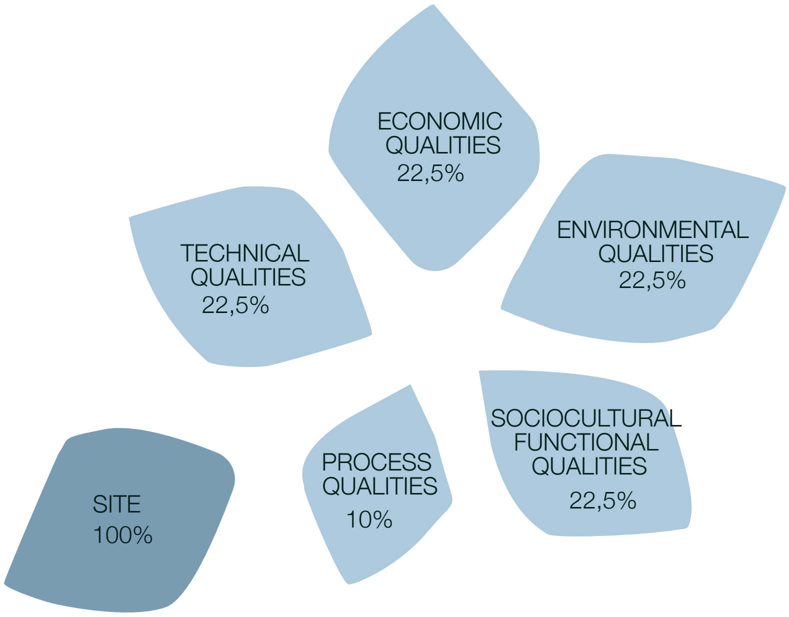
The atmospheric comfort combines the requirements for the CO_2 concentration in the room and also the perceived air quality. Particularly, for the second category the perceived air quality cannot be more than 1,4dp and the percentage of dissatisfied people more than 20%.
As fas as the CO_2 concentration is concerned, according to the Danish standarts for the second class the overall concentration is 850ppm. (Danish Standards DS/EN 15251, 2007).
The design of a food market encompasses also controlling the humidity into the building, since excessive moisture in the products can result to microbial growth, therefore affect the food safety. (National Retail /Grocery Store, 2005) The implementation of mechanical ventilation could help for the control of the humidity in the building.

VISUAL COMFORT

For a satisfactory visual comfort the daylight holds an important role and the area of the glass should be at least 10% of the floor area, considering the building regulations. Moreover, at least 300lux should be ensured into a room and specifically half of the day in at least the half room. (Bygningsreglementet.dk, § 377 - § 384 2019)
Furthermore, the daylight in the enclosed spaces should be adequate, while avoiding at the same time overheating. Direct solar radiation and glare should also be minimized. (Bygningsreglementet.dk, § 377 - § 384 2019)
The possibility to look to the surroundings is also a requirement for the visual comfort, thus the windows should be placed in a way that they allow the view to outside and the possible solar shading should not block the visibility to the surroundings. (Bygningsreglementet.dk, § 377 - § 384 2019)
Finally the approved levels of the artificial light according to the building regulations are: for general ward lighting 100lux, for single office 500lux and for simple examination 300lux. (Danish Standards DS/EN 15251, 2007)

The activities and functions of the food market are more related to the category of general ward lighting (100lux) and in some spaces associated with the food preparation and

Ill. 30 - DGNB



processing to the category of simple office (500lux). An adequate daylight should be ensured in the market, at least 2% for ensuring a good indoor climate both for the users and the staff.

ACOUSTICS

According to the building regulations when ensuring the quality of the acoustics into a room the aspects that should be taken into account are: the transmission of the sound between the rooms, the noise pollution caused by the installations of the building, the reverberation and finally the noise from the surroundings, the railways and streets. The reverberation time for furnished living rooms that can be also related with the food market needs to be 0,9sec or less for 125-4000Hz. (Bygningsreglementet.dk, § 368 - § 376 2019)

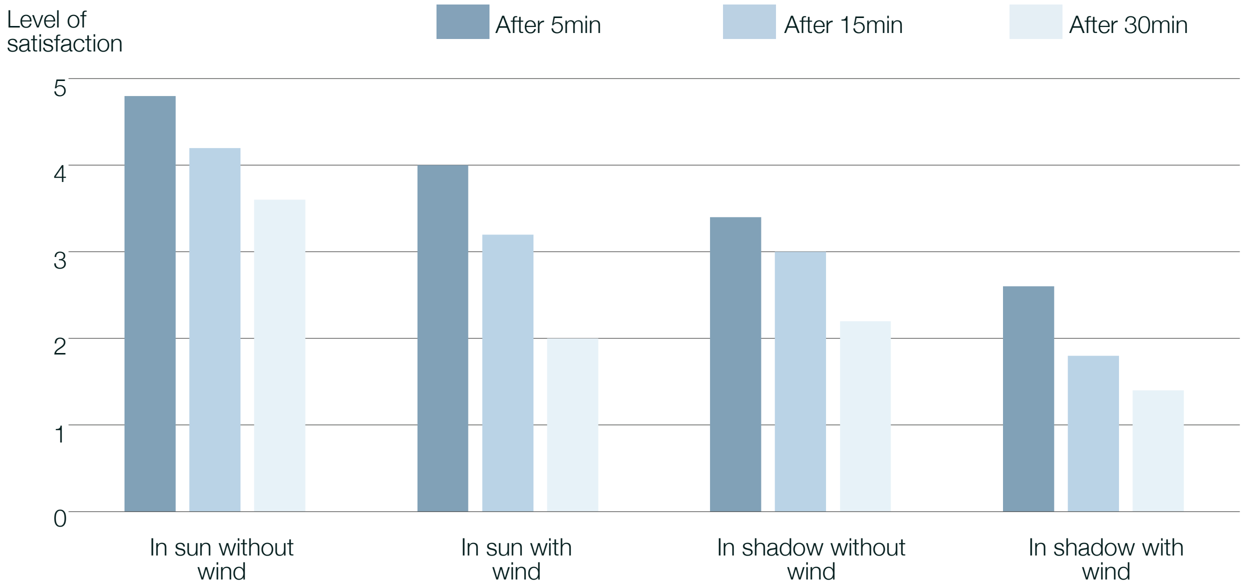
DGNB AND INDOOR CLIMATE

In DGNB, which is the german sustainability certification scheme the sociocultural and functional aspect accounts for 22,5%. (Green Building Council Denmark, 2016)

SOC1.1 Thermal comfort
Humidity, temperature and draught are vital aspects for securing the thermal comfort, so as to ensure a positive working and living environment. (DGNB criterion SOC1.1), 2014)
SOC1.2 Indoor Air Quality
Buildings that emit polluted substances are not approved. Moreover, the use of low-emission materials is recommended for a good score in the indoor air quality category. The ventilation should also be estimated based on the $C0_2$ concentration and the atmospheric comfort. (DGNB criterion SOC1.2), 2014)
SOC1.3 Acoustic Comfort
The acoustics of a space affect significantly the efficiency of the working place and they should be prepared based on the function of the room. (Green Building Council Denmark (DGNB criterion SOC1.3), 2014)
SOC1.4 Visual Comfort
Sufficient daylight and artificial light should be ensured, especially in the working places. Moreover, glare should be prevented and the view to the surroundings should be adequate. (DGNB criterion SOC1.4), 2014)

Evidence-Based Thermal Comfort

Ill. 31 - Experiment (For better understanding of the experiment look at the annexes)



EXPERIMENT

For deciding the different temperatures into the multiple rooms of the food market both the Danish standards as long as the personal sensory experiences will be considered. Therefore, an experiment is prepared, based on the experiences of five different people, that indicates their level of thermal comfort at the same weather conditions. The experiment took place in Sydhavn, in Copenhagen, close to the coast, an area with approximately the same weather conditions as the project's site and it was conducted in the 2nd of February of 2019.

DESCRIPTION

Five people participated in the experiment: two 24-year-old girls, one 21-year-old boy, an man in his sixties and a 7-year-old child. They wore the same typology of coats. The procedure was tested in the same days for the five people and the conditions were: sitting in the sun with wind, sitting in the shadow with wind, sitting in the sun without wind and sitting in the shadow without wind. The evaluation scale for the perceived thermal comfort that was used is from 1 to 5, where 1 shows the least satisfaction and 5 the most satisfaction. They were asked for their level of comfort in a temperature of 10ºC after a period of time of 5, 15 and 30 minutes. (1:less satisfied, 5:the most satisfied)

LIMITATIONS AND ACKNOWLEDGMENT

The experiment should be further developed and consider also other parameters such as the personal perceptions and experiences, or the different background and habits. Moreover, it should be tested also in alternative weather conditions, such as snow and rain. However, the initial purpose was to use it as an indicator for the decisions on the temperatures in the enclosed spaces of the food market. In particular, the factor of the wind was considered since in Denmark the wind is in general strong and the results could be used while designing the outdoor spaces.

OUTCOMES

The experiment outcomes showed that, while sitting in the sun without wind in a temperature of about 10°C, all of the people were feeling comfortable while wearing their coats. After thirty minutes the level was still satisfying. On the other hand, sitting under the shadow with wind, was the worst scenario and people started complaining in the first 15 minutes. Sitting in the sun with wind was also a positive scenario with the exception of the one girl and the child that after 30 minutes were the least satisfied.

PROJECT

Some conclusions that could be implemented in the food market are that firstly, in general, a temperature of about 10°C does not affect the level of thermal comfort of the people, when they are well dressed. Therefore, this temperature could be retained in the rooms that people are expected to remain with their coats.

As afore-mentioned, the clothing and the level of activity, are some of the most important parameters when deciding the temperatures inside the different functions. For instance, inside a grocery or a food market, people are dressed well and also walk. Furthemore, the same is implemented for areas where the users will constantly work and the level of activity is increased, thus a temperature around 10°C is more than enough. Besides that food products, such as vegetables and fruits need to be stored in low temperatures and also the temperature should be low while displaying them. (Nunes, 2008)

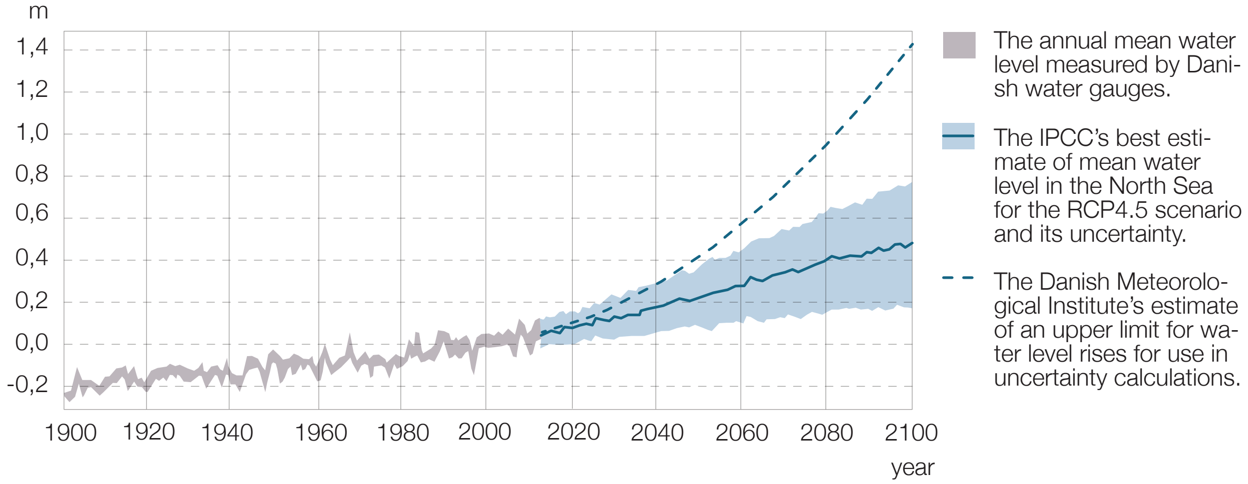
On the other hand, In the common areas that people are gathering for sitting and enjoying the food experience it is important to control the temperatures between 25 C° during the summer season and 16 C° during winter. (Danish Standards DS/EN 15251, 2007). In this way a restaurant-like environment, which is warm during winter and cool during summer will be ensured.

As far as the outdoor spaces are concerned, the weather conditions, such as the sun, shadow and wind will be considered, according to the the character of the outdoor space.

Concluding, the temperatures of the different rooms will be decided after the above mentioned conclusions. The different temperatures will be tested during the design phase on different digital programs, such as the BSim, to ensure a comfortable indoor climate. In the optimization of the energy performance, lowering the temperatures set of the indoor spaces can grant a higher level of effinciency. The assessment of reaching a Zero Energy Building will become easier to achieve. However, a limitation must be taken into account in the use of the Be18 software. The program, in fact, considers only the building envelope in the calculation of the energy performance and the temperature is supposed to be the same in all the interior spaces in the whole building. Therefore, the Bsim simulation tool will be utilized for more detailed calculations.

CLIMATE CHANGES CHALLENGE
The phenomenon of flooding

Ill. 32 - Global mean sea-level rise



Nowadays, global climate changes are forcing more and more cities around the world to face the problem of the rising level of the sea water and the challenges related to these problems are not just physical, but also social and cultural. Architecture works are hugely affected by this phenomenon, and therefore, the architects' goal should be to implement climate changes considerations in the future architectural solutions in order to enhance an open and more aware approach. (State of Green, 2019)

The increasing temperatures that the Planet is experiencing are the main causes of the frequent rainfalls and of the rising sea level phenomenon. However, cities are not able to handle these destabished weather conditions and therefore they need new resilient solutions with an approach based on co-creation, dialogue among the community and humanistic nature-based design solutions. (State of green, 2019)

Denmark consists of the Jutland peninsula and more than 400 islands. The country is for great part lowland and the highest hill is approximately 170 metres above sea level. The danish coasts count 7300 km and among them, around 1800 km of coastline is already protected by permanent installations such as dikes. Moreover, about 80% of the population lives in urban areas connected to the coast (Danish Ministry of the Environment, 2005). It is a country which has a deep connection with the water, each city is never more than 50 km distant from the sea coast. In this scenario, dealing with the water resource becomes not only suitable, but also necessary in a long term prospect. (Foreground.com.au, 2019).

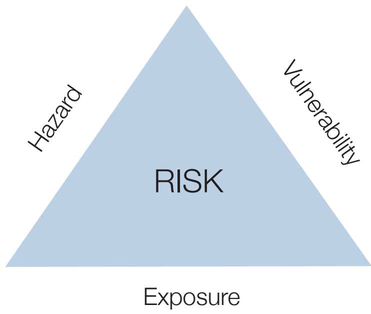
In Denmarks' adaptation strategies is assumed a sea level rise of 0.1 - 0.5 m by 2050 and 0.2 - 1.4 m by 2100 and in the meanwhile a land rise of 0 - 0.1 m by 2050 and 0 - 0.2 m will occur as well by 2100 (Niemeyer et al., 2016). Moreover, the uncertainty about how the sea and ice will react to climate change must be considered too (ill. 32). Different scenarios have been calculated to forecast all the different possibilities. The table in the ill. 33 shows the different projected global mean sea level rises in metres in the diffe-

Ill. 33 - Global mean sea-level rise projections

Scena-rio	2046-2065 Mean	2046-2065 Likely range	2081-2100 Mean	2081-2100 Likely range
Low (RCP2.6)	0.24	0.17 to 0.32	0.40	0.26 to 0.55
Medium low (RCP4.5)	0.26	0.19 to 0.33	0.47	0.32 to 0.63
Medium high (RCP6.0)	0.25	0.18 to 0.32	0.48	0.33 to 0.63
High (RCP8.5)	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Ill. 34 - The Cricton triangle

(Possible) Hazard X Vulnerability X Exposure = (Possible) Impact



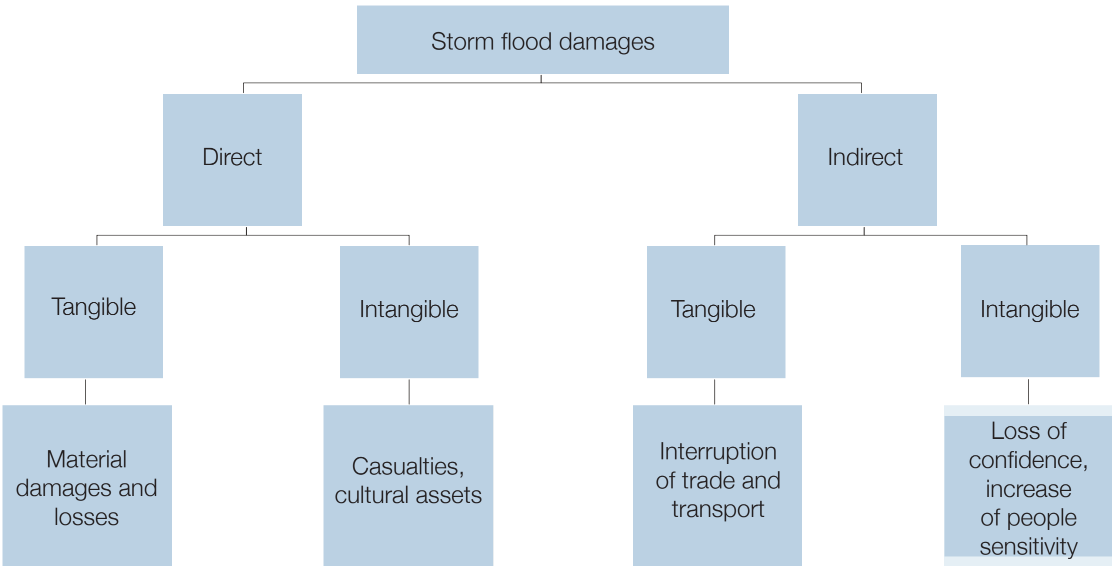
rent future scenarios, calculated by the Intergovernmental Panel on Climate Change (IPCC, 2013).

The risk calculation is important, in order to water-proof the coastlines threatened by inundation. To provide rankings of possible impacts it is important to target at first the areas wth the highest risk factors . As the Crichton risk triangle explains in the ill. 34, the three paramentres that play a role in the definition of the level of risk are hazard, vulnerability and exposure. Hazard is defined as the size of the risk and the likelyhood that an event will occur; exposure is related to the geographical location, latitude and the current risk to water inundation; vulnerability is the lack of ability people may have to adapt to sea level rise. (Crichton, 2001)

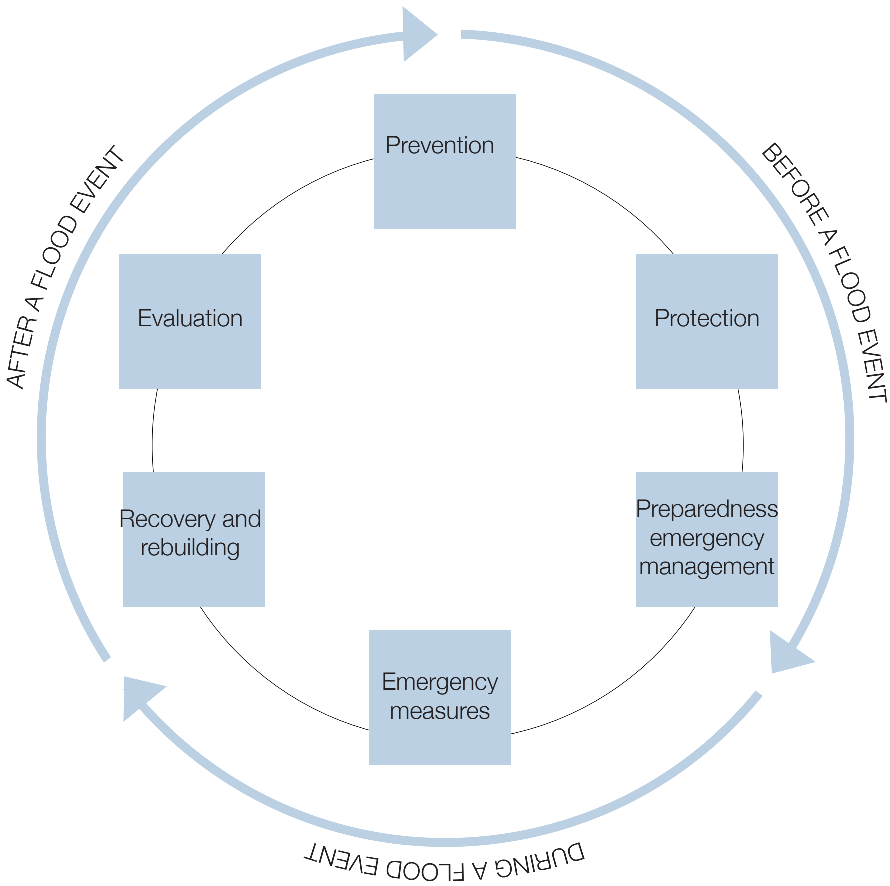
It is important to consider the vulnerability aspect that a certain site presents. The analysis of the level of vulnerability depends on the damages that would result from a flood event. They could be direct or indirect and they could have tangible or intangible consequences. Direct damages are the most visible ones and consist of material damages and losses, the intangible are casualties and cultural assets. Concerning the indirect ones, they could be either tangible, for instance the interruption of trade and transport, or intangible as the ones regarding the loss of confidence and the increase of the people sensitivity (ill.35). (Nordress.hi.is., 2019)

Finally, it is important to be aware of all the phases that a flood event involves to define how and when the designer's intervention can occur. As shown in the ill. 36, the three main phases are before, during and after a flood event. In particular, the field of interest that relates to architectural issues in which it can be possible to operate regards, not only with prevention of new risks and protection through the reduction of the existing risk, but also with emergency management. In fact, most of the solutions regards with the prevention and protection phases, but considering the visibility and the central position of the project site it could become interesting to design a structure

Ill. 35 - Storm flood damages



Ill. 36 - Flood event cycle



that concerns also with the management of preparedness emergency. The result would be the creation of a landmark visible from the city centre that has also a function of warning the community in case of emergencies.

COPENHAGEN DISTRICT

Copenhagen, due to its position adjacent to the water, since it is the most populated and urbanized area in Denmark and due to the relatively sudden episodes of flooding that have occured, presents one of the highest risk for the danish country. (Jebens, Sorensen and Piontkowitz, 2016)
In particular, the city, like lots of other coastal urbanized areas, is facing the critical climate changes and a growing population. Its exposure to the sea and its flat topography makes it easily affectionable from the enviromental changes that are taking place, such as frequent cloudburst and sea level rise, but also waste management issues and water pollution. (Foreground.com.au, 2019)

Copenhagen has experience cases of inundations multiple times in the last years, resulting in different damages. Among the latest ones, particularly harmful were the one in June 2011, that affected large parts of Copenhagen (Landezine.com, 2015), the one in 2017 that affected the south part of Copenhagen when the water reached 157 cm above the sea level (Cphpost.dk, 2017), and the latest one registered in January of this year that has affected great part of the southern Denmark (Thelocal.dk, 2019).

Nowadays, rainfalls are the main issue that threatens the city creating multiple damages due to the flooding phenomenon. However, in the close future, by 2050, the raising sea level will be the main cause to the stagnation of water in the urbanized areas too. (Foreground.com.au, 2019)

ARCHITECTURAL APPROACHES

Different architectural approaches can be investigated when dealing with sites at risk of flooding. In order to widen the knowledge on the topic, we have consulted the Phd student of Aalborg University Mikkel Poulsen (February 2019), who is carrying out a research about the different approaches in climate change adaptation of sustainable buildings.

One rare option consists of the retreat from the shoreline and it is also the least likely to happen. It implies abandoning the land at risk to move to a higher ground and it is usually considered appliable after a large-scale disaster (Sfpublicpress.org, 2015). However, other options can be applied on site. In particular, these approaches can be reassumed in defensive, reactive and embedded. (Poulsen, 2019)

The defensive approach consists of protecting and fortifying the area. The principle is to keep the water out, just from the indoors spaces or also from both the indoors and outdoors built areas. (Poulsen, 2019) One solution could be for example to raise the occupied floors above the flood level (Sfpublicpress.org, 2015).
Another example could be to build levees, such as dams or seawalls. Therefore, the concept is to protect the area through the installment of effective barriers that can stop the water inundation (Sfpublicpress.org, 2015).

Finally, an option is to consider the materials properties. Therefore, the solution would be the construction of some flood-proof structures or the placement of some absorbent surfaces. (Sasaki.com, 2014)

Instead, the reactive approach consists of reacting to extreme events through dynamic mechanisms. In this case, the costruction should adapt when the changes occur. Along with the changes caused by the climate also the building should change. Therefore, the aim is that of mitigating the impact though some dynamic technology systems. (Poulsen, 2019)

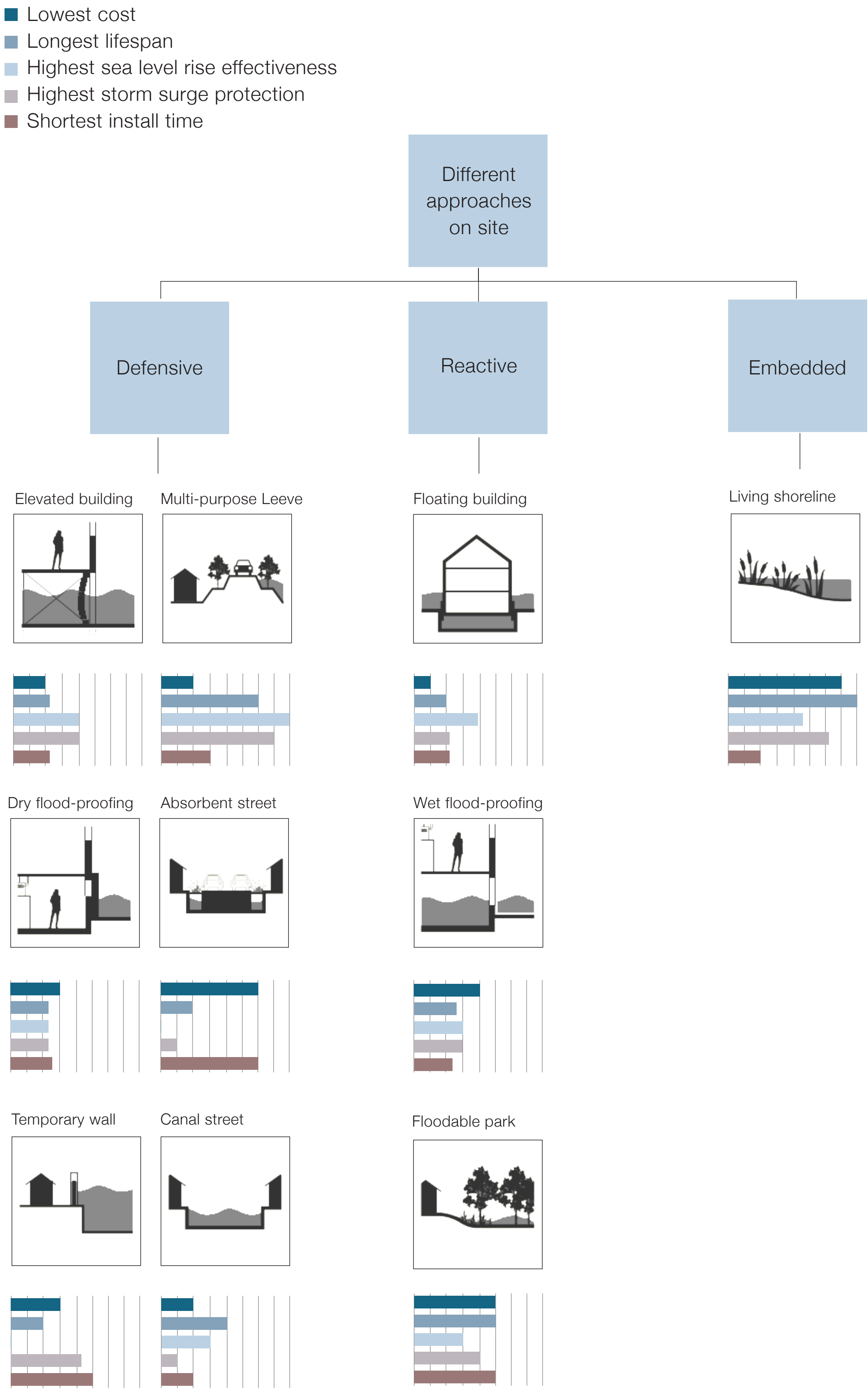
An example of this approach is the concept of floating architecture. The idea behind this concept is still at an experimental stage. Even though, some solutions have been applied in practice and this strategy is good for preventing water damages, some criticism could be moved since it implies high costs and the structures are susceptible to rocking and drifting, and it could result also in producing possible lack of comfort to its users. Moreover, it is particularly problematic to be applied in large scale projects. (Scholarcommons.usf.edu, 2009)
Another option is the installment and the activation of some bumps, embankments, ditches and kerbs which can help to redirect water into areas where water causes least damage, such as sportsgrounds, parks and open spaces that are wet-proof. (Sfpublicpress.org, 2015)

Finally, the third approach is the embedded approach. It implies a strong connection with the local landscape and ecology. It consists in the design of some regenerative solutions by benefitting of the local ecology. The building results in being deeply linked to the site itself and to its microclimate. (Poulsen, 2019)
This approach focuses more on taking advantage of the phenomenon with effective architectural solutions. In particular, the water is not seen as something from which there is a need to take distance, but as a fruitful resource. This approach could be translated for example in the restoration of a new habitat through the establishment of a living shoreline. Natural habitats like marshes sandbars and creek beds absorb the energy of storms, mitigating the risk from sea level rise and establishing a new nature. The outcome will be an increased habitat, wave attenuation and pollutant filtration (Sasaki.com, 2014).
Another option could be the concept of aquaculture and maritime industry. Aquaculture is about the farming of aquatic animals or plants, in all types of water environments in controlled conditions. It can efficiently been applied in the concept of a food market as it is used to produce food and commercial products. Moreover it restores and creates healthier habitats. (Fao.org, 2019)

Each of these approaches can be translated in some practical strategies that are reassumed in the ill. 37. Moreover, in order to evaluate the effectiveness of these solutions five parameters have to be kept into consideration: the cost, the lifespan, the sea level rise effectiveness, the level of storm surge protection and the required install time. (Sasaki.com, 2014)
Furthermore, it is important to mention the possibility of combining these approaches in hybrids solutions. Every solution does not exclude the other possibilities. Different strategies can be equally implemented at the same moment.(Poulsen, 2019)

In conclusion, considering the character of the project and its sustainability goals, the most fitting and effective solutions will be investigated, keeping in mind also the importance of the location of the specific site and of its level and typology of risk.

Ill. 37 - Different strategies on site



Adaptation solutions in architecture

Ill. 38 - The Soul of Nørrebro

THE SOUL OF NØRREBRO by SLA, L. Andersson

The first example is the SLA's "The Soul of Nørrebro". This project is an integrated urban design and at the same time represents a climate adaption in Hans Tavsens Park and Korsgade in Nørrebro, Copenhagen. The city nature, the local community combined with some effective cloudburst solutions are the main feautures. This proposal aims to prevent wastewater from overflowing, using the rainwater locally, while directioning excess water through cloudbursts from the park to Peblinge Lake. The interesting character of The Soul of Norrebro is the approach of using terrain embankments, bumps, ditches and kerbs to help to lead the water into areas where it causes least damage. (Sla.dk, 2019) In particular, this example can be considered both a defensive and an embodied strategy, as the lanscape architecture is used for both protecting some areas, but also to establish in the future scenario new possible ecologies.

Ill. 39 - Urgan Rigger student housing

URBAN RIGGER by BIG

The Urban Rigger's student housing of BIG is located less than 500 metres from the chosen site. In the case of Urban Rigger, the architecture is dealing with the issue of the sea level rise through the concept of the floating architecture and therefor it can be considered an example of reactive architecture. Morever, the project consists in assembling some modular shipping containers. These modules are powered by a photovoltaic array and use a heat-exchange system that draws upon the thermal mass of water in order to warm and cool the interiors. In this solution, the approach is of seeing the water as an element with some potential and not as cause of risk and therefore, the architecture assumes also an embodied character. (Archinect, 2019)

Ill. 40 - Water Shore Habitat

Ill. 41 - The Thames Barrier

WATER SHORE HABITAT by MAP Architects

The Water Shore Habitat, designed by MAP Architects is about the renovation of the old industrial Rotterdam harbour, by implementing some parks, recreation, sports activities, energy generation and even agricultural / greenhouse production. For these reasons, it can be considered a case of embodied architecture, since it aims to create new ecologies. Moreover, architecture has a supplementary aim to point out the current water levels and it serves as well as a visual flood alarm in case of sea water level rises. (MAP Architects, 2011)

THE THAMES BARRIER by R. Walters

The Thames Barrier of Roger Walters in London gives a clear example of a system that aims to protect from damages by stopping the water from reaching the city banks. Its purpose is to protect London from being flooded using a high tide moving up from the sea and therefore, the applied approach is the defensive one. (ArchiTravel, 2019)

ARCHITECTURE AND SENSES
Markets, places for sensory experiences

The historical context of the market, which in the past represented a necessity for the survival of the city and the community center, today, represents a tourist destination rather than a key function for our daily routine. In fact our livelihood needs are now satisfied with the convenience of a supermarket and online shopping. “The market has become a place for social interaction, where the connection of sensory experiences gives space meaning” (Mesher, 2009).

The integration of the sensory experience into the designed space is an approach that has been put to architects and designers as a way of addressing how spaces are felt and how we interact with them (Mesher, 2009). It is important to know that space and body are inevitably related, not only through sight, but also through the other senses such as touch, auditory, olfactory and even taste. People measure the world throughout the whole body, which is in constant dialogue and interaction with its surroundings (Pallasmaa 2005). Architecture that deals with sight only limits the possibility of space and the human understanding of it. Hearing, smelling, touching and tasting can create a better memory than sight can alone: a multi-sensory eperience of architecture will result in spaces that speak a powerful dialogue with human body and memory. (Yeung 2006)

The multi-sensory experience can also produce temporary connections between people; commercial interiors nowadays are somehow missing part of the sensory quality of space (Knueppel, 2008). Therefore, when talking about market design, it is important to consider all the senses of the human body, thus creating a pleasant environment for a sensory experience and thus encouraging social interactions (Mesher, 2009).

Considering the five human senses in relation to architecture means, considering the eyes, not only as judges of the aesthetic result, but also as receivers, capable of releasing sensations and emotions at the sight of different lights, colors and materials (Pallasmaa 2005).

Specifically when it comes to a food market, considering the senses also means being able to control possible problems related to smell. The challenge is to do it without nullifying the very nature of the market, thus turning the aroma of food into a protagonist and not into a problem to be eliminated (Yeung 2006).

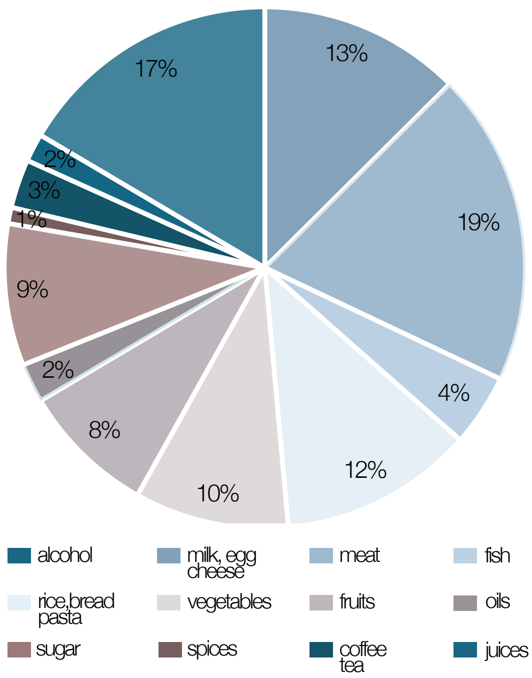
The same applies to noise, since a place like a market it is not expected as quiet and peaceful, but rather a place where voices, music and noises has to be heard in order to recognize the identity of the place. In this case the designers’ task is to ensure the adequate acoustic of the building, without making the place silent, but only by guaranteering that sounds will not become annoying due to excessive echoes or rumbles (Pallasmaa 2005).

And then the taste, which is the last, but perhaps the most important when speaking about a market. The final goal of visiting a place like this is, indeed, to enjoy and discover new tastes. Speaking about taste is therfore important to consider that “nowadays food is served as tiny, provocative and almost explosive experiences, where the sensuous effect of the food is obtained through manipulation sense modalities” not only gustatory but also, visually, auditory, olfactory and tactile” (Fisker and Doktor Olsen, 2009). So, the food, one of the unquestionable protagonists of the place, becomes as well as the architecture itself, a complex sensorial experience.

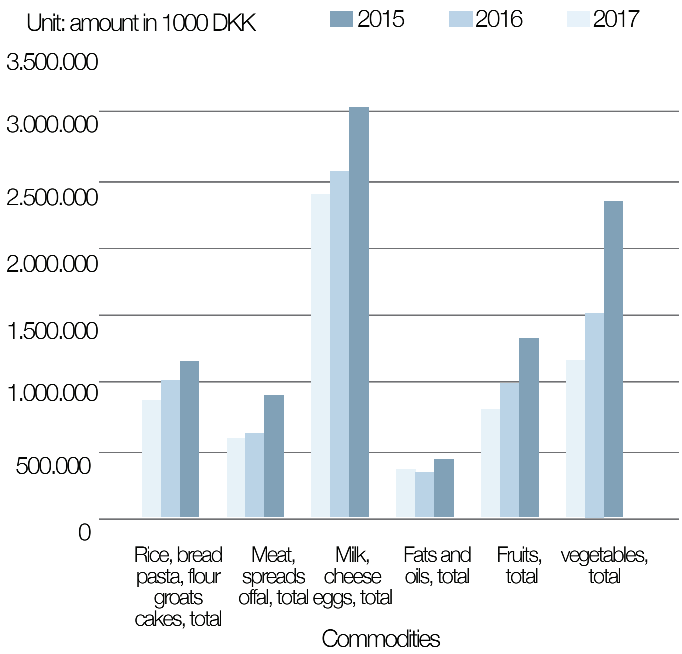
All these considerations will be implemented in the design of the “food hub”, so as to obtain a dynamic space that can generate different sensory experience.

FOOD CONSUMPTION AND PRODUCTION
Danish food consumption

Ill. 42 - Danish food consumption 2017



Ill. 43 - Turnover of organic foods in retail shops



STATISTICS AND DANISH FOOD HABITS

A meticulous research towards the Danish food habits, concerning the type of food and products they consume and also the danish regulations for food will provide more specific information for the focus of the design. It is important to acknowledge what are the habits of the potential users concerning food, so as to know what products are going to be included in the market and what functions are necessary for the retail and storage of these products.

The food consumption, as also indicated from the ill. 42 in Denmark mainly consists of meat products, which holds a 19% of the total consumption, while milk, eggs, pasta, bread and vegetables are also consumed greatly. The statistics are based on the consumption of the different products during 2017. (Dst.dk, 2019)

ORGANIC FOOD

In Denmark organic agriculture and food have a predominant position in the food cluster and particularly 7% of the food is produced organically. Furthermore, statistics indicate that Danish consumers buy more and more organic food and products and therefore the retail section includes more organic products while the years pass. (Dst.dk, 2019)

Moreover, the organic production is thoroughly inspected by the Danish autorities from the production to the consumption, which results in the consumers' confidence of buying organic products. (Facts and figures Denmark – a Food and Farming Country, 2016)

These information will be usefull when deciding what type of products are going to be sold in the future food market, considering always the user groups' preferences and respectively what functions are suitable for the storage and retail of such kind of products.

DANISH FOOD REGULATIONS

The Ministry of Food, agriculture and Fisheries in Denmark does not involve specific requirements of how food should be stored and served in Denmark.

However, all facilities that are engaged with the food cluster, such as restaurants and stores should carry out a self-regulation, that assists them secure the food safety, the positive hygiene proceedings and the obedience to the laws related to food. (Self-regulation In stores and restaurants, 2009)

The retailers should acknowledge the rules for food safety, the hygiene practices and how not to waste food. Proper and daily measure of the temperature of the products during receiving, storage and serving would procastinate issues, such as the contanimation of the food and subsequently the cause of illnesses to the consumers. (Self-regulation In stores and restaurants, 2009)

Vital for the design of the food market is the process when receiving and storaging the food products, therefore the sellers should be aware of the practices of how to store the products. Particularly, the Ministry of Food, Agriculture and Fisheries suggests that in order to avoid the growth of bacteria in the products, the retailer should agree with the supplier to secure the cold transportation of the food and deliver the products when they can instantly be tranfered to the cold storage. (Self-regulation In stores and restaurants, 2009) Therefore, when designing the market it is important to arrange an appropriate storage space and the area where the products are received should be directly connected with the storage, without getting infected by external factors. A storage space close to the entrance would make it easier to follow the above mentioned requirements.

During the production of the food, the products should not be contaminated by each other, the employees or by the inappropriate management during heating and cooling. (Self-regulation In stores and restaurants, 2009). Considering the latter, when designing the market, the stalls should be appropriate eqquiped, with a sufficient number of sinks and adequate space for heating and cooling devices. A more meticulous research on the design of the stalls would be necessary during the design phase, to ensure appropriate working conditions and adequate spaces for selling the products.

Sustainable food production and consumption

RELATION BETWEEN SUSTAINABLE PRODUCTION AND CONSUMPTION

A research towards the sustainable food production and consumption is significant to develop a project and spaces that appeal to the needs of such a function and accommodate activities that secure the demands of a sustainable design. Especially in a country such as Denmark, where sustainable production is of great focus and is recognized for its sustainability towards the food cluster it is vital to ensure a food market where sustainability on the food section is well considered. 'The Danish food cluster is home to one of the most sustainable and least polluting productions in the world'. (Foodnation, 2019) Moreover, this complies with the future development of the Refshaleøen area that encompasses the design of a sustainable place that accommodates sustainable businesses and houses.

Sustainable food production and consumption has been a burning issue the last years and the predominant question is how to sustainably feed the population that is growing and at the same time reduce the impact to the environment. (Smith and Gregory, 2012). Moreover, sustainable consumption and production is a consumer-driven concept that integrates the application of sustainable motifs of food production and consumption, considering at the same time the environment. The consumers' preferences determine in a high degree the production of food through the ways they transport, buy, preserve and consume the food and in turn, food consumption is affected by factors such as the availability, accessibility, the sale of the food and the preferences on it. (Fao.org, 2019)

Concluding, sustainable food consumption and production are interacting with each other and particularly the consumption is directly connected with the food availibility and accessibility. For these reason, changes are necessary both in the consumption and production methods, to achieve a sustainable result.

IMPACTS AND SUSTAINABLE AGRICULTURE

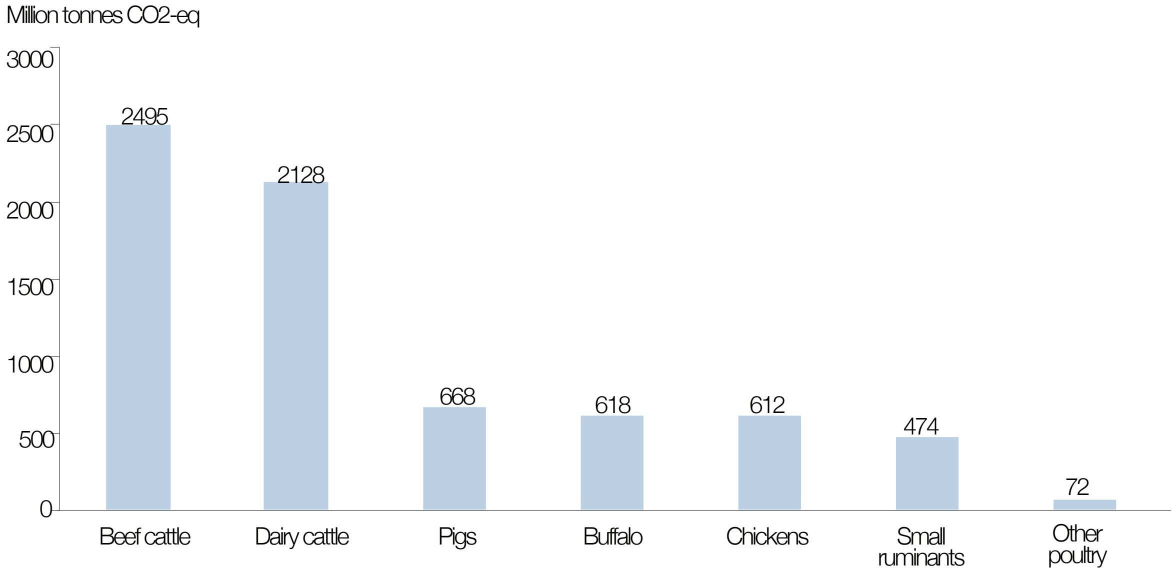
The impacts of the food sector, both during production and consumption vary . Firstly, taking into account the environmental aspect, food has one of the largest influences on the environment, from the production stage to the final consumption. Particularly, the major effects towards the environment are during the production. It is undoubtedly important to consider that 30% of the food sector's energy demands comes from the agricultural production and moreover a 40% of this comes from chemical fertilizers and pesticides. (Reisch, Eberle and Lorek, 2013, pg 11,12)

Considering the health aspect, numerous studies indicated that people all around the world deal with health issues related with food. Obesity and diabetes are only few of them caused by 'rich foods', while health risks occur due to the existence of undesired substances into the food. (Reisch, Eberle and Lorek, 2013, pg 14). The solution to this problem would be following sustainable diets and a sustainable way of living.

Taking all the previous issues into consideration, agriculture and the way it is managed is of great significance. Particularly, 'The goal of sustainable agriculture is to meet society's food and textile needs in the present without compromising the ability of future generations to meet their own needs'. (Asi.ucdavis.edu, 2019)
It focuses on the environmental impact and at the same time on providing a good quality of food. In this goal, all the participants, such as the farmers, the researchers, the retailers and the consumers should have an active role, since each group contributes in a different way. (Asi.ucdavis.edu, 2019)

Concluding, the sale of the products is significant for dealing with the already mentioned issues, therefore when designing the

Ill. 44 - Global estimates of emissions by species



food market it is important to consider how to sustainably trade the products and both the retailers and consumers should have an active role.

VEGETERIAN AND VEGAN FRIENDLY MARKET

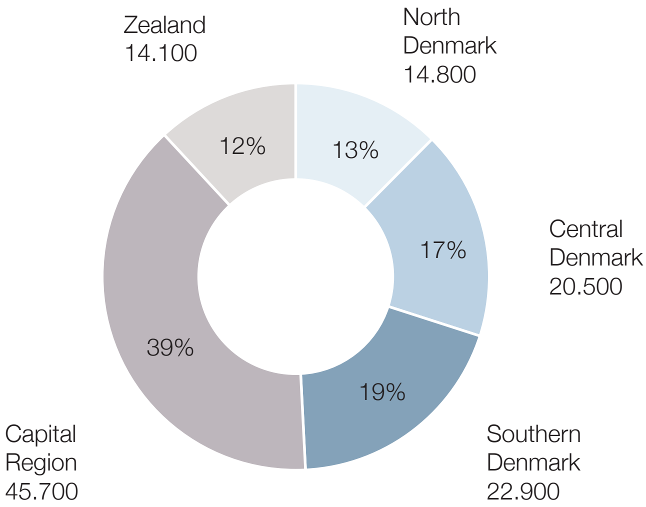
It is undoubtedly important to consider the recent trend of vegeterianism and veganism, when discussing about sustainable production and consumption. Veganism has been one of the biggest trends during 2018 and the demand for meet-free products raised by 987% in 2017. (The Vegan Society, 2019) Denmark and particularly Copenhagen is the sixth Europe city that provides a great amount of vegan friendly eateries, compared with its population size. (Cphpost.dk, 2019)

Taking into account the sustainability aspect, the effects of the animal products exceed significally the ones of the vegetable substances. (Poore and Nemecek, 2018). Moreover, in order to avoid the climate change the reduction of the global emissions is a primary requirement. The total greenhouse gases emissions are estimated 7.1 gigatonnes CO2-eq for 2005 from livestock supply chains. As indicated in the ill. 44 cattle contributes the most to the emissions, with an amount of 4.6 gigatonnes CO2-eq, while beef and dairy cattle produce similar quantities of emissions. (Napolitano et al., 2013)

Concluding, all the above mentioned will be taken into consideration while deciding the different functions of the food market and during the design process. The aim of obtaining a sustainable food market will be accomplished by balancing the different preferences and needs of the users. Some initial thoughts are providing a function in the market that appeals to the preferences of the vegetarians and also producing and growing our own vegetables and herbs. Therefore appropriate spaces, such as greenhouses should be arranged and planned. This could also be assisted by the close connection to the sea- water. Finally, educating the users through workshops for the sustainable food consumption.

TOURISM

Ill. 45 - Jobs related to tourism



Tourism, both international and local, is a growing phenomenon in Denmark (Ill. 45), and Copenhagen, as capital of the country, is considered the first touristic destination. In a market project, it is important to be aware of how advantageous can result to comprehend also tourism as a parametre (Mesher, 2009).

As shown by the ill. 46, tourism is one of Denmark's biggest export industries, together with construction services, electrical machinery etc, food and transort. In particular, international tourists spend around 38.9 billion DKK in Denmark. Therefore, also the economic aspect that is implied must be considered. (Visitdenmark.dk, 2015)

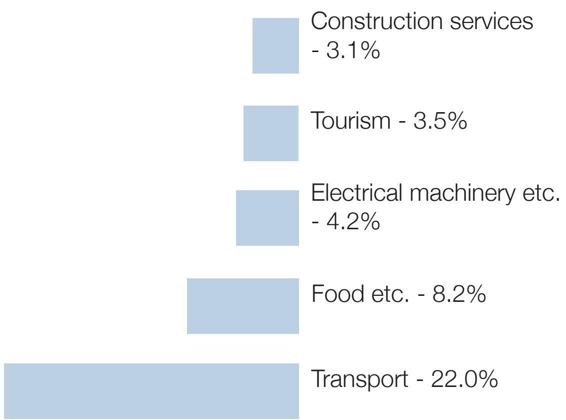
Another reason that makes considering tourism a fruitful resource is that it has been estimated that tourism creates just in the region of Copenhagen around 45.700 jobs, and around 118.000 in the whole Denmark.

Moreover, tourism of internationals is growing in the latest years, especially in the capital region. Therefore, the project of a street food market must provide a service to the city considering also this typology of users. (Visitdenmark.dk, 2015)

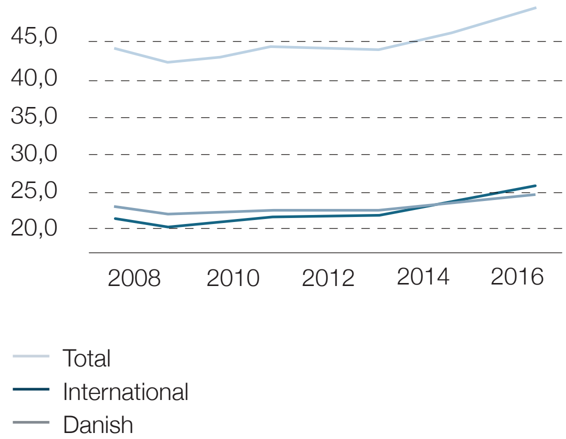
It is important also to consider the background from which the project idea was born. It finds its origin from the famous Copenhagen street food "Papirøen" that has been closed in the beginning of 2018. The touristic appeal of the previous street food sets some expectations over a similar project. In fact, the previous Papirøen, located in the "Paper Island", was a famous attraction for the Copenhagen tourists. It was suggested as one of the main destinations from several blogs and web pages about tourism and in particular in TripAdvisor, that is the world's largest travel site, it was given a certificate of excellence from 2016 to 2018, with around 3.500 reviews and a rate of 4.5/5 (Tripadvisor.com, 2019).
Some example reviews shows how such a concept was working particularly well in the Copenhagen context.

For examples, one review says:
"Been traveling most of the world and

Ill. 46 - Export industries in Denmark



Ill. 47 - Bednights in Denmark in millions



tried street wood in Asia, US and Europe. The concept in Copenhagen is brilliant ! Put it all together indoor - you are not suffering from rain and choices are endless! So far so good". (Tripadvisor.com, 2019)

Another review of a tourist from Miami, Florida says:
"Been there three or four times now, it never disappoints. Fantastic atmosphere with people of all ages and just about every food option you may crave. Great views of the city as well. A must for any trip to beautiful Copenhagen.". (Tripadvisor.com, 2019)

Finally a review from a local living in Copenhagen says:
"I discovered this place thanks to my friends. Unfortunately, it turned out that it would be closed soon. I hope, however, that in 2018 we will get to know a new place of their place!". (Tripadvisor.com, 2019)

In conclusion, while designing the project, it is important to have some considerations on the expectations and desires of the people that used and are going to used these facilities. The new street food market doesn't have only to grant a service to the city, but it is important also to take into account all the implications behind the project of some spaces that have to replace an older facility that was a beloved attraction for the tourists of the area. Moreover, the challenge will be to exploit the position of the new area, overcoming the deficits and taking advantage of the unexpressed potential.

CASE STUDIES
Markthall Rotterdam / MVRDV

Ill. 48 - Markthall Rotterdam

Ill. 49 - Markthall Rotterdam

Markthal is located in the city centre of Rotterdam, in the historic Laurenskwartier. The project is part of the city council's intention to transform this district into a lively and vibrant area. Markthal with its daily fresh food market, shops and apartments, creates coherence and connections with the neighborhood, which will reach a new centrality. (Domus.it, 2019)

The building is a real mix of functions.The ground and first floors accomondate 20 retail units, restaurants and cafés. A supermarket in the basement is also included. "The World of Taste", a centre for education, information and innovation in the field of food opened on 1 January 2015. (Domus.it, 2019)

Despite the open character of the market and the inviting entrance, the open sides had to be protected from the rain and cold. So the decision was to keep them as transparent as possible, opting for a fully glazed facade. As in a tennis racket, the prestressed steel cables create a suspended net, where between its meshes, the sheets of glass are hung. (Domus.it, 2019)

Markthal is a good example of sustainability too, as it has received a BREEAM Very Good certificate. The building is connected to district heating and a heat storage system underneath the building, that also heats and cools a number of adjacent buildings in the surrounding area. The various functions of the building can exchange heat and cold. Research has been carried out concerning the main hall itself, to create a comfortable indoor climate with extremely low energy consumption. The room is naturally ventilated: fresh air enters under the glass façade, rises to the roof and leaves the room through the ventilation ducts in the roof. It is a thermal system that can work without mechanical installations. The combination of housing, shopping centres, car parks and market halls makes the installation technology more efficient. Within the market, an information panel illustrates the building's energy consumption and CO2 savings. (Archdaily.com, 2019)

Moreover, in order to push the sustainable ambition beyond the simple building envelope, Markthal's tenants have signed a Green Lease Agreement on sustainable performance requirements. This contract covers the use of water, energy, waste and healthy building materials. (Archdaily.com, 2019)

Markthalle Panzerhalle / Smartvoll Architects

Ill. 50 - Markthalle Panzerhalle

Ill. 51 - Markthalle Panzerhalle

Markthalle Panzerhall, located in Salzburg outskirts has been designed by Smartvoll architects. The building's historic industrial character is transformed, due to a complex and modern concept, into a "melting pot of producers of high-quality regional goods, that are presented in a manner that transcends shopping and creates a world of enjoyment" (Archdaily.com, 2019).

While the ancient brick walls have been maintained, as far as the implemented structures are concerned, the predominant white containers immediately pop up. These dictated the rhythm of the space and besides keeping an industrial atmosphere throughout the modern building, they also provided rooms of different sizes and heights.

Moreover the containers fulfill a very pragmatic purpose: they contain the building's mechanical and electrical equipment.

As far as the materiality is concerned, ceramic tiles are repeated in numerous variations and reappear depending on the goods that a store offers. The type of the tiles used to cover the ceiling is the unifying element of the different areas. Each seller also has access to exclusive exhibition areas, on steel weathering shelves or on complex wooden constructions. In addition to shop windows, shelves and presentation areas, tables of varying heights are also used, thus ensuring that the work and the service spaces are designed individually.

Panzerhalle works like an extraordinary microcosm on an area of almost 18,000 square meters. It can be consider as a multi-functional building, since the offer extends beyond the market hall and can also perform external functions. For instance, the restaurant has a connected event room, while the elegant loft above can be used for small private events. (Archdaily.com, 2019)

DESIGN BASIS

VISION

The project will be a future-oriented architecture able to perform when challenged from the environment. It will also exploit the potential of the area and its proximity to the water. At the same time, it will address to social sustainability by creating a melting pot that engages with the future development of the area and improves the city environment, as well as the users well being. The project will stimulate all the human senses, that influence the spaces, becoming an integral part of the architecture. Finally, to design a zero energy food market with a strong focus on the indoor climate will be a goal of the project.

DESIGN CRITERIA

SOCIAL

-Considering the future development of the area and enhance the community gathering, aiming to achieve a socially sustainable project.
-The architecture design should address to all the human senses
-The building should be a tourist attraction as well as a service for the local people.
-Considering the possibility of a relation with the Department of Food Science (UCPH FOOD) of the University of Copehagen for the organization of some workshops in the site area.

ENVIRONMENTAL

-Future oriented design / able to face the climate changes (the phenomenon of floods) and adjust to the future development of the area according to the local plan.
-Emphasizing the connection to the water.
-Spaces adjustable to the weather conditions.

TECHNICAL

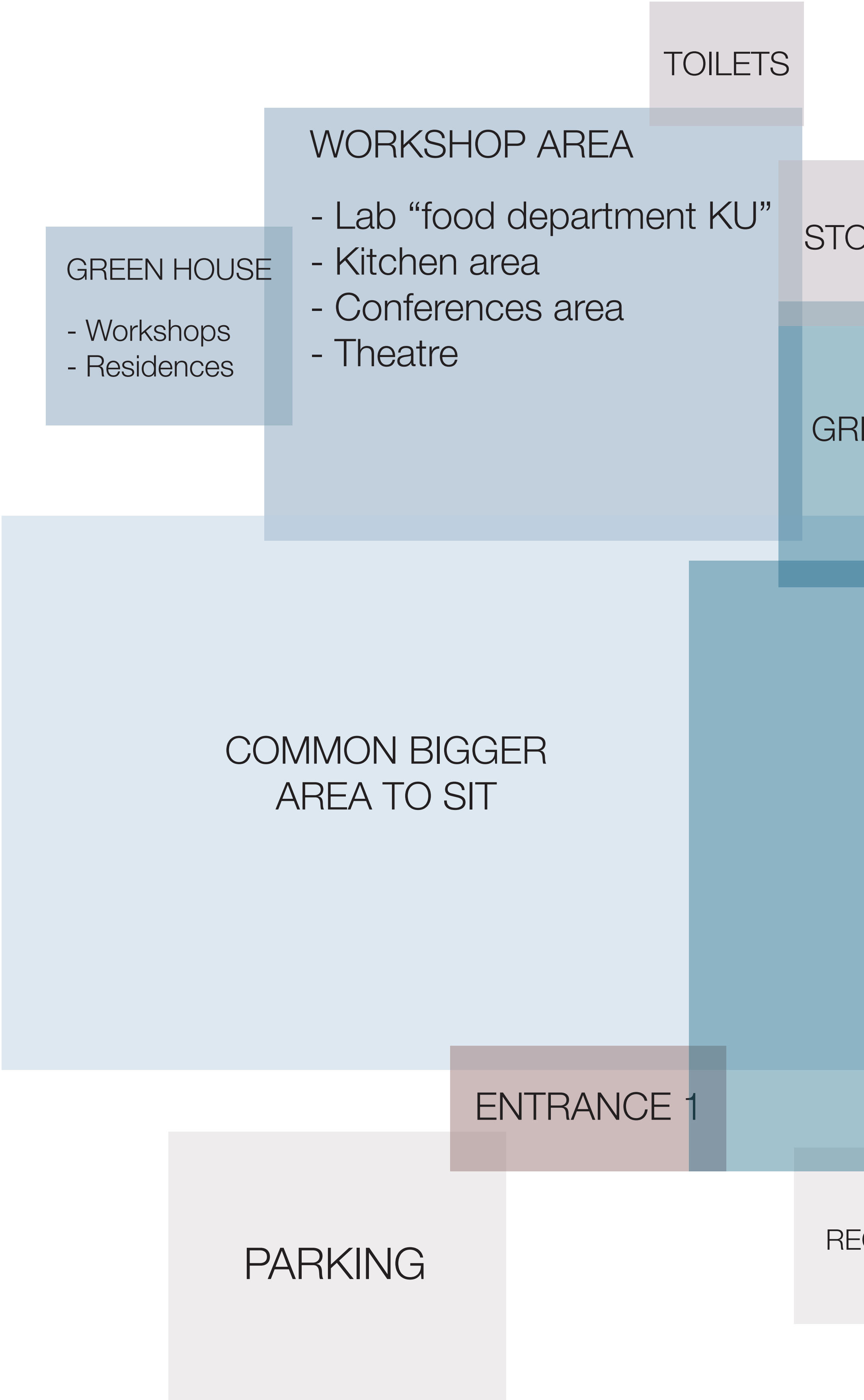
-Taking advantages of the microclimate conditions of our site implementing the passive strategies and after active strategies.
-Trying to implement some personal perceptions in the indoor climate investigation in order to experiment the possibility of a possible better energy performance.
-Providing a comfortable indoor environment for the users and the employees, considering thermal, acoustic, visual and atmospheric comfort.

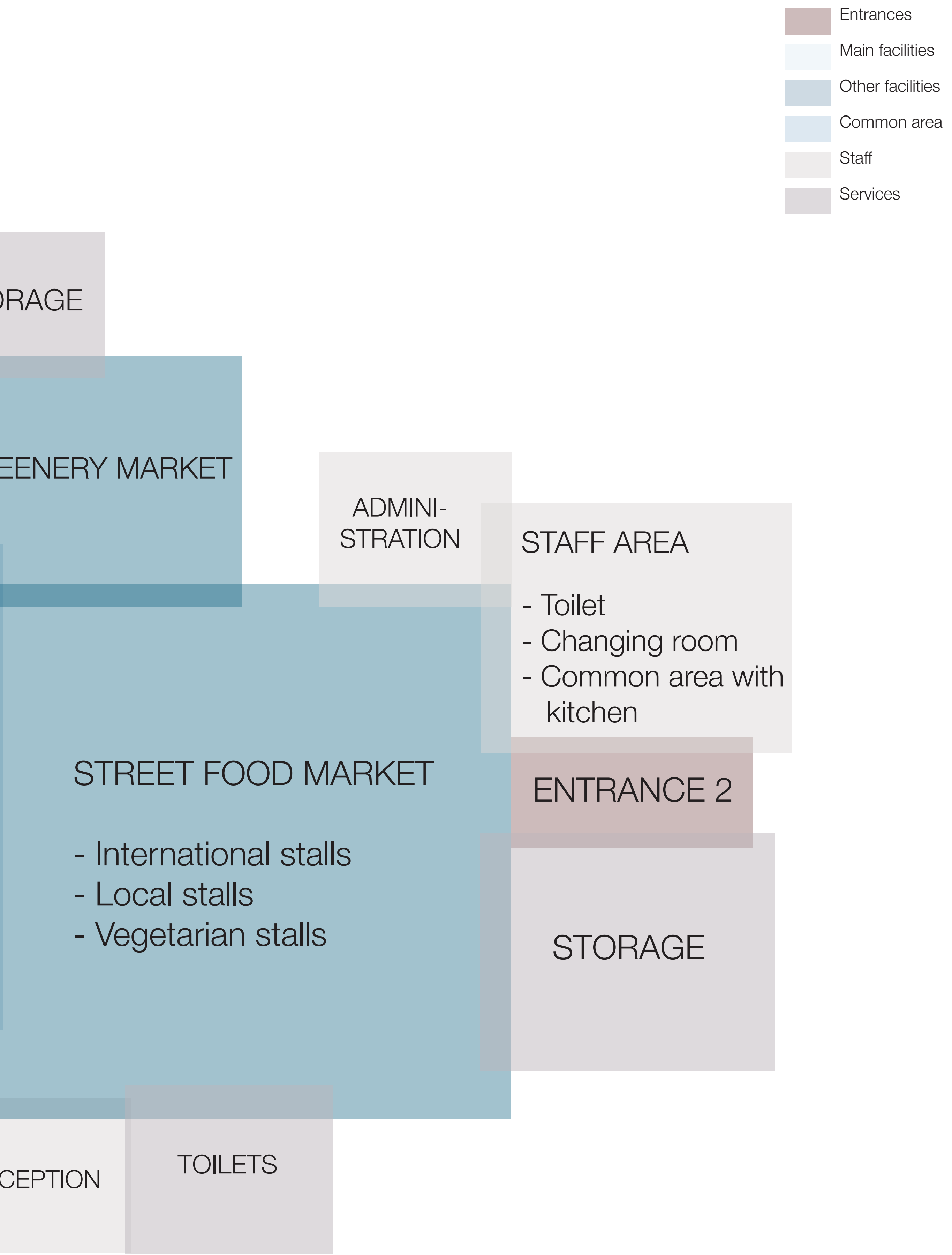
ARCHITECTURAL

-Drawing attention to the views towards Copenhagen city centre.
-The main functions of the market should be connected, both visually and physically.
-The building should be attractive from the outside and at the same time, the outside should express the functions that are supposed to take place indoors, in order to take advantage of the position of the site, visible from the city centre.
-Engaging with the character of the surroundings and implementing its materials diversity in the architectural design.
-Providing easy access for efficient movement of people and goods.

FUNCTION DIAGRAM

Ill. 52 - Function diagram




Entrances
Main facilities
Other facilities
Common area
Staff
Services
ORAGE
EENERY MARKET
ADMINI-
STRATION
STAFF AREA
- Toilet
- Changing room
- Common area with
kitchen
STREET FOOD MARKET
- International stalls
- Local stalls
- Vegetarian stalls
ENTRANCE 2
STORAGE
CEPTION
TOILETS

ROOM PROGRAM

Reference		(Neufert, Kister, Brockhaus, Lohmann and Merkel P., 2014)	h=heating season c=cooling season	(Danish Standards (2007) DS/ EN 15251.); (Danish Standards DS/ CEN/CR 1752, 2001)	(Danish Standards DS/ CEN/CR 1752, 2001)	(Danish Standards DS/ EN 15251, 2007)
Unit		m²		ppm	dp	**degrees celsius for 0,5 clo**
Street food market						
stalls	16	180	Mec(h,c) / Nat(c)	850	1,4	21,5-25,5
corridors/small sitting areas		490	Mec(h) / Nat(c)	850	1,4	21,5-25,5
Greenery market	1	320	Mec(h) / Nat(c)	850	1,4	17,0-20,0
Workshop area						
Laboratory- ki-	1	110	Mec(h) / Nat(c)	850	1,4	23,0-26,0
tchen	1	40	Mec(h,c) / Nat(c)	850	1,4	21,5-25,5
Conferences area	2	200	Mec(h) / Nat(c)	850	1,4	23,0-26,0
Green houses	6	300	Nat(c,h)	850	1,4	23,0-26,0
Common area	1	900	Mec(h) / Nat(c)	850	1,4	23,0-26,0
Storage	2	200	Mec(h) / Nat(c)	850	1,4	17,0-20,0
Staff area						
Canteen	1	120	Mec(h,c) / Nat(c)	850	1,4	23,0-26,0
Common area	1	110	Mec(h) / Nat(c)	850	1,4	23,0-26,0
Toilet	5	15	Mec(h,c) / Nat(c)	850	1,4	23,0-26,0
Changing area	2	70	Mec(h) / Nat(c)	850	1,4	23,0-26,0

	Thermal comfort winter	Daylight factor	Artificial light	Atmosphere
	(Danish Standards DS/EN 15251, 2007)	(Bygningsregle-mentet (§ 377 - § 384), 2018)	(Danish Standards DS/ EN 15251, 2007)	
s	**degrees celsius for 1 clo**	**%**	**lux**	
	14,0-18,0	2-3	100	Active, bustling
	14,0-18,0	2-3	100	
	8,0-12,0	2-3	100	Active, bustling
	17,5-22,5	2-3	300	Inspiring, creative, stimulating
	17,5-22,5	2-3	300	
	20,0-24,0	2-3	100	
	max 26,0			
	20,0-24,0	2-3	100	Bustling
	8,0-12,0		100	
	20,0-24,0	2-3	100	Comfortable, relaxing, home-like
	20,0-24,0	2-3	100	
	20,0-24,0		100	
	20,0-24,0		100	

Reference		(Neufert, Kister, Brockhaus, Lohmann and Merkel P., 2014)	h=heating season c=cooling season	(Danish Standards (2007) DS/EN 15251.); (Danish Standards DS/CEN/CR 1752, 2001)	(Danish Standards DS/CEN/CR 1752, 2001)	(Danish Standards DS/EN 15251, 2007)
Unit		**m²**		**ppm**	**dp**	**degrees celsius for 1 clo**
Reception	1	12	Mec(h) / Nat(c)	850	1,4	23,0-26,0
Toilets	25	75	Mec(h,c) / Nat(c)	850	1,4	23,0-26,0

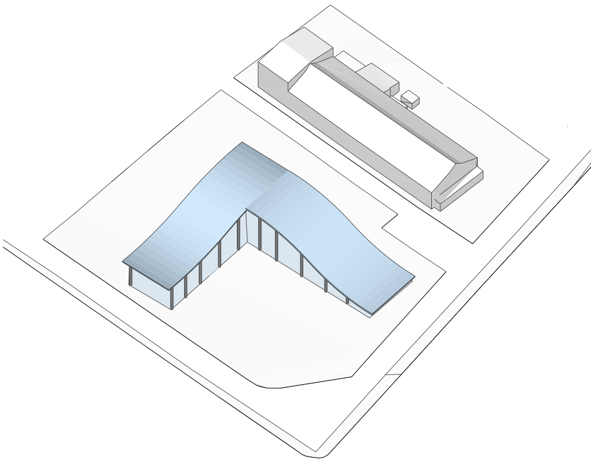
	Thermal comfort winter	Daylight factor	Artificial light	Atmosphere
	(Danish Standards DS/EN 15251, 2007)	(Bygningsreglementet (§ 377 - § 384), 2018) 300 lux in half of the room,	(Danish Standards DS/EN 15251, 2007)	
	degrees celsius for 0,5 clo	**%**	**lux**	
	20,0-24,0	2-3	500	Informative, welcoming
	20,0-24,0		100	

DESIGN PROCESS

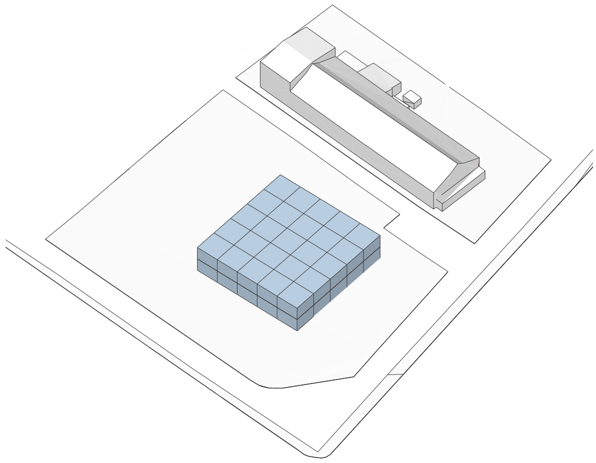
This chapter describes the design process from initial ideas until the final design proposal. The chapter provides insight in specific studies concerning different aspect of the design.

VOLUME STUDY

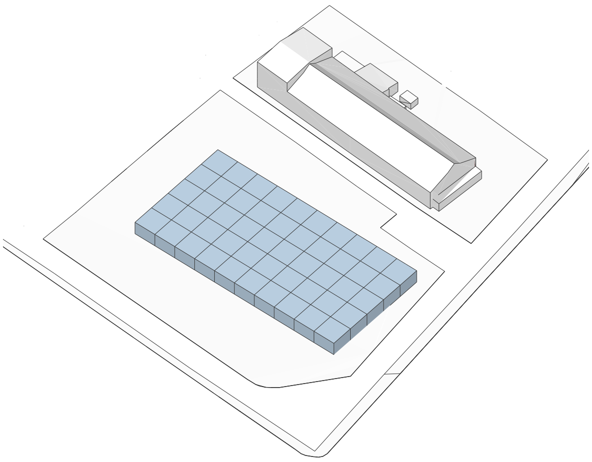
Ill. 53 - Wave concept



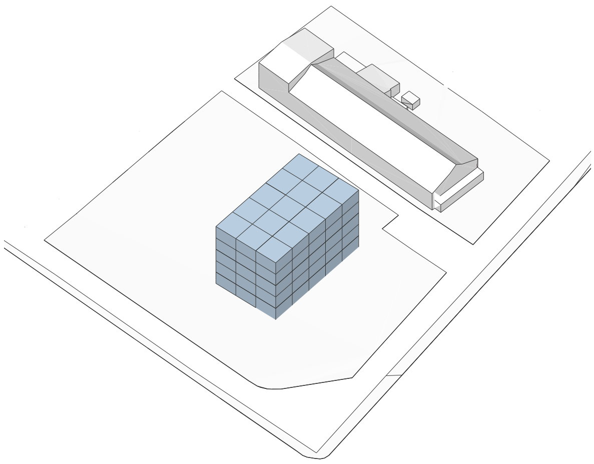
Ill. 54 - Grid concept



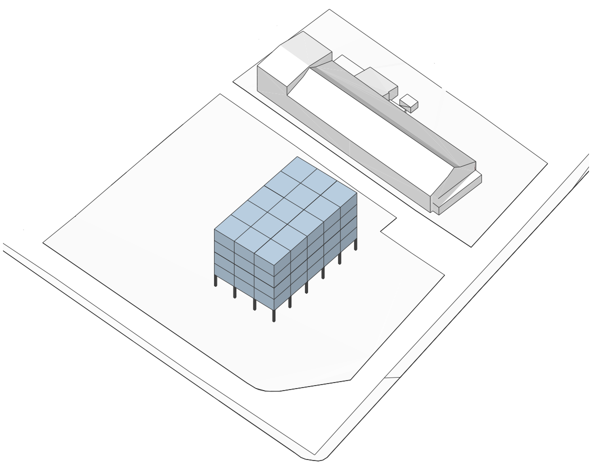
Ill. 55 - Phase 1



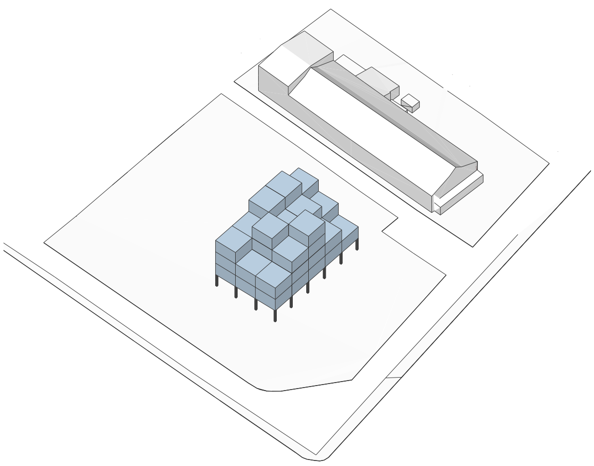
Ill. 56 - Phase 2



Ill. 57 - Phase 3



Ill. 58 - Phase 4



CONCEPT DEVELOPMENT

The first concepts that have been taken into consideration in the beginning of the design phase are following two different principles.

In the first option (ill. 53), the volume of the building is characterized by a pyramidal shape. The initial idea was to create this triangular shape with the peak point along the corner facing the land and with the two edges that step down till they meet the water. Moreover, the envelope of the roof wants to imitate the flow of the seawaves in order to strenghten the relation with the element of the water. In fact, one of the design criteria is to maintain a deep connection with the seaside site and the organic shape itself is able to respond to this purpose.

Instead, in the second option (ill. 54) the concept is to create a modular building that can give more flexibility and freedom during the design phase itself, as well as in the future development of the building. In fact, the grid concept allows not to be restricted by a rigid envelope but to be always able to disassemble or to extend the built area. In particular, this factor has been significant in the final decision when it was decided to develop the second option.

VOLUME DEVELOPMENT

The first step of the design was to determine the footprint of the building according to the room program previously drafted. In the first phase, the volume has been spread on one level.

Instead, in the second phase, the building has been raised up to 4 levels. In particular, this decision aims to take advantage of the position of the site in order to create a volume visible from the opposite shore of the canal where the city centre of Copenhagen is.

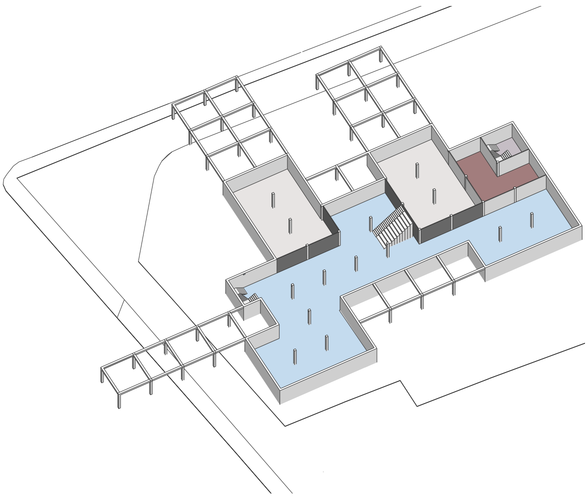
The third phase takes into consideration the sensibility of the site. In order to deal with the problem of the risk of flooding that the site will be facing the initial idea is to protect the building by minimizing the square metres in contact with the ground.

Finally, in the phase 4 some moduls have been removed in order to create some more dynamic interior spaces and some outdoor spaces facing the water protected from the wind.

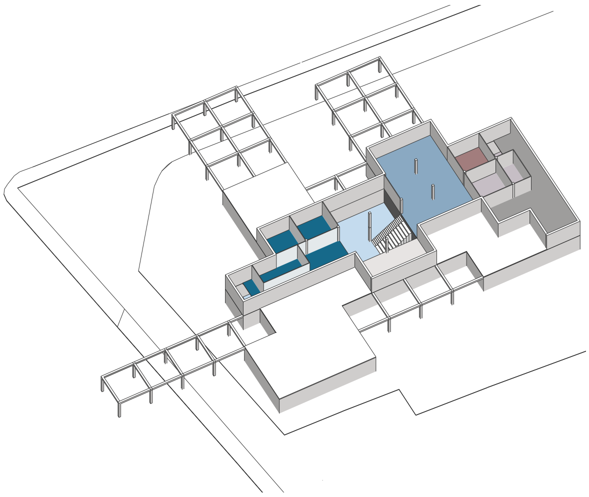
In conclusion, starting from this initial ideas some layouts have been developed in the following pages.

LAYOUT 1

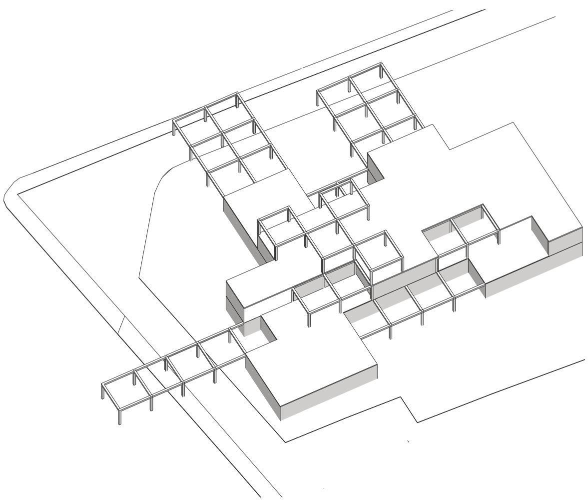
Ill. 59 - L1, ground floor



Ill. 60 - L1, first floor



Ill. 61 - L1, second floor



The first solution that has been taken into consideration is more spread in the site and is developed only on two levels. The grid modul is 7 m x 7 m x 4,5 m.

The main entrance is leading directly to the streetfood market with two big common areas. In the same floor, there is also a storage and the entrance for the staff area. One of the most distinctive elements is the big central stairs that are leading to the greenery market. Close to the greenery market there is a small storage and the main area for the staff. Finally, also the workshop area is placed on the upper floor.

Some criticism to this solution could be the low rise character that makes the building less visible from the city centre of Copenhagen. Moreover, the position of the greenery market does not allow to keep this place thermally isolated from the other zones, according to our program of setting lower temperatures to minimize the energy demand. Finally, the visual connection between all the functions of the building is not emphasized.

Street food market

Common area

Greenery market

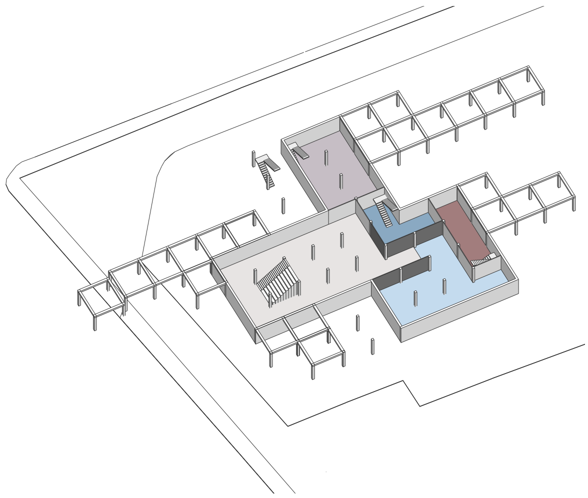
Workshop area

Staff

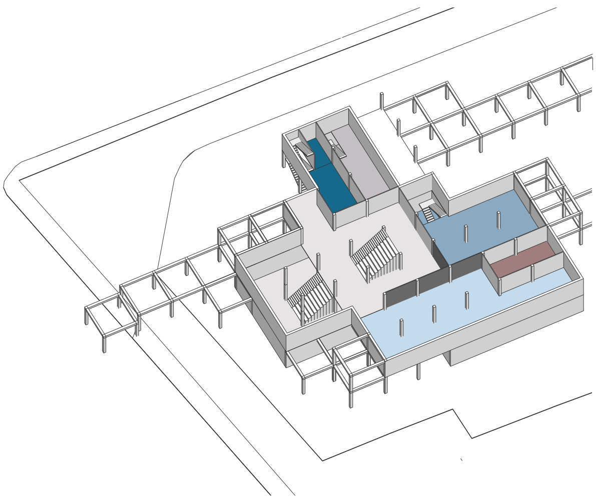
Storage / Services

LAYOUT 2

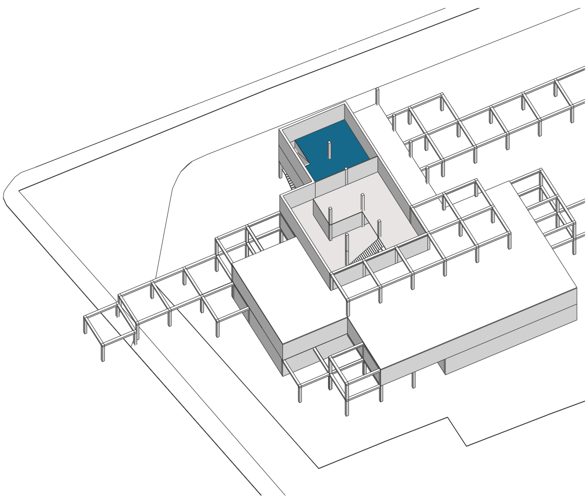
Ill. 62 - L2, ground floor



Ill. 63 - L2, first floor



Ill. 64 - L2, second floor



The second solution aims to maintain the common area in the central position and the other different functions are spread all around. The grid modul is 6 m x 6 m x 4 m.

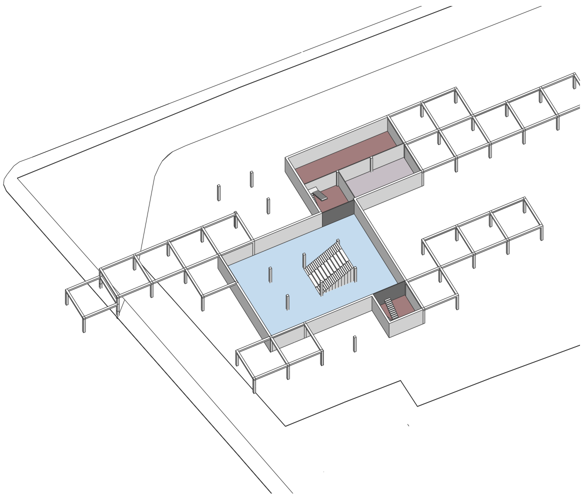
The main entrance is facing the common area and the first element that can be seen is the two main stairs that are leading to the upper floors. All the other functions are placed on the edges of the common area and they are supposed to stand by themself with a private entrance for each.

Few critical aspects could be moved also for this solution. First of all, the dimension of the grid itself that limits the interior organization of the spaces and the overall atmosphere compared to the 7 m x 7 m modul.
Moreover, the necessity to place the storage towards south in order to serve the greenery market and the streetfood market at the same time does not exploit the potential of this position that should be opened up to the surroundings. Finally, the disposition of the functions around the common area and in different levels requires an excessive number of staircases needed to reach the different zones.

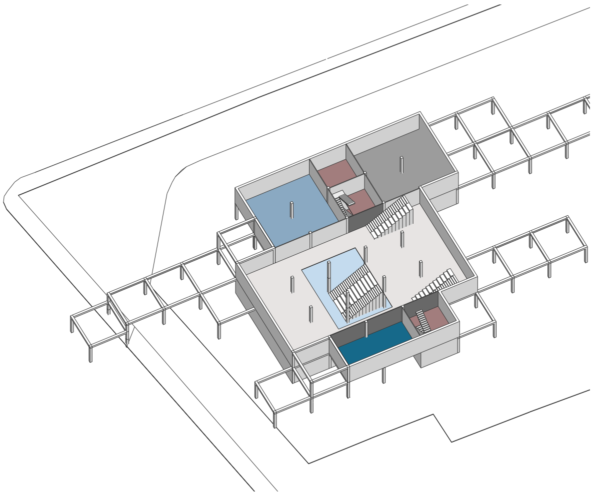
- Street food market
- Common area
- Greenery market
- Workshop area
- Staff
- Storage / Services

LAYOUT 3

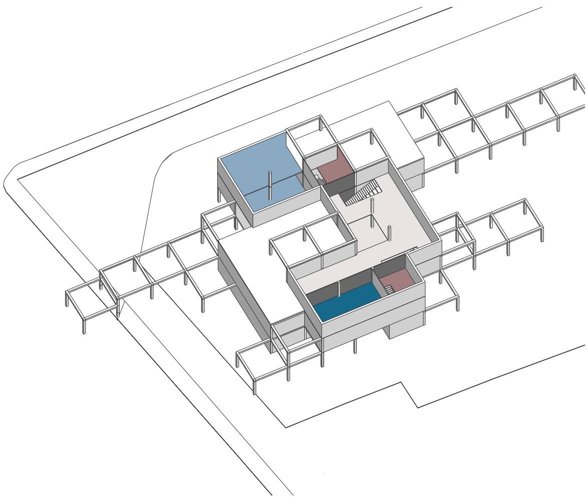
Ill. 65 - L3, ground floor



Ill. 66 - L3, first floor



Ill. 67 - L3, second floor



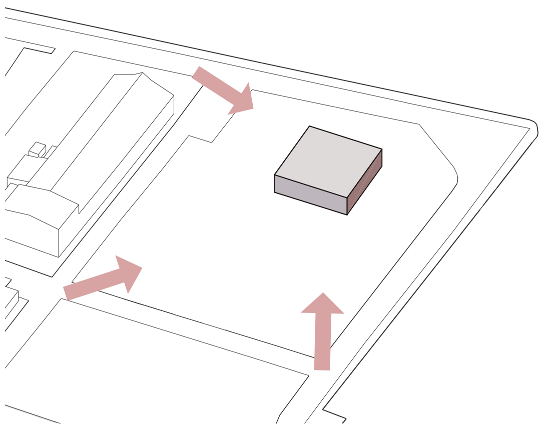
Finally, the third solution is the solution that has been developed the most, and that has been used as a basis for the following phases. The grid modul is still 7 m x 7 m x 4,5 m as in the first layout. The entrance is facing the streetfood market that is considered the main function as well as the most accessible. On the centre of the streetfood market the big stairs are leading to the first floor to the common area that is connected to the greenery market and the workshop area.

A positive aspect of the layout is that on both the building sides there are two service staircases with two service staircases with elevators which are leading to the greenery market and the workshop area directly from the ground floor. Moreover, the building has also a strong visual connection between the functions. The interior distribution is developed in order to be able from each floor to see where all the functions are placed. Finally, on the second floor the big outdoor terrace is protected by the wind and is facing Copenhagen city centre.

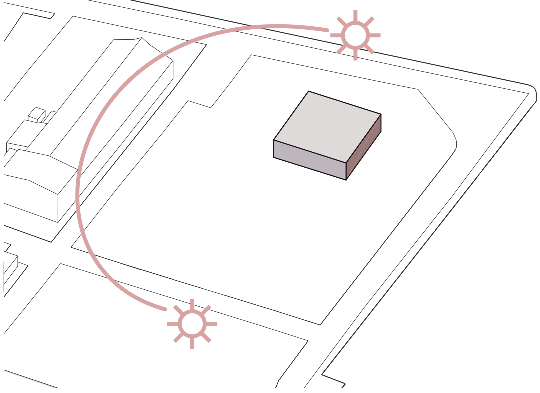
- Street food market
- Common area
- Greenery market
- Workshop area
- Staff
- Storage / Services

LANDSCAPE DEVELOPMENT

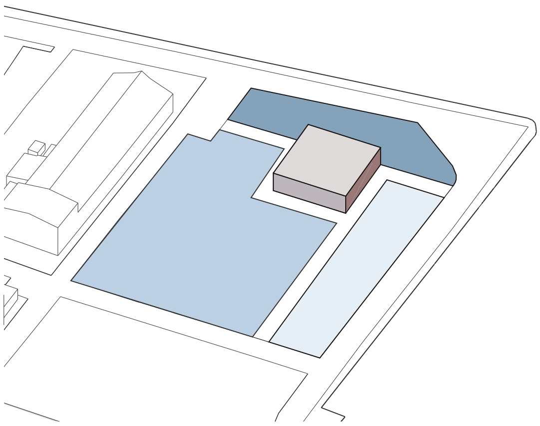
Ill. 68 - Site accessibility



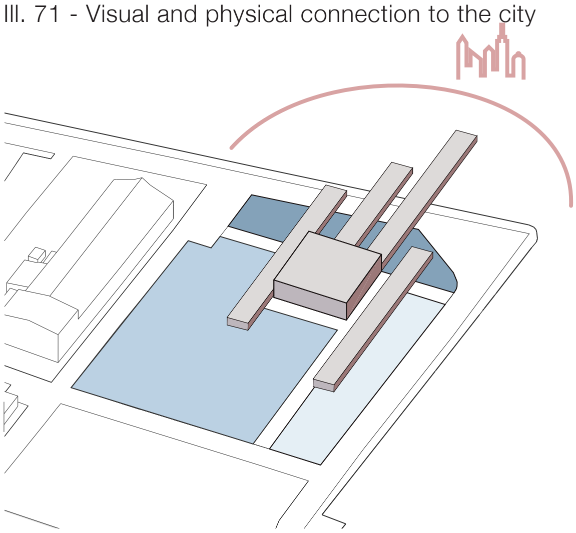
Ill. 69 - Sun radiation



Ill. 70 - Areas division



Ill. 71 - Visual and physical connection to the city

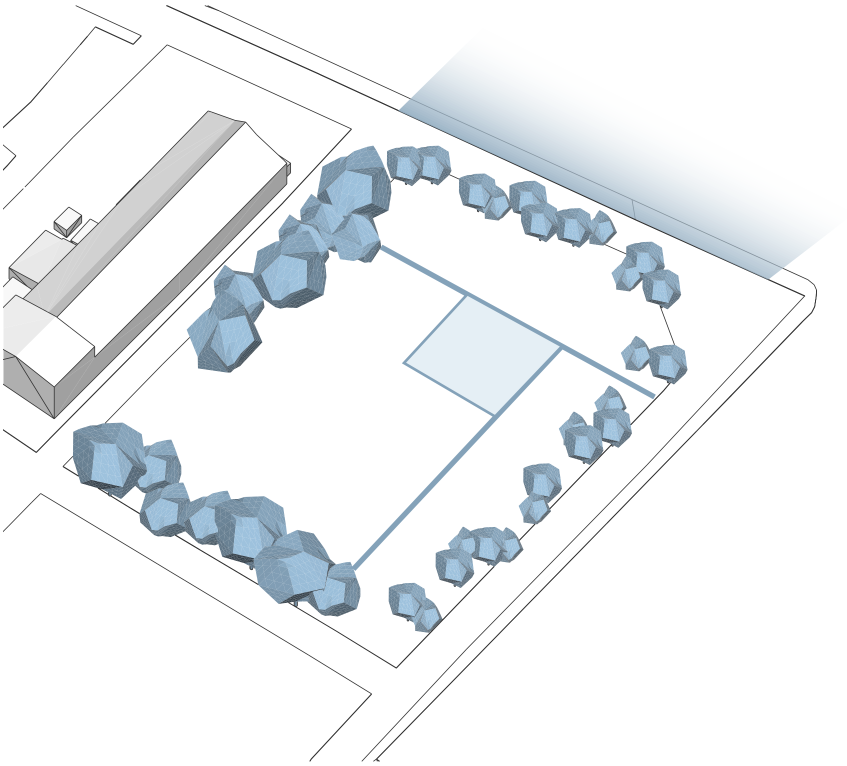


The first considerations about the landscape layout concern the accessibility to the site and the microclimate conditions of sun and wind in particular.

From this starting point, three different areas have been defined. The zone 1 is close to the access from the wide road that can be exploited for the traffic of big trucks needed for the delivery to the site of the different goods for both the greenery market and the streetfood market. The second zone is facing south and is the biggest one where the most of the outdoor activities will take place. In fact, the surrounding buildings reach a level of height that do not affect greatly the space in terms of shadowing. Finally, the third zone is not attractive according to the microclimate conditions of the site, but it is crucial because of the physical and visual connection to the water and to the city centre. For this reason, one idea is to establish this connection through the placement of some walkways that lead close to the shoreline.

VEGETATION INVESTIGATION

Ill. 72 - Vegetation scheme



Ill. 73 - Ailanthus altissima

Ill. 74 - Acer platanoides

Ill. 75 - Gray birch

Ill. 76 - Rugosa roses

Ill. 77 - Lonicera Tatarica

Ill. 78 - Spartina alterniflora

Some further considerations about the landscape concern the vegetation. In particular, the site itself require an investigation about what typologies of plants and trees could grow in the site. In fact, the vegetation that is going to be placed in the urban spaces should take into account the different wind and sun conditions, the specific soil conditions and moreover the specific use of the outdoor area. In fact, the vegetation itself can become an architectural element with its own aethetical and functional properties.

Firstly, the site is placed in a position where the typology is clay soil (Lawrence, 2015). Moreover, the project site is in an area that implies specific requirements. Due to the proximity to the sea, the plants must be moderately tolerant or tolerant to salt spray.

The distribution and the typologies of vegetation can be reassumed in the scheme of ill. 72. In particular, the idea is to create a buffer zone that is able to reduce the visibility towards the industrial buildings of the surrounding area. Moreover, some other elevated trees (approx 20 m high) are supposed to be planted also along the south west edge in order to protect from the wind the outdoor area where a summer streetfood market could be implemented in the future. As can be seen, the idea is to place some big trees on the South East edge. The specific typology could be the Ailanthus altissima (ill. 73) that presents an elevated resiliance to salty environments. In particular, this tree is able to grow really fast and can reach the height of 15 m in 20 years. (Trifilò et al., 2003) Another possibility is the use of the Acer platanoides - Norway maple (ill. 74) whose hornamental aspect and resistance to the salt spray makes it a reasonable choice.

Instead, the trees along the water sides are supposed to have a more hornamental role. As well as the low bushes, whose function will be mostly to divide the different areas and the different pavements. A medium size tree adaptable to this environment could be the Gray birch which can grow from 6 m to 9 m.

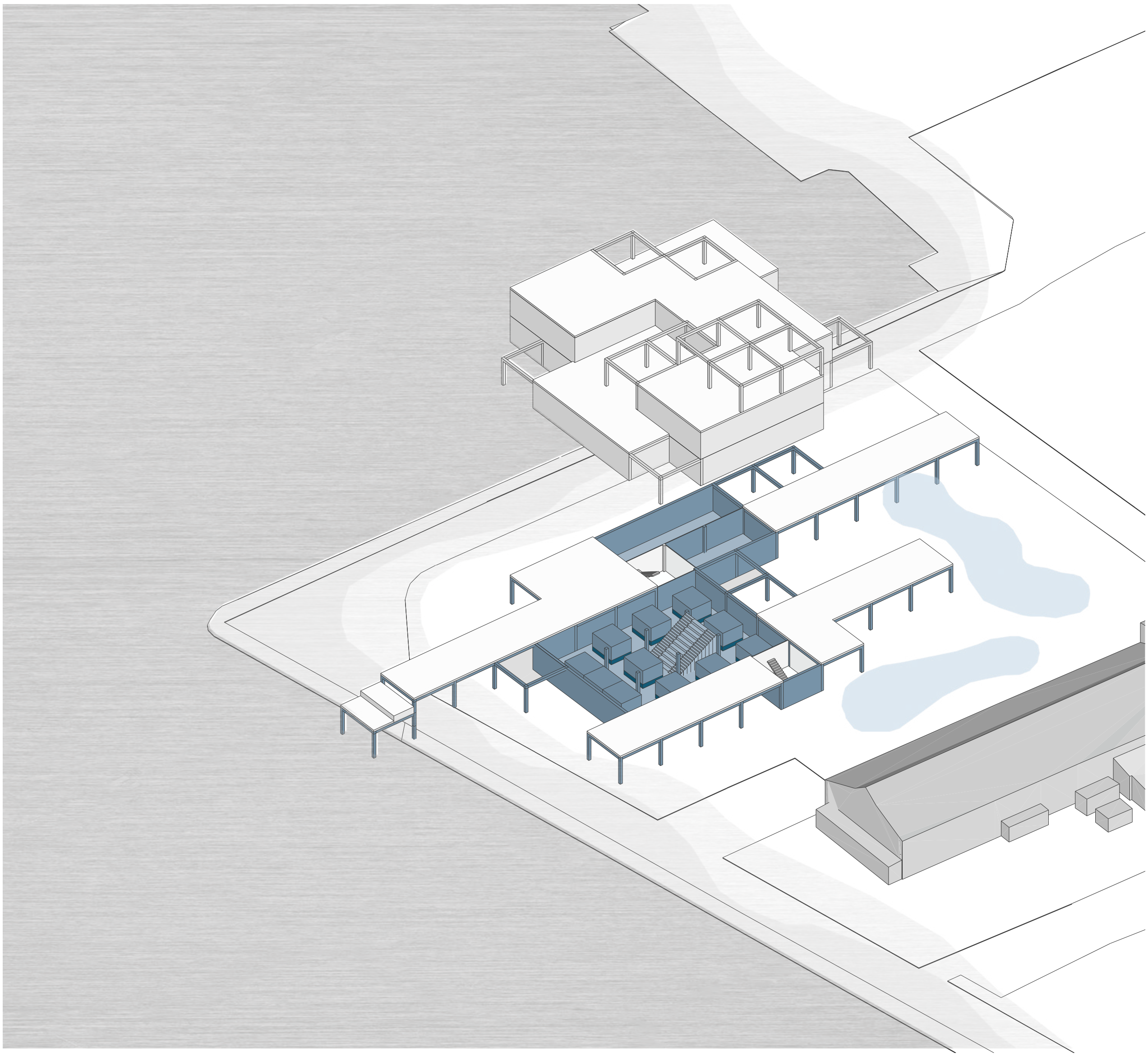
Instead, as long as lower vegetation is concerned, some bushes, which grow in the temperate european countries and present less sensitivity to salt, are the Lonicera Tatarica as well as some types of roses like the Rugosa roses. (homeguides.sfgate.com, 2019). Furthermore also some typologies of grass can not only survive to occasional sea water inundations but they can also be watered with sea water (Hoffmannursery.com, 2018).

The final zone facing the water front concerns some different considerantions as the vegetation that will grow close to the seashore has to be totally tolerant and adaptable to the seasalt. In these case a good option is to consider Halophytes (ill. 78) that are salt-tolerant plants that grow in waters of high salinity and that are coming into contact with saline water through their roots. (Pariona, 2017)

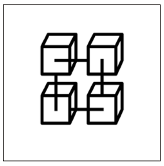
Finally, since our project has a future oriented character and wants to create a food hub where people are supposed to get fully in touch with the concept of food and sustainability, it coud be interesting to implement also the possibility of giving the space for some agricultural cultivations sperimentation. In particular, a lot of research are focusing on crops of vegetables with high or medium salt tolerance. Some of these cultivations are beetroot, kale, asparagus, spinach, tomato, broccoli, cabagge, cauliflower, sweet corn, broad bean, squash, pumpkins and cucumber (FAO, 2005). However, in order to choose the correct vegetation species is necessary to understand that their sensitivity to salt depends not only on the plant specie, but also on the stage of growth and other environmental conditions, and therefore, a consultation with an expert would be necessary. (Gould, 2013)

CLIMATE CHALLENGES

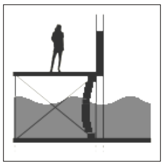
Ill. 79 - Climate challenges strategies



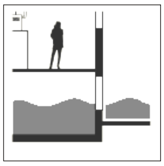
Functions layout



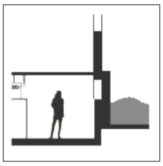
Elevated building



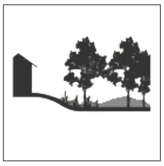
Wet flood-proofing



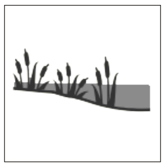
Dry flood-proofing



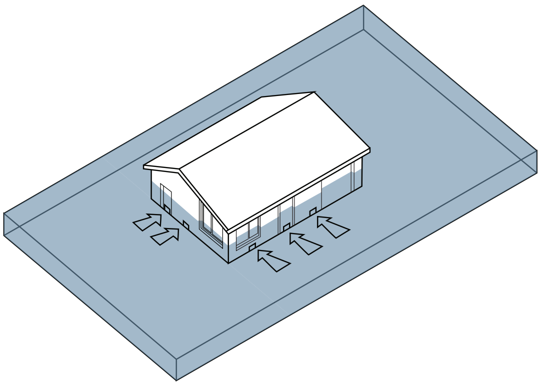
Floodable park



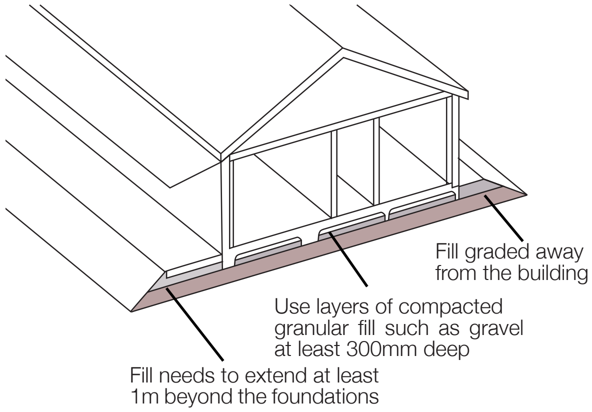
Living shoreline



Ill. 80 - Wet flood proofing allows water to enter the building



Ill. 81 - Raising the slab on alternative fill



Facing the problem of the uprising sea water is one of the aims of the project. In order to accomplish these intentions, some strategies have been integrated in the design from the beginning of the sketching phase.

Firstly, the functions layout itself can be considered a strategy. In fact, the streetfood market has been placed on the ground floor with the stalls in an elevated position so that the water can be ”welcomed” without causing significant damages. A possibility would be also to raise the whole building in a platform in order to minimize the damages that could occur in case of flooding without also affecting the use of the building (ill. 79).

Related to this strategy is the solution of an elevated building. In fact, all the sensible functions are placed on the upper levels. The grid concept responds to this requirement and in this way, the potential of a modular design can be fully exploited.

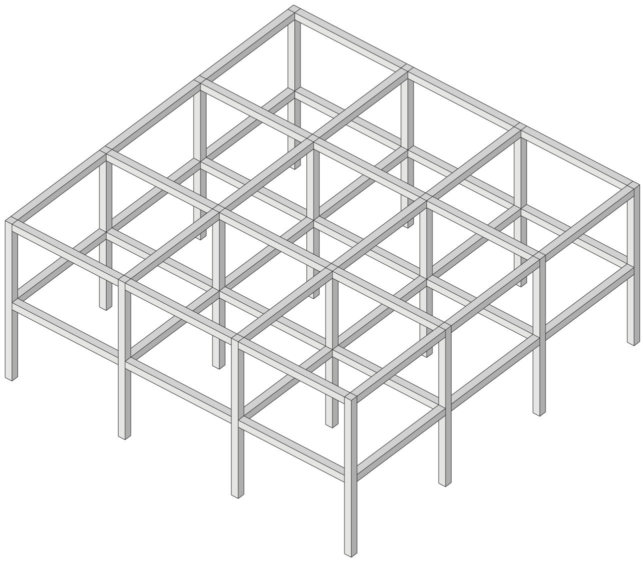
Another possible consideration is to place dry flood proofing materials (white). In particular, according to the scheme in the ill. 79, these materials would be positioned only on the two service staircase blocks, while wet flood proofing materials (blue) would be placed on the rest of the ground floor. Wet proof construction is the method that allows the lower part of the building to be temporary flooded. To avoid damage, water resistant materials or materials that can be easily replaced or repaired are used. Electrical lines should be placed above the expected flood level and the construction parts should be designed in a way that can be dried easily after flooding. (Building flood resilience measures, 2012)

Instead, as long as the outdoor spaces are concerned, the idea is to use absorbent materials like gravel and ground soil placed in a lower position in order to direct the water to these areas in case of flooding.

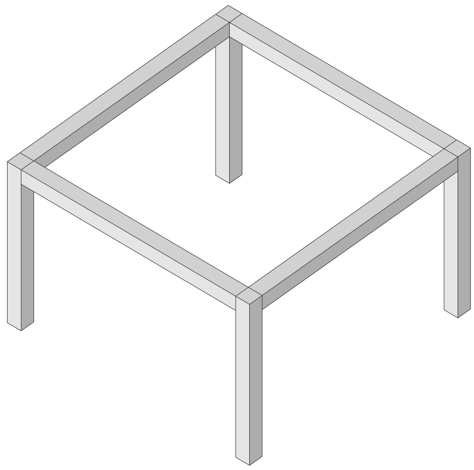
Finally, as afore mentioned, the aim is also to design an embodied architecture that will take advantage of the future incoming of the water creating new ecologies in the landscape area. In particular, the idea is to give the possibility in the future for the development of a living shoreline along the edges of the site facing the sea.

CONSTRUCTION

Ill. 82 - Grid structure



Ill. 83 - Module



CONSTRUCTION MATERIALS

Since the concept of the grid was decided, the considerations for the construction material were crucial during the design process. Three materials, concrete, steel and wood are used as construction materials and were all taken into consideration. The possibility of using concrete precast or cast in place is the optimal one, related also to its water resistant properties. However, concrete is a heavy material that is not flexible, and therefore it did not comply with the concept of the project. Steel is also a strong and flexible material and according to the National flood insurance program, is acceptable when in contact with the water. Nevertheless, it is not recommended in areas endangered by salt water flooding, thus it was not applicable with the particular project, which is situated close to the sea. (FEMA, 2008) Finally, wood was selected as the structural material, since it was the most relevant with the flooding concept, the flexibility and the overall architectural impression of the food market.

FRAME CONSTRUCTION

Frame construction is one of the three construction methods that dominate for the wood construction. The other two are panel and solid construction. The intention was to obtain a visible and dynamic grid that could be flexible and complement the future oriented food market. Therefore, the frame construction was embraced.

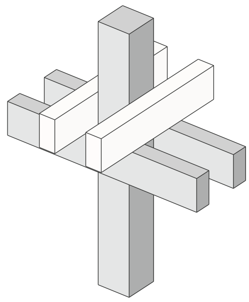
Particularly, the frame construction consists usually of glulam beams and columns that are positioned in a regular grid and are connected usually with steel components. The primary structure is the one that carries the loads and tranfers them to the foundation and glued laminated timber is prefered due to its stability properties, therefore, it is selected for the particular project. The columns can also carry high loads since the wood is high efficient when it is parallel to the grain. The external walls that are enclosing the structure are placed either inside or outside the loadbearing structure. Furthermore, in sustainable designs the loadbearing construction is usually situated inside the insulation, so as to avoid penetrations and thermal bridges. Finally, the internal walls are also independently placed providing even more flexibility. (Kolb, DGfH - German Society of Wood Research and Li-

gnum - Holzwirtschaft Schweiz, n.d.)
For all the above mentioned reasons this type of construction better fitted the project and a column 40*40cm with spacing of 7 m * 7 m was decided.

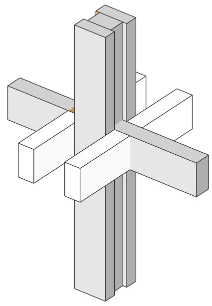
Moreover, considerations about the configuration of the column and the beam were important for the architectural detailing and the possibilities of assembly and dissasembly. There are five different forms of construction that they are more common according to the joint between the column and the beam. The columns and compound beams that comprehends of one part of columns and two parts of beams. It is a construction that allows for high floor buildings and an economic solution. In the beams and compound columns there is one part of beams and one part of columns that are connected with fasteners. The main disadvantage is that the beams should penetrate the walls, with the exception if the walls are placed on the structure. The columns and oversailing beams is appropriate for single storey buildings. The beam lays over the column while the secondary structure is baired on the main beams. In the beams and columns the column is continuous and the beams are connected with the column and they are at the same vertical plane. The main advantage of this structure is that the connections with the column are possible in all the four sides and the connection of the beam and the column is possible in every level, allowing for more flexibility. The walls are usually kept on the outside of the structure. Finally, the forked columns is the form where on storey columns support the beams. It is a construction that can carry high loads (Kolb, DGfH - German Society of Wood Research and Lignum - Holzwirtschaft Schweiz, n.d.)

From these five choices the continuous column and beam was chosen, since it is a flexible solution. Moreover, the connections between the column and beam are not visible and the possibility of placing the walls outside of the main structure would minimize the ther

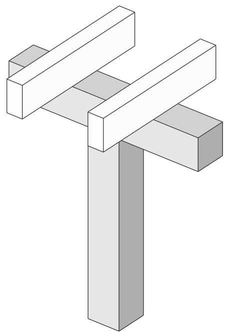
Ill. 84 - Columns and compound beams



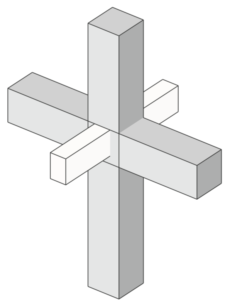
Ill. 85 - Beams and compound columns



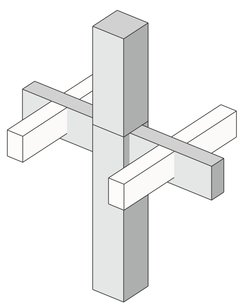
Ill. 86 - Columns and oversailing beams



Ill. 87 - Beams and continuous columns



Ill. 88 - Forked columns



mal bridges.
Finally, the considerations for the resistancy of the material towards the water were important when deciding for the use of the glue-laminated timber. According to the National flood insurance program the structure woods that are acceptable when in contact with the water are the solid standard, solid decay-resistant (such as heart wood or redwood) and solid preservative-treated lumber. (FEMA 2008) Even though glulam does not usually have the need for preservative treatment, this is required in the case of the project , since one of the flooding strategies followed is the use of wet proofing materials, particularly in the ground floor.

WOOD AND SUSTAINABILITY

One of the main reasons why wood was optimal for a construction material, besides the flood concept and the use of the grid, was also to the focus of the project towards sustainability. One of the design parameters from the early beginning of the project was the focus towards environmental, economic and social sustainability.

Regarding the environmental sustainability , is important to consider the performance of the wood in the life cycle assessment (LCA). The LCA is the technique to estimate the impact of the materials on the environment. In a life cycle assessment that was conducted by the FPInnovations for the Wood Innovation and Design Centre (WIDC) two similar buildings were compared for their impacts towards the environment. The first building was constructed with concrete and the second with cross laminated timber. The results indicated that the wood construction performed better in all of the categories for at least 10% more compared to the concrete base building. According to this report the differences between the LCA results were mainly due to their structural system (wood and concrete). Moreover, the production of 1 ton of steel releases 2 tons of CO2, while 1 ton of concrete releases 1 ton of CO2 (Naturally wood, 2015). Important also is that nearly 3,9 tons of carbon dioxide can be discarded from the atmosphere by using wood as a structural material (Mayo, 2015). Concluding, wood has the possibility to be a more environmentally friendly material than concrete and steel, considering the effects on the environment.

As far as the economic factor is concerned, all the timber constructions are related to prefabrication in some degree. Particularly, the frame construction allows to use prefabricated elements in a whole spectrum. This fabrication possibility can reduce the work time on site, therefore, the construction could be completed in few days. (Kolb, DGfH - German Society of Wood Research and Lignum - Holzwirtschaft Schweiz, n.d.) By using standard-sized columns and beams , material waste will be reduced, the transportation will be easier and cheaper by setting standard sizes for the prefabricated elements.

When discussing about a sustainable construction, the whole building lifecycle should be taken into consideration, from the construction until the end of life. Therefore, the assembly and dissassembly should be flexible and easy. By using the beam and continuous column form of frame construction, the design is flexible and the choice of the joint between column and beam could be easy to disassemble.

Finally, the choice of treating the glue laminated timber may not be the optimal economic solution, even though a compromise was necessary due to the flooding considerations and the need of using waterproof materials.

CASE STUDIES-GRID

Ill. 89 - Canada square pavilion

The project is a cafe pavilion in Canada square designed by William Conway's team and it is hosting different events during the year. The project was completed in the summer of 2018. (Wma.co, 2019)

It has a square grid of 3,5*3,5m. It is constructed by wood and the construction is left exposed both to the inside and outside. Moreover, the connections between the different elements are visible and in general the building has a light impression, which is enhanced with the whole glazing facade in the main entrance. The facade material is steel, which creates an interesting contrast with the wood.

It opens up towards the square, with the intention to become a continuation of the park and connect to it. Moreover during summer the facade is openable complementing even more the relation of the inside and outside. (Wma.co, 2019)

The visible wooden construction in the interior and the interplay between the interior and the exterior, which is enhanced with the continuation of the grid to the outside were an inspiration for the project and were elements that were integrated into the final design solution.

Ill. 90 - Rebel, A10- Kop Zuidas, Amstardam

Rebel is a competition proposal by Rebel A10 in Amsterdam. It combines diverse functions, apartments, restaurants, workspaces, different amenities and public spaces.
The design is taking advantage of the grid and allows for spatial flexibility. It is a project that stands out of the context and becomes a landmark for the urban area, due to the visible grid on all its three dimensions. Moreover, it is a future oriented proposal that enables the addition of functions, if required in the future. The relation between the interior and exterior is strong since different outdoor spaces are integrated with the interior and there is an interplay between the voids and the enclosed spaces.
The grid is constructed by wood and the structure is visible. The facade is cladded with concrete and the greenery is integrated in the interior of the building.

(Welch et al., 2019)

The visible grid and its flexibility were concepts that were applied into the food market. The interplay between the voids and enclosed spaces was also a concept that was considered in the beginning of the design phase, however in the final solution it was not applied since it did not allow to raise the building in more than two storeys and become in this way a landmark for the area.

MATERIALS INVESTIGATION

After the initial considerations about the material of the grid structure, an investigation of the cladding materials is carried out.

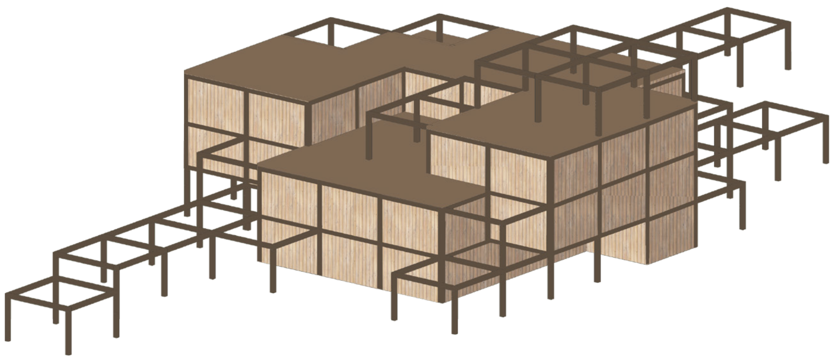
In the first phase the idea was to keep the wood material also for the cladding of the building walls. This decision was taken into consideration in order to keep a coherent approach with the load bearing structure. Moreover, the use of wood emphasizes the impression of a ”green” building, thanks to the sustainable properties of the wood material.

The solutions that could be follewed are two. The grid could be visible (ill. 91) or it could be hidden (ill. 92). In the first option, the grid becomes part of the cladding and the modular character of the building is emphasized. Instead, in the second option, the grid is hidden by the exterior cladding of the building.

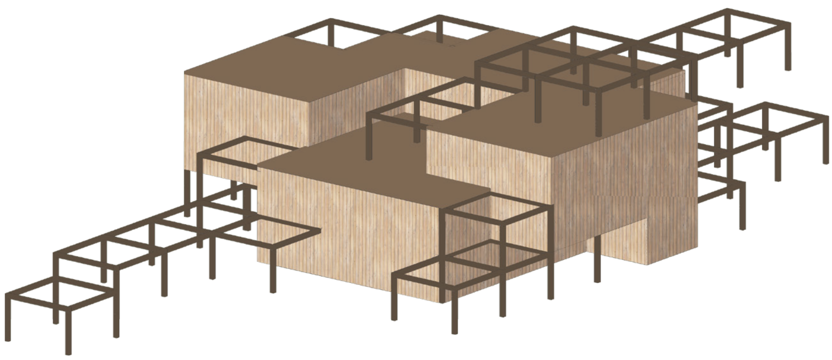
Initially, both the options have been developed in order to understand the technical issues that could raise up by the each choice. In particular, in the option with the visible grid the main concern is about dealing with the thermal bridge issues that would inevitably occur. However, not only some technical but also some aesthetical considerations lead to the decision of developing the option with the hidden grid.

In the third option a further step is shown. In order to keep the impression of the modular structure an hybrid construction of wood and concrete has been considered. The main idea was to keep an heavier and more durable costruction on the lower levels and a lighter and warmer cladding in the more sensible upper levels and in the two service staircase towers. As afore mentioned, the concrete performs really well also in contact with the sea water.
A criticism that can be moved is that integrating a concrete structure in the building would compromise the grid concept. Moreover, the environmental impact of concrete, as already said, is bigger compared to a wooden structure. For these reasons, also the third step has been developed further after the implementation of the windows study in a solution where the concrete structure is limited to the two towers of the service staircases.

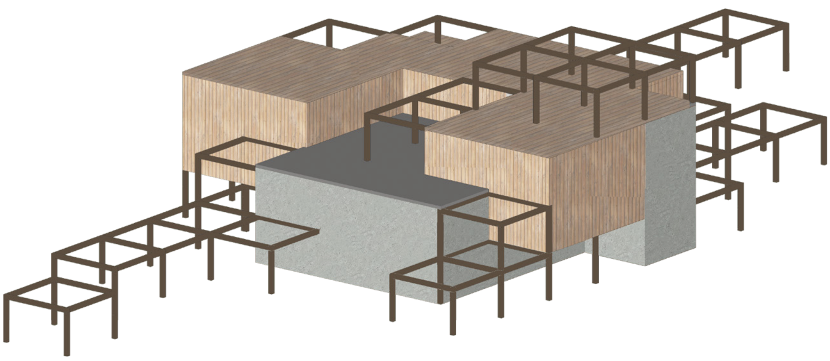
Ill. 91 - Wooden cladding



Ill. 92 - Wooden cladding with visible grid

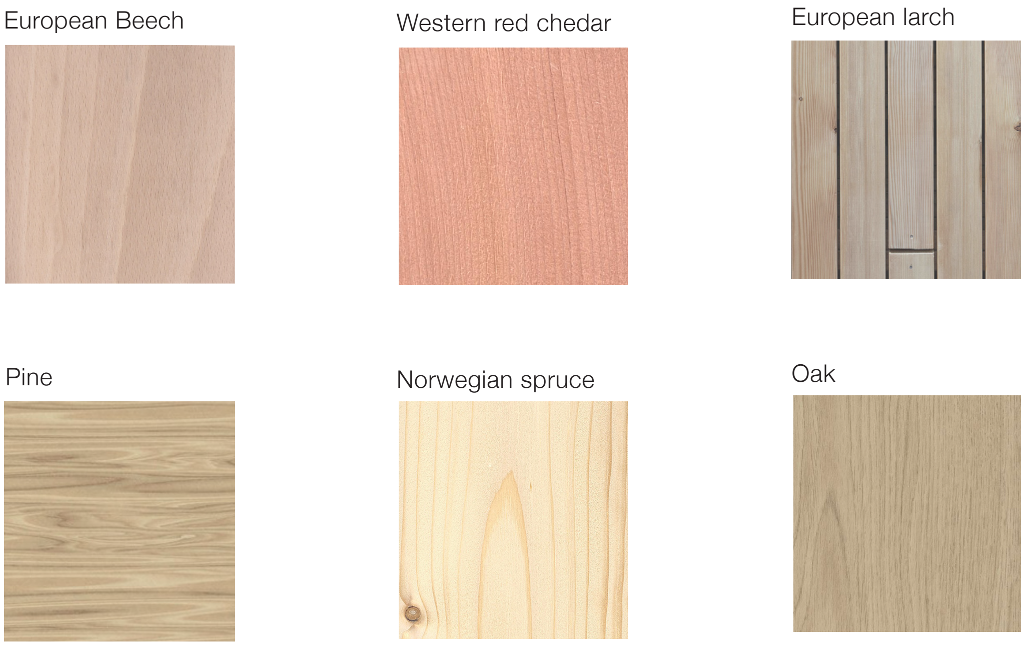


Ill. 93 - Hybrid construction of concrete and wood



Wood typologies and cladding

Ill. 94 - Wood typologies



Different types of wood for the cladding materials were investigated, to see which better fits with the concept and the context of the site. European beech, western red chedar, european larch, oak, pine and norwegian spruce are indicated on the left since they are the most commonly used wood types in Denmark. Particularly, the European beech grows naturally in Denmark and is considered the most sustainable certified hardwood. It has a light colour, it is durable and it is not so expensive. It is mainly used for furniture and domestic flooring. (European beech: durable, sustainable and versatile, 2012)

Western red chedar is a wood mainly cut and profiled for facade cladding. It has a very high durability, natural resistance to the rot and fungus and it is imported from Canada and North America. Therefore, it is more suitable to use a wood that grows in Denmark and is not necessary to import it. Moreover, the redish dark colour that it appears with, does not fit perfectly with the concrete that is used on the two 'towers' and the light impression that the building should have. (Beck, 2019)

European larch has an expected service life of 30-40 years. It is used for its robustness and if not treated it turns to a silver grey colour. (Greenspec, 2019)

European oak has nearly the best natural duration. It is mainly used for flashings, window and roof coverings and not for the whole facade because it is quite expensive. (Beck, 2019)

Norwegian spruce is really durable as well. Moreover, it is logical to use it in a Danish environment since it does not require to be imported and it is cheaper than oak. Finally, it lets throung only a little amount of water and it is really resistant to moisture. Therefore, Norwegian spruce better fits with the whole concept of the project, especially related to the flooding concept, which requires a durable materials highly resistant to the water. (Wood Products, 2019)

THERMALLY TREATED WOOD

In order to increase the durability of the wood, since the main concept of the project is the resistance to the water, in order to deal with the phenomenon of flooding, the thermal treatment of the wood is necessary.

The heat treatment of the wood is operated with the absence of air in temperatures between 160º and 260º. The high temperature twist reduces the shrinkage and swelling of the wood by 50% and this allows its use in high humidity conditions. Moreover, the thermal treatment of the wood can increase the lifespan of the materials up to 25 years.

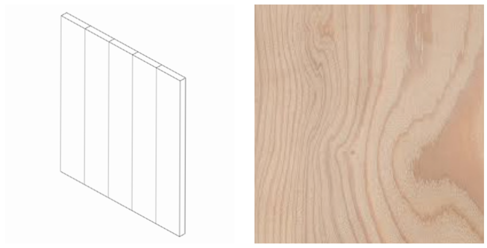
In order to preserve the original appearance of the wood special chemicals should be used for repair and maintenance. Once a year chemicals should be used for cleaning the wood and then it should be coated with maintenance oil, so as not to change colour over time due to the sun exposure. In this way, the silver patina that is caused to the wood due to the influence of the solar radiation will be avoided. (Ivanovic-Sekularac, Sekularac and Cikic Tovarovic, 2012)

DIFFERENT WAYS OF CLADDING THE WOOD

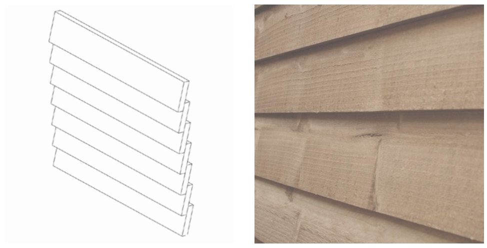
After the spruce from Norway was decided to be used as a cladding material, different ways of cladding the wood were tested. The most common used techniques in Denmark are the vertical and horizontal boards, while the shingles are the most uncommon and lamellas are gaining more and more interest.
In terms of construction the best solution are the vertical boards, considering that the water can easily run behind the wood without creating ponds. The vertical lamellas were decided as the final solution because of their thin size, that keeps up with the human scale that the building wants to preserve. Finally, they were chosen since the spacing and the size of the lamellas present great tactility qualities, therefore, they could activate more the human senses. Finally since the building is quite tall the different pieces of lamellas will overlap each other without being visible when looking at the facades.

Ill.95 - Cladding typologies

Vertical boards

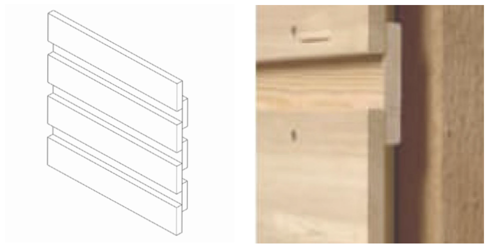


Horizontal boards

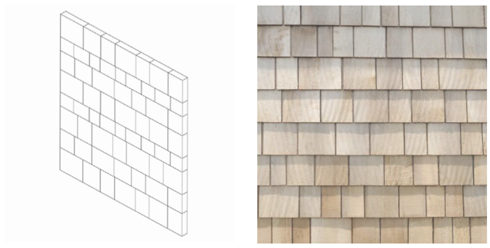


Overlapping boards

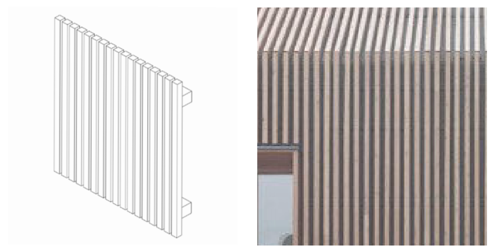
Two on one horizontal boards



Shingles



Vertical lamellas



WINDOWS STUDY

In the following step, a windows investigation has been carried out. In particular, the considerations for the placement and the dimensioning of the openings wanted to respond to the different requirements according to the function and the indoor climate of each room and the orientation and microclimate of the building itself.

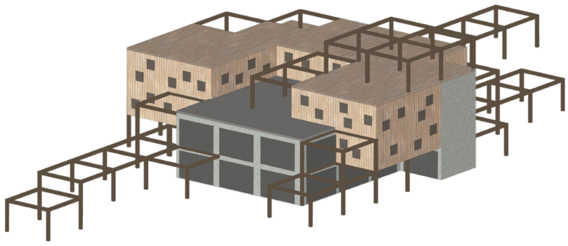
In the option 1, the concept is that the bigger openings are placed in the streetfood and in the common areas, while the smaller openings are placed in the other functions where direct light is less needed. In particular, all the openings present the same dimensions but are placed at different heights.

In the option 2, the principle is the same even though the openings have different dimensions.

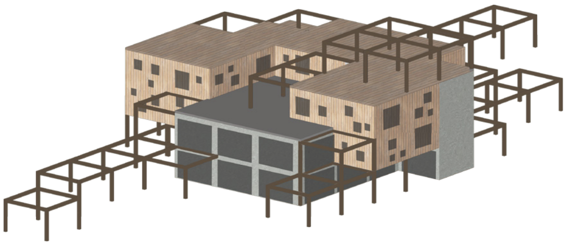
In the other two options (3, 4) the windows are following two different concepts. While in the first one the principle is still to reduce the windows dimensions on the upper levels on the last option the windows have been placed considering the function and the position according to the site. However, both the cases have been developed more in the annex 9, also respecting the 15% of window / floor area ratio per each room.

In conclusion, the outcomes from this investigation were particularly useful to understand the general impression and the future look that the building could obtain. In the end, the decision was to choose a solution that could combine the third and the fourth options.

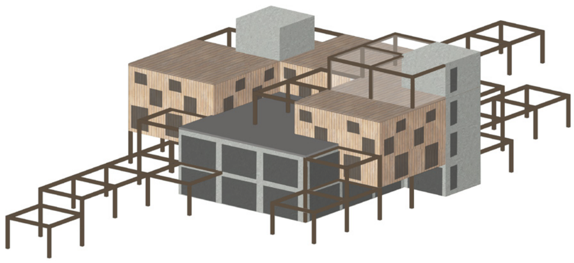
Ill. 96 - Windows option 1



Ill. 97 - Windows option 2



Ill. 98 - Windows option 3



Ill. 99 - Windows option 4

LIGHT FACADE STUDY

The choice of an hybrid construction of wood and concrete has been questioned during the design process because of the great environmental impact and because of the grid concept that would have been weakened. For these reasons, the idea was to keep the wooden load bearing structure and to implement a glazed facade as a replacement to the concrete structure. In this way, the original idea of having more dynamism on the building envelop is kept, and however, the wooden grid concept is maintained and also emphasized thanks to the transparency of the glass that allows the view also to the indoor spaces where the wooden structure is kept visible.

Moreover, glass as a building material is in a continuous improvement in terms of thermal insulation performance and it is becoming a significant construction material also in sustainable buildings with low energy performance. The main quality of glass is that it allows the maximum daylight into the building and can easily through some shading systems control an limit the solar heat gains, according to the required indoor climate and to the energy requirements. Glazed surfaces can also provide a visual contact with the outdoor spaces that contributes to the social and economic pillars of sustainability. In fact, creating a better indoor environment enhances also the productivity as well as the well being of the users. Moreover, great glass use can reduce the energy demand as lower artificial lighting is necessary. Finally, according also to the life-cycle assessment of the material, the impact that glass has on the environment from the manifacture to the construction and demolition phases is much lower than other alternatives. Therefore, the environmental sustainability of the building is increased. Furthermore, the raw materials used to produce glass are mostly non polluting and the process generates low level of waste. Finally, since the building is following a future oriented approach open to further additions or disassemblings, it must be considered that the majority of glass products are recyclable and according to a life-cycle approach has to be considered even more environmentally friendly. (Glass for Europe, 2019)

In particular, some solutions have been taken into consideration according to some specific case studies of low energy buildings which present some interesting and appliable strategies for glass facades. One strategy is the high thermal performance of the aerogel material with a thermal conductivity of 0.014W/m²K. (Ribaproductselector.com, 2019). The aesthetical impression is opaque and light. One example is the Lago conference and events –commercial project in Rishon Lezion by Pitsou Kedem architects that can be seen in the ill. 103. (Griffiths, 2019)

Another example is the Torre de Cristal in Madrid (ill. 104). The glazed facade of the building is composed of selective solar-control glass used to reduce the cooling demand and ensure a good thermal performance with the maximum of the daylight. (Glass for Europe, 2019)

Finally a third strategy is explained in the example of the GlashusEtt in Hammarby Sjöstad Stockholm. The solution is a double-glazed facade of this building where extra clear glass can be used in order to minimize the need for artificial lighting. (Glass for Europe, 2019)

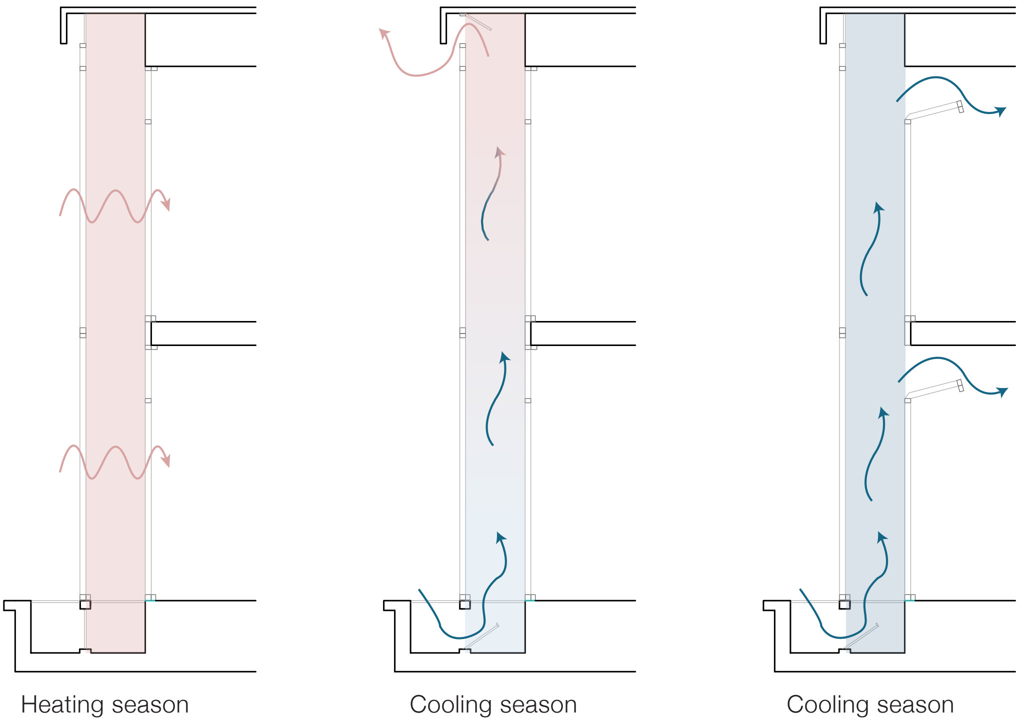
In particular, since the aim is to maintain as transparent as possible the facade, the third choice appears as the one that fits the most with our project. Moreover the double facade can be exploited for ventilating the interior space. In the ill. 100 a schematic diagram is explaining how this solution can increase the heat gain during the heating season, limit the overheating through enhancing the natural ventilation and through ventilating the air gap during the cooling season. A u-value has been calculated as well in the annexes, to import this solution in the energy simulation (Annex 11). For this project, the deci-

Ill. 100 - Lago events

Ill. 101 - The Crystal Palace

Ill. 102 - The GlashusEtt

Ill. 103 - Double-glazed facade solution



sion was to hide the openings as much as possible under the pavement and behind the ceiling covering.

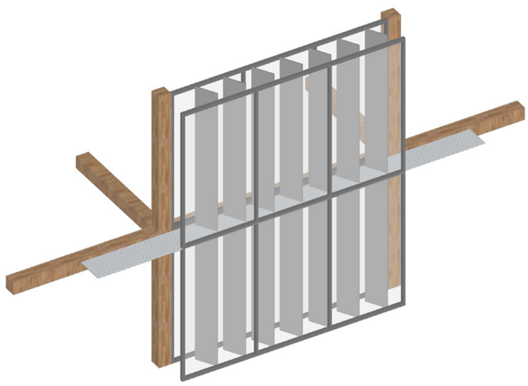
In conclusion, in order to accomplish the requirements of for the flooding risk the most suitable door and window frames are plastc/synthetic, aluminium or steel. (FEMA, 2008)

The final decision was to place aluminium frames because of the lightweight aspect, the strenght and the durability of the material. Morevover, its high recyclable character makes the choice good to grant the environmental sustaibility of the building. (Aluminum.org, 2019)

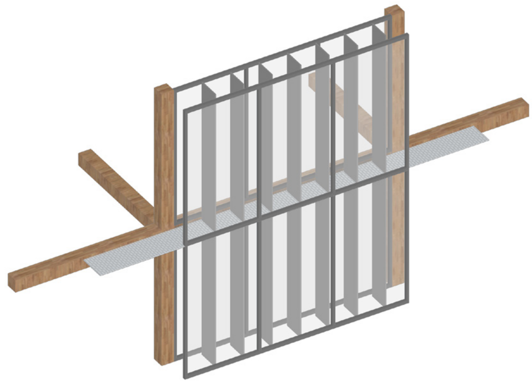
Shading system

Ill. 104 - Shading system

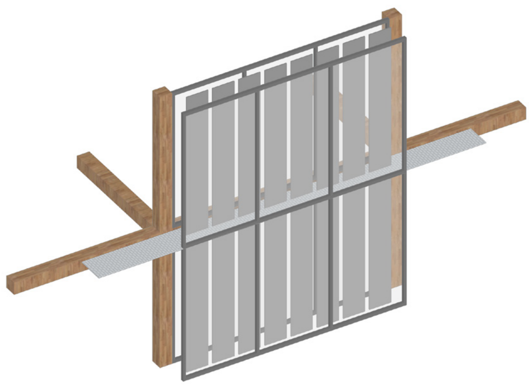
Summer morning



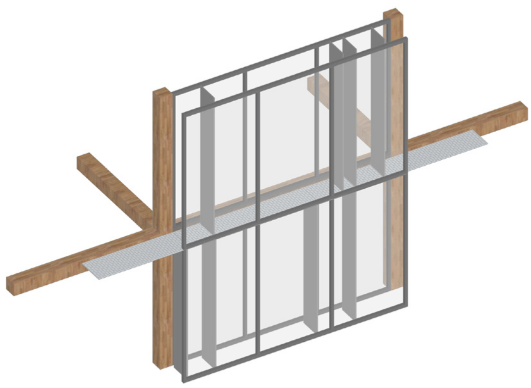
Summer midday



Summer afternoon



Winter season



After deciding the double-glazed facade solution, it is important to control the light and heat income to grant a high quality indoor environment. For this reason, in such a open facade it is necessary to think of a shading system that minimize the heat gain during the cooling season and the glare issues in the afternoon sun when the sun rays are lower.

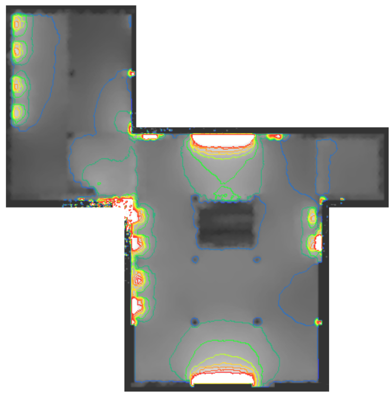
The shading solution is made of some light curtain units 900 mm x 4500 mm supported by a metal substructure in the two ends. The orientation is vertical since the double glazed facade is only the one facing the west side. It is placed in the gap of air in between the two glazings and at a distance of 1100 mm one from the other. They are supposed to be movable and not fixed and their orientation depends on the time of the day. To grant the efficiency, the system is not supposed to be controlled by the users, but only automatically or by the staff.

DAYLIGHT STUDIES

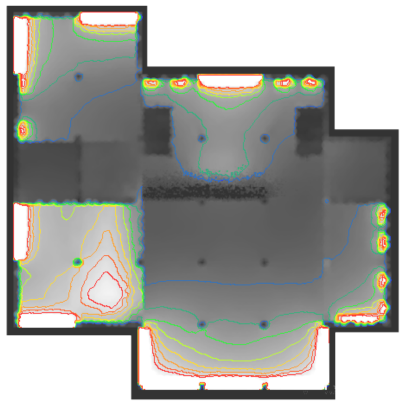
During the design process Velux was used as a tool to simulate the daylight factor of the food market. A good daylight is important in order to ensure a good indoor environment and, according to the regulations, an average daylight factor of at least 2% should be ensured in each room. (Bygningsreglementet.dk, § 377 - § 384 2019)

Different tries were made during the design process and in the illustrations 105, 106, 107 it is indicated one of the initial investigations for the windows. The windows shown are 15% of the total floor area ratio and as it is shown in the illustration the daylight factor is less than 1% in the majority of the rooms. Therefore, it was necessary to increase the windows area. The next step was to try with a window area of 20% of the total floor area ratio and the daylight was improved. By adding the big glazing facade in both common area and streetfood, the daylight was optimized but there was still a low a daylight factor, less than 2%, in the common area. For this reason two skylights were added in the roof of the common area.

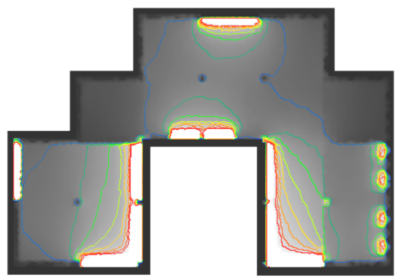
Ill. 105 - Velux study ground floor

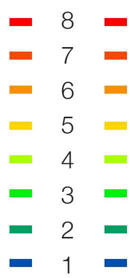


Ill. 106 - Velux study first floor



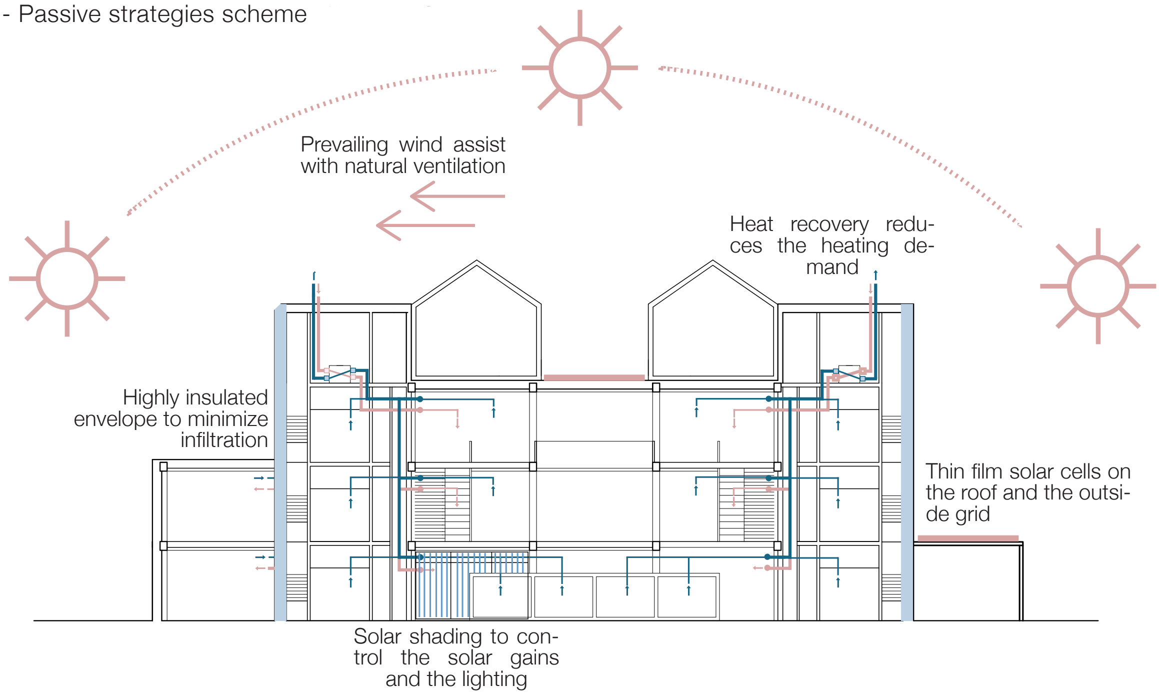
Ill. 107 - Velux study second floor





PASSIVE STRATEGIES

Ill. 108 - Passive strategies scheme



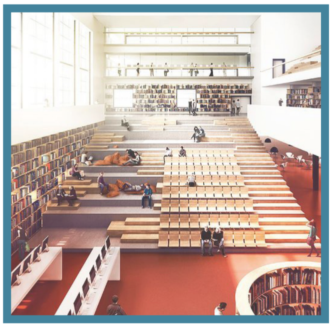
In order to reach the Zero energy goal that is set diverse passive initiatives were implemented, in order to reduce the energy demand of the building.
Firstly, the microclimate was taken into consideration. For instance in the placement and in the dimensioning of the windows both the orientation and the function have played a role in the designing phase and and example are the storage openings that are smaller and higher.
A highly insulated envelope was important in order to reduce the heat losses through infiltration and transmission losses. The considerations of the grid and the meeting of the wall and the columns were also important, in order to avoid the thermal bridges. Moreover, the use of the concrete in the ground floor can be exploited as a thermal mass to retain the heat and release it when the temperature of the building falls.
To obtain an adequate daylight, different window sizes were experimented and finally by implementing the large glazing area in the common area and the streetfood the daylight factor was optimized.
Moreover, in order to manage the overheating that is caused in the greenery market, solar shading is applied, to ensure a good indoor environment. For the control of the lighting, movable solar shading is also implemented in the big glazing facade. Also for aesthetic considerations the solar shading is movable and is controlled either from the staff or it is automatic according to the sun.
The double glazing facade, besides the aesthetic reasons and the light impression that gives to the building it also performs as an insulation for the food market.
Furthermore, in order to ensure a good atmospheric comfort and lower the energy use, natural ventilation is used during summer. Single sided ventilation was used when the room configuration required, while cross ventilation is used in almost every room. Due to the temperate climate of Denmark and the fact that the food is affected by humidity a hybrid ventilation system was required, and mechanical ventilation with heat recovery system is used in all of the rooms. The advantage of using heat recovery in the mechanical ventilation is that energy is saved, since the heat recovery uses the waste heat to pre-heat the air that comes into the room.

ATMOSPHERE REFERENCES

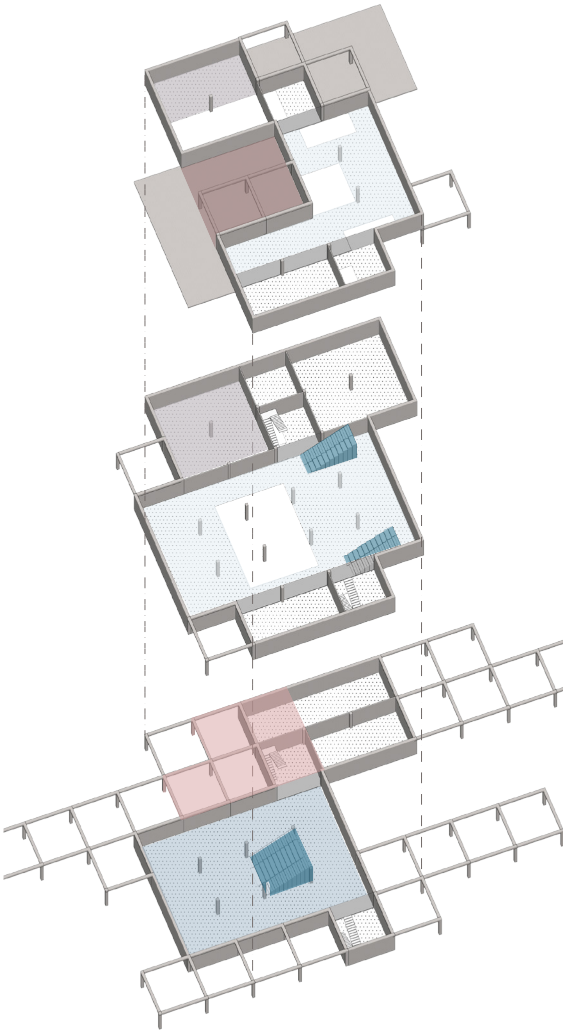
Ill. 109 (a-f) - Atmosphere references

a. Outdoor playground

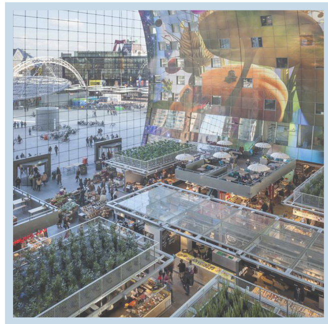
b. Central stairs



c. Common area



d. Streetfood market



e. Theatre

f. Greenery market

A lot of attention should be given also to the interior spaces. In particular in this illustration is explained the overall atmospheres wanted for the different areas.

In the first one it is possible to see how an external playground and how outdoor furnitures can be implemented into the grid. The second one is showing the architectural feature of the staircase which works as a connection and as a place for gathering. In the third picture, it is shown the importance of the visual connection between the different levels. In the fourth one, the possible characteristic of the stalls that could have green and walkable roofs. Picture 5 is showing some flexible and partially movable seating places that could be implemented in the theatre terrace. Finally, the last picture shows the greenery market atmosphere, where the products are not just sold, but people have also the possibility to learn about the process to produce the goods through some interactive screens placed on the top of each counter.

INTERIOR MATERIALS

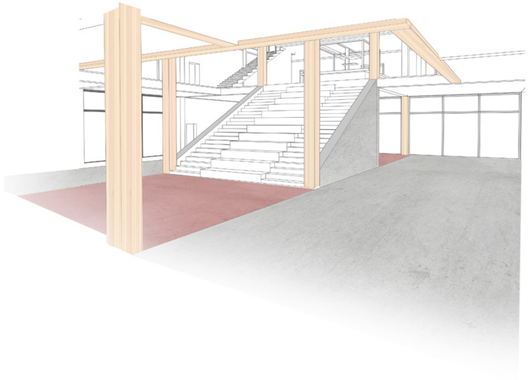
As long as the interior spaces are concerned, some initial views have been sketched to understand how the spaces are going to be developed inside the building.

The first view is about the streetfood atmosphere. It is placed in the ground floor and the aim is to maintain the industrial character of the surrounding buildings. Moreover, the groundfloor is considered to be the space more exposed to a risk of flooding in the future. For this reason, the materials are going to be more rough. The floor is going to be polished concrete that is going to be finished with a red colour along the principle pathways. While along all the perimenter there is the double glazed facade. In the streetfood and in general in the common areas the wooden grid structure is going to be partially visible. A suspended ceiling will grant the space for the electrical lines. The mechanical ventilation pipes are instead going to be visible to grant the desired industrial look.

The second view describes the inner atmosphere of the common areas that is cozier thanks to the wooden floor. The walls are instead of white polished plaster on the inner sides and the aluminium windows are also bordered by a european beech wooden frame of a slightly darker tone than the outside planks. The furniture is also going to be mostly wooden.

The third view shows the workshop laboratory with the cooking places. The atmosphere and the materials are similar to the ones of the common areas. However, the idea is to have the suspended ceiling at a lower height since the rooms are smaller. In the suspended ceiling also all the electrical and ventilation lines will be hosted. In the same way, also the staff and storage area are going to be designed.

Ill. 110 - Streetfood atmosphere

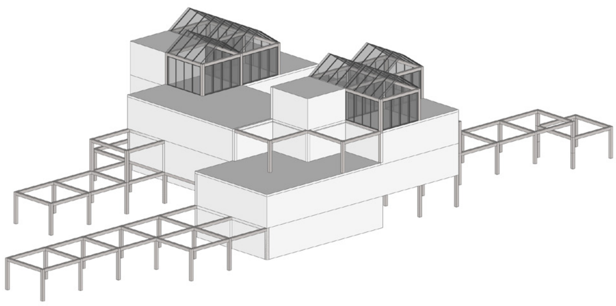


Ill. 111 - Common area atmosphere

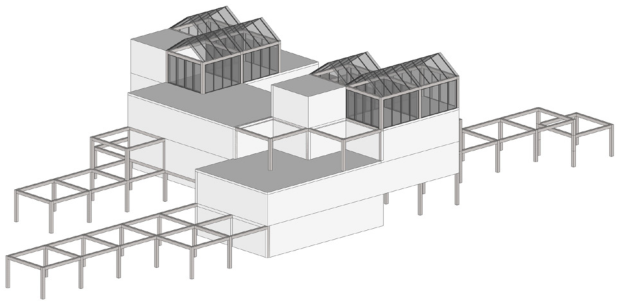
Ill. 112 - Workshop atmosphere

GREENHOUSES

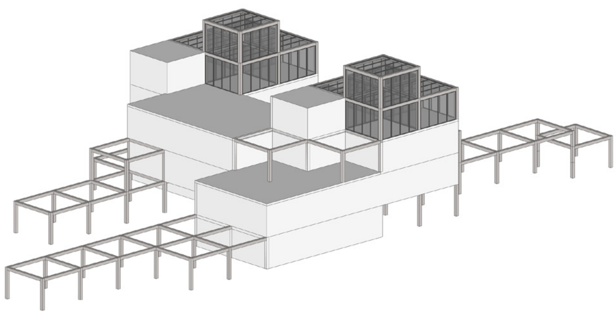
Ill. 113 - Greenhouses, option 1



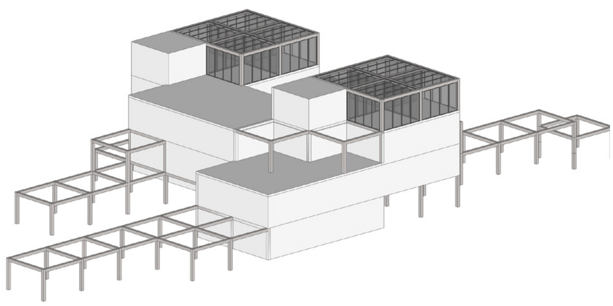
Ill. 114 - Greenhouses, option 2



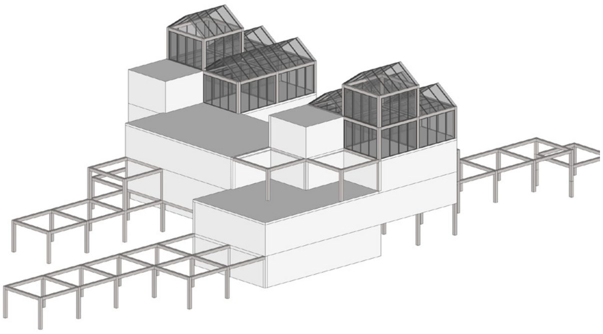
Ill. 115 - Greenhouses, option 3



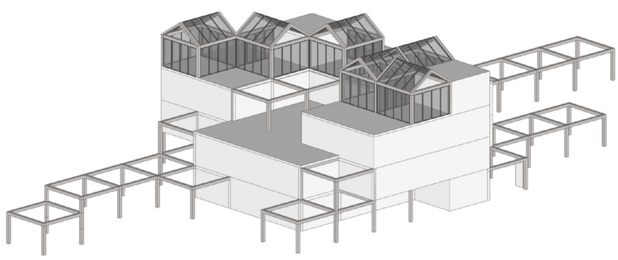
Ill. 116 - Greenhouses, option 4



Ill. 117 - Greenhouses, option 5



Ill. 118 - Greenhouses, option 6



In order to make also the roof a walkable space the service staircases on the two sides of the structure have been extended of an additional floor.

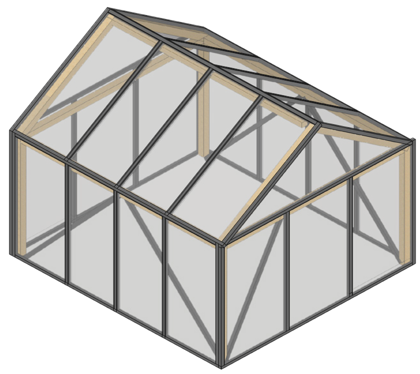
In particular, six different options have been taken into consideration. The high position of the greenhouses depends on the necessity to place the greenhouses close to the workshop area to which they are related. The greenhouses aim to host in fact also some spaces for practical classes for the university of Copenhagen and for the public in general. Some more greenhouses are supposed to be added on the ground floor as well for the residents of the area. Therefore, the idea is also to give the space for some communal gardens for the future people that will live in the area according to the local plan predictions. However, an easy accessibility to these places is necessary and as a consequence the greenhouses have been splitted in two different positions.

Since some of these units have been placed on the roof of the building, it is important to realise the potential of this position. In fact, the city centre of Copenhagen is placed on the opposite bank of the canal and therefore, the elevated building is going to be widely visible. The top floor will be particularly exposed and for this reason it is important to define the character that the building will obtain.

The main decision was to choose if the greenhouses were ending in a flat or in a pitched roof. Moreover, a possibility was also to develop them in one or in a double storey. In the end the final decision was the option 6 that was giving the desired dynamism to the structure and making it more appealing both from a human perspective on the site, as well as from a further perspective from distance.

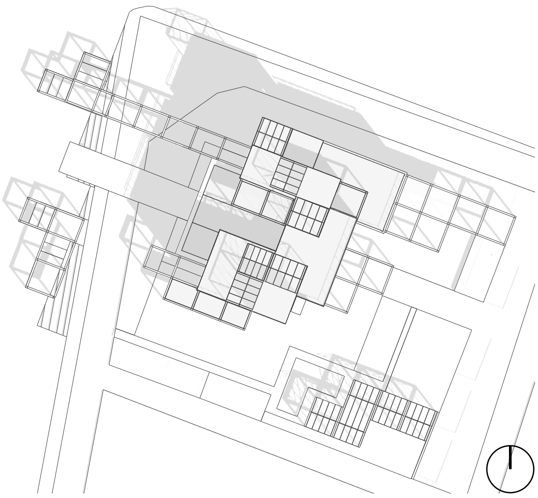
However, the high position is not only visually exposed, but also physically unprotected from the wind. For this reason the pitched roof has also been prefered due to its higher aerodynamism as well as for the drainage of the rain water and the ability to carry heavier weight levels. To streghten the structure some diagonal steel bracing frame have been implemented to the basic wooden frame. (Ill. 119)

Ill. 119 - Greenhouse detail

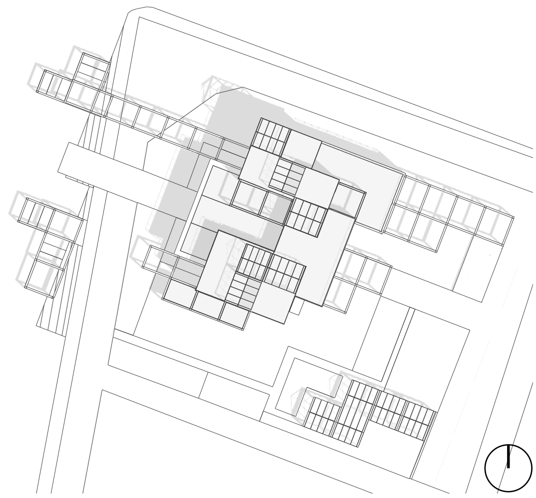


SHADOWS ANALYSIS

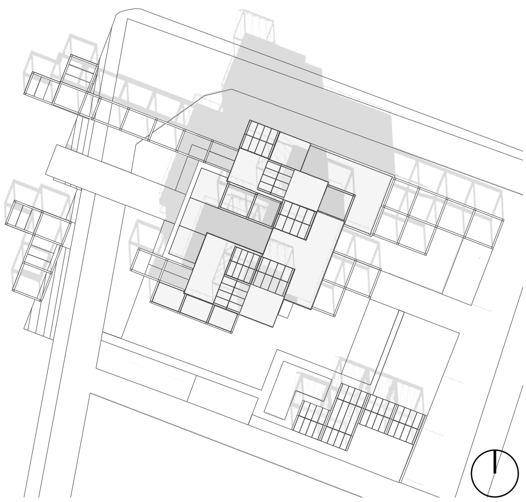
Ill. 120 - 21 March _ 10.00 am



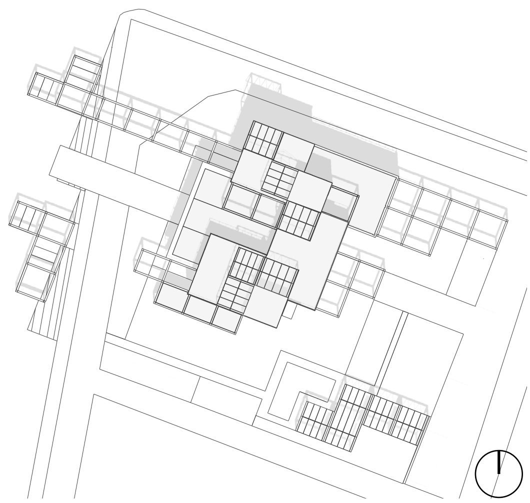
Ill. 121 - 21 June _ 10.00 am



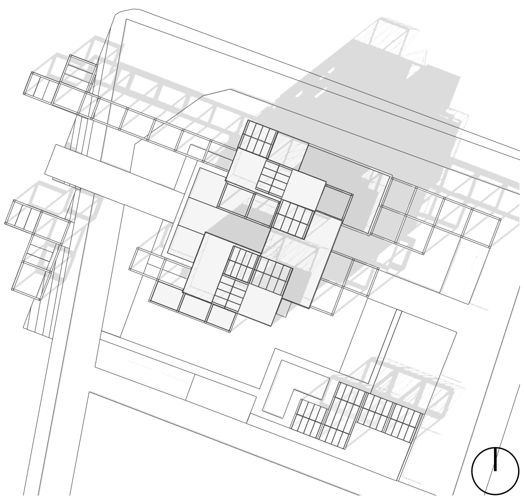
Ill. 122 - 21 March _ 12.00 am



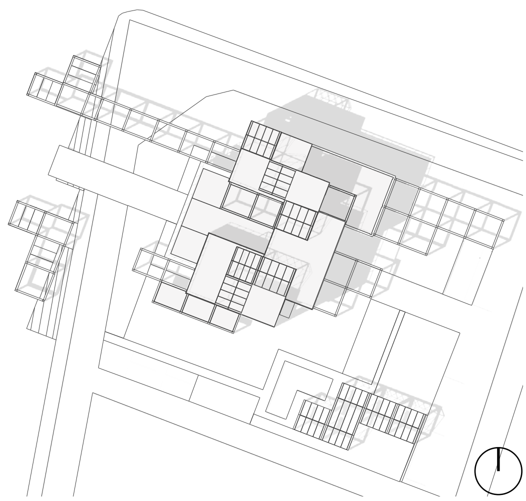
Ill. 123 - 21 June _ 12.00 am



Ill. 124 - 23 September _ 3.00 pm



Ill. 125 - 21 June _ 3.00 pm



After having finalized the building shape and volumes a shadows study is necessary. In particular, during the design of the outdoor spaces it is not only important to define how much the shadows of the surrounding buildings and vegetation are affecting the site, but also to see how the project construction is altering the site in which it is positioned.

Furthermore, since the building is high and is developed on 4 levels, it has been positioned in order to exploit as much as possible the site area that is not largely affected by the neighboring constructions.

Another factor that has to be considered is the analysis of when and how the exterior spaces are going to be used by the people. Following this idea the useful time of the day have been selected to be analysed. In general, people are supposed to use the building and therefore, the outdoor spaces are going to be occupied mostly during the lunch and dinner time when the streetfood market, that is going to be the main attraction, is working the most. Therefore, the times of the day that have been considered are 10.00, 12,00 and 15,00 am. As can be seen, the building is mostly shadowing the northern area of the site, letting the greatest part of the site to be used. Moreover, as long as the outdoor terraces are concerned, in the afternoon the outdoor space that is facing Copenhagen city centre is completely shadowed after 3 pm. However, it is the only critical space and even though it is shadowed in these hours it is an area that is still protected by the wind and with a panoramic view towards the sea, and therefore still usable and enjoyable.

The greenhouses on the ground have also been placed in order to get the maximum of possible daylight and as can be seen their light and low structures are not influencing the outdoor spaces.

Finally, this study has been useful for the placement of the solar panels. In particular, the time of the day that have been mostly considered are also the selected hours 10,00 am, 12,00 am and 3,00 pm in the winter time when the sun rays are lower (Annex 14).

BE18 AND ENERGY PERFORMANCE

The Be18 simulation program was used during the design phase in order to calculate the energy consumption of the building. Since the building is set as not residential, according to the regulations for the class 2020 a maximun energy consumption of 25kWh/m^2 is required. (Bygningsreglementet.dk, 2019)

According to the experiment that is conducted during the analysis phase, different temperatures were set for the distinct rooms of the food market, based on the level of comfort and satisfaction of the users and also since the building is related to food, some temperatures should be kept for the preservation of the goods. As reported into the room program, the temperatures for the streetfood market in the ground floor are set to $21,5^0$-$25,5^0$ during summer and 14^0-18^0 during winter. Moreover, the temperatures for the common area, the staff and the workshop area are set to 23^0-28^0 during summer and $17,5^0$-$22,5^0$ during winter. Finally the temperatures for the greenery market, the storage rooms and the service rooms are set to 17^0-20^0 during summer and 8^0-12^0 during winter. By lowering down the temperatures in rooms that don't require to follow the regulations according to the experiment, energy will be saved during winter, when the heating period is running.

Consequently, after setting the different temperatures in the rooms, the whole building has been divided into three distinct zones, whose rooms had similar required conditions. These zones are the first zone, the streetfood market, which is situated in the ground floor, the second zone which comprehends the common area, the staff and workshop area in the first and second floor and the third zone, which consists of the greenery market, the service rooms and the storages, which are placed in the ground floor, first and second floor. Particularly, the third zone that is set with the lower temperatures is thermally separated from the others. Service rooms are separated with 100mm of insulation from the other zones and the greenery market is divided from the other rooms with polycarbonate in order also to keep the visual possibility in a certain degree.

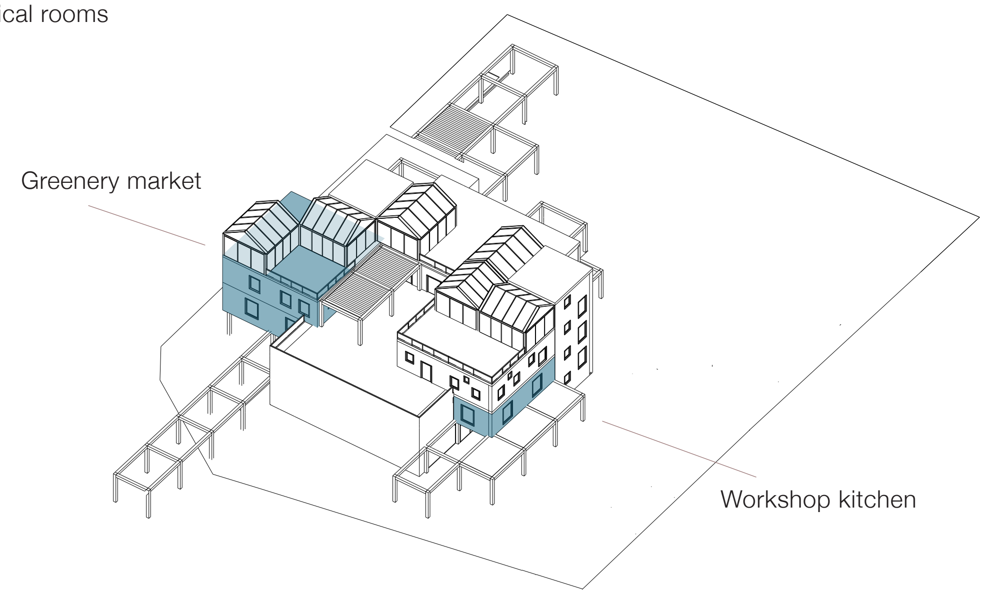
In this way three different Be18 simulations were prepared for each of the three zones. In each zone temperature is regulated in Be18 as the average temperature between summer and winter. As a result , the temperature for the first zone is set in $19,5^0$, in the second zone is left as default in 20^0 and in the third zone is set to 14^0.

During the design process, Be18 was used in the different design phases. For instance, when changing the different windows Be18 was utilized as a process tool, in order to examine the different energy demands of the zones. In the Annex 12, the results of the first zone are indicated (streetfood market), with a 15% and 20% windows of floor area ratio. In the final solution, the area with 20% windows of floor area ratio is kept, but the glazing facade in the streetfood is added in order to give a lighter impression of the building. Some other adjustments that were made in order to optimize the energy consumption were also changing the sun thermal transmission and the solar shading of the big glazing facade in the common area (second zone) and in the streetfood (first zone).

The Be18 program gives only the possibility to assess the overheating on a general level, and considers the building as a whole, so further investigations about the influence of the windows are better explained in the Bsim simulations.

INDOOR CLIMATE SIMULATIONS

Ill. 126 - Critical rooms



The tool that has been used to evaluate the quality of the indoor spaces is the Bsim software. The process requires to choose the critical rooms that could present issues for example regarding the overheating in the cooling season and the concentration of CO_2 during the whole year and specifically in the hours in which the rooms are supposed to be used. The rooms that have been taken into consideration in the investigation because of their critical conditions are the kitchen workshop area of the first floor and the greenery market.

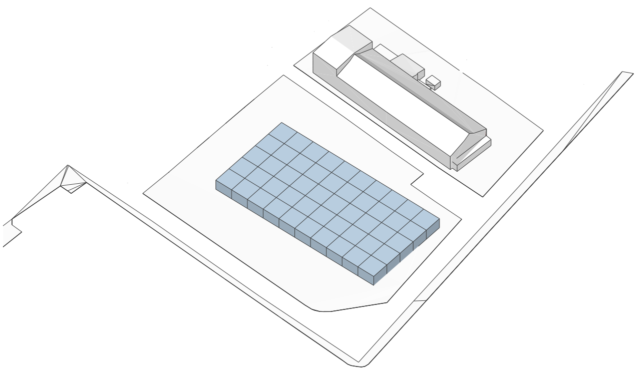
The reasons for choosing the kitchen laboratory of the workshop area is mostly, because the space is smaller and is exposed to both the midday and afternoon direct sunlight. Moreover, the openings in the walls are wide in order to grant a higher connection to the outside and in order to provide a more comfortable environment for the people taking classes inside. In the total load calculation also the people load and the equipement load affect the environment and it is necessary to consider all the implications of when and how the room is utilized. The strategies applied in order to limit the indoor climate possible issues are the implementation of some exterior curtains, whose outdoor position can even more minimize the heat from entering the room.

The second zone that was chosen to be tested is the greenery market. In fact, this is one of the building's most sensible areas, due to the strict requirements that it demands in terms of temperature and humidity. Regarding the temperatures control, the strategies that have been utilised are the decrease of the original big openings and the implementation of the same shading system of the workshop area. At the same time ,two moduls of pergolas have been added in the wall facing south. In fact, the direct light should not touch the products in sell in order not to affect their quality. Moreover, it is required to focus not only on the temperature control, but also on the dehumidification of the spaces. For markets, a good humidity level reduces energy usage and maintains product appearance and quality, furthermore, it keeps the glass surfaces of the case clear for displaying better the goods. For this reason a good ventilation system is necessary and has to be well distributed. (Apogee Interactive. Inc., 2019) To comply these demands, the more steady mechanical ventilation has been set during the all year for the greenery market, in order to monitor better its specific requirements.

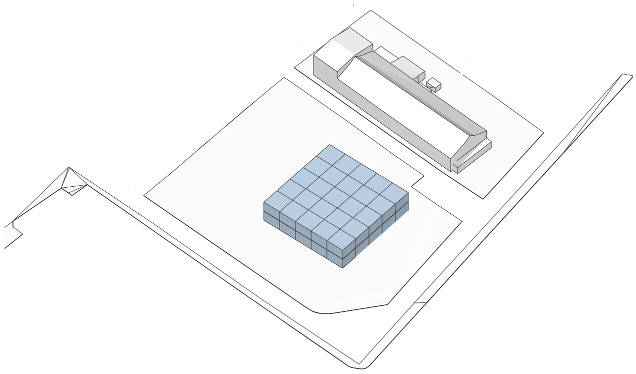
SOLAR PANELS

Ill. 127 - Solar panels investigation

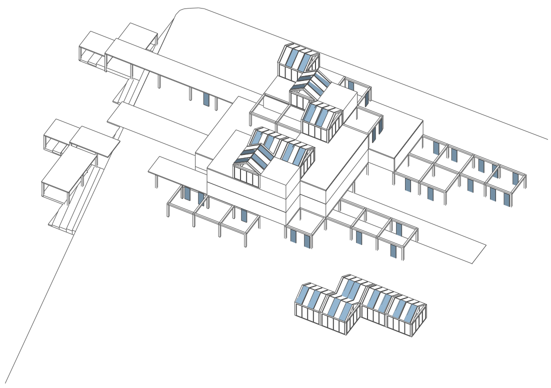
Polycrystalline on the greenhouses roofs



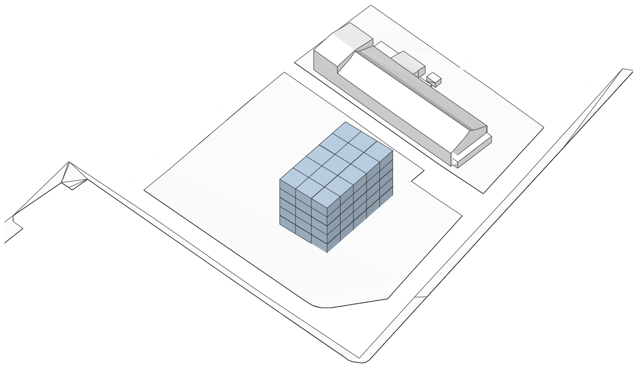
Thinn film PVs on the landscape wind breakers



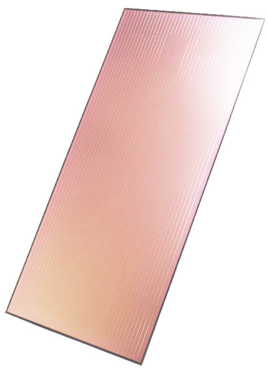
Combination of polycrystalline on the greenhouses roofs and thinn film PVs on the landscape wind breakers



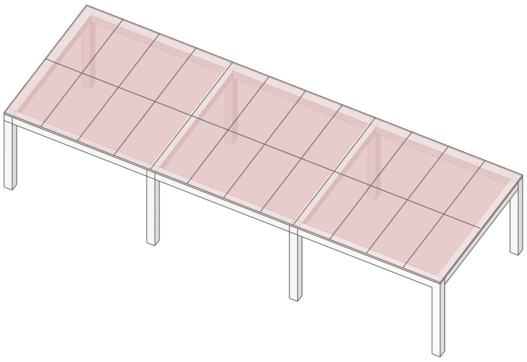
Thinn film PVs on the building flat roof and pergolas



Ill. 128 - Red coloured transparent thin film panel



Ill. 129 - Application of the thin film solar panels



After having implemented the passive strategies in order to minimize the energy demand of the building, some active strategies are applied in order to achieve a sustinable integrated solution. After having decided that the solar panels will comply to provide the energy necessary for the use of the building, different solutions have been considered.

Both the possibility of polycrystalline solar panels and of thin film amorphous solar panels have been discussed. Initially the calculation to evaluate the square metres of solar panels needed has been carried out taking with the value obtained by the Be18 simulation (Annex 15). Since the first idea was to integrate the solar panels on the roof of the greenhouses the first hand calculation has been carried out considering an angle of 30° with the efficiency of 20% and the total amount of PVS was around 240 m^2. In the following steps also other solutions have been considered, where instead of the polycristalline panels, thin film amorphous panels were used. In particular, they have been integrated as wind breakers in the landscape design. A solution was also combining the two previous solutions in order to avoid the implementation of the additional units in the sea. However, in the end it was decided to implement a fourth solution where only the thin film panels are used. The choice was taken because it appeared to be the most integrated solution that could have also some architectural and aesthetical outcomes thanks to the variety of the thin film panels solution. In fact, this typology of photovoltaic panels allows more possibilities and flexibility in the placement. To leave the units of the greenhouses untouched and unaffected the thin film panels have been integrated in the roof of the building and on some pergolas that according to the shadows study are in an effective position in terms of solar gain. Moreover, even though these panels can not provide the same efficiency of the polycrystalline ones, they can still grant a lower cost. Furthermore, differently from the crystalline option, they are effective also when they are partially shadowed and they are efficient also at lower angles, that is the case of our project where the solar panels are placed on a flat roof at 0° of slope. Finally, since the project wants to keep a future oriented character, the thin film option is a technology that is emerging. Therefore, it is a solution still in experimentation phase and that in the next years will be developed and improved. In fact, the future expectations compared to the sylicon solutions are much more promising. (Richardson, 2019)

Moreover, thin film panels can grant more flexibility not only on the placement and on the orientation, but also on the aesthetical aspect. To make them more integrated it is possible to used the panels not only as a technical device to produce energy, but also as an architectural element with its own aesthetical qualities. In particular, for this project the it was chosen to implement red coloured transparent thin film panels.

In conclusion, in the annexes has been calculated how many square metres of photovoltaic panels are necessary to comply our energy demand through lowering the efficiency to 12% and considering 0° for the angle of the pvs in order to obtain the same results. The total square metres necessary are 115 more than the crystalline solution. Therefore, the necessary amount is going to be 350 m^2. (Annex 16)

PRESENTATION

This chapter introduces the final design through the use of diagrams, plans, elevations, sections, construction details and renders. In the chapter are also presented and discussed the results of the technical calculations about indoor climate and energy consumption.

EXTERIOR VIEW FROM THE SEA

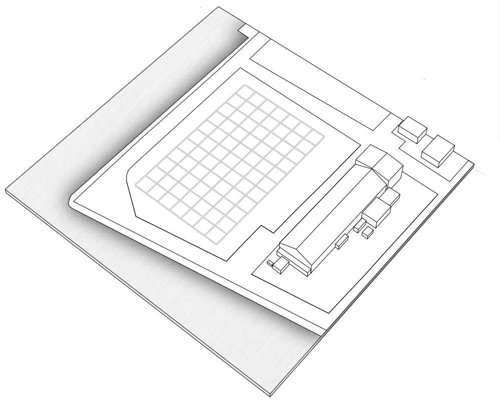
Ill. 130 - Render, exterior view from the sea

The sustainable food hub is visible from the city center of Copenhagen, with the glassed greenhouses standing out on the top of the building. The wood cladding material, the wooden grid construction and the greenery in the greenhouses enhance the sustainable character of the building. The big glazing facade gives a light expression to the design, while the continuation of the grid to the outdoors connect the food market to the water.

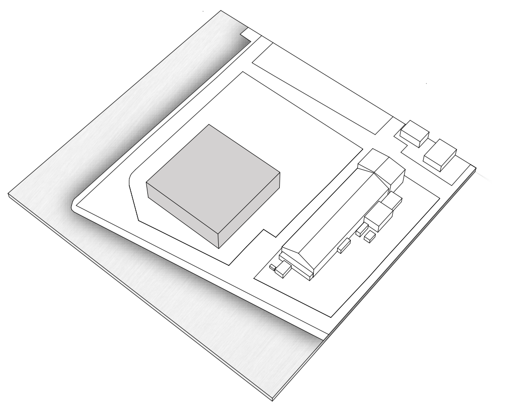
CONCEPT DIAGRAM

Ill. 131 - Concept diagram

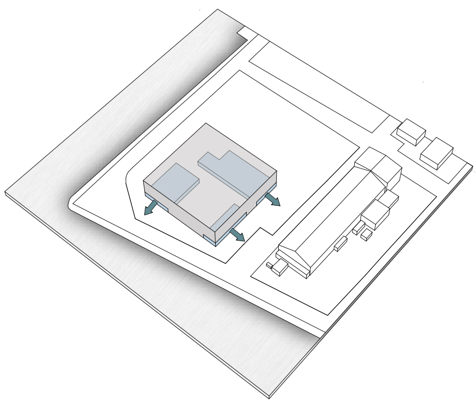
1. Base grid



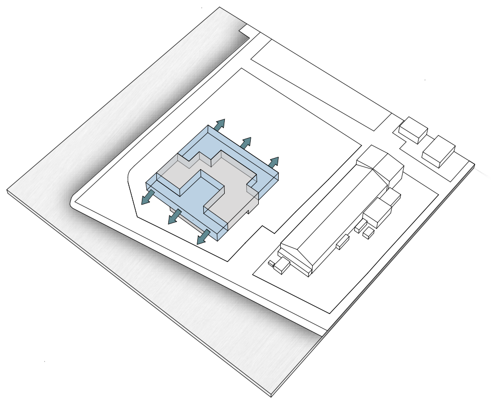
2. Initial cubic volume extruded from the grid



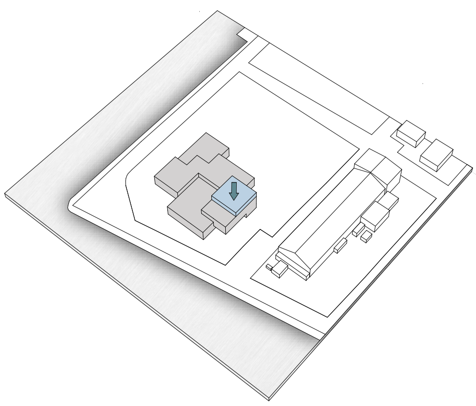
3. Volumes removed from the ground floor



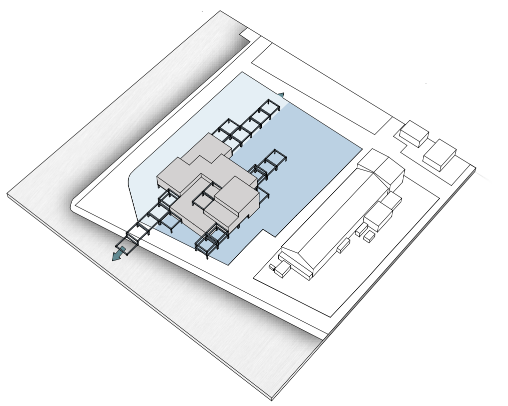
4. Volumes remuved from the upper floor



5. Green houses addition



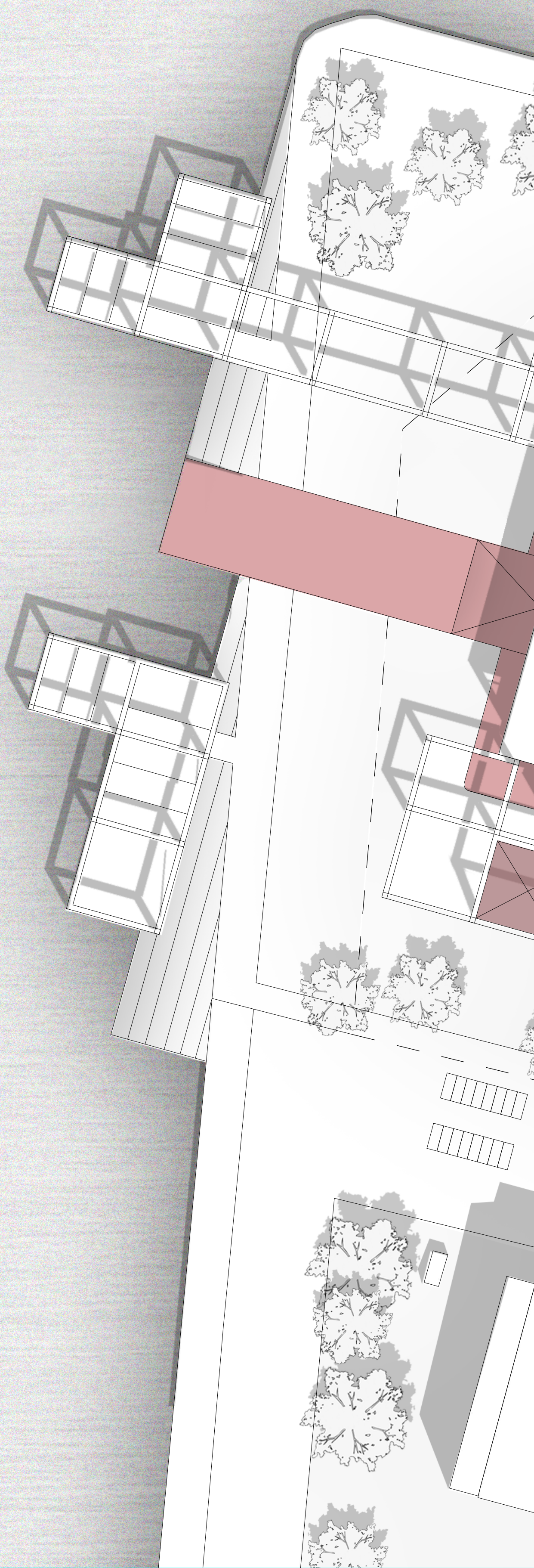
6. Outdoors area definitions



The design concept is based on a 7 x 7 metres grid. The building was designed starting from a cube from which volumes were later removed, according to functional and technical needs.
The surface on the ground floor has been considerably reduced in response to the problem of flooding. On the upper floors, volumes have been removed to create open terraces. The operation was carried out taking into account the sunpath, the direction of the wind and also the visual connection with the fjord.
Extending the grid outside, a public area facing south and a semi-private one facing north, intended for staff and loading/unloading operations were defined. The external continuation of the grid also takes into account the relation to the internal functions. Indeed, in the future, in case of rising waters, this could be used as raised walkways in order to access the building.

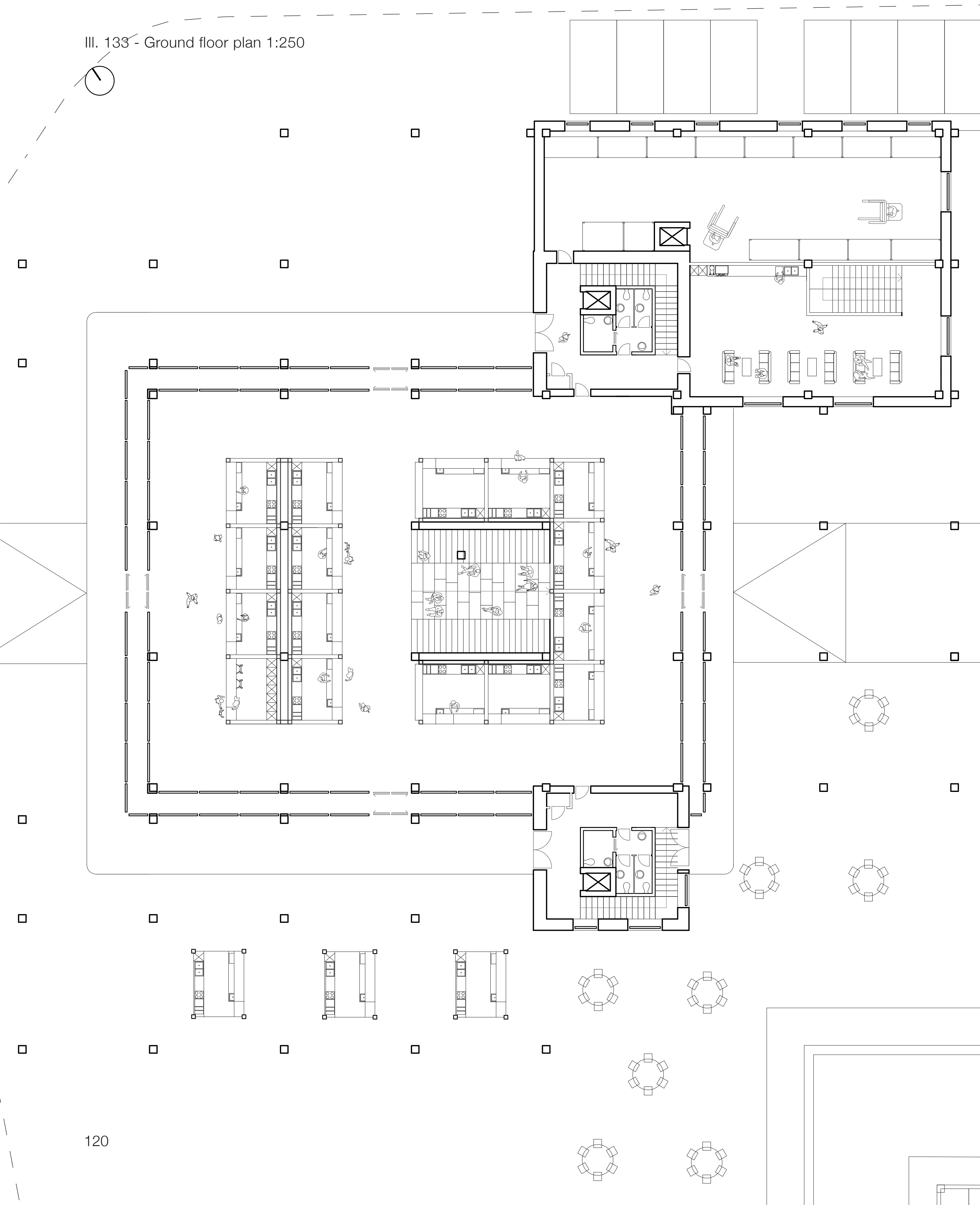
MASTER PLAN

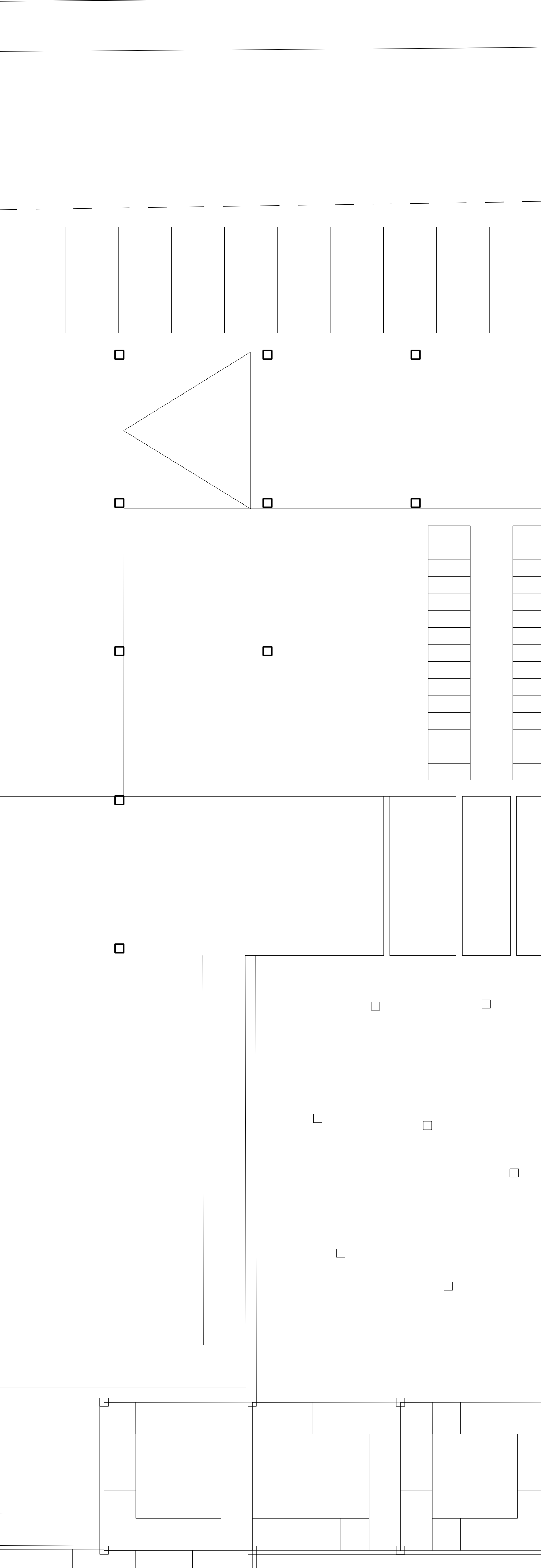
Ill. 132 - Masterplan 1:500

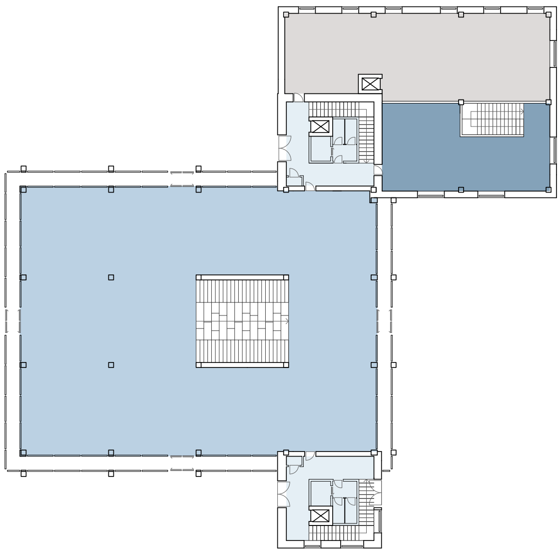


The Master Plan shows the building in relation to its surroundings. The access to the site is open both from south and south-east by land and from north-west by sea. The site's accessibility is reflected in the layout of the building itself, which has been designed with four entrances related to the four cardinal points, thus avoiding having a front and a back, and therefore, being flexible for users and well related to the context.
The grid that continues from the building outwards is used to divide the area into two areas: a semi-private one, to the north, for staff and loading and unloading operations and a public one to the south. In line not only with the main topic of the project, i.e. food, but also with what is foreseen in the local plan regarding the increase of urban gardens in Refshaløen, in the south side area green houses for public use have been planned in addition to those for educational purposes located on the roof.
The streetfood on the ground floor continues externally with some stalls located under the grid to the south, in which red thin films pvs have been implemented, thus creating, with their light, a special atmosphere in the space below and also providing protection in the case of rainfall.
The Platforms that have been implemented along the fjord, not only allow to enjoy the beautiful view of Copenhagen city center, but also function as a tool for measuring the uprising water, since the steps incorporated in them help to easily perceive the level of water rise.
The red strip of concrete that runs from south east to north west, connects the site with the water, (or vice versa, depending on where people enter) establishing a main path within the area and highlighting at the same time the close relationship between the water, the building and the urban context.

GROUND FLOOR PLAN


Ill. 133 - Ground floor plan 1:250

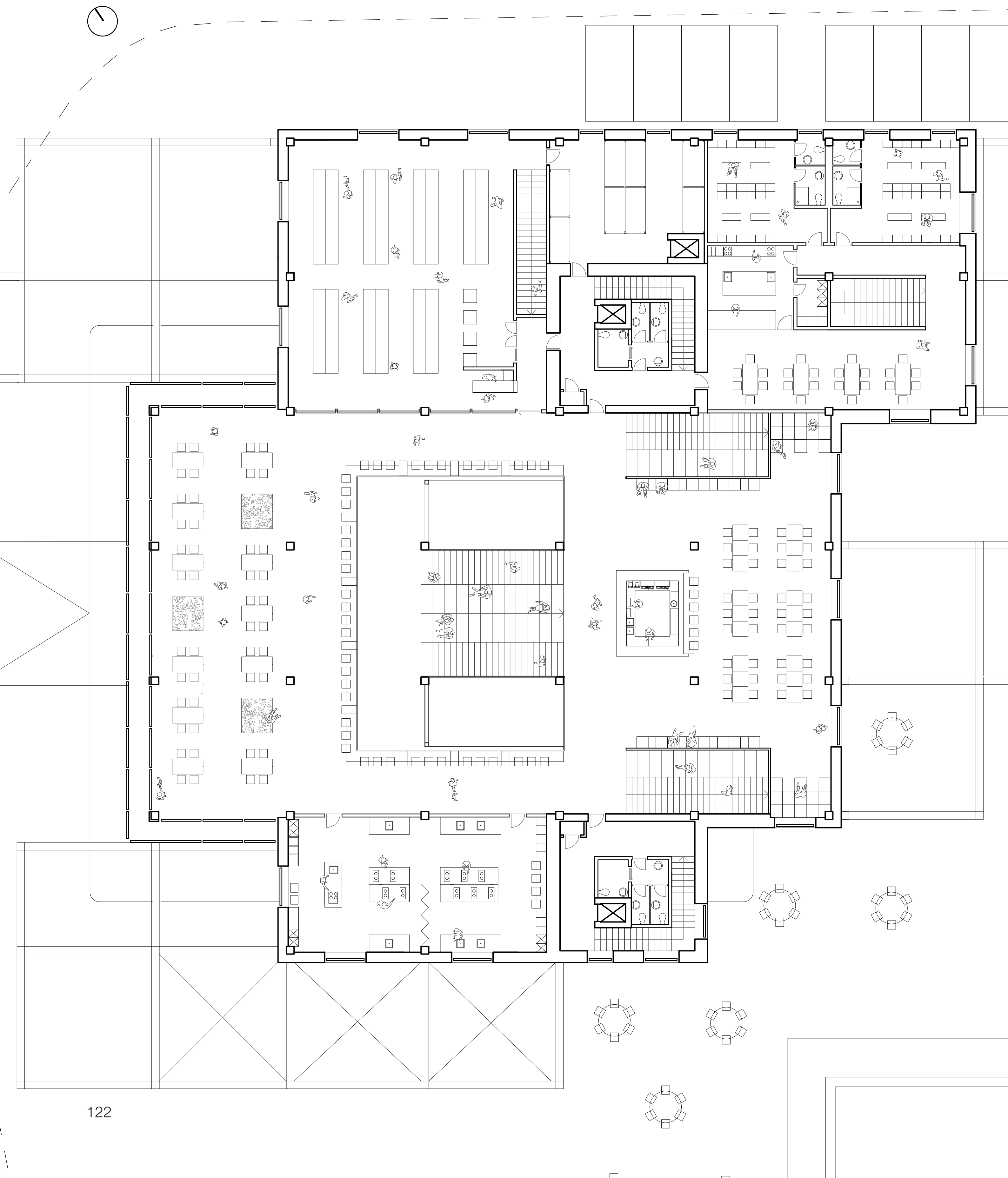




Service towers
Streetfood market
Staff area
Storage

FIRST FLOOR PLAN

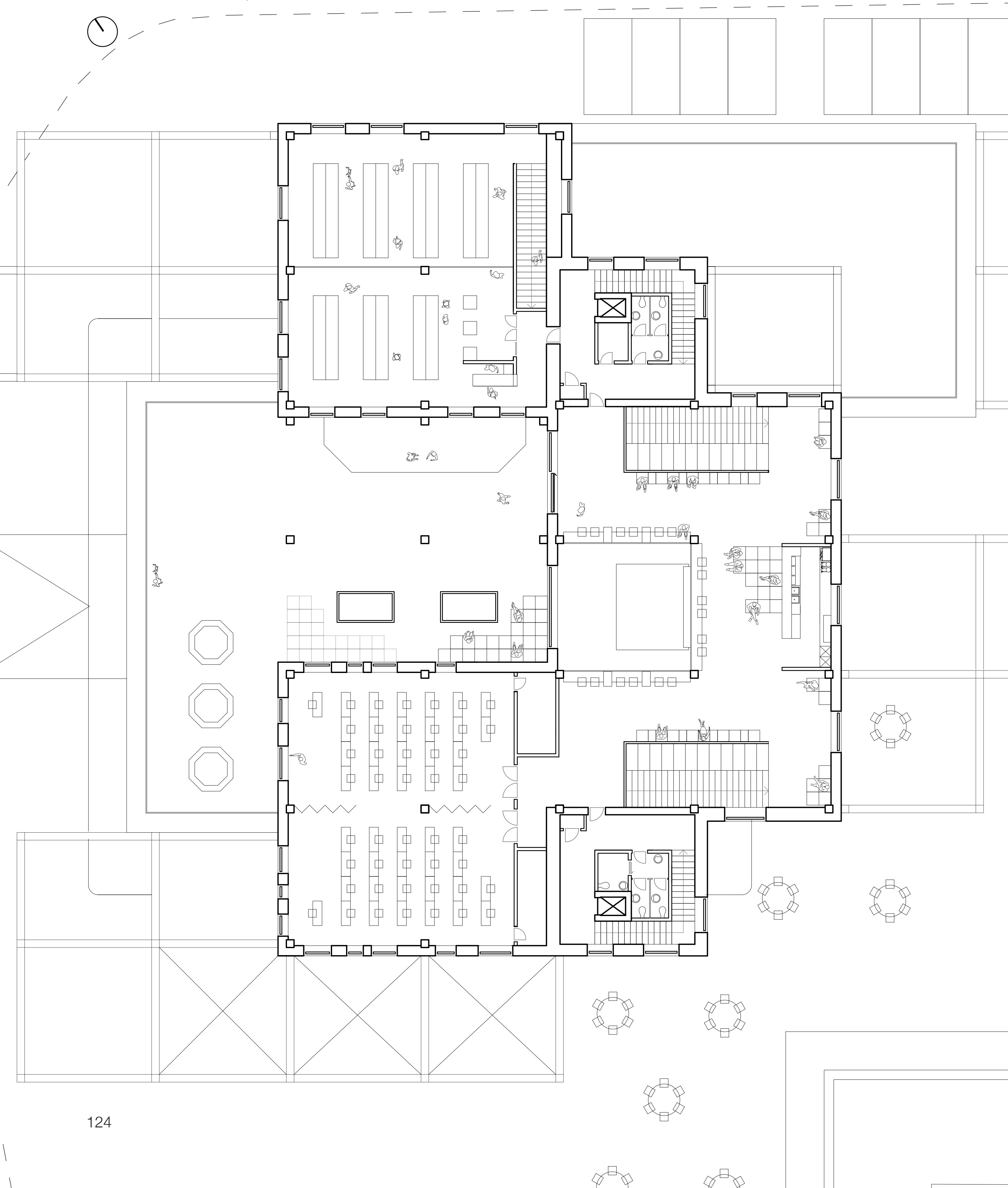
Ill. 134 - First floor plan 1:250



Service towers
Common area
Staff area
Workshop area
Storage
Greenery market

SECOND FLOOR PLAN

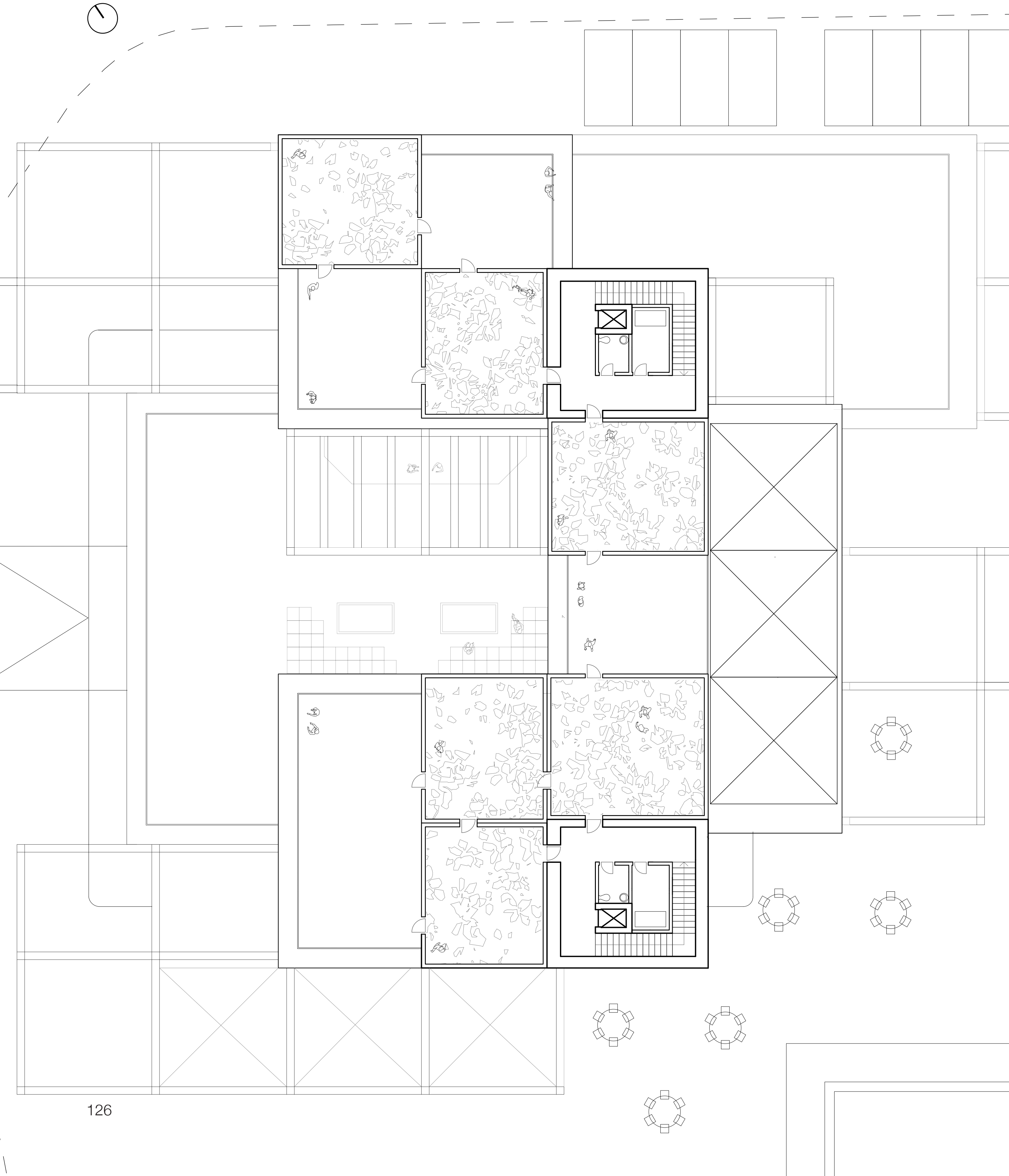
Ill. 135 - Second floor plan 1:250

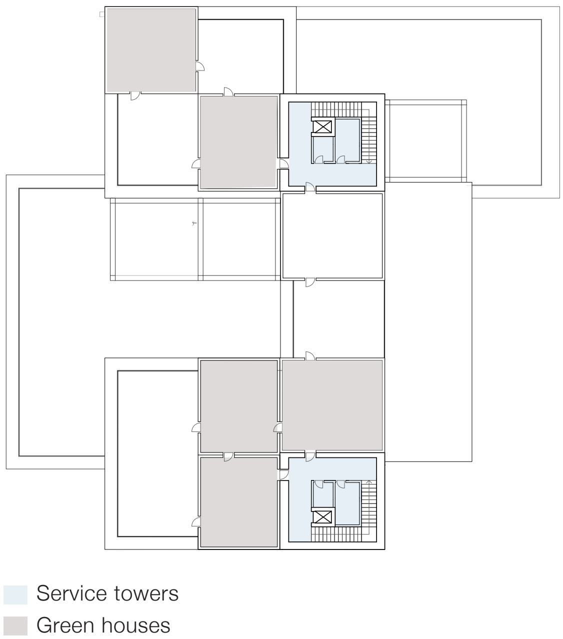


Service towers
Common area
Staff area
Workshop area
Greenery market

THIRD FLOOR PLAN

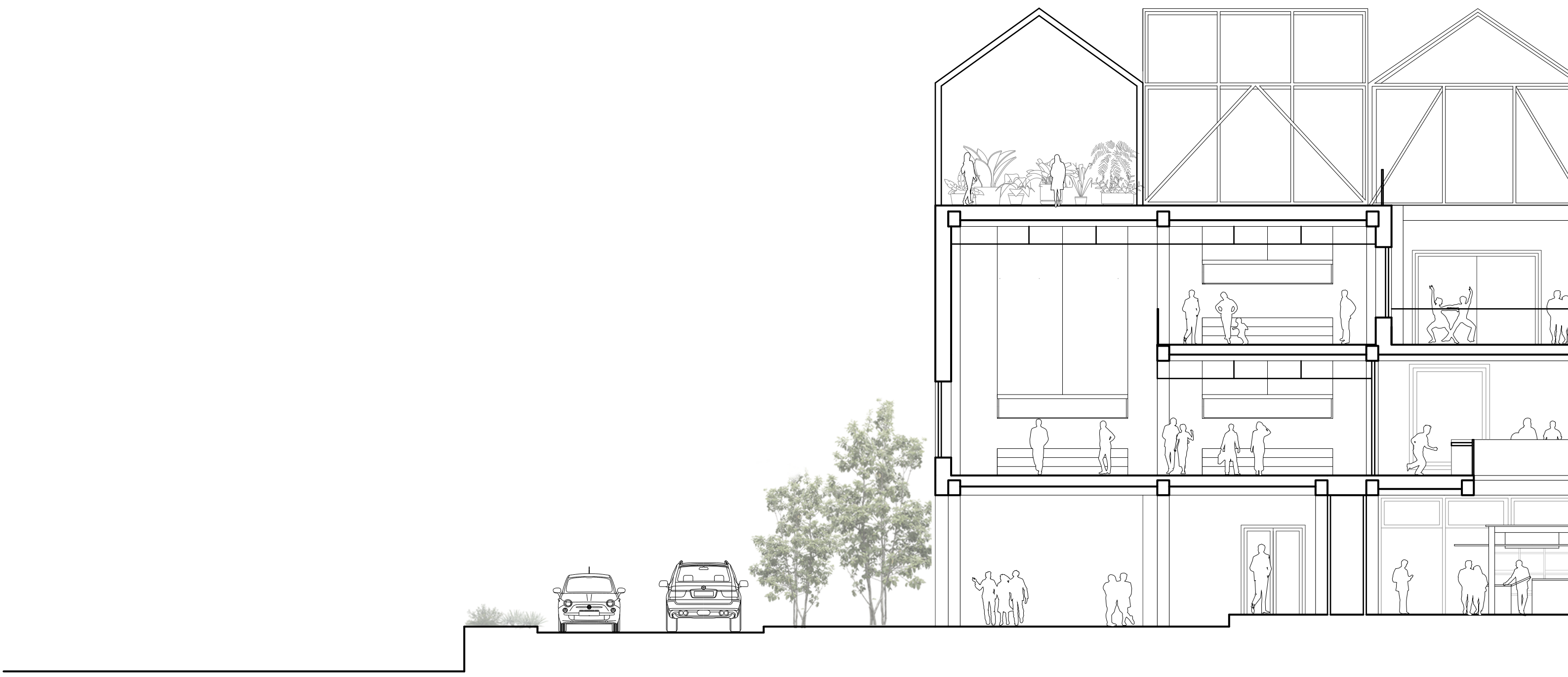
Ill. 136 - Third floor plan 1:250

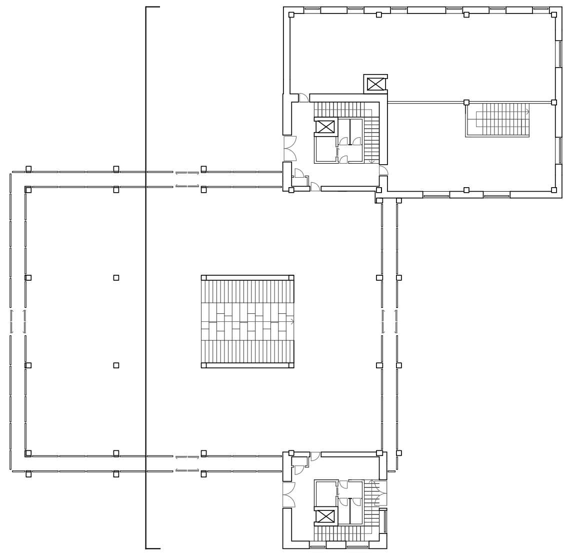



Service towers
Green houses

SECTION A-A

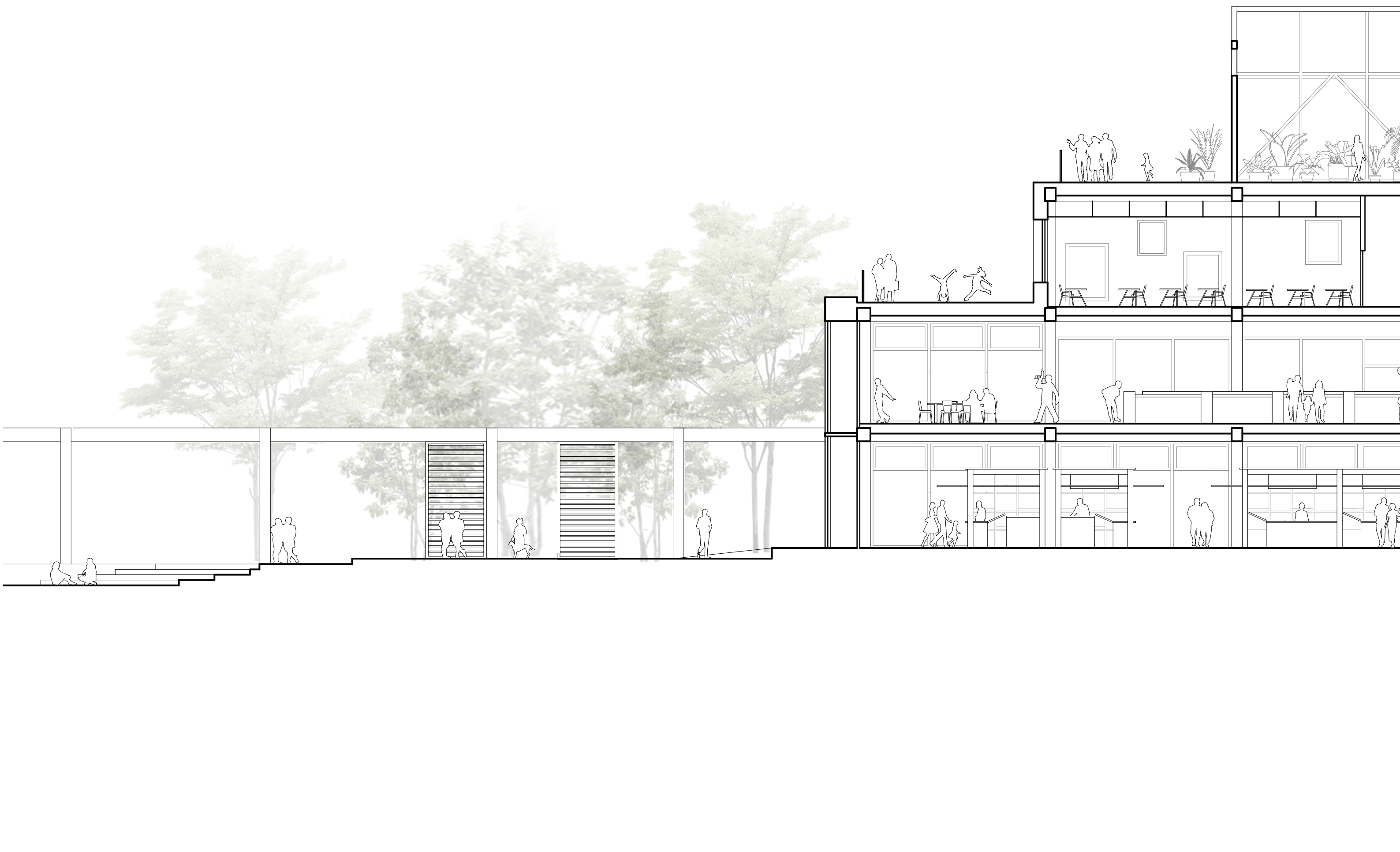
Ill. 137 - Third floor plan 1:250

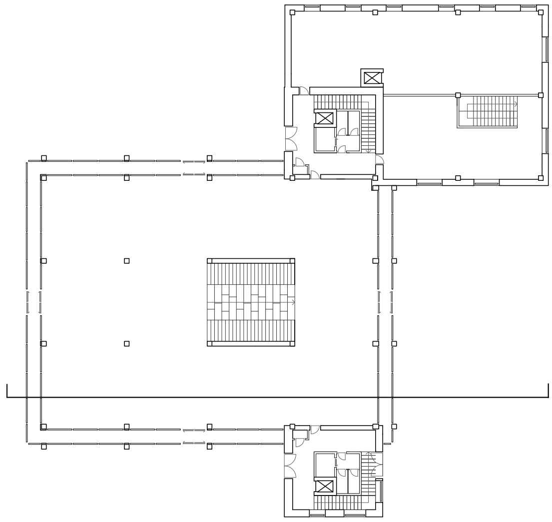


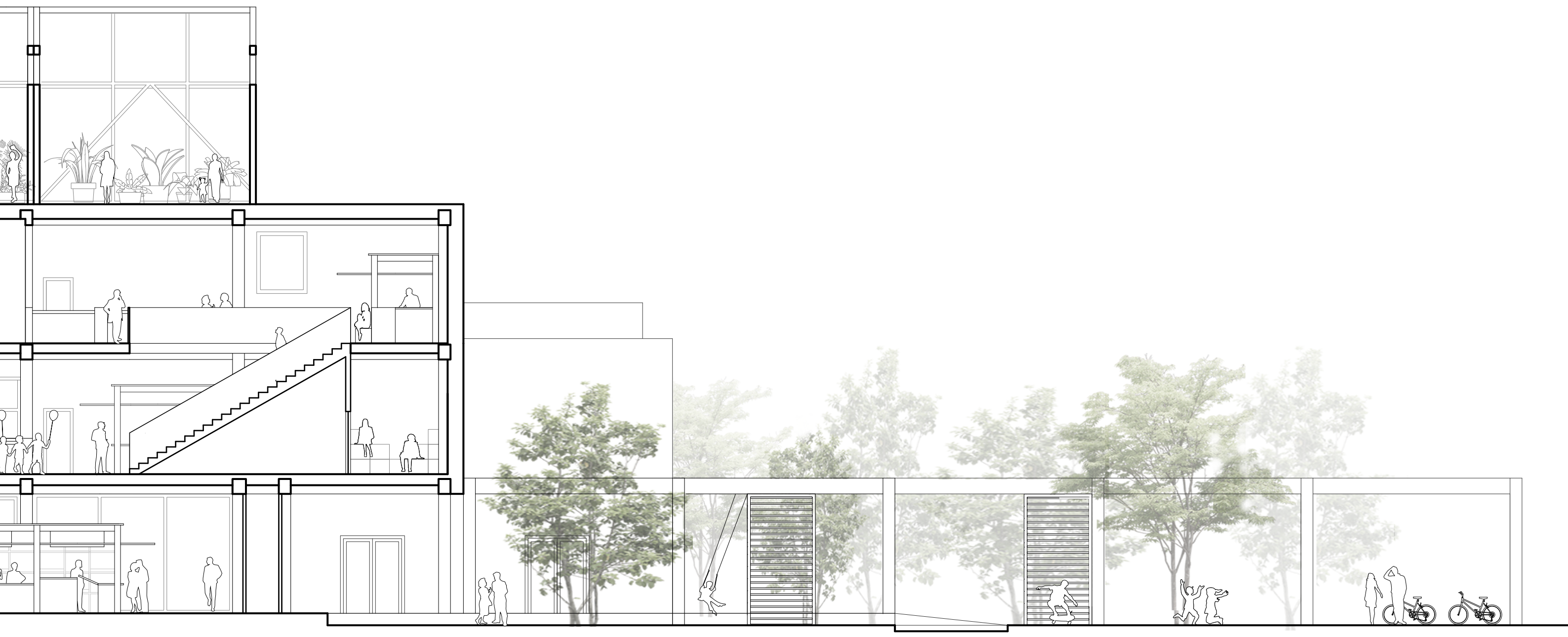


SECTION B-B

Ill. 138 - Third floor plan 1:250







THE STREETFOOD MARKET

Ill. 139 - Render, the streetfood market

The streetfood market in the ground floor has a more industrial character. The visible wooden grid, the concrete on the floor and the visible pipes of the mechanical ventilation give a more strict character to the interior. Only the colours of the food and the red concrete floor emerge. The stalls follow the same concept of the grid but they have their own structure strengthening the concept of flexibility.

THE COMMON AREA

Ill. 140 - Render, the common area

The common area in the first floor has a cozier atmosphere, with the wood used for the construction and as a floor covering. The big stairs, which are also used as sitting places allow for the visual connection and the interaction between the users. In particular, what stands out in these interior views is the load-bearing structure itself, that is emphasized and defines the spaces.

THE GREENERY MARKET

Ill. 141 - Render, the greenery market

The greenery market appears with neutral colours. The wooden construction contrasts with the colourful fruits and vegetables in the stalls. The two floors have visual connection through the double height room. The possibility of the users to interact with screens provides them with the possibility to extend their interest and knowledge of the particular product that they are purchasing.

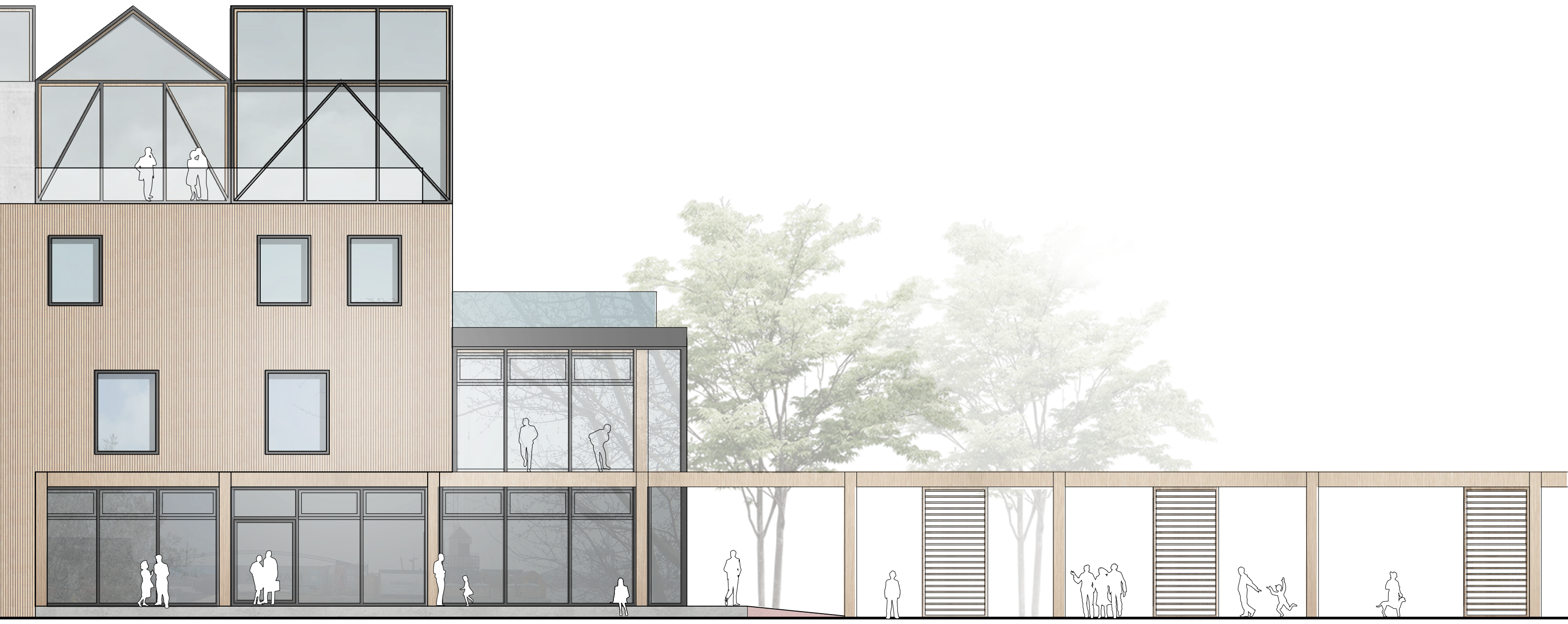

WHAT ARE WE EATING?
HEALTHY EATING
FOOD REVOLUTION NETWORK
HEALTHY EATING

NORTH WEST FACADE

Ill. 142 - South west facade 1:250

NORTH EAST FACADE

Ill. 143 - Nord east facade 1:250



SOUTH EAST FACADE

Ill. 144 - South east facade 1:250

SOUTH WEST FACADE

Ill. 145 - South east facade 1:250

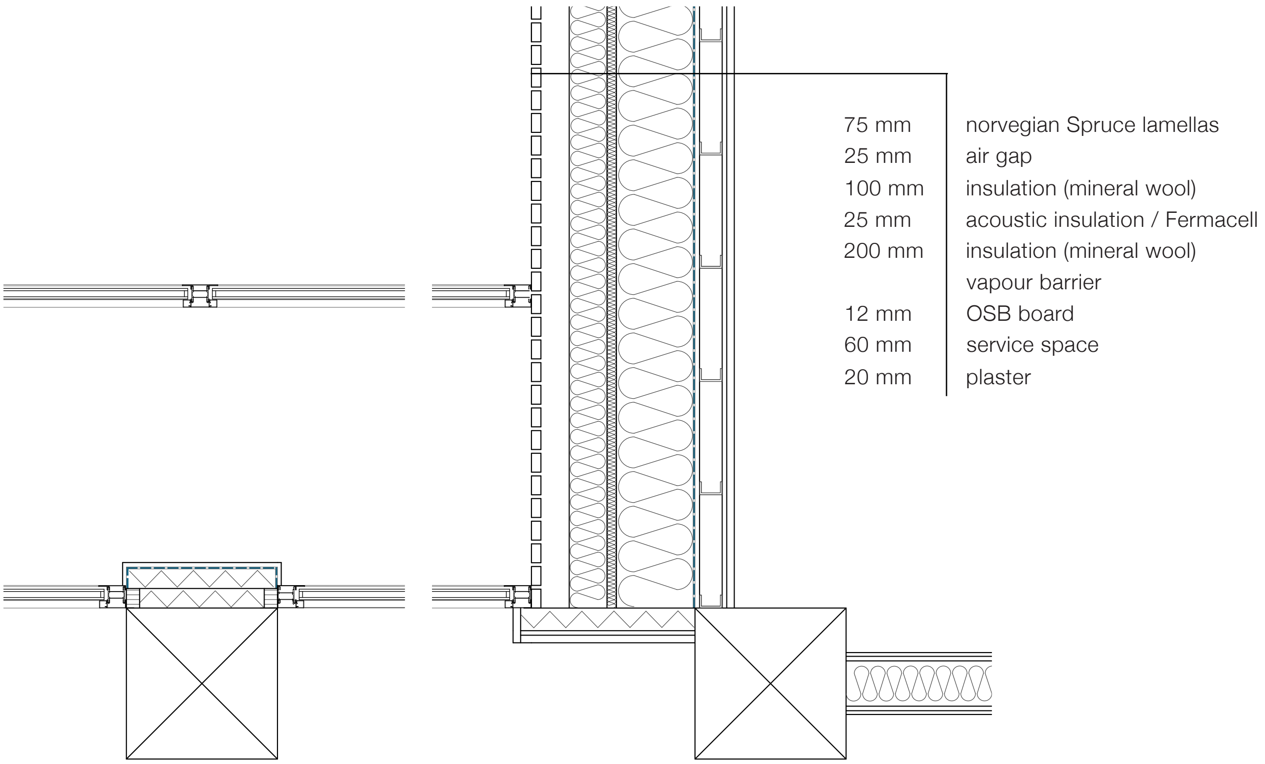
THE COMMUNAL GARDENS

Ill. 146 - Render, the greenery market

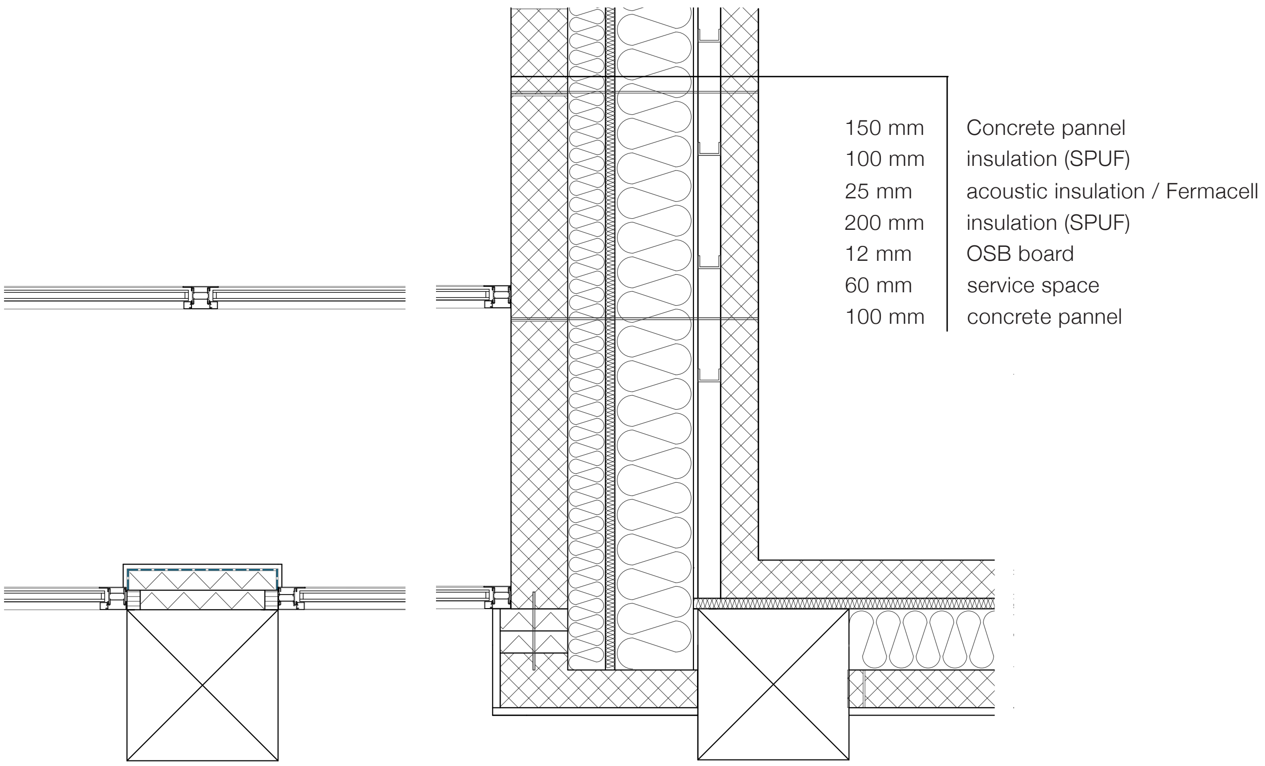
Arriving from the south west the wood cladding engages with the concrete on the service towers, intensifying the diversity in materiality. The greenhouses are arranged for the residents and the playground next to them give life to the urban spaces. The south east terrace allows the users to enjoy the sunny days in Refshaleøen.

HORIZONTAL DETAILS

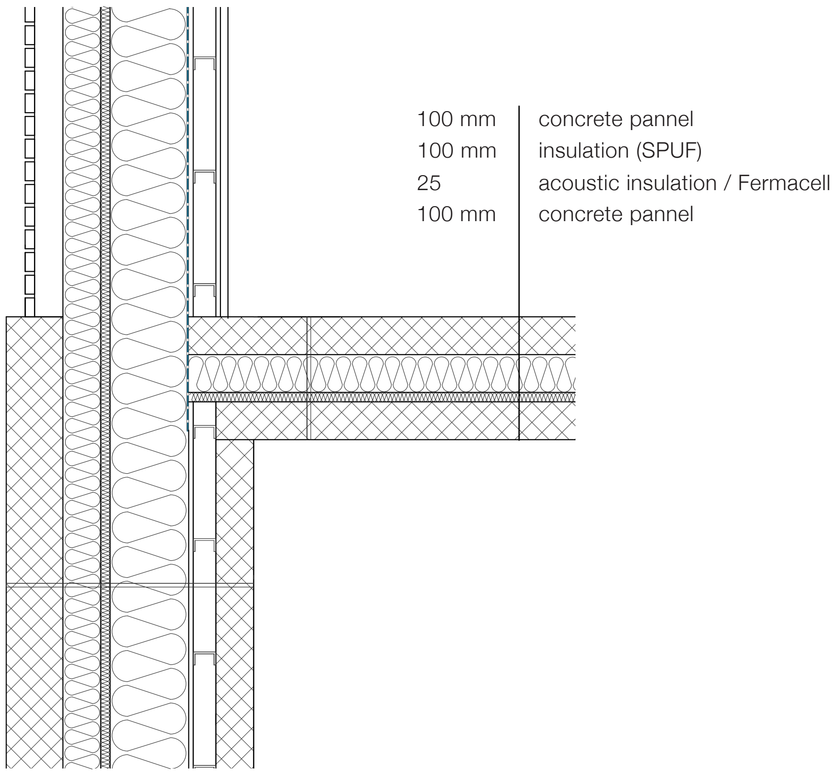
Ill. 147 - Meeting between wooden wall and double glazde facade 1:20



Ill. 148 - Meeting between concrete wall and double glazed facade

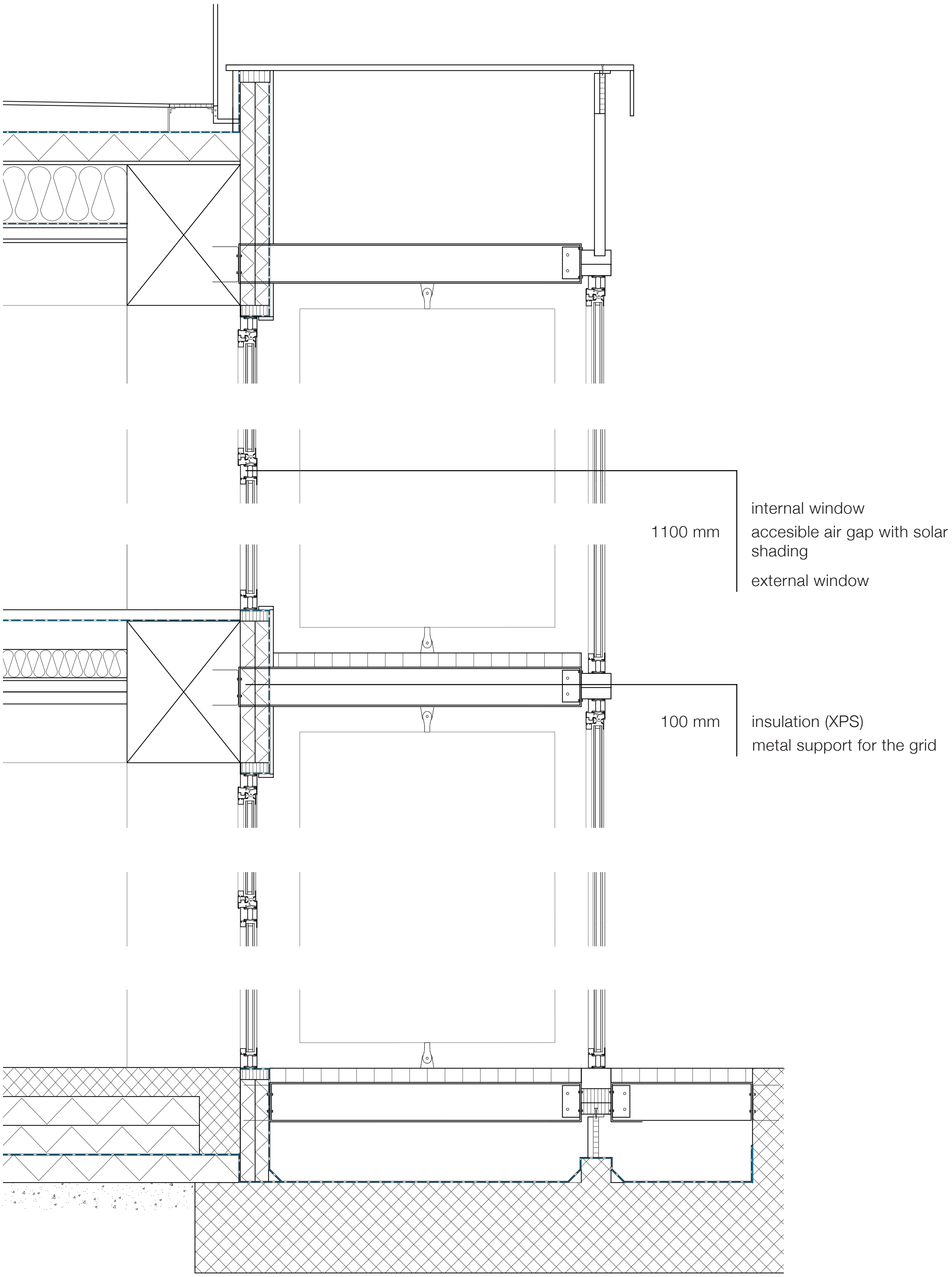


Ill. 149 - Meeting between wooden wall and concrete wall 1:20

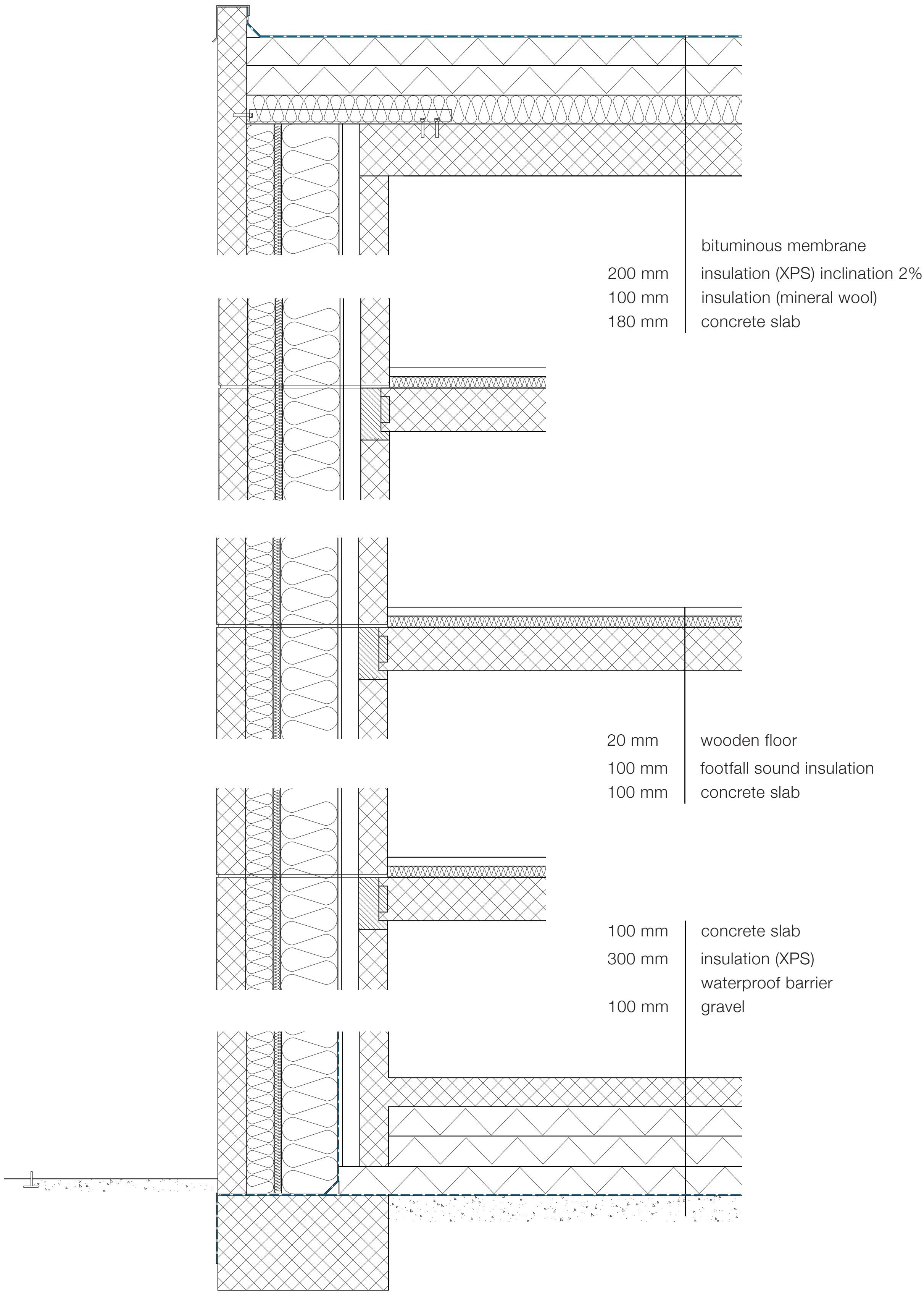


VERTICAL DETAILS

Ill. 150 - Double glazed facades 1:20

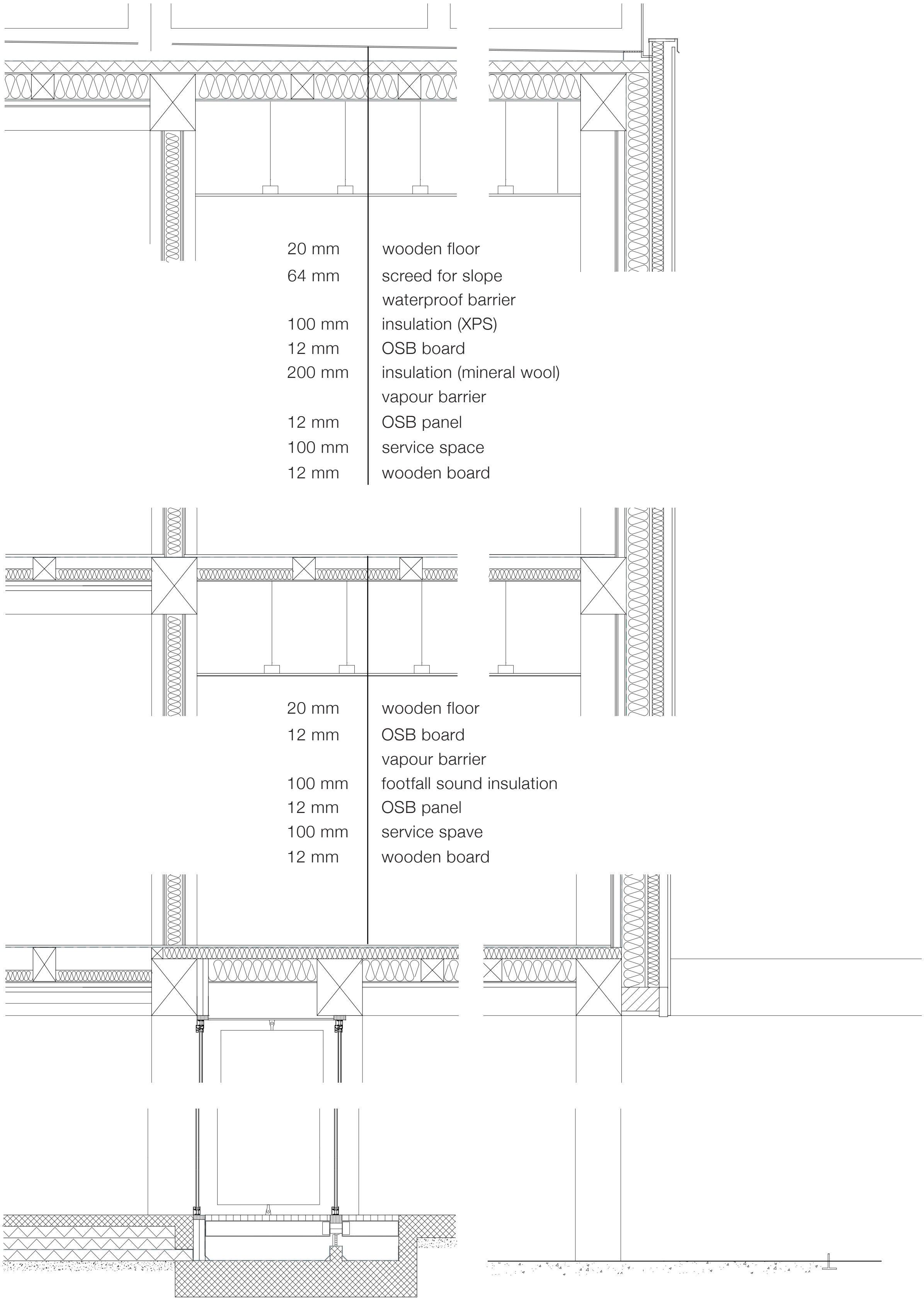


Ill. 151 - Services tower 1:20



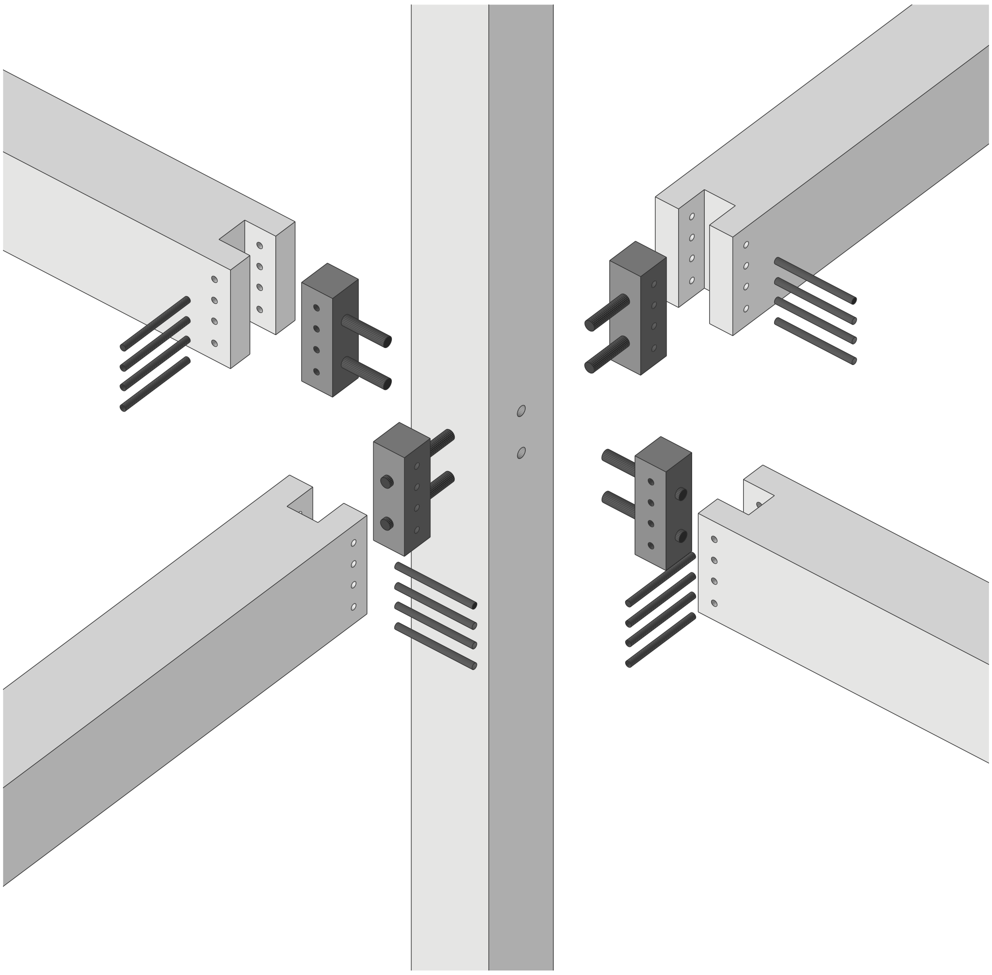
VERTICAL DETAILS

Ill. 152 - Meeting between double galzed facade and wooden structure 1:50



PILLARS AND BEAMS JOINT

Ill. 153 - Pillars and beams joint



In the illustration 153 is represented the joint used for the construction of the grid. In principle, the beams are attached to the pillars, which instead continues along the entire height of the building.
The choice of the joint was dictated by both functional and aesthetic reasons.
In addition to the fact that the metal profiles of the joint and the screws are not visible, thus giving the grid a simple and clean appearance, the configuration of the joint allows for easy assembly and disassembly.

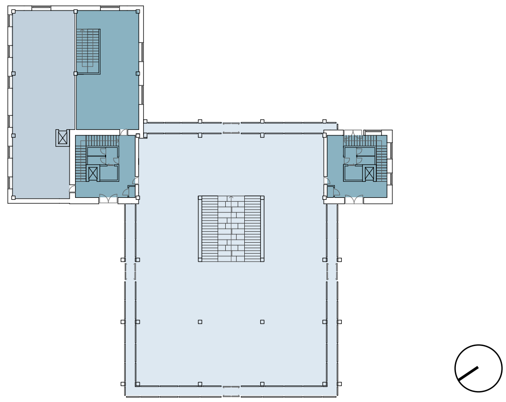
VENTILATION CALCULATIONS

During the design phase, while implementing the passive strategies to minimize the energy demand of the building, the ventilation system plays an important role in the cooling strategies. Therefore, natural ventilation is added to all the rooms except for the greenery market, and the toilets. In order to lower the energy consumption of the building, mechanical ventilation with a recovery system will run during the heating season to limit the heat losses, while in the services, in the workshop and staff kitchen and in the greenery market it will work for the whole year.

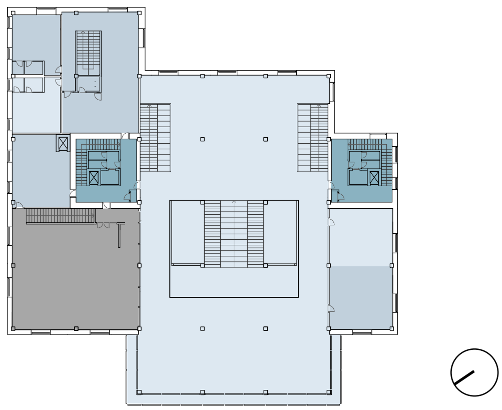
As can be seen by the ill. 154-155-156, cross ventilation can be implemented in almost all the rooms except for the changing room of the staff area and the workshop laboratory kitchen only when the separatory wall is closed. Moreover, since the big common area could be more complicated to be naturally ventilated considering the openings chosen for the double glazed facade, there would be always the possibility of implementing some skylights on the rooftop of the 3rd floor, in order to exploit the stack effect. In particular, in some rooms also thermal buoyancy can be a driving force, like in the service towers and in the staff's common area.

Calculations to evaluate the air change rate and the air flow rate can be seen in the annex 13, while the more detailed calculations for the natural ventilation have been carried out for the workshop kitchen area in the case where the separatory wall is opened. These values have been useful for both the simulations of the energy consumption in Be18 and of the indoor climate in Bsim.

Ill. 154 - Ventilation study ground flo-



Ill. 155 - Ventilation study first floor



Ill. 156 - Ventlation study second floor

Single sided ventilation

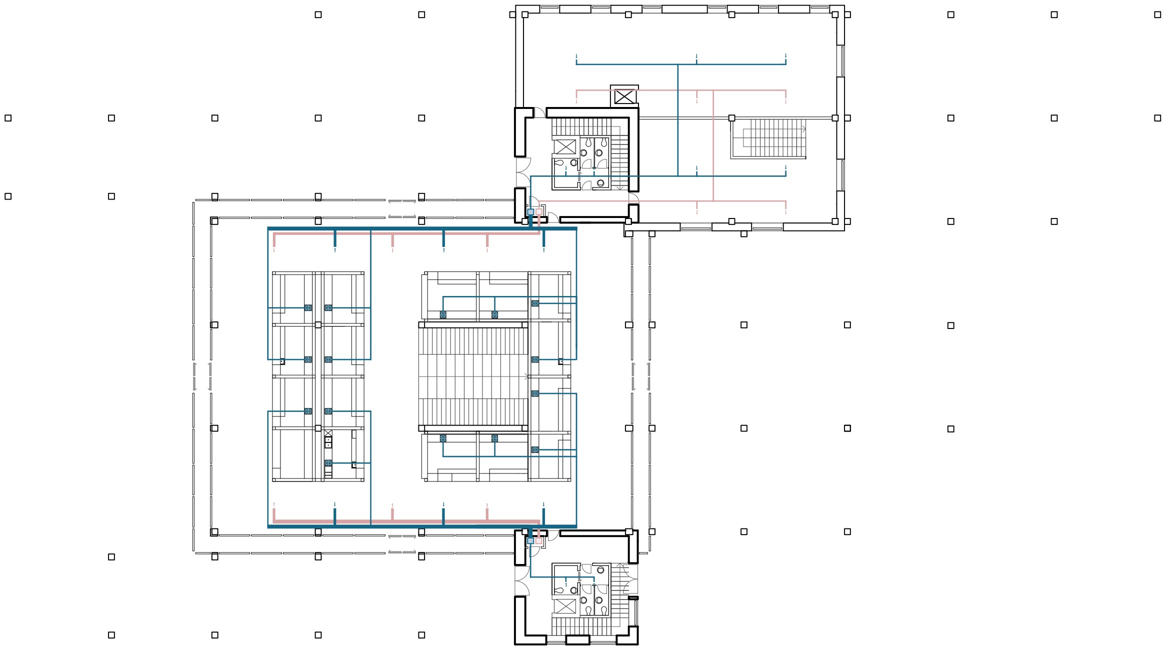
Cross ventilation

Combined cross and stack ventilaton

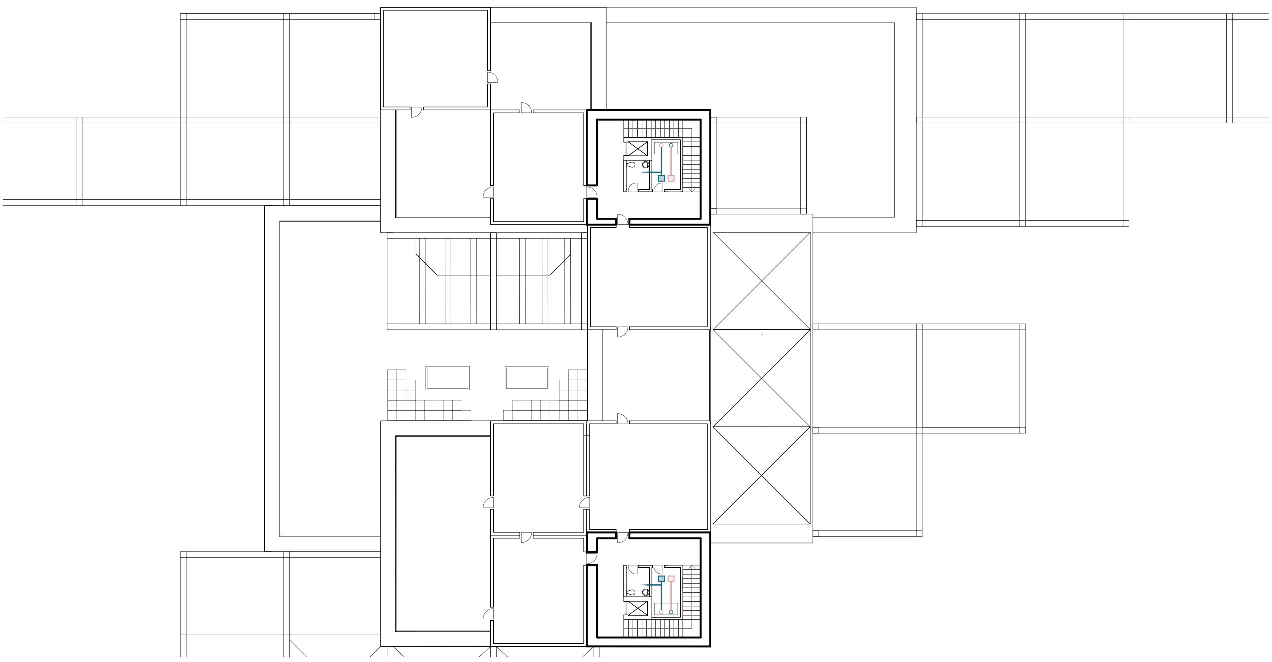
Only mechanical ventilation

MECHANICAL VENTILATION

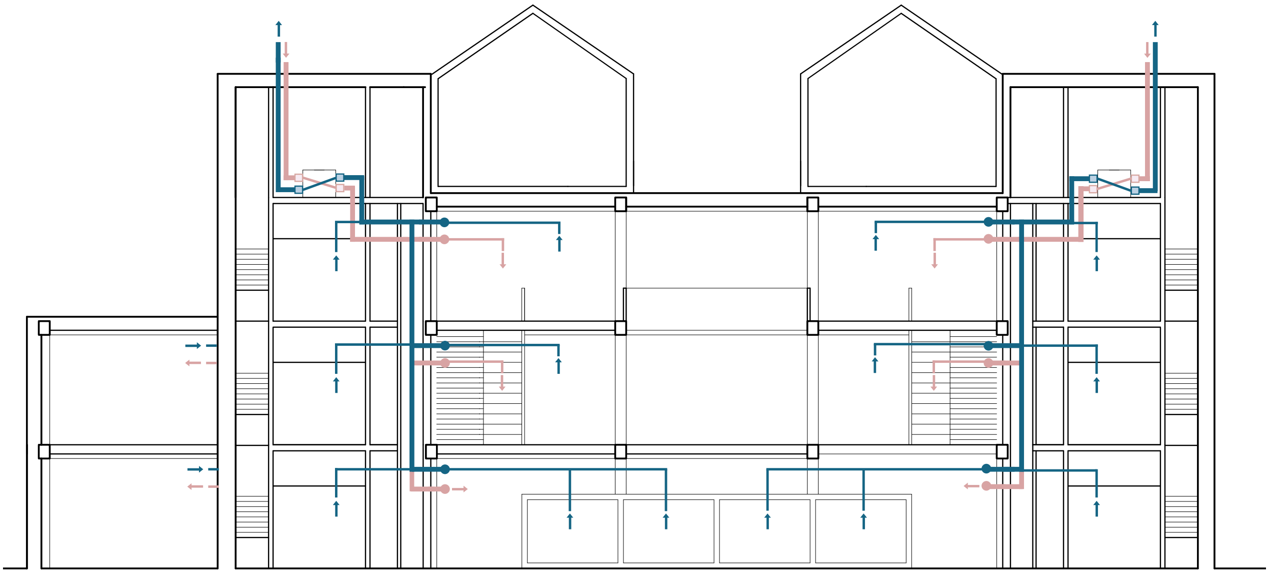
Ill. 157 - Ventilation pipes ground floor



Ill. 158 - Ventilation pipes third floor



Ill. 159 - Ventilation pipes in section



As already mentioned in the natural ventilation chapter, the building uses mechanical mixed flow ventilation with heat recovery in winter and natural ventilation in summer. Mechanical ventilation works for the whole year in toilets, kitchens as far as extraction is concerned, and in the greenery market, as it controls the condensation caused by the high humidity inside the space, which is necessary to preserve the goods.

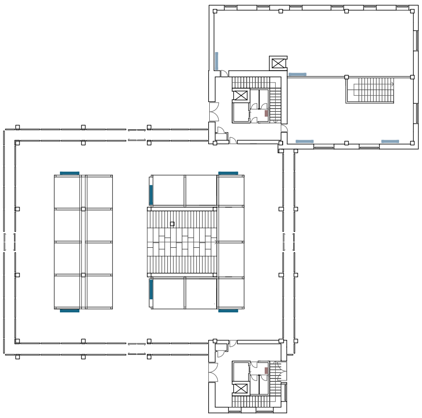
Considering the size of the building, it was decided to divide the ventilation system into two sections.

The initial layout of the pipes planned the positioning of two technical rooms under the staircases on the first floor.

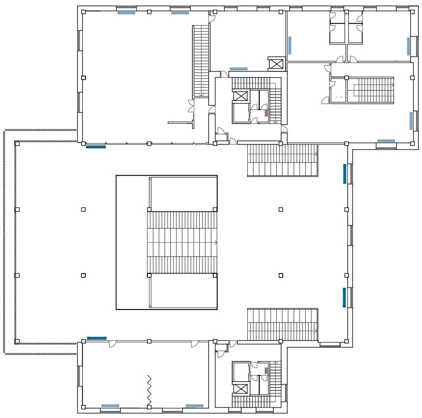
Subsequently it was decided to place the technical rooms on the third floor, inside the two concrete towers (Illustration 158). Through the implementation of a technical shaft attached to the concrete wall, this solution compared to the previous one has allowed to exploit the verticality of the towers to connect the pipes to the different floors of the building.
Conceptually, in the common areas of the building and in the street food on the ground floor (illustration 157) the pipes run, at sight, along the walls adjacent to the concrete towers, giving to these areas a desired industrial appearance. As far as the greenery market, the workshop areas, the toilets and the staff area are concerned, the pipes run above a suspended ceiling, as in these functions a warmer and welcoming aspect was desired. (Illustration 159)

HEATING SYSTEM

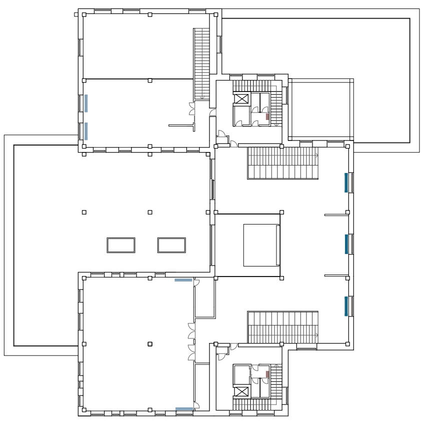
Ill. 160 - Radiators ground floor



Ill. 161 - Radiators first floor



Ill. 162 - Radiators second floor



With regards to the heating of the building, the installation of radiators was chosen, rather than the implementation of underfloor heating, since radiators are more reactive and easily controllable in such a big building.

The number of radiators was calculated for each room taking into account the volume of the room, a thermal coefficient of 40 Kcal/mc, the power of the individual heater and the number of heater for each radiator. (Annex 21)

The only exception is the greenery market, where in accordance with our room program temperature must be kept lower than in other areas for the preservation of fruit and vegetables. Hence, no extra radiator has been added.

For aesthetic reasons we tried to place the radiators under the windows, so the size of the latter changes depending on the size of the openings in the different areas of the building.
In the toilets they measure 400 x 300 mm, in the common areas, where the windows are 2000 mm wide, the radiators measure 1800 mm x 300 mm. The same radiators were used on the ground floor, in the street food market, but in this case we tried to implement the radiator into the structure of the different stalls.
In all the other areas, the radiators are 1600 x 300 mm.

Radiators 1800 x 300 mm

Radiators 1600 x 300 mm

Radiators 400 x 300 mm

BE18 AND ENERGY PERFORMANCE

With the passive and active shading -passive with overhangs that are created by the morphology of the building and active with the implementation of the solar shading in the big glazing facade in the common area and the streetfood area- the implementation of natural ventilation during summer and mechanical ventilation with heat recovery during winter and by keeping the U-values of the building envelope low the food market reached the energy goals for building class 2020.
Particularly, in the first zone, the streetfood market, the energy consumption before the implementation of active strategies is 19,4kWh/m^2 . After applying 75m^2 of thin film solar cells the goal for reaching a zero energy building is achieved. In the second zone the energy consumption is 24kWh/m^2 and 190m^2 of thin film solar cells produce enough energy in order to reach the goal of a zero enery building. Finally in the third zone, the energy consumption is 19,9kWh/m^2 and after the solar cells it reaches the zero energy building goal.
In the results in the Annex 18 it is indicated that there is some excessive in the rooms in all the zones. In the first and second zone the level is still low. However, in the third zone, where the temperatures are set lower it is higher. Nevertheless, as already mentioned Be18 is a tool that calculates the whole building, therefore, further investigations are made in the Bsim for the indoor climate.
The energy consumption for the first and third zone that the temperatures are set lower is mainly from the electricity for operation of the building, while there is not a lot of need for heating. This is due to the fact that the temperatures are set lower in the program than the default 20^0 value. On the other hand, in the secondzone where the temperature is kept with the default value the energy consumption is mainly from room heating. Room heating is usually the requirement with the highest consumption, because of the ventilation and transmission losses.

The final result, with and without solar cells can be seen in the Annex 12.

Ill. 163 - Be18, key numbers without solar cells, first zone

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
98,2	1,5	99,7
Total energy requirement		19,4

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
73,7	1,5	75,2
Total energy requirement		19,4

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
42,5	1,5	44,0
Total energy requirement		19,4

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		19,4

Contribution to energy requirement

Heat	2,1
El. for operation of bulding	8,8
Excessive in rooms	0,9

Net requirement

Room heating	2,1
Domestic hot water	5,3
Cooling	0,0

Selected electricity requirements

Lighting	3,9
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	4,8
Pumps	0,0
Cooling	0,0
Total el. consumption	32,3

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

Ill. 164 - Be18, key numbers without solar cells, second zone

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
96,6	1,5	98,1
Total energy requirement		24,0

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
72,5	1,5	74,0
Total energy requirement		24,0

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
41,7	1,5	43,2
Total energy requirement		24,0

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		24,0

Contribution to energy requirement

Heat	8,7
El. for operation of bulding	8,3
Excessive in rooms	0,8

Net requirement

Room heating	8,7
Domestic hot water	5,2
Cooling	0,0

Selected electricity requirements

Lighting	3,8
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	4,5
Pumps	0,0
Cooling	0,0
Total el. consumption	31,0

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

Ill. 165 - Be18, key numbers without solar cells, third zone

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
97,3	1,5	98,8
Total energy requirement		19,9

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
73,0	1,5	74,5
Total energy requirement		19,9

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
42,0	1,5	43,5
Total energy requirement		19,9

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		19,9

Contribution to energy requirement

Heat	4,6
El. for operation of bulding	6,9
Excessive in rooms	2,8

Net requirement

Room heating	4,6
Domestic hot water	5,3
Cooling	0,0

Selected electricity requirements

Lighting	4,4
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	2,5
Pumps	0,0
Cooling	0,0
Total el. consumption	33,2

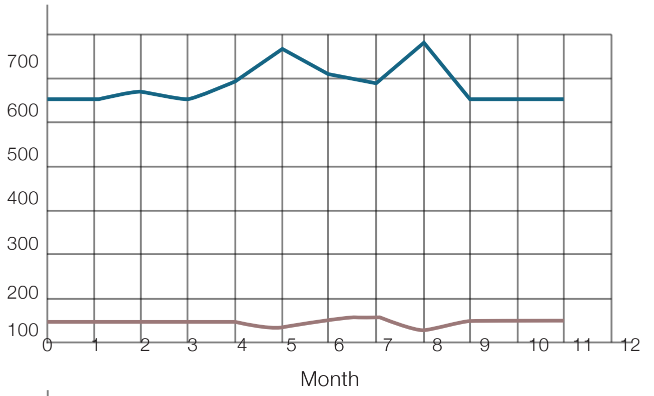
Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

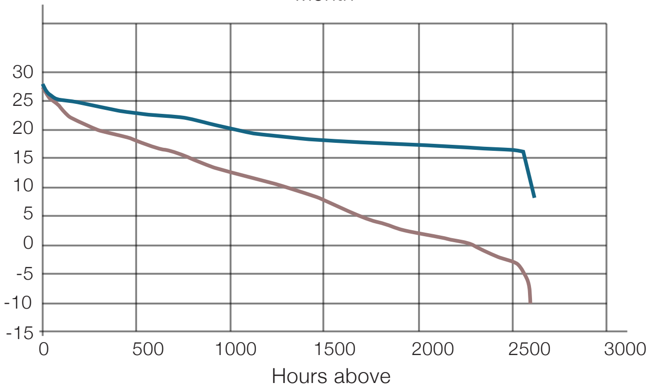
INDOOR CLIMATE SIMULATIONS



Ill. 166 - CO2 concentration in a year during the working hours WORKSHOP

CO2 Thermal zone 1

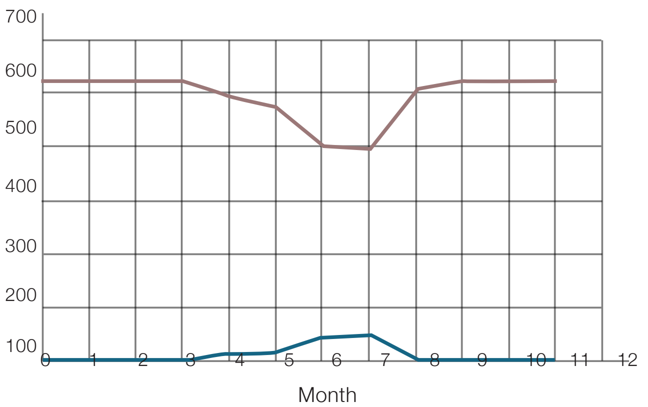
10*Airchange (Thermal zone 1)



Ill. 167 - Average temperature in a year during the working hours WORKSHOP

Top mean Thermal zone 1

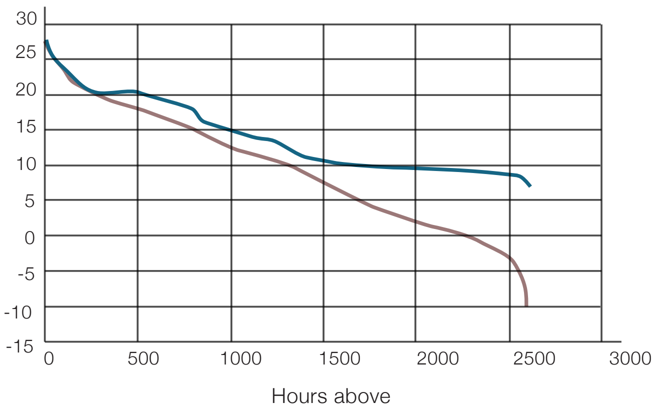
Ext temp (outdoor)



Ill. 168 - CO2 concentration in a year during the working hours GREENERY MARKET

CO2 Thermal zone 1

10*Airchange (Thermal zone 1)



Ill. 169 - Average temperature in a year during the working hours GREENERY MARKET

Top mean Thermal zone 1

Ext temp (outdoor)

The investigation regarding the indoor climate quality has been carried out using Bsim software tool. The critical rooms that have been analysed are the kitchen in the workshop area and the greenery market. The study has considered in particular, the possible overheating issues and the CO_2 concentration during the working hours. Different strategies have been applied during the design process and the results can be seen by the graphs in the illustrations in the previous page.

In particular, from the results it is interesting to notice that thanks to the addition of a curtain shading system to the windows and with the addition of some pergolas in the terrace in both the rooms the hours do not exceed the limit of 100 hours above 26° and 25 hours above 27°. Moreover, the CO_2 level also when people load is at the maximum is acceptable thanks to the implemented ventilation system. In particular, in the greenery market area the ventilation is only mechanical in order to provide a better control of the temperature and of the humidity in the air to respond to the specific requirements that this function demands. An additional consideration concerns the amount of hours that exceeds the preset temperatures according to the plan of the room program for the greenery market. From Be18, the results show ”excessive in room” that is due to the lower setting of the temperatures in some zones of the building. This overheating issue is visible also from the Bsim simulation of the greenery market that is the area in which the temperatures are the lowest. For this reason, a cooling system should be implemented in order to assure the correct wanted temperatures in the 608 hours that are exceeding the limit. However, the cooling system could be also activated by a misting system of spraying water that can both lower the temperature and preserve the products quality through the humidification.

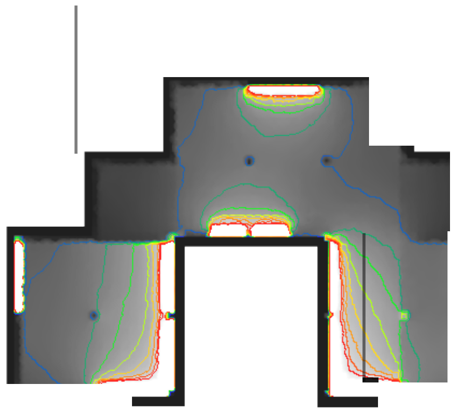
DAYLIGHT ANALYSIS

In the streetfood market and in the common area the big glazing facade was added in order to give the architectural impression of a light building but also to ensure a good daylight into the rooms. Since, both of them are big rooms and due to the morphology and compactiness of the building it was a requirement to have big windows, in order to ensure an adequate daylight of at least 2% and secure the visual comfort of both users and staff.
As already mentioned in the process chapter in page 98, in the beginning the windows were small of 1*2,2m and the daylight was not adequate.
The final solution ensures a satisfactory daylight of at least 2% in the majority of the streetfood with the exception of the toilets in the service rooms, that are going to use mainly artificial light. In the first floor almost all the rooms have adequate daylight and the windows allow for the view to the sea and the surroundings. Only in some parts of the common area the daylight is 1% and this could be solved if the theater in the terrace was rearranged and some more skylights were added. In the workshop area, the daylight is less than the other rooms , since it mainly requires working artificial light and less windows were added. Finally in the second floor the daylight is also 2% in all the rooms fullfilling the requirements.

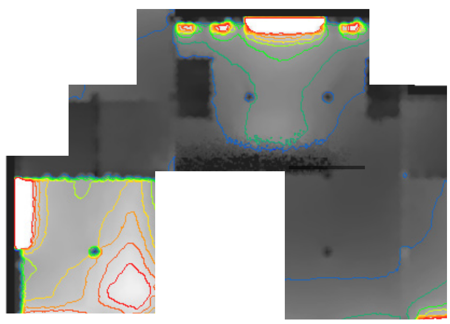
When the windows were designed, both daylight, aesthetic considerations, indoor climate and the temperatures that we set for every different zone were taken into account. Especially, the indoor climate was examined also in Bsim, in order to secure that the project fullfills the requirements.

Ill. 170 - Ground floor, Velux

Ill. 171 - First floor, Velux



Ill. 172 - Second floor, Velux



CONCLUSION

Located in an area with diverse impressions, functions and materialities, that is expected to be developed in the near future and is visualized as a sustainable melting pot, the future oriented food market will serve both the current and future users. The purpose was to design a building that is accessible from all four sides and welcomes the visitors with its completely open ground floor.
A landmark for the area, that currently stands out of the context and will be integrated with the surroundings in the future is obtained, through the honest use of the wood as a cladding and structure material, the visible grid and the implementation of the greenhouses pitched roofs on the top, that are visible from Copenhagen city centre, that lays on the west of the building.
The concept and implementation of the grid enhanced the design of a future oriented building, that is flexible and has potential to extend and adjust to the development of the Refshaleøen area. The considerations for the flooding phenomenons were resolved with the use of waterproof materials on the groundfloor, such as concrete in the slab and the service rooms, by raising the streetfood of 40cm and by treating both the structure and facade wood.
Moreover, the utilization of the grid promoted the connection between the outdoor and indoor spaces, by extending it towards the outdoors. Particularly, the streetfood market is extended outside to the south west, giving the possibility, when the weather conditions allow it, to place the stalls ouside and enjoy the sun. Moreover, in the terrace on the first floor, the outdoor theater is visually connected and accessible from the interior, strengthening in this way the relation between the indoor and outdoor spaces.
All the functions are connected one to each other with the two service towers optimizing the accessibilty. The visual connection is accomplished with the big stairs on the streetfood market and with the opening on the floor of the common area. In this way, there is an interplay between the different functions, and the smell of the foods circulates into the building stimulating the senses. Moreover, through the use of the wood in the visible construction in the interior and the concrete in the service towers, the tactility sense is integrated with the vision and the taste.
The interior of the streetfood market and the common area has an industrial character, with the visible wooden construction, the pipes of the ventilation that are left exposed and the neutral colours that dominate the spaces. Only the colours of the foods and fruits pop up in the interior, proving the function of the building. The workshop and staff area retain a cozier and warm atmosphere. Finally, the connection with the sea is visual through the big glazing facade in the common area and the streetfood, but is also physical, with the continuation of the grid in the water and the extension of two wooden platforms on the water.
The focus on sustainability was vital from the early beginning of the project. The food market accomplished the requirements of 2020 energy frame by implementing passive strategies in the beginning, in order to minimize the energy consumption. Later on, active strategies were used by integrating solar cells in the flat terraces and in the roof of the outside grid in the streetfood market, so that the market could produce as much energy as it consumes. A highly insulated envelope, in order to minimize losses, the mechanical ventilation with heat recovery during the heating period and the natural ventilation through the big windows are some of them. Moreover, the large glazing area in both common area and streetfood, and the sufficient size of the windows areas, secure an adequate daylight.
Finally, vital for the particular project was the division into three different thermal zones, according to the temperature requirements of each of them. Each zone was calculated separately and should meet the requirements of 2020 energy frame. By lowering down the temperatures in some zones, the heating demand was also decreased, therefore it was possible to save energy during the winter.

REFLECTION

Important, once the project is complete, is to evaluate it having a critical approach in such a way as to analyse the weaknesses and subsequently rectify them.
In the following paragraphs some of these points are going to be discus.

Firstly, considerations and detailed investigation on the materials that are used in the project were conducted, related to their impact towards the environment and their resistance to the water. Particularly, glue laminated timber was chosen as the construction material, since it is a strong material that can carry high loads and because of its beneficial performance in the LCA. A research on the latter has been carried out, however, it could be even more exploited by using ths LCAbyg calculation tool.

Furthermore, as aforementioned, the food market is divided in three zones, according to the setting of different temperatures in each zone, in order to reduce the heating demands. The energy performance of each zone was seperately calculated in the Be18 simulation tool. However, there are some limitations and some assumptions that had to be considered. For instance, some walls that in the case of the project were considered internal walls were set as external since they were the dividing walls from the other zones.

Moreover, one of the major considerations was related to the grid structure and one initial thought was to keep the grid visible both internal and external. However, this created numerous thermal bridges and even though multiple tries were made, the final decision was to keep the grid visible only in the interior.

As far as the natural ventilation is concerned, calculations for the air change rate, the air flow rate and more detailed for workshop area have been carried out, in order to secure a good indoor climate. Regarding the common area, since is a big size room, is more complicated to be ventilated naturally. However, by adding some skylights in the roof of the food market, it would be possible to consider the thermal buoyancy and strengthen the natural ventilation.

Finally, also related to the natural ventilation the design of the double glazed facade has to be taken into account. In fact the design choices for this type of construction include hiding the window frame from the bottom of the facade. Due to this choice, the air , in order to enter into the gap, has to pass from the ground, beeing therfore less efficent. Aware of the problem, it was anyway decided to compromise this techinical aspect in support of architectural results.

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Ill. 52 - Ill. 72 _ Own production

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Ill. 94 - Ill. 95 _ [image online] available at: http://textures.com

Ill. 96 - Ill. 99 _ Own production

Ill. 100 _ [image online] available at: http://www.expansion.com/empresas/inmobiliario/2016/03/29/56faa105ca474125338b45b5.html

Ill. 101 _ [image online] available at: https://www.dezeen.com/2016/04/10/lago-events-hall-pitsou-kedem-concrete-glass-rishon-lezion-tel-aviv-israel/

Ill. 102 _ [image online] available at: http://www.stockholmvattenochavfall.se/om-oss/vara-kontor-och-anlaggningar/glashusett/

Ill. 103 - 108 _ Own production

ill.109 a. [immage online] available at http://www.namelessarchitecture.com/work/25_intheair.html

Ill. 109 b. [immage online] available at https://www.dexigner.com/news/27610

ill.109 c. [immage online] available at https://www.arch2o.com/

Ill. 109 d. [immage online] available at https://www.bocadolobo.com/en/inspiration-and-ideas/perfect-colorful-architecture-world-instagram/

Ill. 109 e. [immage online] available at https://www.broadsheet.com.au/melbourne/food-and-drink/article/chasing-kitsune-truck-hassell-sale

Ill. 109 f. [immage online] available at https://www.mark-up.it/i-robot-abb-nel-supermercato-del-futuro-di-expo/

Ill. 110 - Ill.172 _ Own production

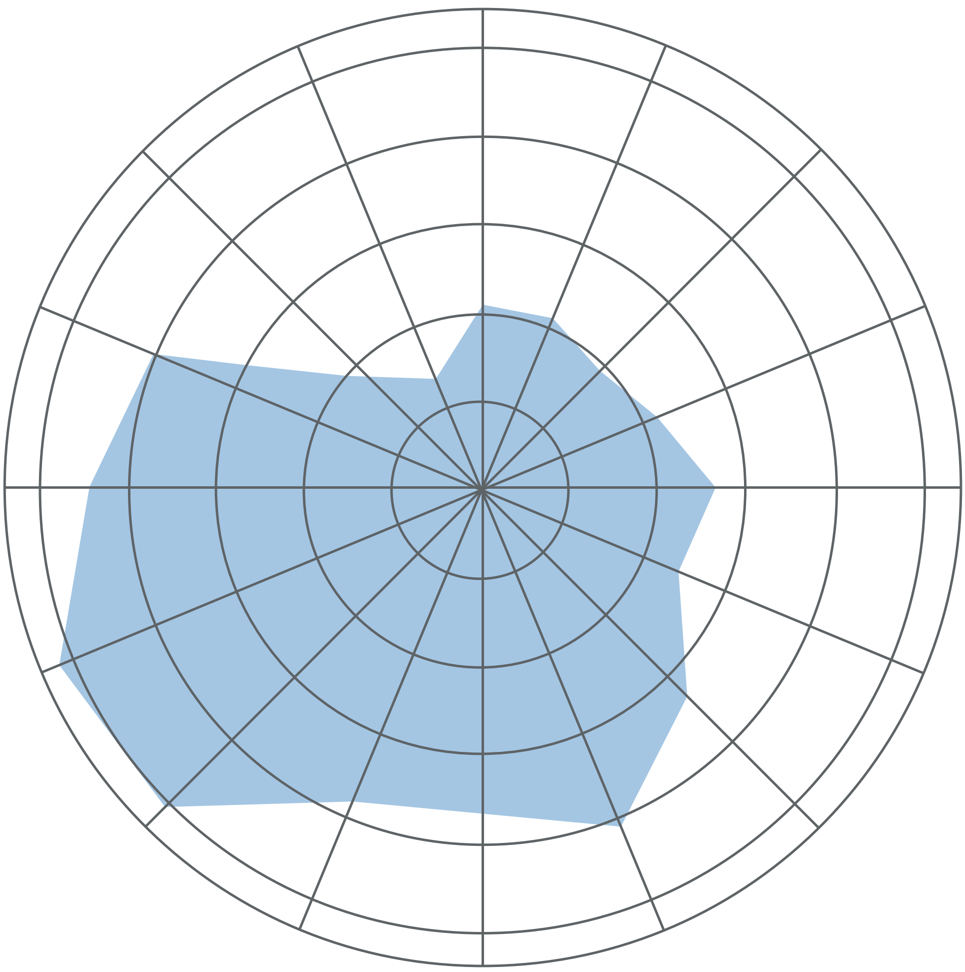
ANNEXES

ANNEX 1
Wind diagram

Wind diagram

	N	30	60	Ø	120	150	S	210	240	V	300	330	Ialt
%	5.1	4.9	5.0	7.7	5.6	7.7	8.0	9.7	14.6	15.3	10.0	4.2	98.0
% 0.2-5.0m/s	2.1	2.8	2.4	3.3	3.0	3.8	3.5	4.4	5.1	6.3	3.9	2.1	42.7
% 5.0-11.0m/s	2.8	2.0	2.5	4.2	2.6	3.8	4.4	5.1	8.8	8.0	5.6	2.0	51.7
% > 11.0m/s	0.2	0.1	0.1	0.1	0.0	0.2	0.2	0.3	0.8	1.0	0.5	0.1	3.6
Middel hastighed	5.9	5.0	5.2	5.5	5.0	5.2	5.5	5.6	6.3	6.0	6.1	5.3	5.7
Største hastighed	18.0	16.5	13.9	17.0	12.9	15.0	16.5	14.9	21.6	19.6	18.0	14.4	21.6

Totalt antal observationer = 29189 Kilde: DMI
Vindstille defineret som hastighed <= 0.2m/s
Antal observationer med vindstille/varierende vind: 580 = 2.0%



ANNEX 2
Experiment indoor climate

Experiment for the indoor climate requirements

AFTER30MIN	4	3	4	3	4	3,6

SITTING IN SUN WITH WIND

	GIRL 1	GIRL 2	BOY	OLD MAN	CHILD	
AFTER 5MIN	4	3	5	4	4	4
AFTER15MIN	3	3	4	3	3	3,2
AFTER30MIN	3	1	3	2	1	2

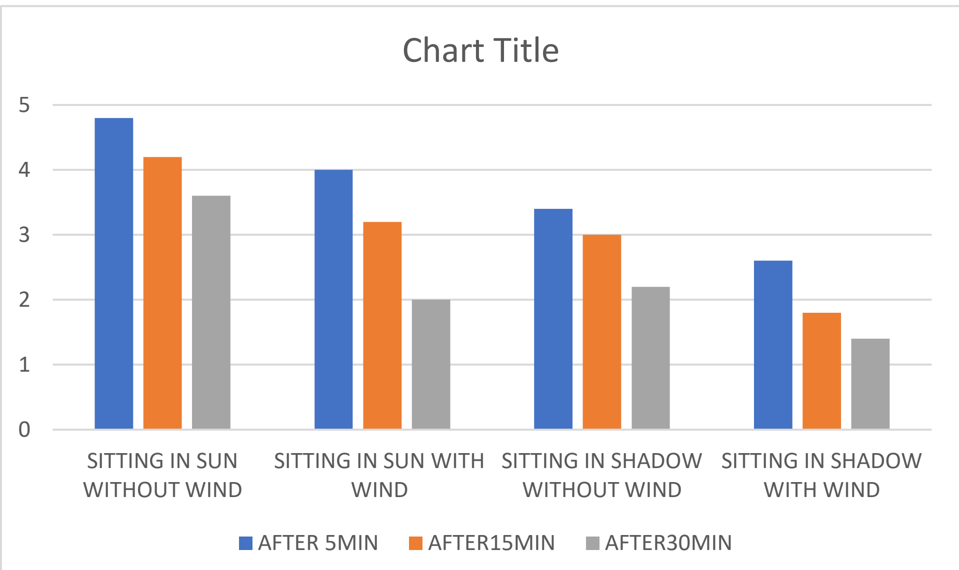
SITTING IN SHADOW WITHOUT WIND

	GIRL 1	GIRL 2	BOY	OLD MAN	CHILD	
AFTER 5MIN	3	3	4	3	4	3,4
AFTER15MIN	3	2	4	3	3	3
AFTER30MIN	2	1	3	2	3	2,2

SITTING IN SHADOW WITH WIND

	GIRL 1	GIRL 2	BOY	OLD MAN	CHILD	
AFTER 5MIN	2	2	3	3	3	2,6
AFTER15MIN	2	1	3	2	1	1,8
AFTER30MIN	1	1	2	2	1	1,4

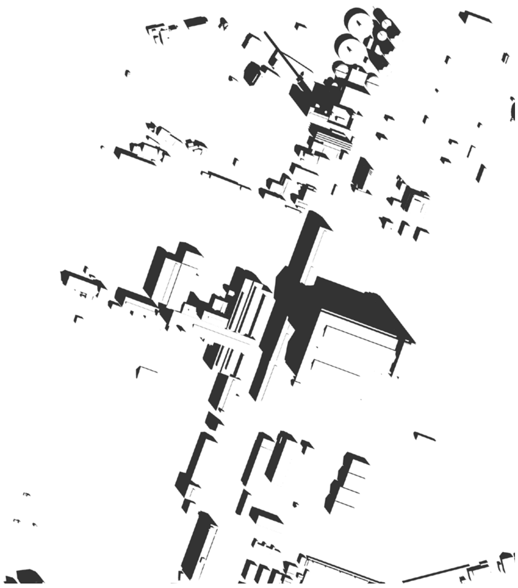
	AFTER 5MI	AFTER15M	AFTER30MIN
SITTING IN SU	4,8	4,2	3,6
SITTING IN SU	4	3,2	2
SITTING IN SH	3,4	3	2,2
SITTING IN SH	2,6	1,8	1,4



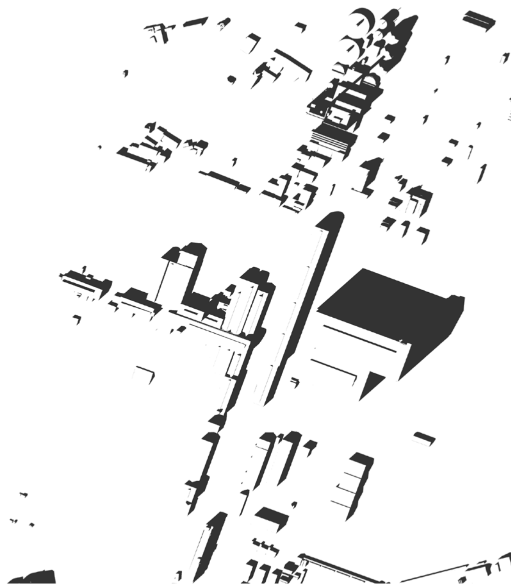
ANNEX 3
Shadows studies

Shadows studies

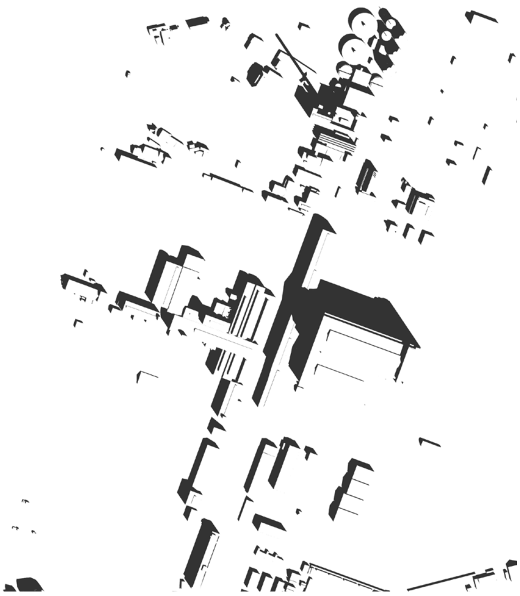
March at 10.00



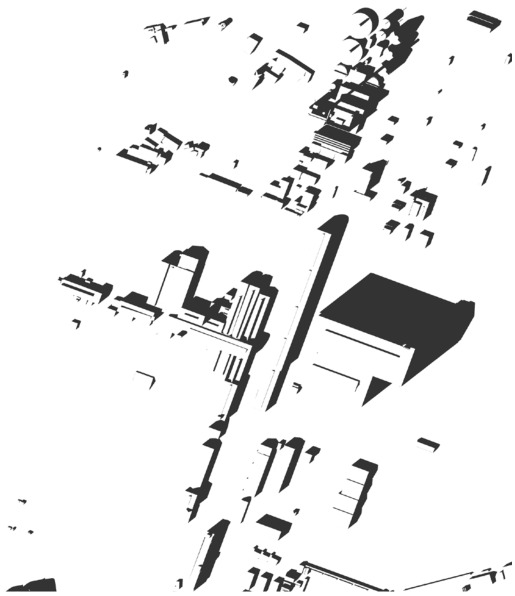
March at 15.00



September at 10.00

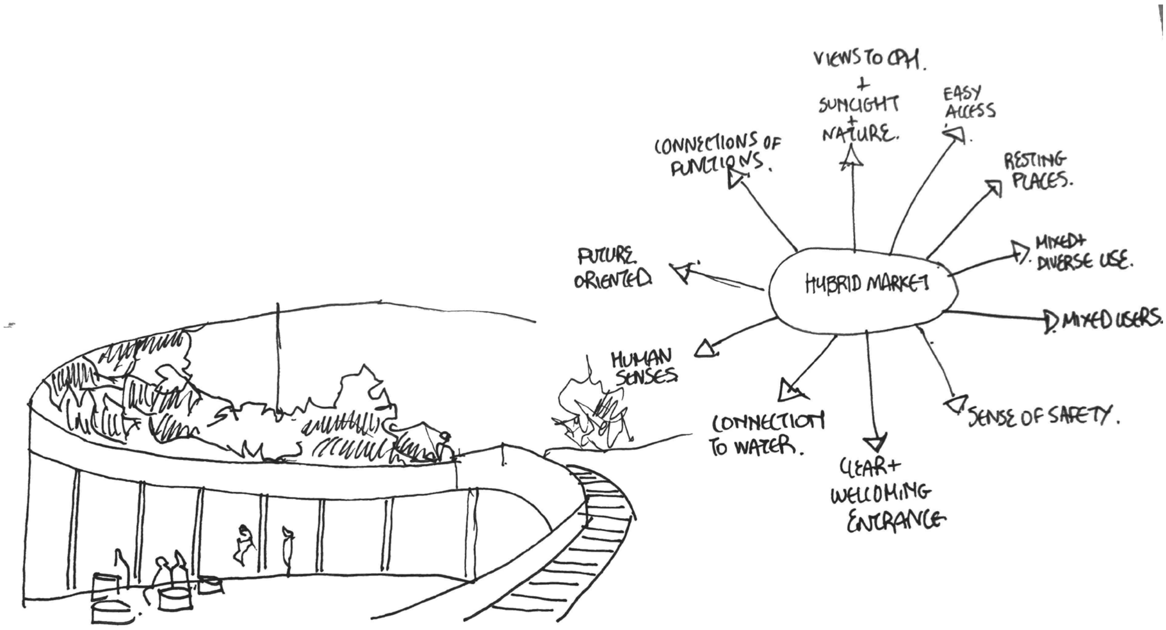


September at 15.00



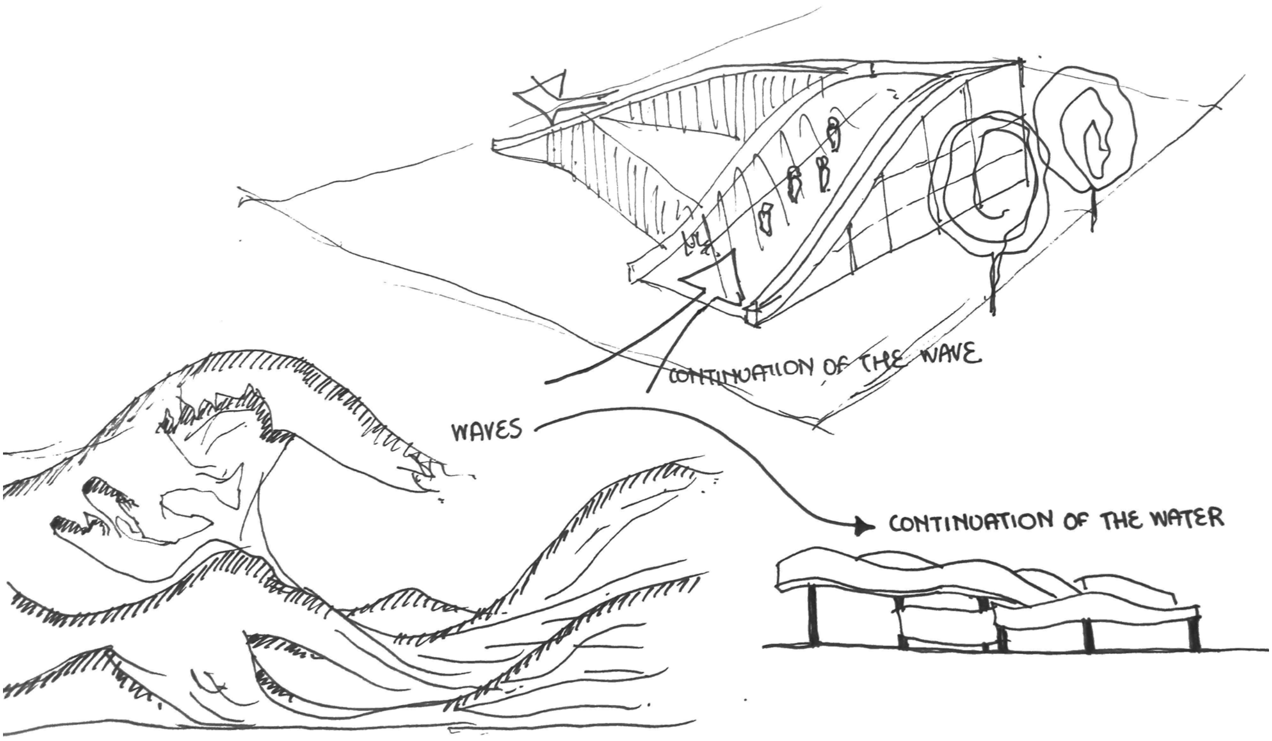
ANNEX 4

Initial sketch showing the wave concept



ANNEX 5
Sketches wave

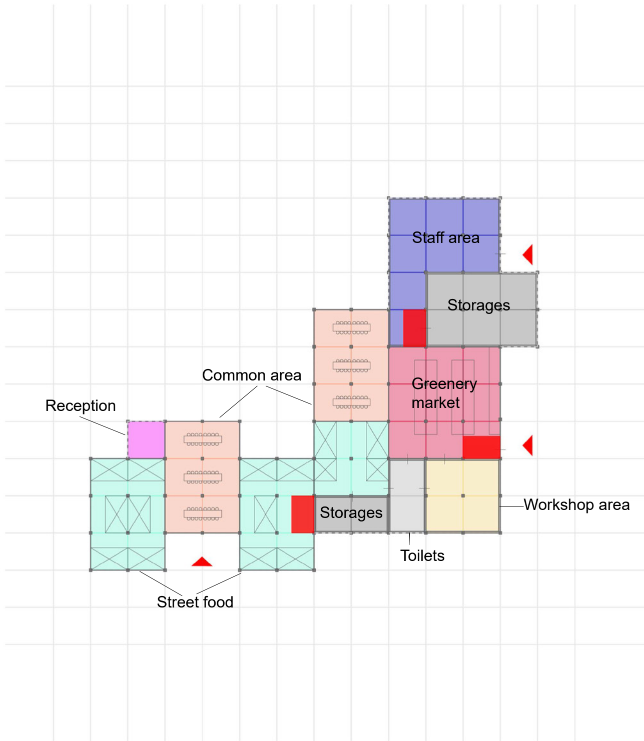
Initial sketches of the wave concpet



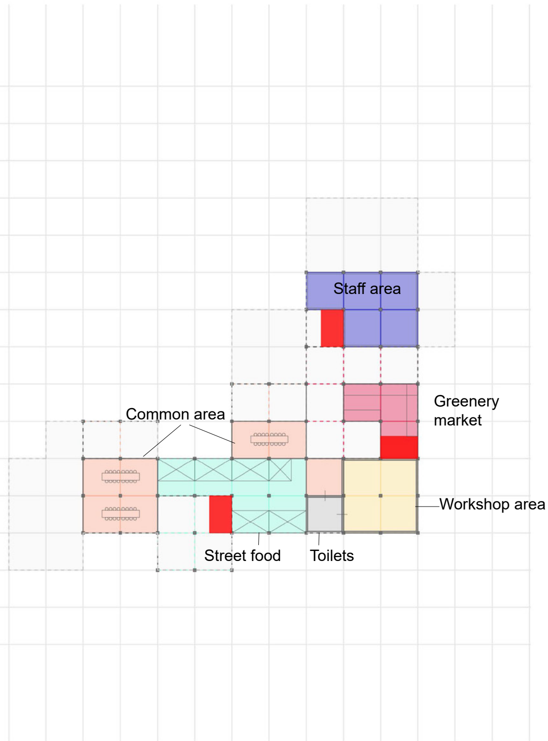
ANNEX 6
Function diagrams wave

Diagrams indicating the function of the wave concept of the grid, ground floor

LEVEL 1



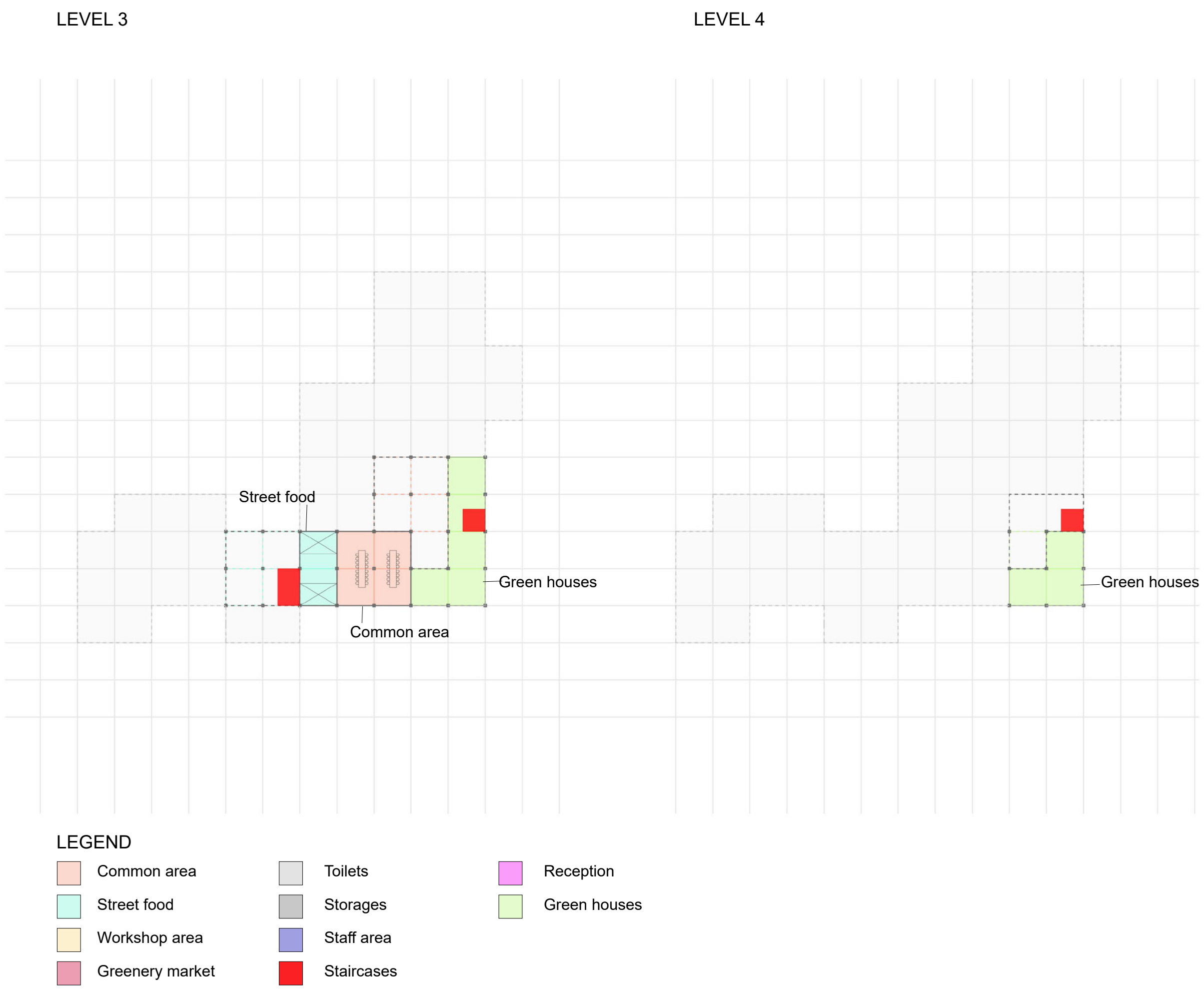
LEVEL 2



LEGEND

- Common area
- Street food
- Workshop area
- Greenery market
- Toilets
- Storages
- Staff area
- Staircases
- Reception
- Green houses

Diagrams indicating the function of the wave first and second floor

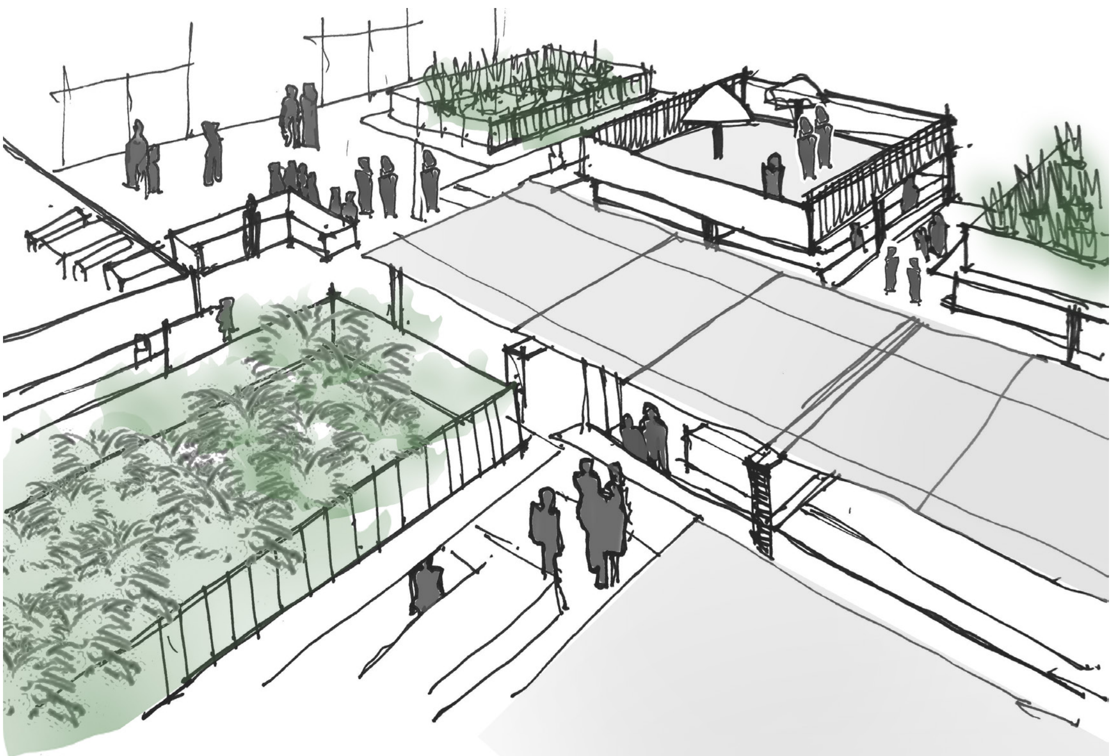


ANNEX 7
Sketched grid

Sketching showing the grid concept, inner courtyards perspective

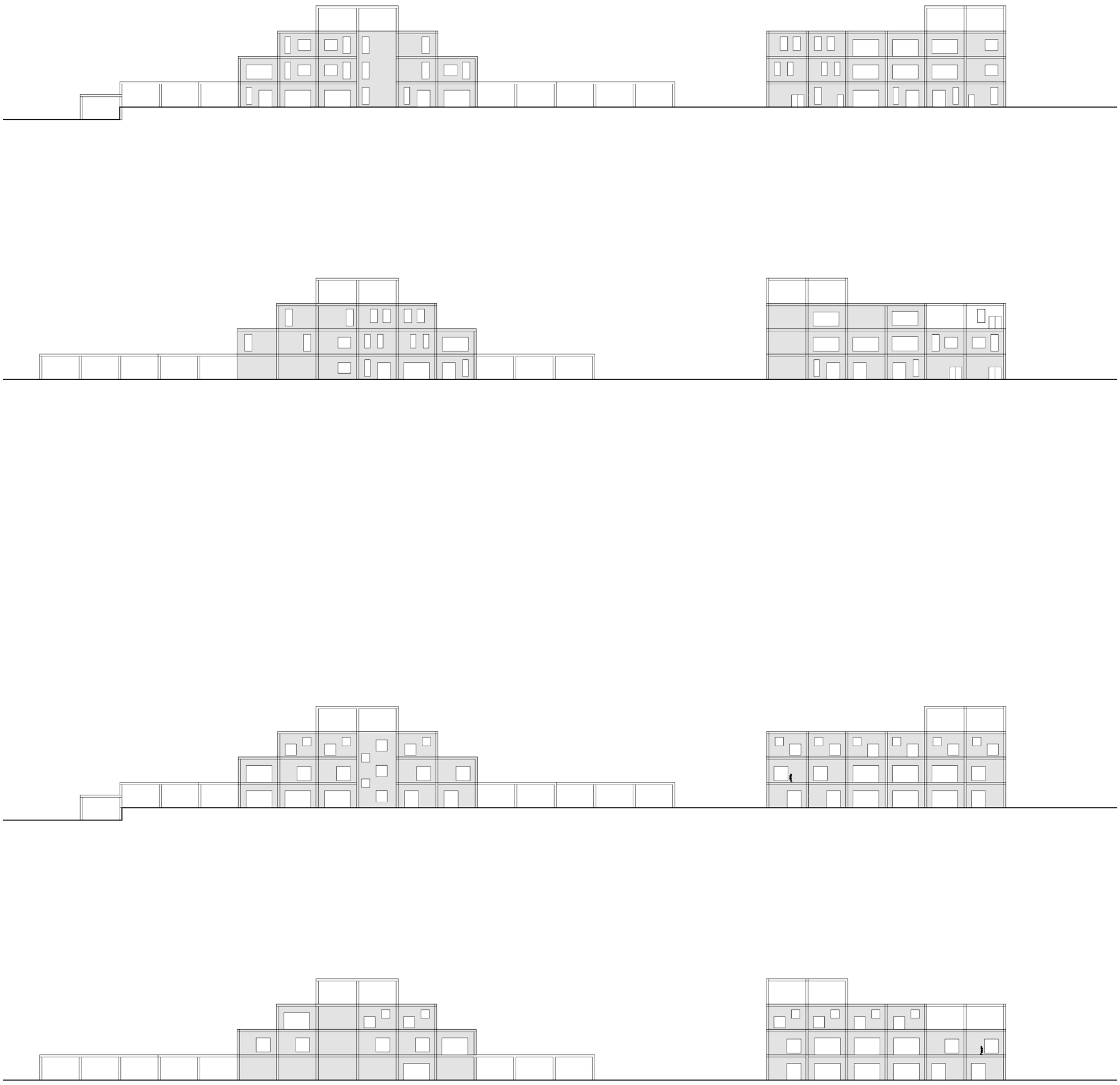
ANNEX 8
Sketches grid

Sketch showing exterior visulisation of the market and the interior of the stalls



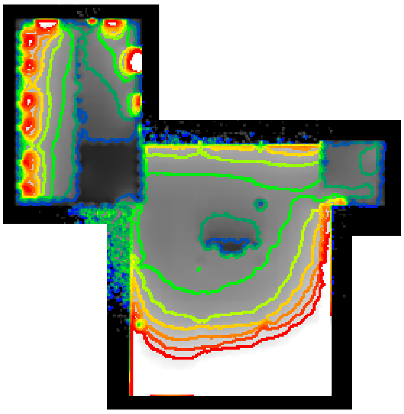
ANNEX 9
Windows studies

Diagrams showing the different windows configuration

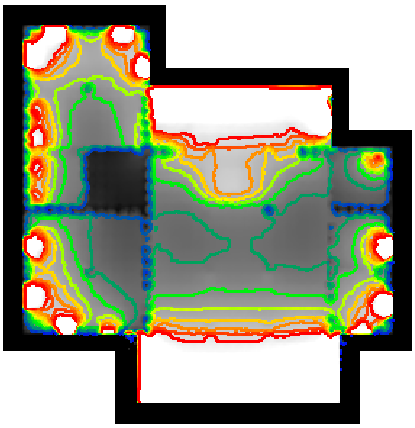


ANNEX 10
Velux process

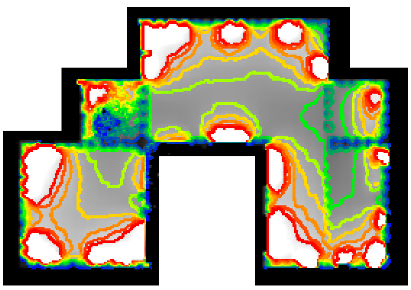
Velux, Window glazing facade, ground floor



Velux, Window glazing facade, first floor



Velux, Window glazing facade, second floor



ANNEX 11
U-value calculation glazing facade

Thermal conductivity of the materials:

Glass: 0,96 W/mK

Air gap: 0,026 W/mK

$$\text{U-value} = \frac{1}{R_{se} + R_{glass} + R_{air\ gap} + R_{glass} + R_{si}}$$

$$\text{U-value} = \frac{1}{0{,}04 + \dfrac{0{,}05}{0{,}96} + \dfrac{0{,}85}{0{,}026} + \dfrac{0{,}05}{0{,}96} + 0{,}17}$$

U-value = 0,03 W/m²K

ANNEX 12
Be18 process

Be18, 15% of windows, streetfood

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
98,6	1,5	100,1
Total energy requirement		21,0

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
74,0	1,5	75,5
Total energy requirement		21,0

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
42,6	1,5	44,1
Total energy requirement		21,0

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		21,0

Contribution to energy requirement

Heat	3,1
El. for operation of bulding	9,2
Excessive in rooms	0,9

Net requirement

Room heating	3,1
Domestic hot water	5,2
Cooling	0,0

Selected electricity requirements

Lighting	4,4
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	4,8
Pumps	0,0
Cooling	0,0
Total el. consumption	35,5

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

Be18, 20% of windows, streetfood

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
98,6	1,5	100,1
Total energy requirement		24,8

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
74,0	1,5	75,5
Total energy requirement		24,8

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
42,6	1,5	44,1
Total energy requirement		24,8

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		24,8

Contribution to energy requirement

Heat	4,6
El. for operation of bulding	11,0
Excessive in rooms	0,0

Net requirement

Room heating	4,6
Domestic hot water	5,2
Cooling	0,0

Selected electricity requirements

Lighting	4,4
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	6,6
Pumps	0,0
Cooling	0,0
Total el. consumption	37,3

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

ANNEX 13
Natural ventilation

Natural ventilation calculations

	Size	Height	Peopleload		Thermal comfort		A
Room name	*m^2*	*m*	*n*	*[met]*	*Summer*	*Winter*	*Olf*
streetfood market	613.4	3.6	52	1.2	21,5-25,5	14-18	
staff area ground floor	92.65	4.1	10	1	21 - 23	23,5 - 25,5	
storage ground floor	145.82	4.1	5	1.6	17-20	8,5 - 12	
common first floor	590.61	4.1	70	1	21 - 23	23,5 - 25,5	
workshop first floor	95.97	4.10	12	1.6	21 - 23	23,5 - 25,5	
staff first floor	192.06	4.10	15	1	21 - 23	23,5 - 25,5	
greenery first floor	194.86	4.10	20	1.2	17-20	8,5 - 12	
storage first floor	43.92	4.10	5	1.2	17-20	8,5 - 12	
common 2nd floor	254.97	4.10	30	1	21 - 23	23,5 - 25,5	
workshop 2nd floor	189.91	4.10	40	1	21 - 23	23,5 - 25,5	
greenery second floor	101.55	4.10	8	1.2	17-20	8,5 - 12	

Windward	0.25		**Vmeteo**	5.5 m/s
Leeward	-0.8		**Vref**	3.135 m/s
roof	-0.7			
Location of neutral plan,	2.0 m		**Buildingvol.**	
Outdoor temperature	12 C		**Volume**	
Zone temperature	22 C			
Discharge coefficient	0.65		**Internal pressure**	
Air density	1.25 kg/m3			

	Area	Eff. Area	Height	Thermal Buoyancy	AFR (thermal)	Pres Coefficient	Wir
	m2	m2	m	pa	m3/s		
WindowS1	5.1	3.315	3.72	-0.699	-3.51	0.25	
WindowS2	5.1	3.315	3.72	-0.699	-3.51	0.25	
WindowW1	5.1	3.315	3.72	-0.699	-3.51	-0.8	
				Massebalance	0.00		Ma

tmospheric		LUX	
	CO_2		*Ventilation rate [m^3/h](mixing)*
1	700	300	5175.86
1	700	300	916.12
1.4	850	100	1068.76
1	700	300	4059.08
1	700	300	1051.73
1	700	300	1540.36
1	700	300	1862.17
1.4	850	100	554.87
1	700	300	2676.43
1	700	300	3098.85
1	700	300	818.77

Pmin -4.3 pa
Pmax 1.5 pa

m3
m3/section/floor

pa 0.25 -0.45

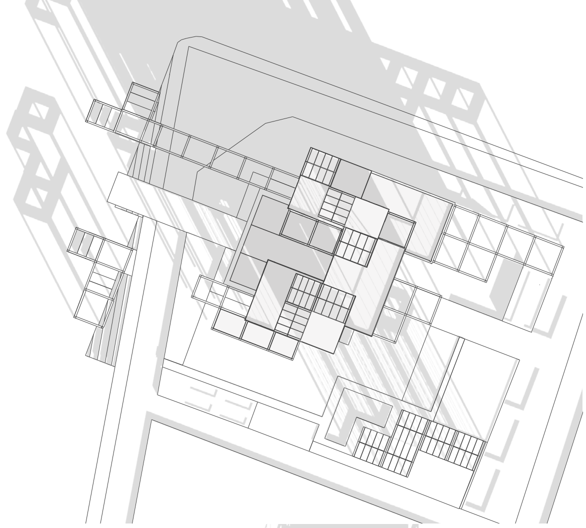
nd pressure pa	**AFR Wind) m3/s**	**Wind pressure pa**	**AFR total m3/s**
1.290	4.762	1.989	4.762
1.290	4.762	1.989	4.762
-5.160	-9.525	-4.461	-9.525

assebalance 0.00 0.00

ANNEX 14
Shadows studies

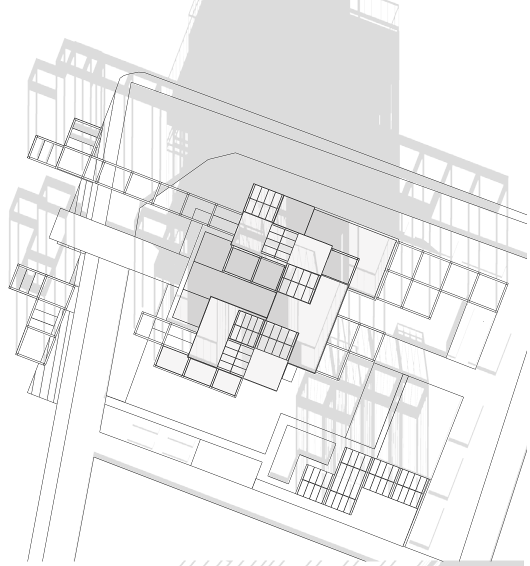
10.00 am _ 21 September

10.00 am _ 21 December

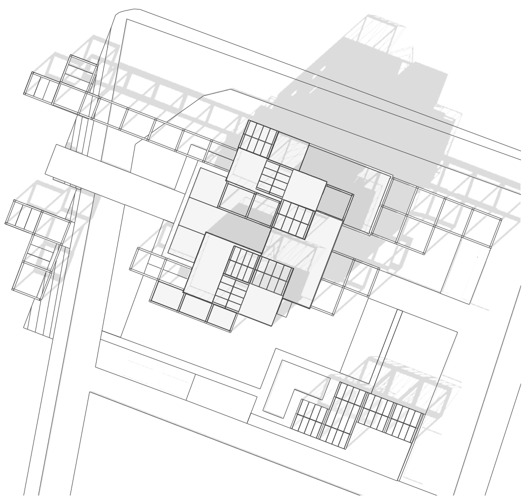


12.00 am _ 21 September

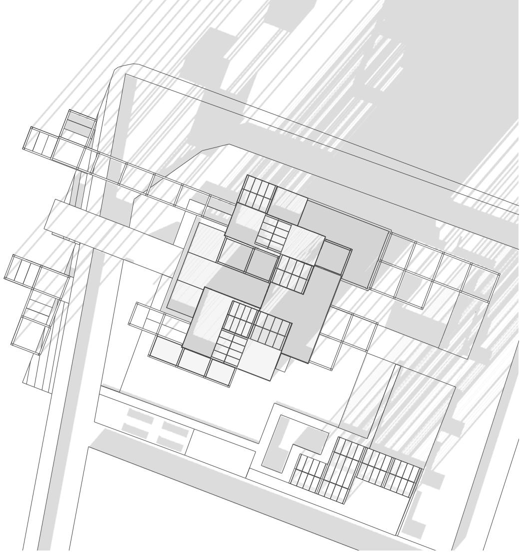
12.00 am _ 21 December



15.00 am _ 21 March



15.00 am _ 21 December



ANNEX 15
Solar cells calculation - First zone streetfood market

The solar cells are calculated for each zone and the energy requirement for each zone is taken from Be18 for every distinct zone. The calculation is made for polycrystaline solar cells with an angle of 30 degrees and after by changing the efficiency of the module, the area and the angle of the solar cells is calculated.

Energy requirement contribution:

Heat : 1,4kWh/m^2 * 0,6 = 0,84kWh/ m^2 year

El. for operation : 8,7kWh/ m^2 * 1,8 = 15,66kWh/ m^2 year

Total energy contribution in Br2020: 0,84+15,66= 16,5kWh/ m^2 year

Energy calculated for the **whole year** of the whole streetfood market (FIRST ZONE):

$$\frac{16{,}5\text{kWh} * 680{,}4\ \text{m}^2}{\text{m}^2\ \text{year}} = 11.226{,}6\text{kWh/ year} \qquad \text{PRIMARY ENERGY}$$

Lighting and appliances:

$$\frac{3{,}9\text{kWh} * 680{,}4\ \text{m}^2}{\text{m}^2\ \text{year}} = 2.653{,}59\text{kWh/ year}$$

2.653,59*1,8=4.776,4kWh/year PRIMARY ENERGY

TOTAL EL. CONSUMPTION:

11.226,6+4.776,4= 16.003kWh/year

Calculation of the PVs in order to cover the energy consumption:

C*D*E*1,8= production (kWh) where

A: the total area of the module in m^2

B: the module efficiency is 18%

C: the installed effect: $\frac{A+B}{100}$ the performance of the PV in case we have full sun (KW peak)

D: the system factor which is freestanding or integrated to the building. In our case it is 0,8.

E: the radiation in kWh/m^2 , the values vary according to the place and from year to year. For horizontally placed PVs, facing south in a slope of 30degrees it is 1152kWh/m^2

A_1 =

$$\frac{100*16.003\text{kWh/year}}{E*B*D*1{,}8} = \frac{100*16.003\ \text{kWh/year}}{1152\text{kWh/m}^2*20*0{,}8*1{,}8} = 50{,}65\ \text{m}^2$$

Solar cells calculation - Second zone common area-staff area-workshop area

Energy requirement contribution:

Heat : 11kWh/m² * 0,6 = 6,6kWh/ m² year

El. for operation : 8,3kWh/ m² * 1,8 = 14,94kWh/ m² year

Total energy contribution in Br2020: 6,6+14,94= 21,54kWh/ m² year

Energy calculated for the **whole year** of the whole SECOND ZONE:

$$\frac{21{,}54\text{kWh} * 1372{,}71\ \text{m}^2}{\text{m}^2\ \text{year}} = 29568{,}17\text{kWh/ year} \quad \text{PRIMARY ENERGY}$$

Lighting and appliances:

$$\frac{3{,}8\text{kWh} * 1372{,}71\text{m}^2}{\text{m}^2\ \text{year}} = 5.216{,}3\text{kWh/ year}$$

5.216,3*1,8=9389,34kWh/year PRIMARY ENERGY

TOTAL EL. CONSUMPTION:

25.568,17+9.389,34= 38.957,51kWh/year

Calculation of the PVs in order to cover the energy consumption:

C*D*E*1,8= production (kWh) where

A: the total area of the module in m²

B: the module efficiency is 18%

C: the installed effect: $\frac{A+B}{100}$ the performance of the PV in case we have full sun (KW peak)

D: the system factor which is freestanding or integrated to the building. In our case it is 0,8.

E: the radiation in kWh/m², the values vary according to the place and from year to year. For horizontally placed PVs, facing south in a slope of 15 degrees it is 1152kWh/m²

A_2 =

$$\frac{100*38.957{,}51\text{kWh/year}}{E*B*D*1{,}8} = \frac{100*38.957{,}51\ \text{kWh/year}}{1152\text{kWh/m}^2*20*0{,}8*1{,}8} = 123{,}31\ \text{m}^2$$

Solar cells calculation - Third zone greenery market-elevators-storage

Energy requirement contribution:

Heat : 0,3kWh/m^2 * 0,6 = 0,18kWh/ m^2 year

El. for operation : 6,9kWh/ m^2 * 1,8 = 12,42kWh/ m^2 year

Total energy contribution in Br2020: 0,18+12,42= 12,6kWh/ m^2 year

Energy calculated for the whole year of the whole SECOND ZONE:

$$\frac{12{,}6kWh * 960{,}24\ m^2}{m^2\ year} = 12.099{,}024kWh/\ year$$ PRIMARY ENERGY

Lighting and appliances:

$$\frac{4{,}4kWh * 960{,}24m^2}{m^2\ year} = 4.225{,}06kWh/\ year$$

4.225,06*1,8=7.605,1kWh/year PRIMARY ENERGY

TOTAL EL. CONSUMPTION:

12.099,024+7.605,1= 19.704,13kWh/year

Calculation of the PVs in order to cover the energy consumption:

C*D*E*1,8= production (kWh) where

A: the total area of the module in m^2

B: the module efficiency is 18%

C: the installed effect: $\frac{A+B}{100}$ the performance of the PV in case we have full sun (KW peak)

D: the system factor which is freestanding or integrated to the building. In our case it is 0,8.

E: the radiation in kWh/m^2 , the values vary according to the place and from year to year. For horizontally placed PVs, facing south in a slope of 15 degrees it is 1152kWh/m^2

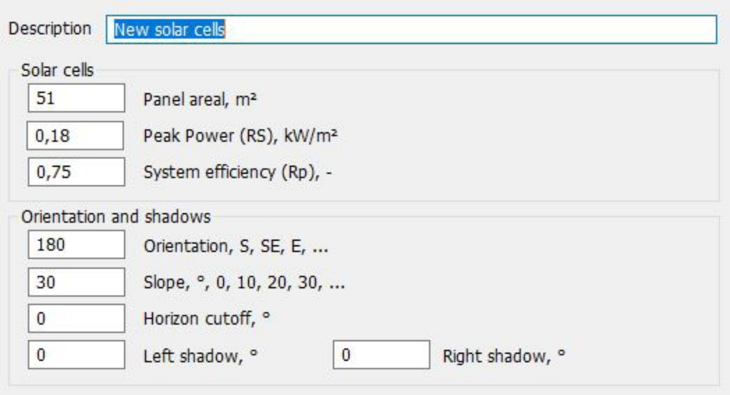
A_3 =

$$\frac{100*19.704{,}13kWh/year}{E*B*D*1{,}8} = \frac{100*19.704{,}13\ kWh/year}{1152kWh/m^2*20*0{,}8*1{,}8} = 62{,}37\ m^2$$

TOTAL AREA: $A_1 + A_2 + A_3$ = 236,33m^2 solar cells

ANNEX 16
Conversion from crystalline to thin film panels

First zone thin film calculation



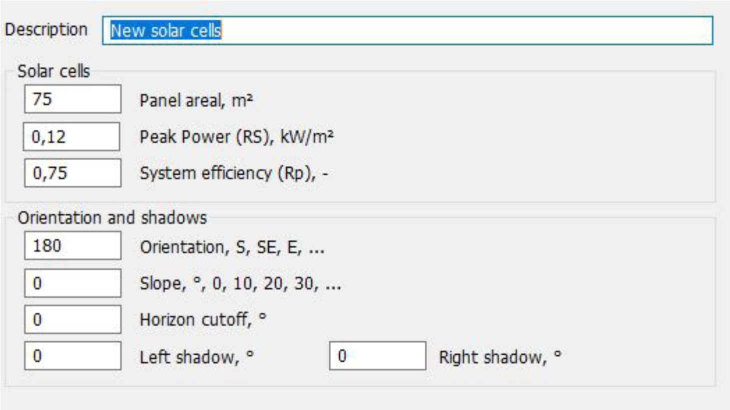
Description: New solar cells

Solar cells

51	Panel areal, m²
0,18	Peak Power (RS), kW/m²
0,75	System efficiency (Rp), -

Orientation and shadows

180	Orientation, S, SE, E, ...		
30	Slope, °, 0, 10, 20, 30, ...		
0	Horizon cutoff, °		
0	Left shadow, °	0	Right shadow, °



Description: New solar cells

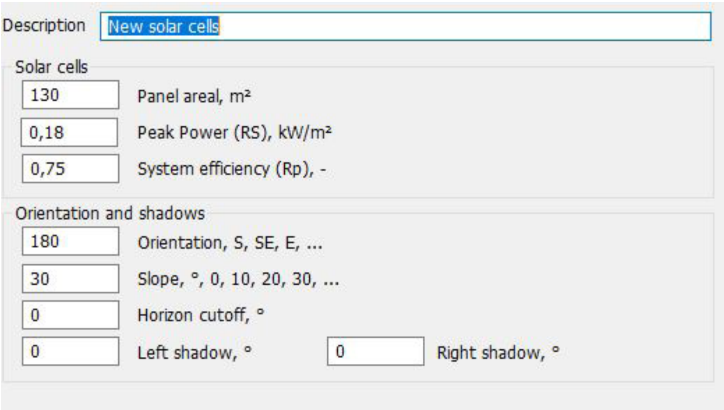
Solar cells

75	Panel areal, m²
0,12	Peak Power (RS), kW/m²
0,75	System efficiency (Rp), -

Orientation and shadows

180	Orientation, S, SE, E, ...		
0	Slope, °, 0, 10, 20, 30, ...		
0	Horizon cutoff, °		
0	Left shadow, °	0	Right shadow, °

Second zone thin film calculation



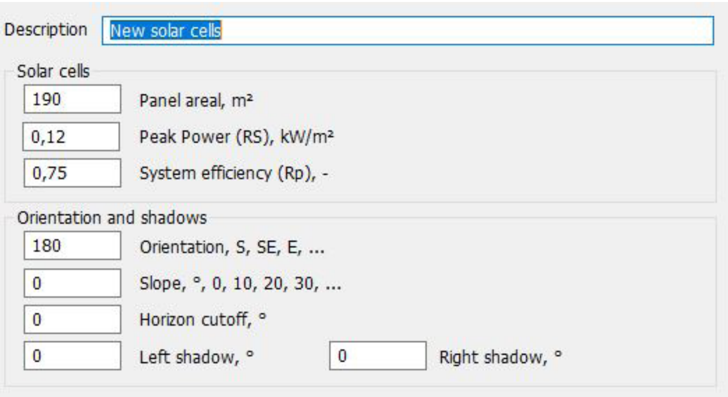
Description: New solar cells

Solar cells

130	Panel areal, m²
0,18	Peak Power (RS), kW/m²
0,75	System efficiency (Rp), -

Orientation and shadows

180	Orientation, S, SE, E, ...		
30	Slope, °, 0, 10, 20, 30, ...		
0	Horizon cutoff, °		
0	Left shadow, °	0	Right shadow, °



Description: New solar cells

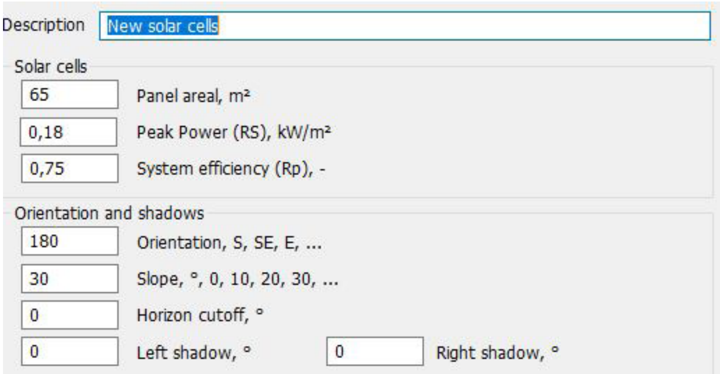
Solar cells

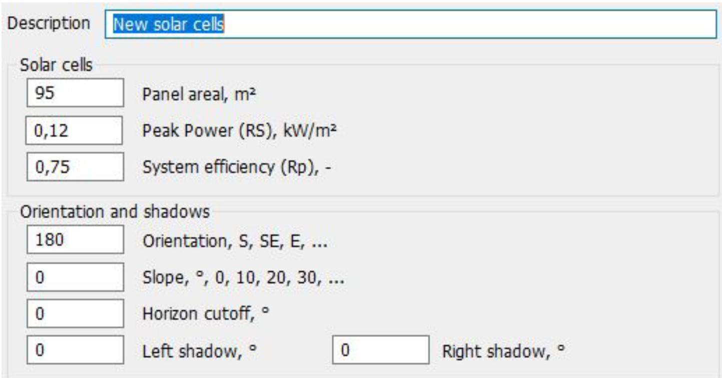
190	Panel areal, m²
0,12	Peak Power (RS), kW/m²
0,75	System efficiency (Rp), -

Orientation and shadows

180	Orientation, S, SE, E, ...		
0	Slope, °, 0, 10, 20, 30, ...		
0	Horizon cutoff, °		
0	Left shadow, °	0	Right shadow, °

Third zone thin film calculation


Description New solar cells
Solar cells
65 Panel areal, m²
0,18 Peak Power (RS), kW/m²
0,75 System efficiency (Rp), -
Orientation and shadows
180 Orientation, S, SE, E, ...
30 Slope, °, 0, 10, 20, 30, ...
0 Horizon cutoff, °
0 Left shadow, ° 0 Right shadow, °


Description New solar cells
Solar cells
95 Panel areal, m²
0,12 Peak Power (RS), kW/m²
0,75 System efficiency (Rp), -
Orientation and shadows
180 Orientation, S, SE, E, ...
0 Slope, °, 0, 10, 20, 30, ...
0 Horizon cutoff, °
0 Left shadow, ° 0 Right shadow, °

ANNEX 18
Be18

Be18, key numbers with solar cells, first zone

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
98,2	1,5	99,7
Total energy requirement		-0,0

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
73,7	1,5	75,2
Total energy requirement		-0,0

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
42,5	1,5	44,0
Total energy requirement		-0,0

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		-0,0

Contribution to energy requirement

Heat	2,1
El. for operation of bulding	-1,4
Excessive in rooms	0,9

Net requirement

Room heating	2,1
Domestic hot water	5,3
Cooling	0,0

Selected electricity requirements

Lighting	3,9
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	4,8
Pumps	0,0
Cooling	0,0
Total el. consumption	32,3

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	10,2
Wind mills	0,0

Be18, key numbers with solar cells, secondzone

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
96,6	1,5	98,1
Total energy requirement		-0,5

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
72,5	1,5	74,0
Total energy requirement		-0,5

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
41,7	1,5	43,2
Total energy requirement		-0,5

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		-0,5

Contribution to energy requirement

Heat	8,7
El. for operation of bulding	-4,6
Excessive in rooms	0,8

Net requirement

Room heating	8,7
Domestic hot water	5,2
Cooling	0,0

Selected electricity requirements

Lighting	3,8
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	4,5
Pumps	0,0
Cooling	0,0
Total el. consumption	31,0

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	12,9
Wind mills	0,0

Be18, key numbers with solar cells, third zone

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
96,6	1,5	98,1
Total energy requirement		-0,5

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
72,5	1,5	74,0
Total energy requirement		-0,5

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
41,7	1,5	43,2
Total energy requirement		-0,5

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
33,0	1,5	34,5
Total energy requirement		-0,5

Contribution to energy requirement

Heat	8,7
El. for operation of bulding	-4,6
Excessive in rooms	0,8

Net requirement

Room heating	8,7
Domestic hot water	5,2
Cooling	0,0

Selected electricity requirements

Lighting	3,8
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	4,5
Pumps	0,0
Cooling	0,0
Total el. consumption	31,0

Heat loss from installations

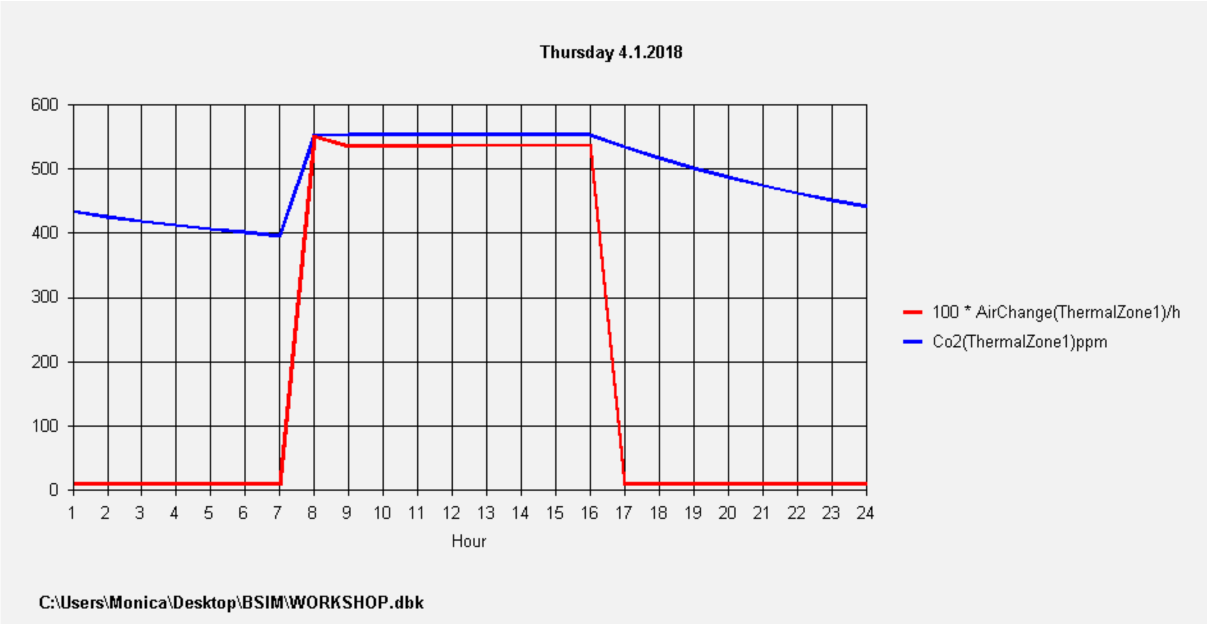
Room heating	0,0
Domestic hot water	0,0

Output from special sources

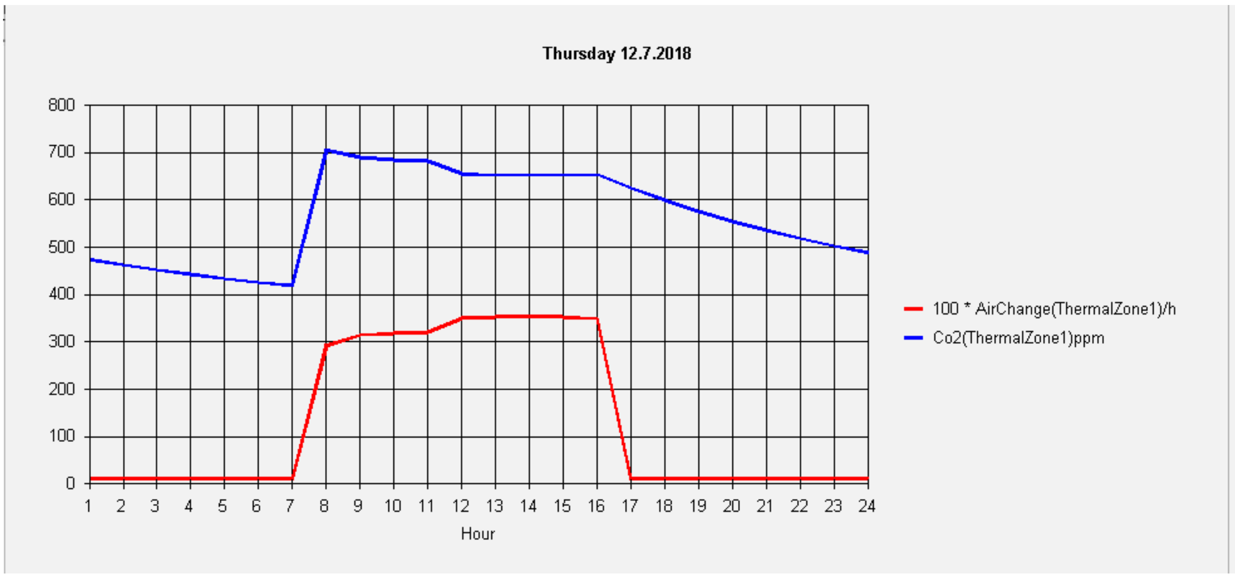
Solar heat	0,0
Heat pump	0,0
Solar cells	12,9
Wind mills	0,0

ANNEX 19
BSim-Workshop

CO2 concentration - 04.01.2018



CO2 concentration - 12.07.2018



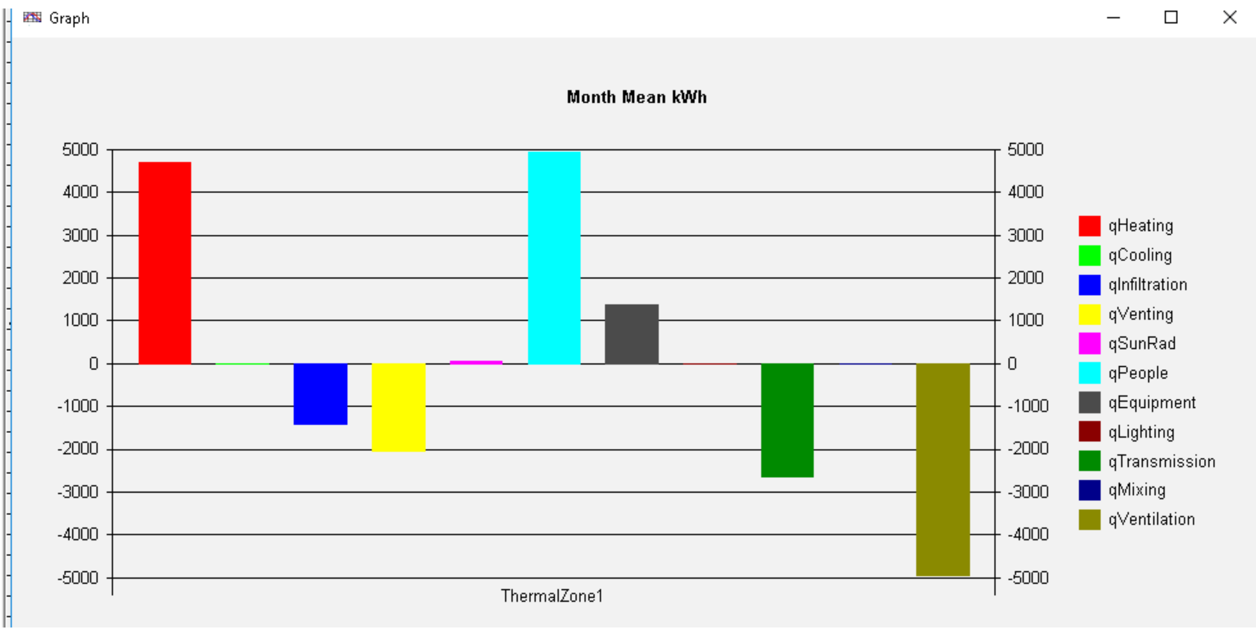
Heat balance table

Options | Moisture | Simulation | HeatBalance | Parameters | Tables

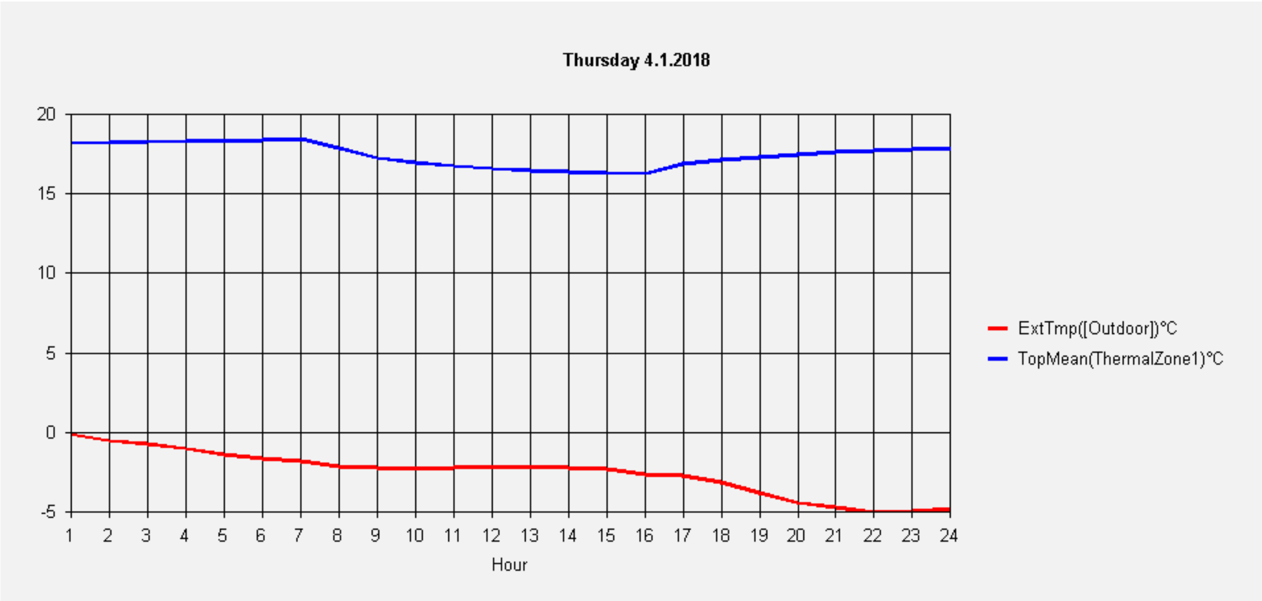
2018 | Month | Hours | ThermalZone1

ThermalZon	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	4698.30	610.67	552.57	617.14	546.73	368.17	175.10	3.55	3.50	127.85	508.31	574.09	610.61
qCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qInfiltration	-1423.14	-174.19	-158.67	-178.57	-119.14	-95.29	-77.60	-59.06	-61.89	-73.05	-103.95	-148.62	-173.10
qVenting	-2050.20	-3.05	0.00	-133.16	0.00	-265.27	-464.96	-370.77	-401.53	-411.47	0.00	0.00	0.00
qSunRad	49.50	1.31	2.31	4.56	5.45	6.11	6.38	5.97	5.78	5.13	3.87	1.63	0.99
qPeople	4932.90	434.70	378.00	415.80	396.90	434.70	396.90	415.80	434.70	378.00	434.70	415.80	396.90
qEquipment	1377.58	142.16	123.62	135.98	91.73	100.47	91.73	96.10	100.47	87.36	142.16	135.98	129.80
qLighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qTransmissio	-2630.32	-343.45	-317.65	-347.67	-221.44	-163.96	-127.56	-91.59	-81.03	-113.83	-182.24	-284.21	-355.69
qMixing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qVentilation	-4954.62	-668.15	-580.19	-514.09	-700.24	-384.92	0.00	0.00	0.00	0.00	-802.85	-694.67	-609.51
Sum	0.00	0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	-0.00
tOutdoor me	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C	20.3	18.1	18.0	17.1	19.5	21.2	22.4	23.9	24.2	22.2	20.4	18.9	18.1
AirChange(/	1.5	1.6	1.5	1.4	1.5	1.5	1.1	1.6	1.9	0.9	1.5	1.5	1.4
Rel. Moistur	40.5	30.8	30.7	29.8	36.0	42.0	49.5	53.1	49.0	50.0	47.2	35.7	31.8
Co2(ppm)	465.1	455.8	452.3	460.3	449.5	471.2	500.6	469.3	461.9	502.6	455.5	455.0	447.5
PAQ(-)	0.5	0.7	0.7	0.8	0.6	0.4	0.2	0.0	0.1	0.2	0.4	0.6	0.7
Hours > 21	3830	0	0	0	128	478	656	744	744	720	307	48	5
Hours > 26	97	0	0	0	0	0	2	44	51	0	0	0	0
Hours > 27	44	0	0	0	0	0	0	24	20	0	0	0	0
Hours < 20	4288	732	665	718	460	142	20	0	0	0	282	560	709
FanPow	1180.27	165.56	143.61	136.76	151.53	112.97	0.00	0.00	0.00	0.00	163.34	156.24	150.25
HtRec	7640.34	1622.34	1356.67	1305.82	456.36	82.31	0.00	0.00	0.00	0.00	229.08	1118.52	1469.24
ClRec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HtCoil	7.09	0.00	0.00	7.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClCoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidif	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorHeat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorCool	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

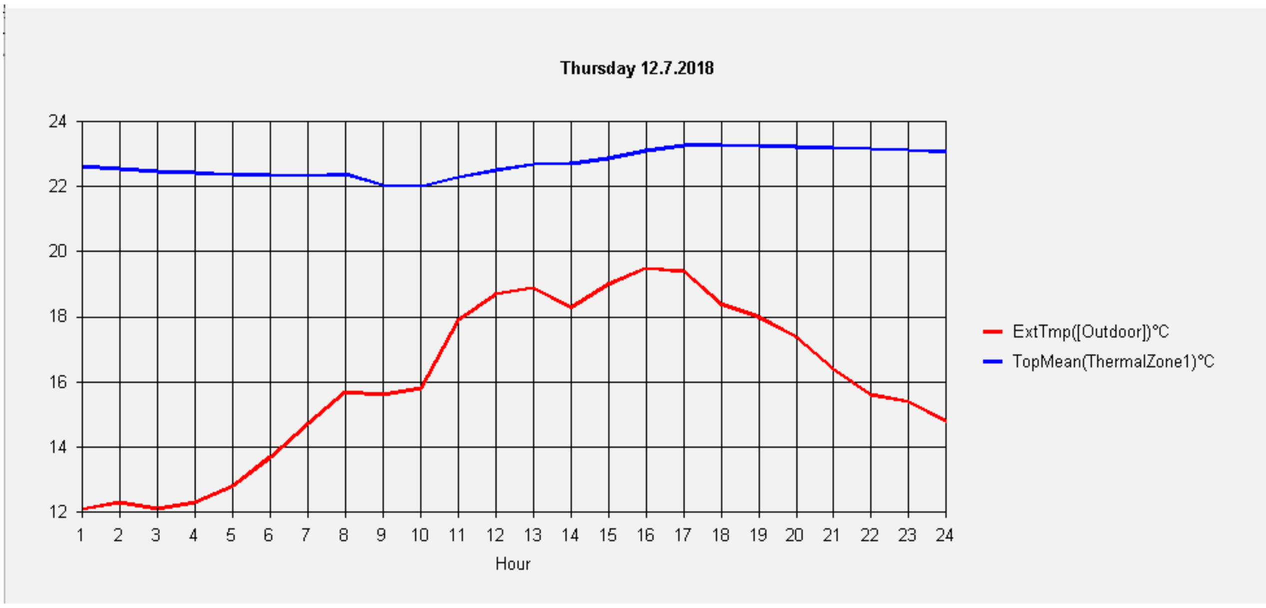
Heat balnce chart



Temperature - 04.01.2018



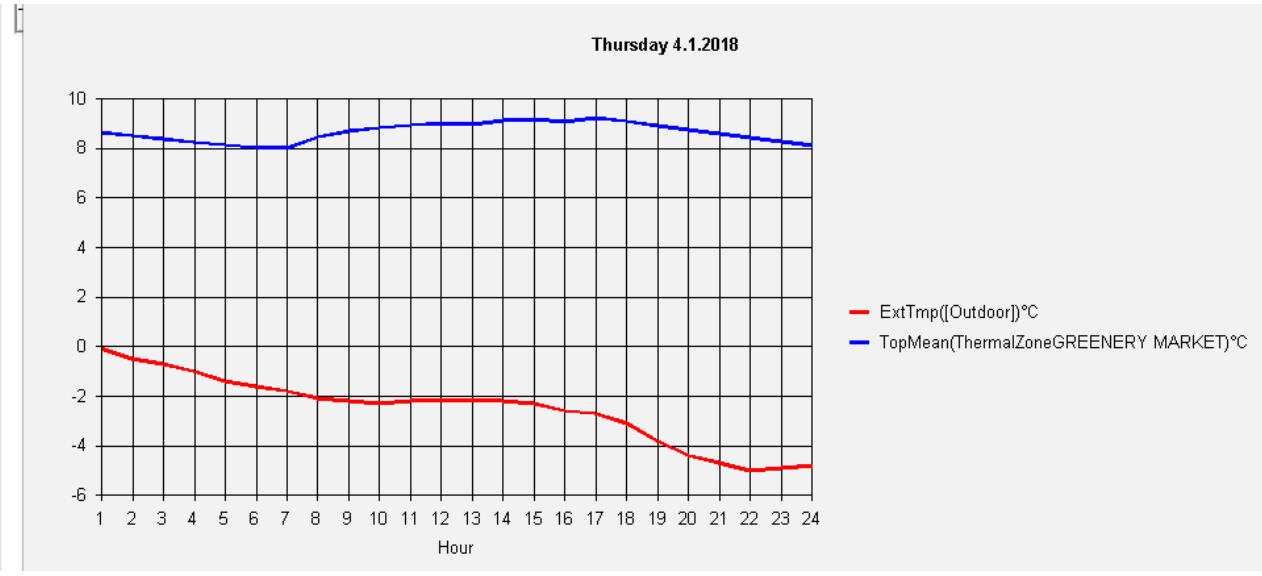
Temperature - 12.07.2018



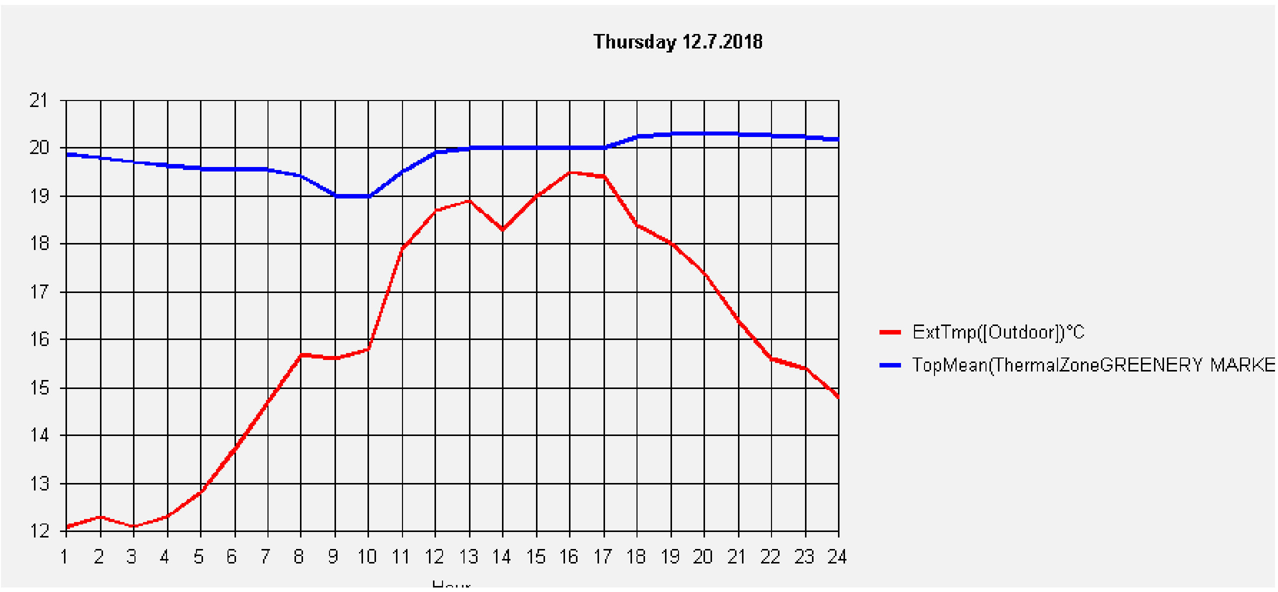
Total temperature in a year, in the working hours

ANNEX 20
BSim-Greenery market

CO2 concentration - 04.01.2018



CO2 concentration - 12.07.2018



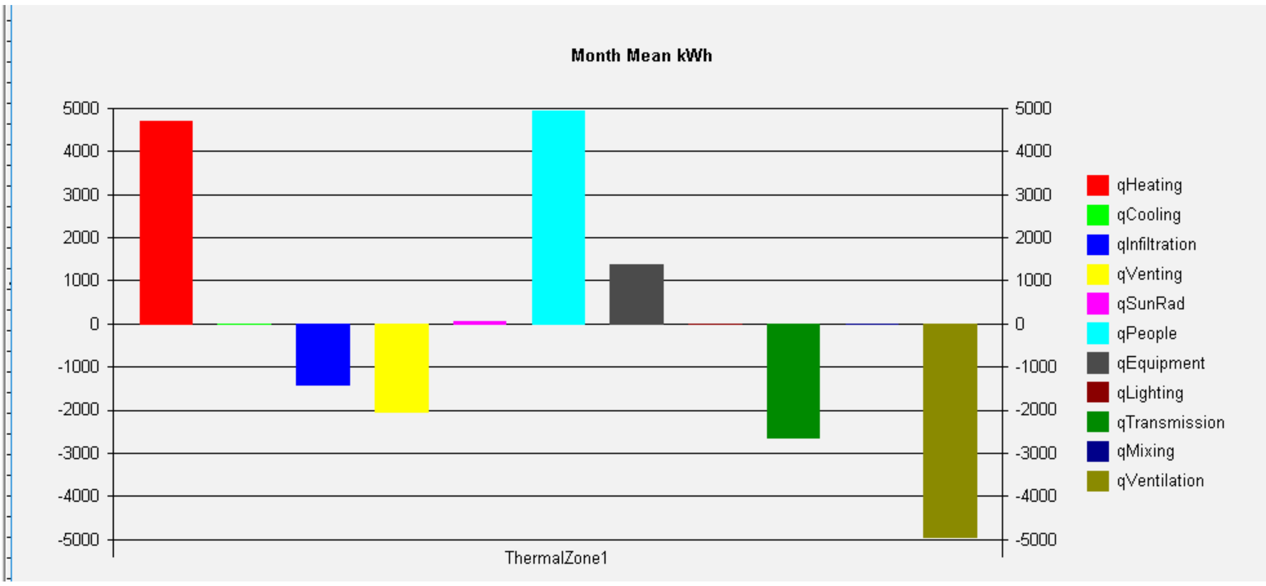
Heat balance table

Options | Moisture | Simulation | HeatBalance | Parameters | Tables

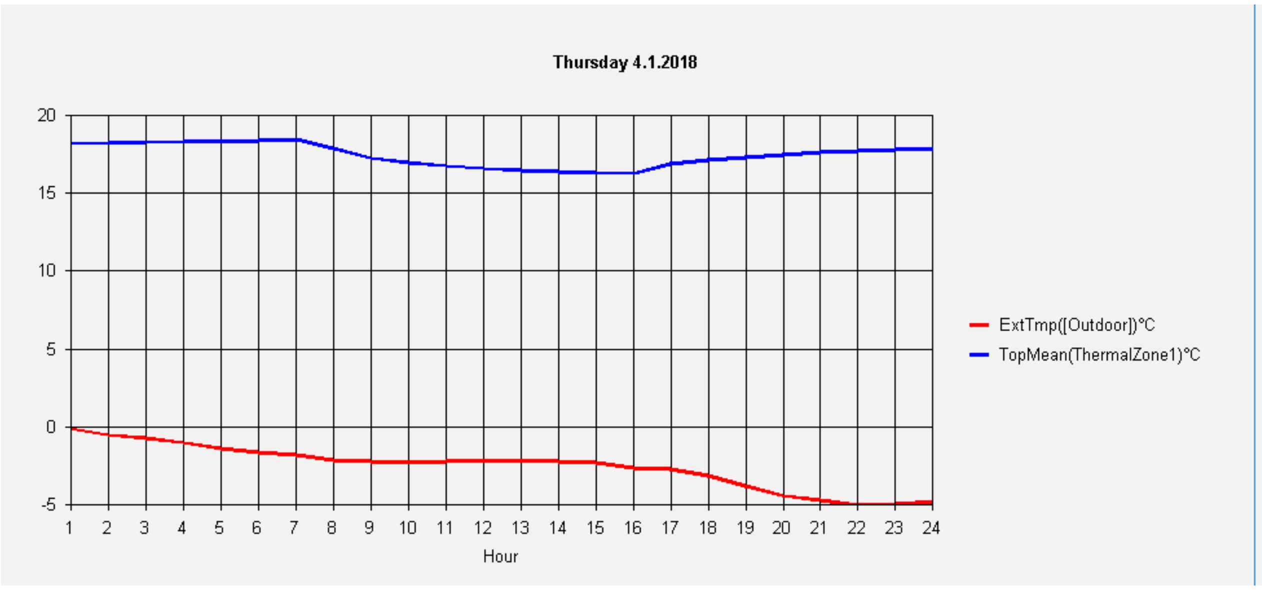
2018 | Month | Hours | ThermaZone1

ThermaZon	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	4698.30	610.67	552.57	617.14	546.73	368.17	175.10	3.55	3.50	127.85	508.31	574.09	610.61
qCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qInfiltration	-1423.14	-174.19	-158.67	-178.57	-119.14	-95.29	-77.60	-59.06	-61.89	-73.05	-103.95	-148.62	-173.10
qVenting	-2050.20	-3.05	0.00	-133.16	0.00	-265.27	-464.96	-370.77	-401.53	-411.47	0.00	0.00	0.00
qSunRad	49.50	1.31	2.31	4.56	5.45	6.11	6.38	5.97	5.78	5.13	3.87	1.63	0.99
qPeople	4932.90	434.70	378.00	415.80	396.90	434.70	396.90	415.80	434.70	378.00	434.70	415.80	396.90
qEquipment	1377.58	142.16	123.62	135.98	91.73	100.47	91.73	96.10	100.47	87.36	142.16	135.98	129.80
qLighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qTransmissi	-2630.32	-343.45	-317.65	-347.67	-221.44	-163.96	-127.56	-91.59	-81.03	-113.83	-182.24	-284.21	-355.69
qMixing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qVentilation	-4954.62	-668.15	-580.19	-514.09	-700.24	-384.92	0.00	0.00	0.00	0.00	-802.85	-694.67	-609.51
Sum	0.00	0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	-0.00
tOutdoor me	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C	20.3	18.1	18.0	17.1	19.5	21.2	22.4	23.9	24.2	22.2	20.4	18.9	18.1
AirChange(/	1.5	1.6	1.5	1.4	1.5	1.5	1.1	1.6	1.9	0.9	1.5	1.5	1.4
Rel. Moistur	40.5	30.8	30.7	29.8	36.0	42.0	49.5	53.1	49.0	50.0	47.2	35.7	31.8
Co2(ppm)	465.1	455.8	452.3	460.3	449.5	471.2	500.6	469.3	461.9	502.6	455.5	455.0	447.5
PAQ(-)	0.5	0.7	0.7	0.8	0.6	0.4	0.2	0.0	0.1	0.2	0.4	0.6	0.7
Hours > 21	3830	0	0	0	128	478	656	744	744	720	307	48	5
Hours > 26	97	0	0	0	0	0	2	44	51	0	0	0	0
Hours > 27	44	0	0	0	0	0	0	24	20	0	0	0	0
Hours < 20	4288	732	665	718	460	142	20	0	0	0	282	560	709
FanPow	1180.27	165.56	143.61	136.76	151.53	112.97	0.00	0.00	0.00	0.00	163.34	156.24	150.25
HtRec	7640.34	1622.34	1356.67	1305.82	456.36	82.31	0.00	0.00	0.00	0.00	229.08	1118.52	1469.24
ClRec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HtCoil	7.09	0.00	0.00	7.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClCoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidif	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorHeat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorCool	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

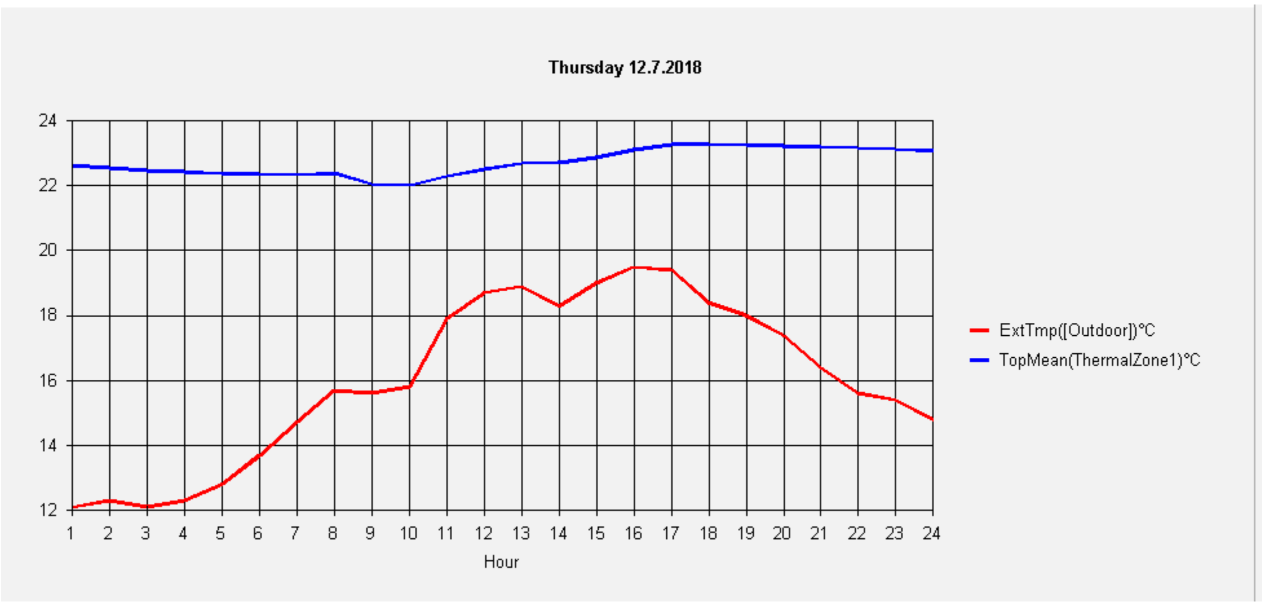
Heat balnce chart



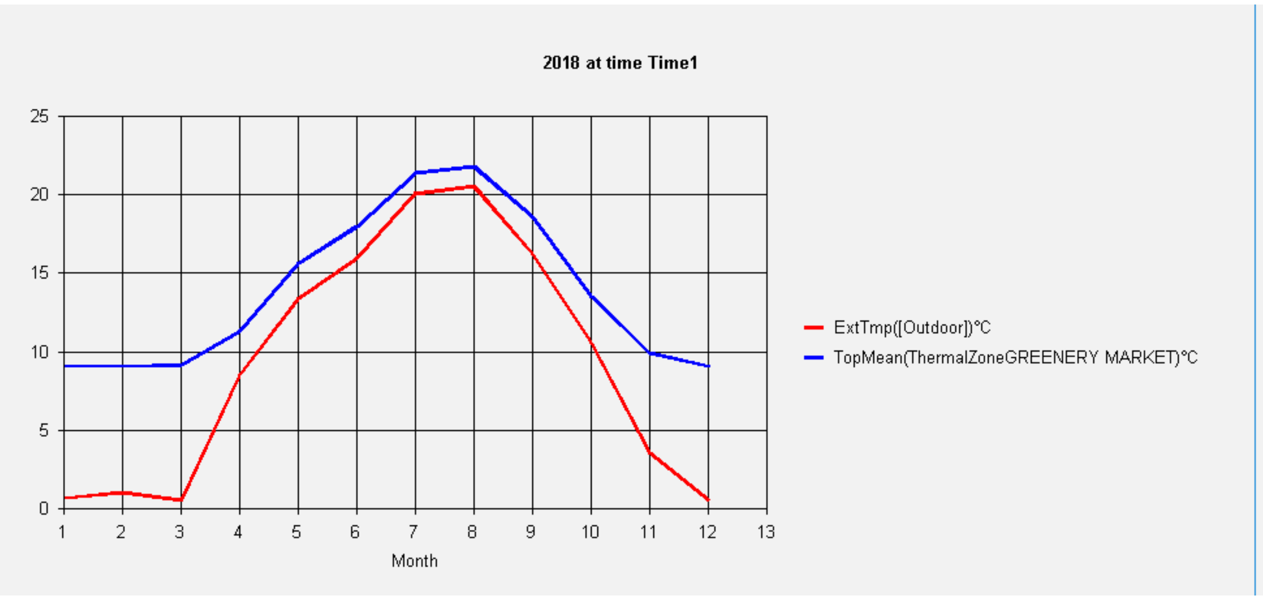
Temperature - 04.01.2018



Temperature - 12.07.2018



Total temperature in a year, in the working hours



ANNEX 21
Heating sistem

Excell calculations for radiator in the toilets

Parameters	
Area (mq)	3592
height of ceilings (m)	3,5
thermal coefficient (Kcal/mc)	40
Power single heater (Watt)	130
Number of heaters for radiator	12

RADIATORS DIMENTIONS: 400 mm x 300 mm							
	square meters	cubic meters	Kcal	Kwatt	Watt	Heaters	Radiator
Ground Floor							
Toilet 1	10	30	1200	1,4	1.392,1	11	1
Toilet 2	10	30	1200	1,4	1.392,1	11	1
First Floor							
Toilet 1	10	30	1200	1,4	1.392,1	11	1
Toilet 2	10	30	1200	1,4	1.392,1	11	1
Second Floor							
Toilet 1	10	30	1200	1,4	1.392,1	11	1
Toilet 2	10	30	1200	1,4	1.392,1	11	1

Excell calculations for radiator in common area and in the streetfood

Parameters	
Area (mq)	3592
height of ceilings (m)	4,5
thermal coefficient (Kcal/mc)	40
Power single heater (Watt)	583
Number of heaters for radiator	54

RADIATORS DIMENTIONS: 1800 mm x 300 mm							
	square meters	cubic meters	Kcal	Kwatt	Watt	Heaters	Radiator
Ground Floor							
Common area	614	2763	110520	128,2	128.213,5	220	4
First Floor							
Common area	580	2030	81200	94,2	94.199,5	162	3
Second Floor							
Common area	350	1225	49000	56,8	56.844,5	98	2

Excell calculations for radiator in greenery market, workshop and staff area

Parameters	
Area (mq)	3592
height of ceilings (m)	4,5
thermal coefficient (Kcal/mc)	40
Power single heater (Watt)	454
Number of heaters for radiator	42

RADIATORS DIMENTIONS: 1600 mm x 300 mm							
	square meters	cubic meters	Kcal	Kwatt	Watt	Heaters	Radiator
Ground Floor							
Storage	155	697,5	27900	32,4	32.366,6	71	2
Staff area	96	336	13440	15,6	15.591,6	34	1
First Floor							
Greenery market	190	665	26600	30,9	30.858,5	68	2
Workshop	90	315	12600	14,6	14.617,2	32	1
Storage	50	225	9000	10,4	10.440,8	23	1
Staff canteen	115	402,5	16100	18,7	18.677,5	41	1