AQUATECTURE

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MASTER THESIS

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Group 4

Bjarne Winther

// READERS GUIDE

The following report documents and publishes the master thesis, Aquatecture, at architecture and design in the spring of 2019 created by group 4: Bjarne Winther. The report documents the research and analysis through sketching to the finished product. The sketching phase is presented to provide the reader context for the process that has led to the finished design. The report is structured into seven parts with an adjacent appendix in the following order: Introduction, Program, Site, Presentation, Sketching phase, Synthesis, Epilogue. The appendix contains further documentation of the technical calculations and simulation data for the finished design along with the iterations that have been tested doing the design process. The referencing is done in accordance with the Harvard system both in-text and the complete reference list at the end of the report.

// ABSTRACT

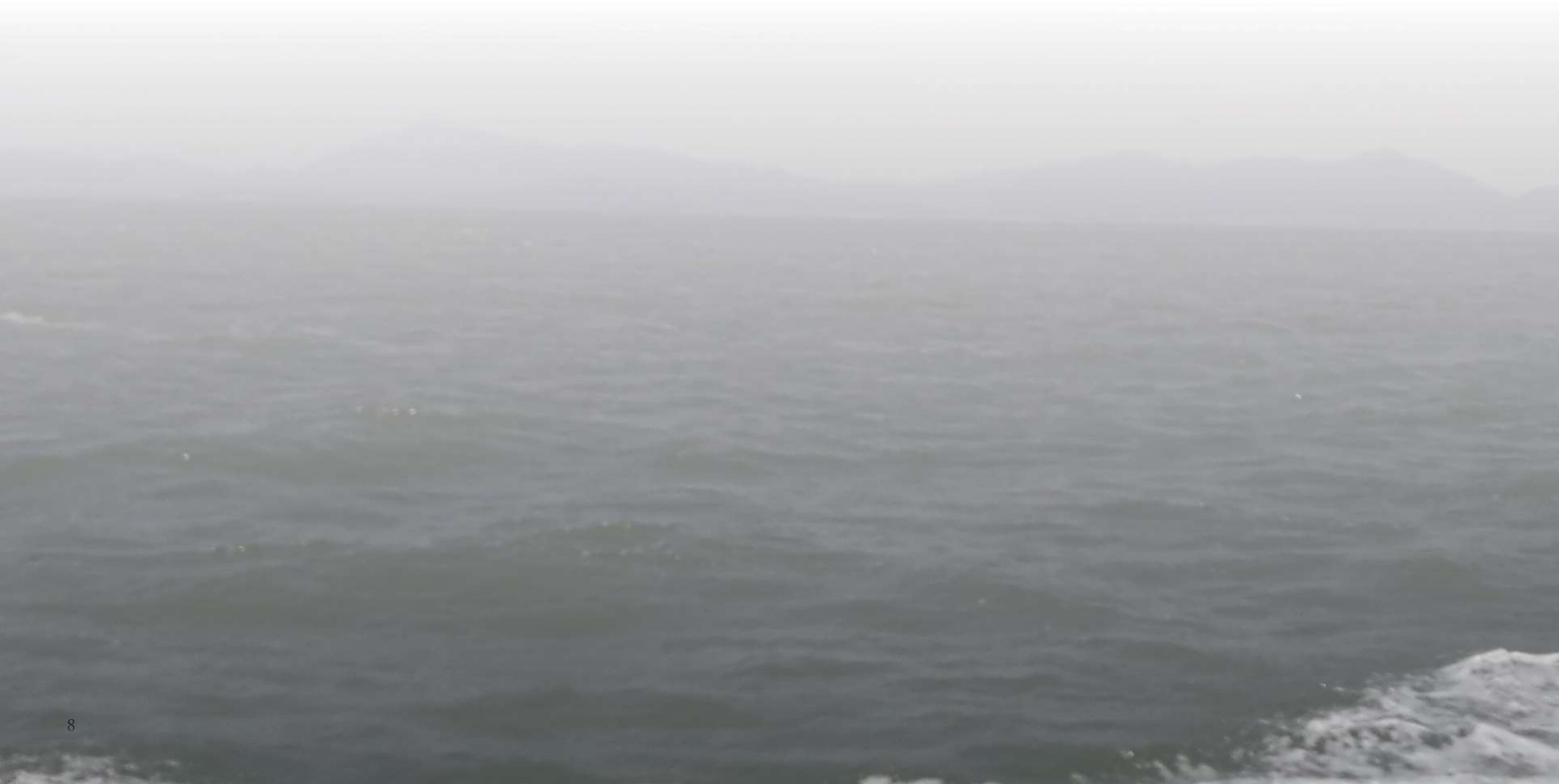
This master thesis, by Bjarne Winther, concentrates on rethinking our way of living, and reconsiders the organisational forming of cities for future generations to come. The title Aquatecture comes from the project's objective of fashioning a housing complex upon the water surface. Interaction between the residents on both land and on water is prioritized as the complex offers the residents an ease of access to an internal courtyard and the surrounding water directly from the homes. The housing complex has for this research been situated in Limfjorden between Aalborg, Egholm and Nørresundby, as aalborg only has a minor part of the city that is not threatened to be submerged and larger areas of the city under threat of periodically flooding. Aquatecture offers a way of living within the city close to water without the risk of being flooded as the building hovers with the rising and falling of the water levels.

Additionally, to rethinking the way of living in cities and on water, the building is built for zero energy standards in consumption of energy and comfortable indoor climates, to offer a justifiable alternative for building strategies in the future for coastal cities, in addition proposing a way of expanding.

Aquatecture takes a holistic design process of the three focal points; sustainability, modern living and the interaction with the water. Thereby, the result of this thesis is a sustainable housing complex dealing with the impending climate changes through; architecture, construction and indoor comfort, the housing complex has been designed to benefit from the close connection to the water foundation whilst securing for submerging as the icecaps melt, providing comfortable living standards in close connection to water.

// INDEX

INTRODUCTION



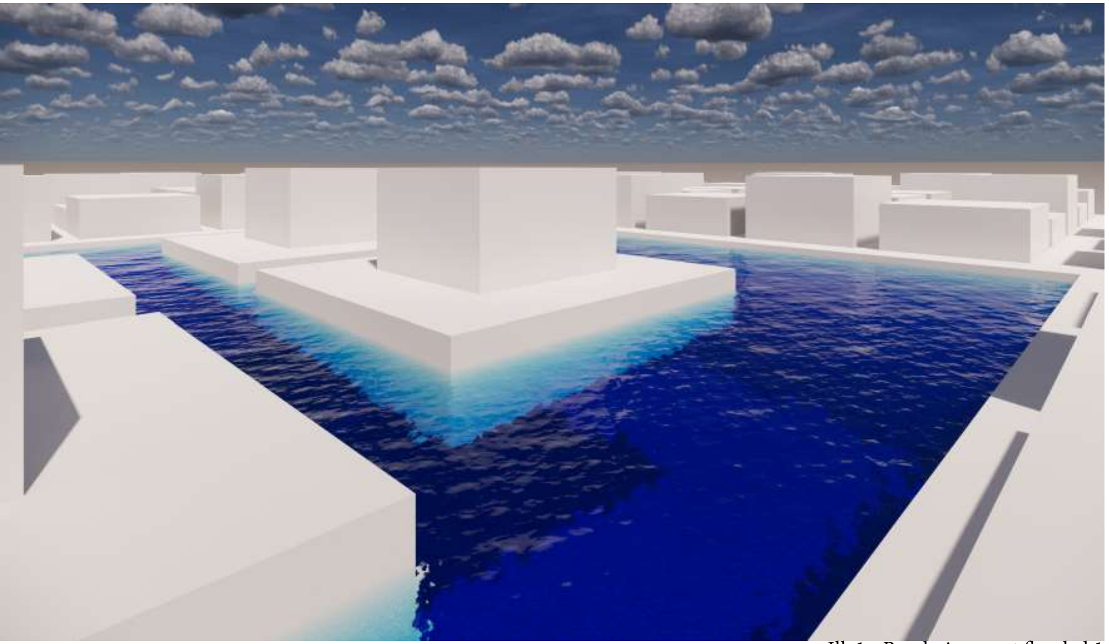
COULD A NEW WAY OF LIVING, BE FLOATING ON WATER?
INSTEAD OF STUCK TO THE GROUND.

// MOTIVATION

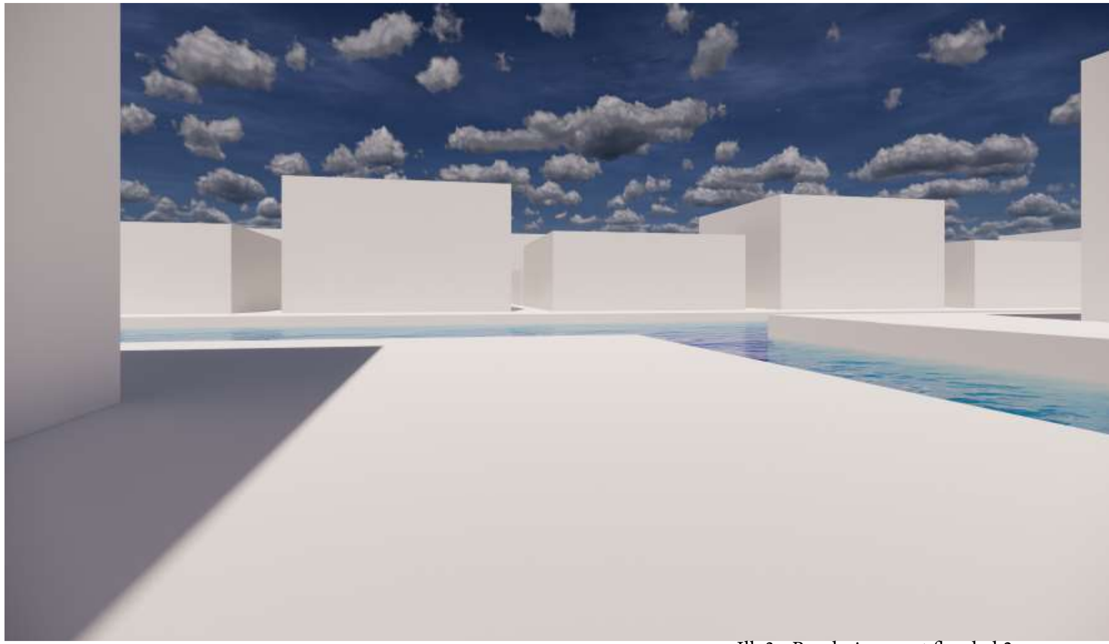
The subject of developing architecture at sea will stand as the primary architectural topic throughout the thesis. The opportunity of rethinking our ways of living, while investigating the architectural principles that can create the framework which facilitates this exploration into living off the coast.
The main drive behind the topic of developing new ideas of living has mainly focused on adapting and dealing with climate changes and the rise in the pollution that comes with living in dense environments and increased living standards during the last century. Looking at the predicted growth in world population, this problem only looks to extend even further as an increased in living standards across the globe is to be expected in the future.
A result of global warming the sea levels are estimated to rise, influencing a large amount of the urban coastal cities around the world, threating a significant amount of the human population on a larger timescale.
This forms a drive to explore and develop innovative solutions within the aspects of architecture and engineering, solving a dilemma which can end up affecting a large proportion of future society.

SOCIAL SUSTAINABILITY
In an era where it's continuously more common not to have contact to your neighbour and the people living in your neighbourhood, the importance of creating spaces facilitating a socially sustainable environment falls largely on the architect. Through working with the functions and the composition that is desired within the project in addition to the functions that can be implemented to create an environment that eases social interaction among the users. Considering which functions that can be shared and fundamentally needed by the individual to achieve an expected living standard.

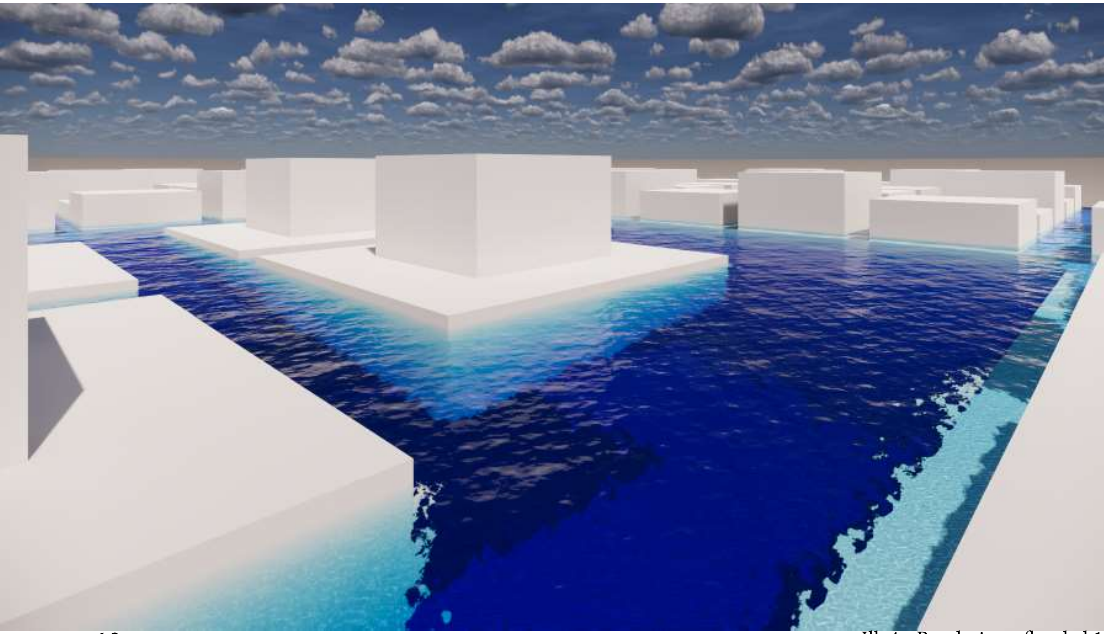
ENVIRONMENTAL SUSTAINABILITY
The prospect of building futuristic concepts release the possibilities of breaking out of the regular constraints within building typologies and norms, aiming for minimising the environmental impact. By using modern technology within passive and active strategies combined with materials lowering the environmental impact of the buildings embedded energy for utilities. By using knowledge and principles of passive and active strategies focusing on reducing the environmental impact, the importance of creating a suitable indoor climate for the inhabitants are still prioritised.



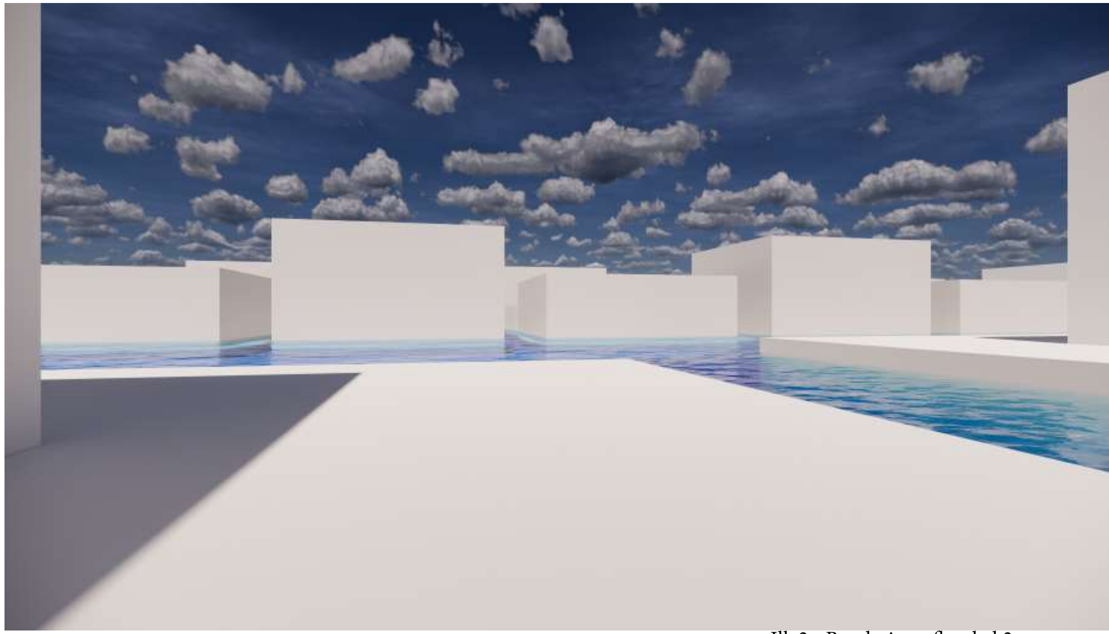
Ill. 1 - Rendering - not flooded 1



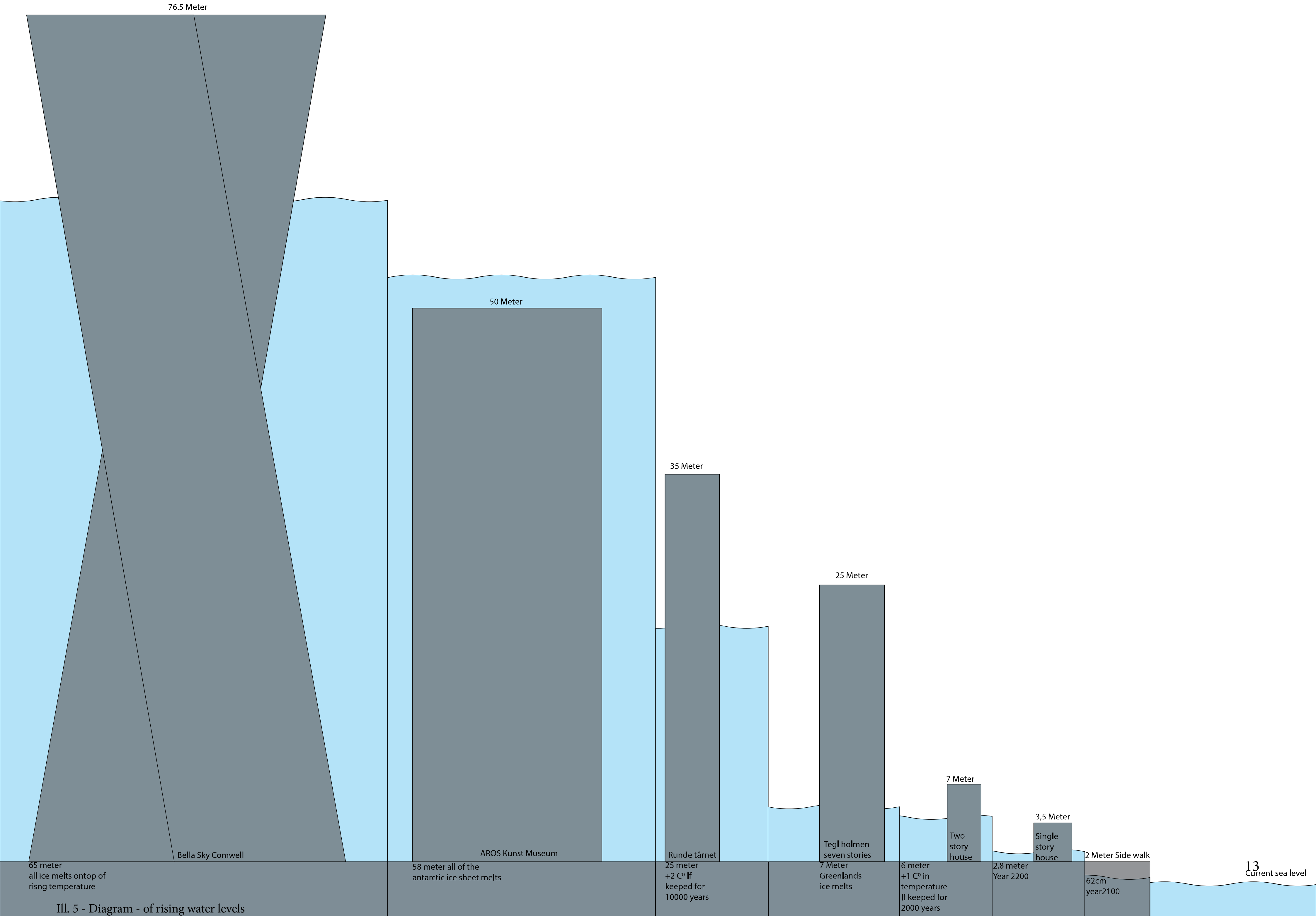
Ill. 3 - Rendering - not flooded 2



Ill. 4 - Rendering - flooded 1



Ill. 2 - Rendering - flooded 2



Ill. 5 - Diagram - of rising water levels

// SUSTAINABILITY

One of the two possible key thematics for the master thesis is sustainability, which in this project has been chosen the primary thematic. As a part of the Brundtland report "Our common future", investigates whether the economic development was compatible with environmental capacities. "Sustainability" was defined in 1987 as "development, that meets the needs of the present without compromising the ability of future generations to meets their own needs" (UN environment Commission in Edwards, 2010, p.25). The task was to increase awareness of the subject globally and facilitate the development of the understanding of economic, environmental, political and social aspects. Even though what's known as the Brundtland definition is still of key relevance, following that the term sustainability has been used in numerous contexts and subjects to countless further sub-definitions. Therefore, if sustainability is going to be a key parameter in the project, a definition needs to be established for the project to better determine a meaning of the word. Overall, Sustainability can be divided into.

1) Environmental sustainability - Impact on the climate, resources and nature
2) Social sustainability - Impact on human health and well-being
3) Economic sustainability - Balance between costs and building quality

For the sake of minimising the build environment's "footprint" on fossil fuels, topography and CO2-emission, technical parameters such as calculations and measurements must be performed to plan energy-efficient structures (here net zero energy). This is done while maintaining a good indoor climate and creating a design solution based on the local climate, while also considering material properties and their embodied energy and their Life Cycle Assessment.

In this project "environmental sustainability" is referring to the built environment "is creation of buildings which are energy efficient, comfortable, healthy, flexible in use and designed for long life" (Edwards, 2010, p.29). Social sustainability is often the lowest prioritised aspect of sustainability (Edwards, 2010) due to placing a higher priority on the two other aspects. However, when aiming to have a holistic approach to sustainability, all three aspects become important. Therefore, it shall be defined to "Marked by vitality, solidarity and a common sense of place among [...] residents [, acting] as a backdrop for lasting and meaningful social relations that meet the social needs of present and future generations" (Yiftachel and Hedgecock, 1993, p.140). In addition to providing a high quality of life in a long-lasting community, a socially sustainable concept should ensure a safe environment where residents are encouraged to embrace a sustainable and common way of living. Economic sustainability "addresses the relationship between human economics and natural ecosystems" (Kibert, 2016, p. 58). When looking at the built environment, the construction industry must use renewable resources, reduce their waste through reuse and recycling and assess life-cycle costs including construction maintenance, operational and occupancy costs, as well end-of life and non-construction costs (Zhong & Wu, 2015, p.749). Although the LCC-assessed buildings are more expensive as an initial investment compared to traditional buildings, focus on durability and systems such as renewable technologies, rainwater harvesting and energy saving lighting which bring short term pay back (Kibert, 2016). Due to the complexity of the subject, only some aspect is included in the project, for example when certain materials are chosen. Nonetheless, the economic strategy should follow principles of producing a good design while reducing resource consumption and optimising building performance through efficient technical solutions. A holistically sustainable design proposal is aiming for, the inclusion of these three aspects of sustainability.

// ZERO ENERGY BUILDING

The goal for the sustainable aspect of the project is to design a self-sustaining building meeting the energy demand need to reach zero energy, therefor having a stable energy source when removed off the grid for an extended amount of time. The general definition of a zero-energy building (ZEB) is a building designed to have a low energy consumption, having the energy demand covered by non-fossil energy sources. The production of renewable energy should equal or exceeds the energy consumed in the building and the combination of energy saving, and renewable energy supply defines the building as a zero-energy building. The production of renewable energy takes place on site, where its either sent into the energy net where it can later be delivered for use or stored and used directly on the site (Bejder et al., 2014). Furthermore, a ZEB must provide a good indoor climate to facilitate smooth operation of the building when the users behave as projected. If that is not the case, the users will work against the building producing an uncomfortable climate, resulting in higher energy consumption than predicted, and thus not reaching the targeted zero energy class. In this project, the aim is to design a zero-energy building by integrating passive with active strategies into the design, working towards the government's goal of solely relying on renewable energy sources by 2050 (Bender et al., 2014). Passive strategies should contribute to low energy demand.

The better the passive strategies perform, the easier it is to reach zero energy standard; hence, applying passive strategies is pivotal for the design process. About Zero energy buildings, there are three sub-categories: nearly ZEB, Net ZEB and ZEB. A nearly zero energy building produces nearly as much energy as it consumes. However, fossil fuels cover the rest of the demand. The other two categories rely solely on renewable energy. A Net zero energy building is connected to one or more pieces of energy infrastructure and actively participates in the energy network, as it feeds energy out into the network for later consumption. A Plus zero energy building considers the lifecycle of the building, i.a. The energy consumed for producing, operating and demolishing the building resulting in the building needing to produce enough surplus energy doing its lifetime to cover those. As this project in connection to the grid, it fits into one of the three subcategories, since the goal is to make a zero-energy building. The building is, therefore, a net-zero-energy building but with the capability to store energy out in the electrical grid. To facilitate the net-zero-energy building, passive and active strategies needs to be implemented and work in unison to make it a well-functioning ZEB with a comfortable indoor climate.

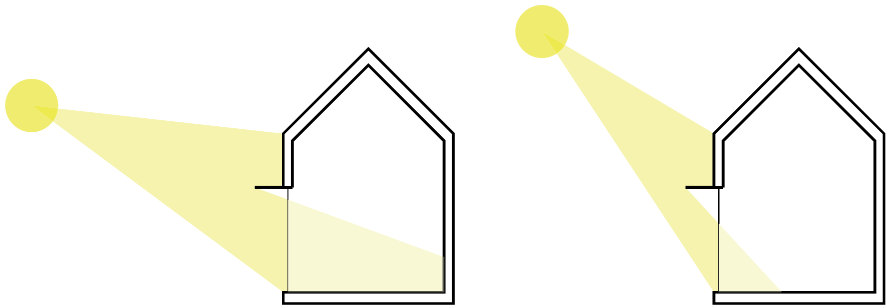
// ZEB - PASSIVE STRATEGIES

To reduce the buildings energy demand, passive strategies are implemented into the building design, while simultaneously benefiting the indoor climate. A passive strategy does not use any purchased energy, but instead, it takes advantage of the microclimatic features such as solar thermal energy, wind energy, temperature differences and sunlight.

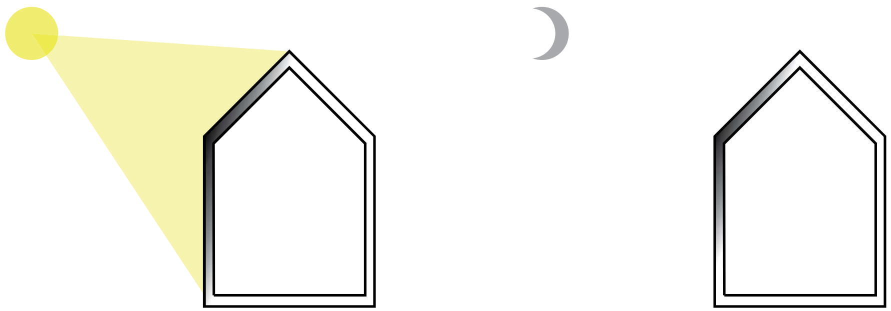
BUILDING ENVELOPE
Optimising the building envelope by reducing U-values and making it more airtight will contribute towards a lower heating or cooling load and corresponding energy, due to a lower transmission loss through the construction and leakage in winter and summer, respectively. This results in a static heat balance (heat loss equals heat gain) with a minimum of heating or cooling required to reach a satisfactory indoor thermal comfort.

WINDOWS
In the building envelope, the glazed areas are one of the critical parts regarding thermal comfort, as it has the highest U-value and causes linear thermal transmittance. Windows that are energy saving have at least triple glazing, with the gaps filled with gas to further insulate it. Furthermore, the choices of glazing and gas influence the g-value, which is the ration between solar radiation hitting the glazed area and solar radiation entering the interior, these must be considered and balanced with the light transmittance to ensure satisfactory daylight conditions and visual comfort.

PASSIVE SOLAR SHADING
Passive solar shading can work as a cooling strategy doing the summer periods this could be overhangs on the windows or large trees, which prevents solar rays from entering the interior of the building and, reducing overheating if not avoiding it. During the heating period, the sun will have a lower inclination (fi g), allowing the sun to penetrate the glazed area and heat the interior spaces, contributing towards a lower heating demand.



Ill. 6 - Diagram - Overhangs
Application of solar shading through a overhang, prevents overheating during the summer, while allowing solar radiation in during the winter time.



Ill. 7 - Diagram - Thermal mass
Thermal mass utilizes the solar energy absorbed and stored throughout the day to then later be released as heating during the colder hours during the night.

// ZEB - PASSIVE STRATEGIES

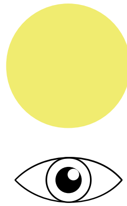
HEAT MODULATION
To create a more stable indoor temperature thermal mass can be introduced. Thermal mass stores solar heat in heavy materials exposed to sunlight doing the daytime, to be released slowly doing night-time when the surrounding temperature falls. Doing the heating period this helps lower the heating demand, while similarly, in the summer period this can be reverted to provide natural cooling by storing the lower temperature from the night time, hence, creating heat modulation that contributes to maintaining a steady indoor temperature.

NATURAL VENTILATION
Natural ventilation can help lower the energy demand, as it relies on natural forces such as wind and thermal buoyancy (stack-effect). Thus, the efficiency of natural ventilation varies depending on the site's microclimate. Three types can be implemented into a design:

1) Single-sided ventilation with an opening in only one facade. Which is the least efficient way of ventilating, since the room depth covered, is limited to 2-2.5 times room height, depending on the number of openings in the facade.

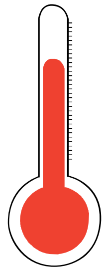
2) Cross ventilation refers to ventilation with openings in two or more facades. Therefore, it creates a more efficient air flow across the rooms, then the single-sided does, which increases the effective room depth to 5 times the room height.

3) Stack ventilation, which is driven by thermal buoyancy, taking fresh air in at lower levels and having exhaust air come out the top. Although natural ventilation is an energy efficient way to lower the energy demand, it should be considered that doing winter time natural ventilation causes heat loss and resulting in an uncomfortably cold indoor climate or increased heating costs. Therefore, mechanical ventilation is often used to create a hybrid system for primarily winter time.


Ill. 10 - Diagram - Visual comfort

Visual comfort

daylight level
>2%


Ill. 9 - Diagram - Thermometer

Thermal comfort

If activity level
1.2 MET

Recommended temp.
Summer(clo 0.5): 23-26
winter(clo 1.0): 20-25


Ill. 8 - Diagram -Co2

Atmospheric comfort

CO_2 level
850 ppm
20% PD

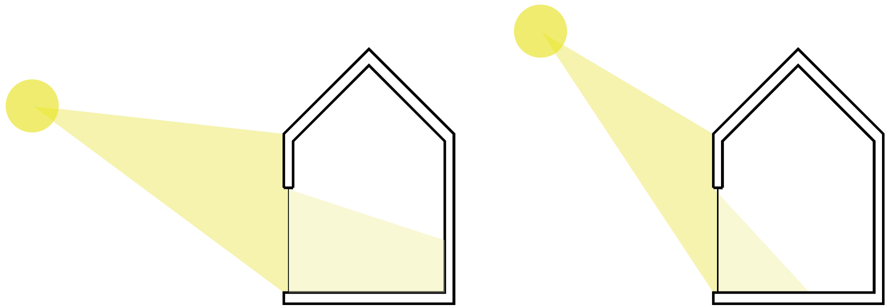
Ventilation rates
Building emissions: 0.7 l/s m^2
non smokers 7 l/s pr person

// ZEB - ACTIVE STRATEGIES

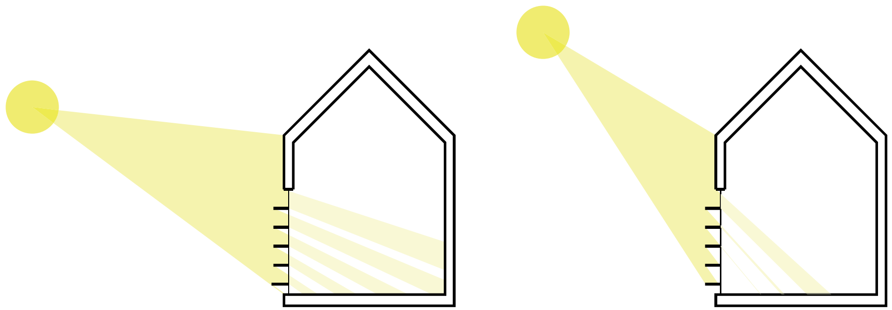
Active strategies define the systems which produce the renewable energy that covers the buildings energy demand and interacts with the grid. There is a variety of different strategies, by taking advantage of a range of natural energy sources to produces electricity or heating respectively.

PHOTOVOLTAICS (PVS)
Photovoltaics is a system which produces electricity by converting the energy from solar radiation, resulting in this methods efficiency being reliant upon the sun and the weather. As electricity is expensive, PVs are a popular source of renewable energy with different types of PVs being available. Monocrystalline cells being the most efficient panel in terms of performance and size, due to the high quality of silicon used, but its also the most expensive. Polycrystalline cells are a cheaper solution, but the efficiency is lower os it requires more square metres to produce the same amount of energy as monocrystalline. The Thinfilm cells' are more flexible in their performance since it's not majorly affected by high temperature and shadow. However, the general effect is very low, and therefore this type requires a lot more square metres.

SOLAR COLLECTORS
Solar collectors produce heat to cover domestic hot water and spatial heat demand using solar energy with only a small amount of electricity to run pumps and related steering equipment. There are two types of collectors which vary in appearance, influencing the buildings aesthetics and performance: flat panels and solar tubes. The latter filled with vacuumed air, improving the insulation qualities and increasing the efficiency of the panels.
Both Photovoltaics and solar collectors must be considered early in the design phase as they increase in efficiency depending on inclination and orientation; furthermore, allowing for a holistic design where the systems are integrated into the aesthetic.



Ill. 11 - Diagram - direct solar radiation
Impact of direct solar radiation doing the summer and winter time without any preventive messures can result in overheating during the summer



Ill. 12 - Diagram - External solar shading
Exterior shutters allow for no to very little direct solar radiation but still reflects light inside preventing overheating in the summer while interior shutters allow solar radiation aswell as reflecting light.

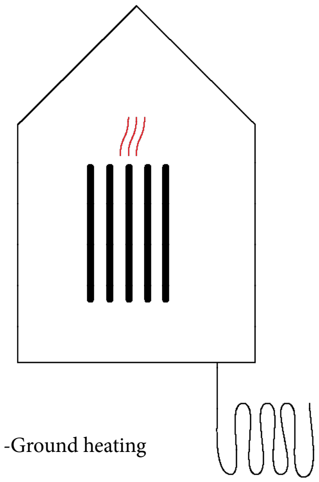
// ZEB - ACTIVE STRATEGIES

HEAT PUMPS
Heat pumps move heat from the outside to the inside. The system takes advantage of the heat energy required or released when a liquid changes from liquid to gas or reverse. There are different types of heat pumps available.

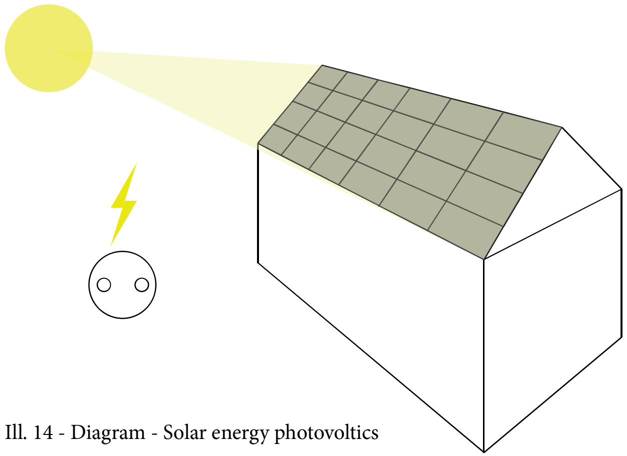
Brine to water pumps draws heat from the ground and is the most efficient and expensive type of heat pumps, as they either require a lot of square meters or digging into the ground. Further, easier to install is an air to the water pump which can be used for domestic hot water and space heating, and air to the air pump, which is only used for space heating.

To reach zero energy standard as well as securing a good indoor climate, there are energy requirements that should be fulfilled, as outlined previously. Tools used to contribute towards reaching this goal are, e.g. Be15, Velux Daylight Visualizer and BSIM. During the design process, passive and active strategies shall be integrated into the design of the exterior of the building to create a holistic expression.

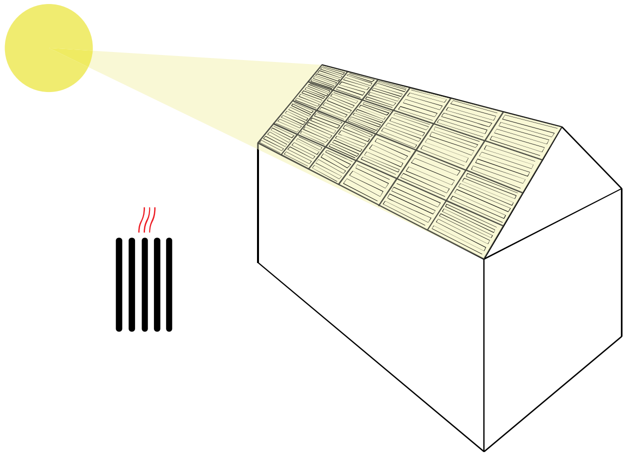
The passive strategies primarily concern the facade layout, i.e. the integration of shading and solar exposure, as well as materiality both on interior surfaces. The active strategies, such as solar collectors and PVs, are more locked in their appearance but it can still be integrated into the roof shape and facades.
To achieve a good indoor climate, natural and mechanical ventilation should be integrated into the layout of the buildings, to eliminate contaminated air and further reduce overheating during the summer period. To reduce energy consumption natural ventilation should primarily be used during the summer period with mechanical ventilation taking over with heat recovery in the winter months.



Ill. 13 - Diagram -Ground heating



Ill. 14 - Diagram - Solar energy photovoltics

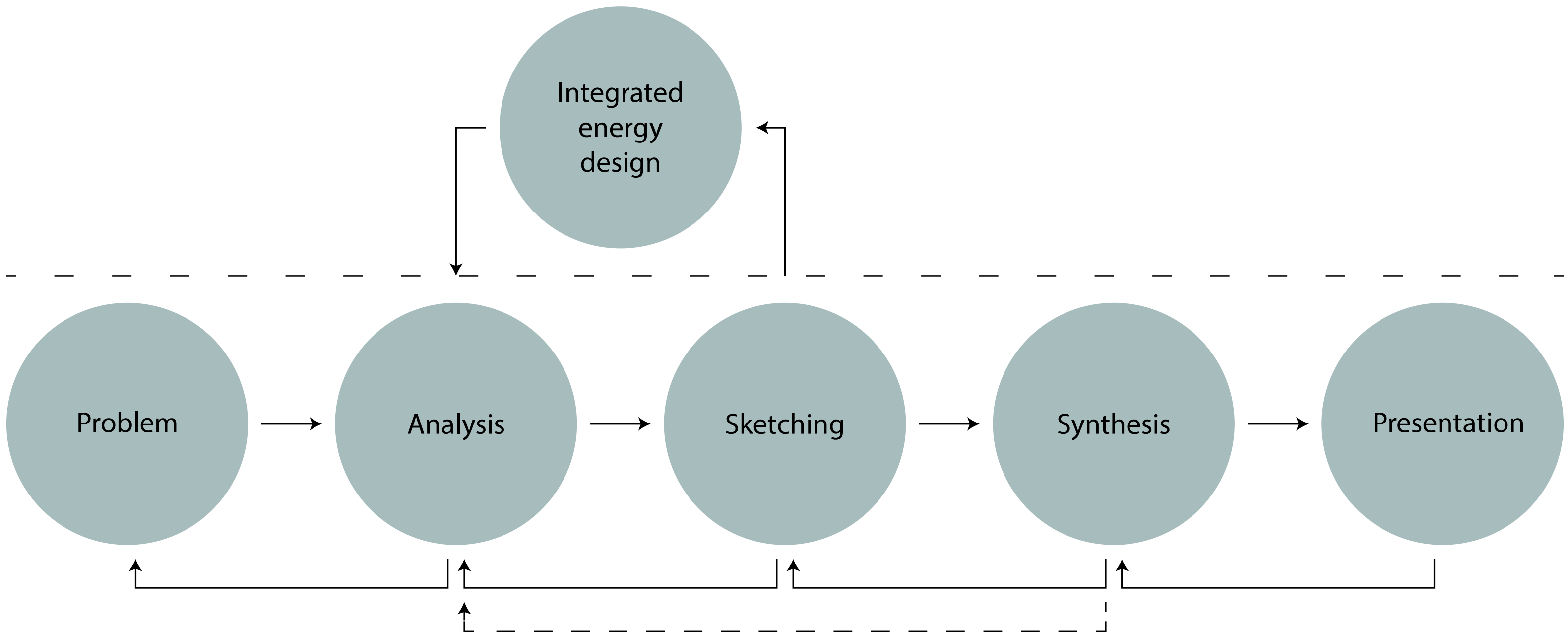


Ill. 15 - Diagram - Solar heating

// METHODOLOGY

INTEGRATED DESIGN PROCESS
the integrated design process (IDP) is a method facilitates a holistic approach, by its ability to systematic integrate academic theory and knowledge with scientific research in an interdisciplinary project, uniting in a final integrated design (Knudstrup, 2004).
Throughout the project methodology of IDP is implemented by working in the five phases proposed herein, presenting the architecture developed through an interdisciplinary approach in architectural and technical aspects, which is traditionally divided.
The historical and predicted climate changes introduce the very first phase of IDP with a problem, that is, how to reduce the build environment impact, and securing it from the climate changes which have already happened.
The problem phase is used to determine the direction and focus of the entire project and serves as clarification for the motivation behind future choices taken in the project.
Analyses are relevant for gathering necessary information which serves as the basic knowledge on how to work and interact with the site and buildings being planed on the site. Therefore, preliminary site and climatic analyses are performed as well as analysis on similar projects to create a basic knowledge to draw from when going further in the process.
The method of Integrated Energy Design is thoroughly analysed to determine how it can be used about IDP to strength the design process, for making a holistic building design with a focus on integrating architecture within a low energy building.
The following phase draws from the knowledge gained in the previous phases, as well as the tools which were introduced herein, various methods of interdisciplinary sketching on the project.
Working with zero energy buildings requires a high level of initial consideration for what technologies are possible to use on the site and building. Therefore, when sketching on the project, a wide range of those elements are considered and integrated into a proposal that creates a base for the final design.
Computational tools emphasise the interrelational approach of architecture and engineering, in both areas of tectonics and sustainability, towards a holistic design.
The synthesis phase stands as a conduit between architectural, technical and functional aspects, and should consist of passive and active strategies in a design, that through an iterative process integrates those aspects and strategies in the process of creating a zero energy building and shaping a final design.
The presentation of the final design is placed in an ordered manner, that best outlines the concept and ideas underlying the project, as well as the decisions leading up to it.

INTEGRATED ENERGY DESIGN
The Methodology of Integrated energy design will be applied in the method of analysing and sketching on the building.
This methodology analyses the building itself as well as how it interacts with the site and microclimate, through the general framework and requirement, for creating a zero energy building and the theories behind integrated energy design.



Ill. 16 - Diagram - Integrated design process in combination with integrated energy design

// INTEGRATED ENERGY DESIGN

The Integrated Energy Design (IED) method is used in the initial analysis phase and through sketching and synthesis phases to develop a strategy for integrating energy reduction into the design as well as considering how renewable energy can be applied to the geometry of the building. IED started with a site analysis to develop data to base the design upon, with initial considerations on lighting conditions, weather and orientation on the site, as well as determining what the goal for the indoor climate and the energy goals for the buildings. Following the initial analysis, a base geometry is starting to be developed while utilising the analysis. There are five steps in IED to develop a geometry ranked in order of flexibility.

Daylight comes first after programming since there's no technical solution if they're not enough daylight in the spaces, there can only be supplemented with artificial lighting which is energy consuming and supplies additional heat that needs to get removed.

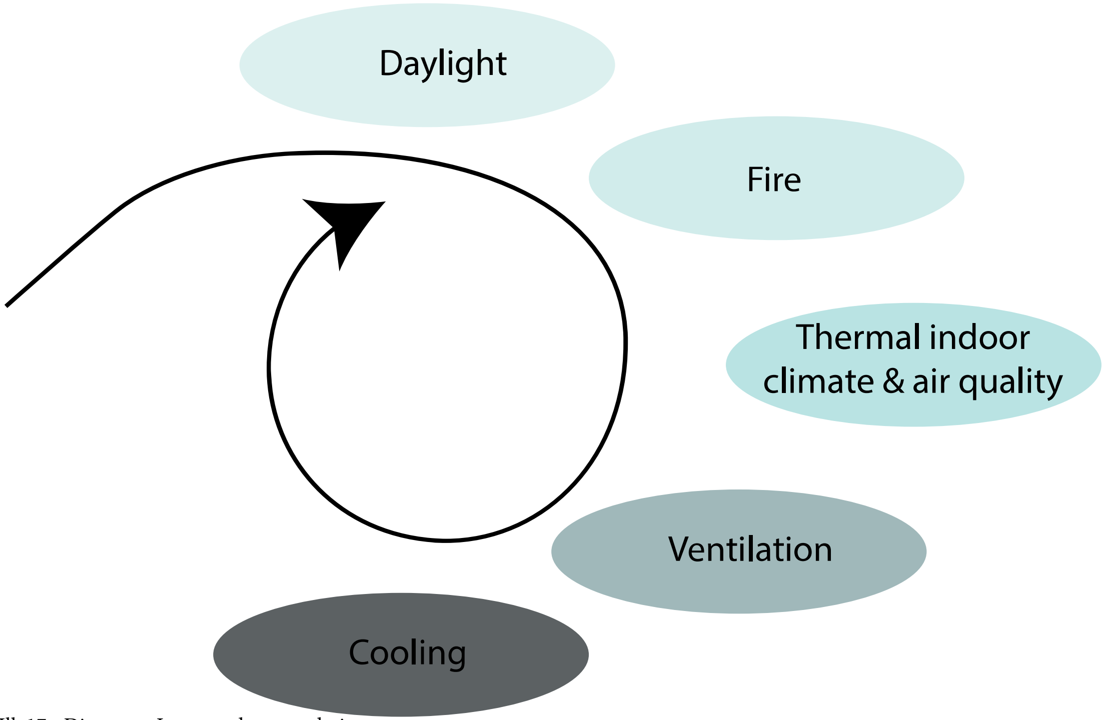
Fire is the next step due to creating free movement and the flow through the building concerning fire, but it also facilitates the possibility for natural comfort ventilation and fire ventilation since they work based on the same principles.

Thermal indoor climate and air quality follow fire and is the most comprehensive part since a lot of parameters are influencing the air quality and thermal comfort in the building. The analysis of this deals with heating, cooling and insulation needs, heat accumulation, heat insulation of windows and specifies the dynamic ventilation needed in the building when weighing them against the energy consumption of the building.

Ventilation is the fourth step; it deals with the analysis of the ventilation and how natural and mechanical ventilation can create a hybrid solution to cover the ventilation demand in the building. First, there's looked at the natural ventilation and based on step two, cross ventilation facilities that free movement of air through the building after securing that possibility the openings are designed to ventilate the space while considering the acoustic and odour of the outdoors to limit how much of that influence the indoor climate. The mechanical ventilation should focus on supporting the natural ventilation in the periods where natural ventilation isn't effective or when the demand is high enough to there is a need to supplement with mechanical ventilation.

Cooling comes as the last step in the IED model where first the options for free-cooling is examined which is the supplemented by mechanical cooling.

After using this process for creating the geometry, a stable base is built for making a sustainable building that can meet the requirements set for the indoor climate and the goals for energy consumption.



Ill. 17 - Diagram - Integrated energy design

// CLIMATE CHANGE

Climate change which is currently occurring in the changes of global climate, this is only sighted to continue where we are closing in on the point of no return where we are locked in for substantial changes to the global and local climate. Where even if it is attempted to lower the emissions in wealthy countries the growth of population and betterment of living standards, and life expectancy in poorer Asian and African countries will bring a significant impact that works in to counteract the improvement.

RISE IN WORLD POPULATION

The current population is 7,6 billion people and is expected to reach 11.2 billion by 2100 which is an increase of 47.3 per cent this results in a massive growth in both the need for housing but also the need for land for producing food. Which places a considerable strain on the land being needed to be cultivated for agriculture and converted to infrastructure that's required to sustain that increasing amount of people.
(United Nations, 2017)
This increase in population creates a significant demand on building materials to have housing, work and support all those peoples daily life, so to gather resources for building to support those people, without promoting deforestation of large areas without a plan to replace the forest that is cut down, which have historically been the case doing the 20th century.

The consequence of the rise in world population and rising living standards makes it hard to prevent further climate change since the two parts are contradictory to each other with more people needing to consume fewer resources to produce less greenhouse gas overall.

The result of that contradiction is the relevance of preparing for a degree of climate change with one of the most severe changes that come along for large coastal cities and building within them, being rising temperature since it brings along increasing sea levels.

RISE IN WATER LEVELS AND TEMPERATURE

The projected increase in sea level is estimated to be 0.54 to 0.74 meters by 2100, which when looking on a global climate is a short time scale. Where the amount of rising in sea level does not seem like a lot for Western countries on a short time scale, it will bring large displacements of people in poor Asian countries. While that rise in sea level is not detrimental in western countries when it's combined with weather phenomenons bringing in large amounts of precipitation or winds blowing water into the harbour that can result in flooding of large urban areas. While looking further out on a time scale of 2200, there's an estimation that a rise in sea level is 0.95 to 2.8 meters so when considering these rises in sea levels it can if not will permanently flood urban coastal cities.
(USGCRP, 2017)
The lead cause to the rising sea levels and the escalating nature of it is due to the increasing temperature which is occurring alongside the rising sea level, which happens due to the melting of the ice sheets and thermal expansion of water. The predicted rise in temperature for the year 2100, is 2.8 degrees as the best estimate but within the range of 1.7-4.4 degrees as a global average.
(AMAP, 2017)

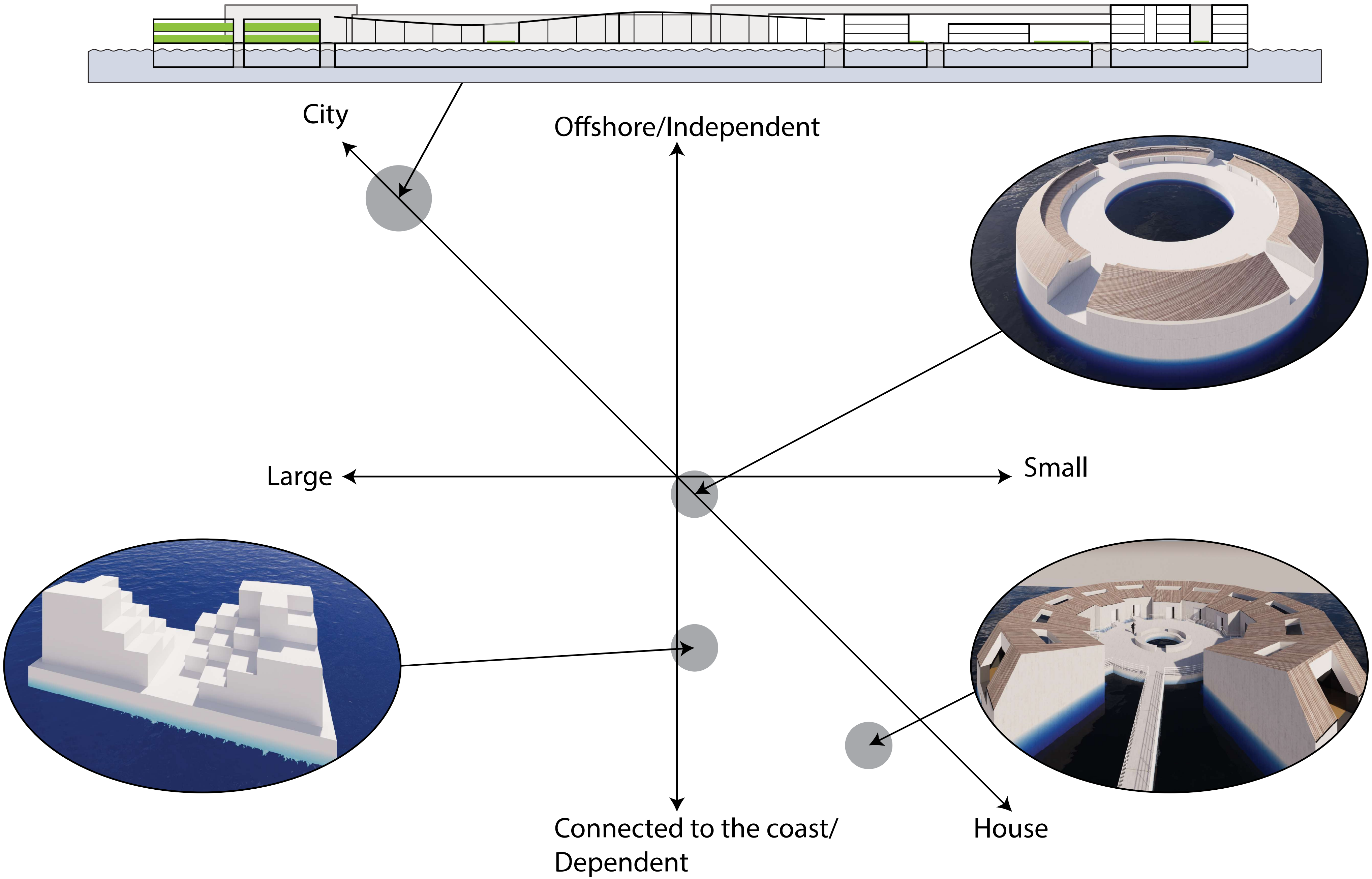
Ill. 18 - Photo of the Crystal in London - which hosts Exhibition on the future of cities

PROGRAM // LIVING ON WATER

// LIVING AT SEA

With the way that larger cities are organised with the center of cities being living, culture, shops and offices with the heavy industry situated on the outskirt characteristically along the waterfront on the periphery of the city. This structure has been developed through the changes in how much industry is present in the city image since most of it have been optimized, making it centralized and placing an emphasis on import and export, which takes a larger part of the supply of products to a city.
This leaves the question of how it could be possible to maintain the identical connection to the water as an important note of infrastructure, if the impending climate changes are happening and the ocean water levels increase. Changes must be completed to retain the access of water to important infrastructure, by protecting from the rising water though either a water lock or by gradually raising the harbour to avoid a flooding.
Considering in what ways to design for raising water levels, in to transition partially or completely live on the water and to hover with the rises in water levels. This however sets new problems, initially with a need to rethink the infrastructure that supports a city with power, water and food combined with the handling of sewerage and trash. This highly influence the independents from the traditional city and its infrastructure and affects the scale of the settlement on the water.

The size and dependency are connected since a small project create a large cost and effort of making it an independent city infrastructure, since it would require complex new set-up all for itself compared to linking it up with the existing infrastructure. When compared to a city sized project the infrastructure still needs to be constructed or expanded significantly to support the new population in the city on water. The size also allows for space to place those functions where the platform the buildings float atop can be filled with functions that keeps the society working but without needing a constant but only periodical maintenance.
Doing the process of developing the project there has been looked at various directions for the project across diverse scales and differing degrees of dependency on external infrastructure. Spanning from a city scale to small housing project where the city scale incorporates all the infrastructure and production of food to be able to function completely separated from infrastructure on land. While the small housing scheme is relaying on all the infrastructure of the city.

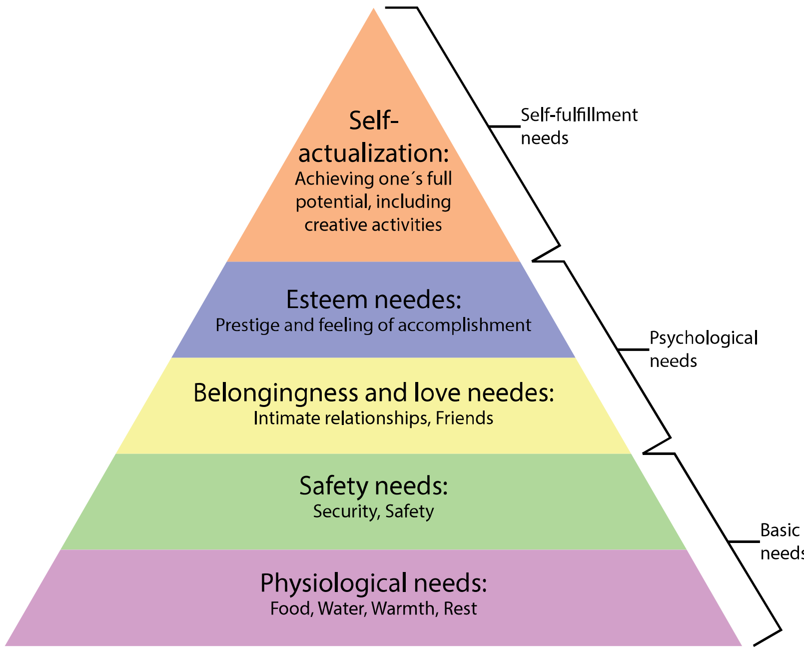


Ill. 19 - Diagram - Size and dependentcy

// HUMAN NEEDS

The selection of functions is derived from Maslow's hierarchy of needs. The hierarchy dictates the needs for living a productive life and fitting in as a part of society; the hierarchy is divided into three different parts basic needs, psychological needs and self-fulfilment needs. The basic needs are paramount for being able to work cause when it's missing the mind being everywhere else than at work. Since the project is at sea separated from mainland society, the priority is to get the essential functions down, to make it comfortable to be living there, followed by the psychological needs and then ending out by providing a way to give them the opportunity to find self-fulfilment. To provide the basic needs of warmth, food, water, rest, security and safety. The water source would come from rainwater collection run through a purification system before its distributed to the residents. While food would need to be either purely transported from the outside and stored in freezers and fridges or supplementing a food production cultivating on the site, either by aquaculture or small amounts of urban farming as a supplement to the food brought in from the outside. The psychological needs entail social behaviour like friendship and intimate relationships, prestige and feeling of accomplishments.

Through these things are more intangible there can be added functions that facilitate a more social behaviour, by allowing for people to meet more often by getting people out of the housing to interact this can be accomplished though open offices, shared kitchens and open areas for recreation where people can meet up and socialize, hopefully creating a social environment. The feeling of accomplishment and prestige and the final aspect self-actualisation fall together, to achieve the goals set in the context of work combined with the personal goals which are established and influenced by the individual. A design containing these however does not guarantee self-actualisation, other than giving a framework for people to have space that can be utilised to what they appreciate spending their time on. Examples of this could be a personal office in the home, a workshop area where there's space for building something or a fitness room with space for personal improvement in the physical aspect of the self-perception.



Ill. 20 - Maslow's hierarchy of needs

// WORK ENVIRONMENT

The office building aims to create a coworking community, by increasing the interaction between the employees in and across professions. The intention behind coworking community is based on the company WeWork, who have the company philosophy to create;

“A place you join as an individual, ‘me’, but where you become part of a greater ‘we’. A place where we’re redefining success measured by personal fulfilment, not just the bottom line. The community is our catalyst.”
[wework, 2019]

Based on an article by K. Steemers “Architecture for well being and health” ((Koen S., 2018) Which describes his theories on the health benefits of a social work environment that facilitates interaction between strangers within the work environment. This should be achievable by using the model for a shared workspace created by Wework with a dedicated desk within the open office space. While outside the workspace, the options for physical exercise covers the other part of what K. steamers talk about the reduction in physical ill-health.
The model for a shared workspace is being compared to the traditional model of individual private office spaces to see if there can be drawn strengths form the conventional way of working, to create a good working environment.

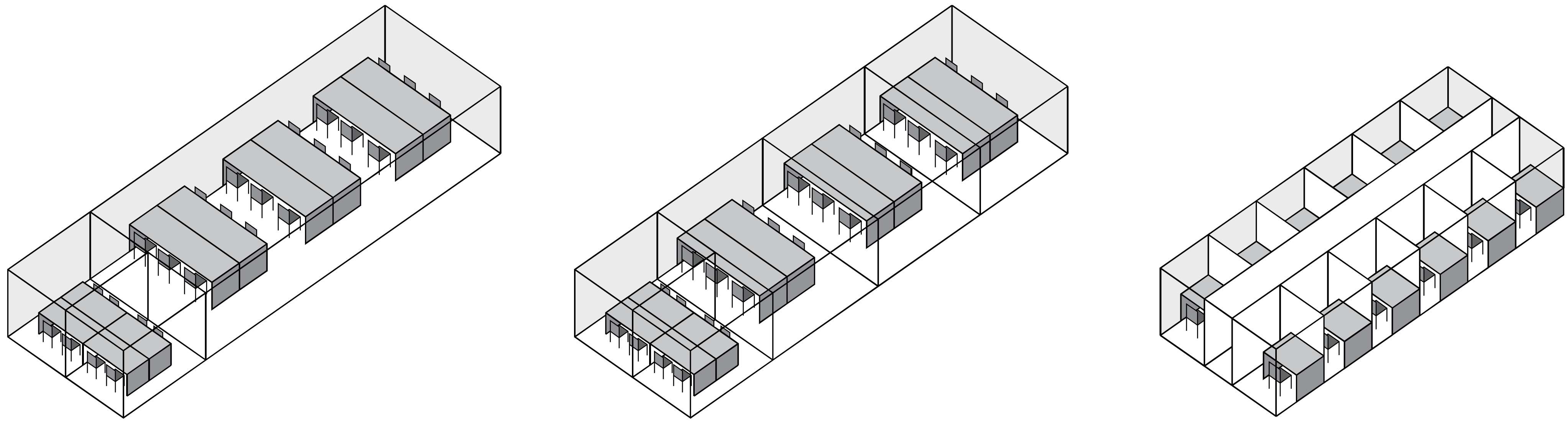
PRIVATE OFFICE SPACES
Creating a private workspace, where focused and calm work environment is facilitated. Where there’s as little external disturbance as possible doing the day, but the negative effect of that is that the social climate at work is almost gone except maybe for the brakes happening when going to get coffee.

DEDICATED DESK
An Open Office layout where all are sharing the space but have their dedicated workspace. This structure of the workplace is best suited for a single person to small sized companies. These shared workspaces focus on cooperation and a sense of community, through interaction and working with others nearby for an extended period.
Having a meeting room adds the possibility to have meetings separate from the office space while not being disturbed by or disturbing the rest of the office

PRIVATE OFFICE SPACES
Twenty small office spaces for 1-3 employees.

DEDICATED DESK
One large office space for 28 employees.
Three large offices spaces for ten employees

The workspace is designed after the Danish building regulations and rules determined herein, There is no defined rule rules for the room size, height or natural light intake, but requires that it is dimensioned with a sufficient size considering the number of employees about safety, health and functionality of the space.
[Building regulation 2019]



Ill. 21 - Diagram - Diffrent office layouts

A Open Office layout where all are sharing one large room focusing on cooperation and common discussions.

An Open Office layout, but divided into smaller rooms which still facilitate cooperation and common discussions, but more minded to companies filling out there own space.

Small individual workspaces are creating a focused and calm work environment. At the loss of most social interaction and discussion.

// RECREATIONAL SPACE

ACTIVITY

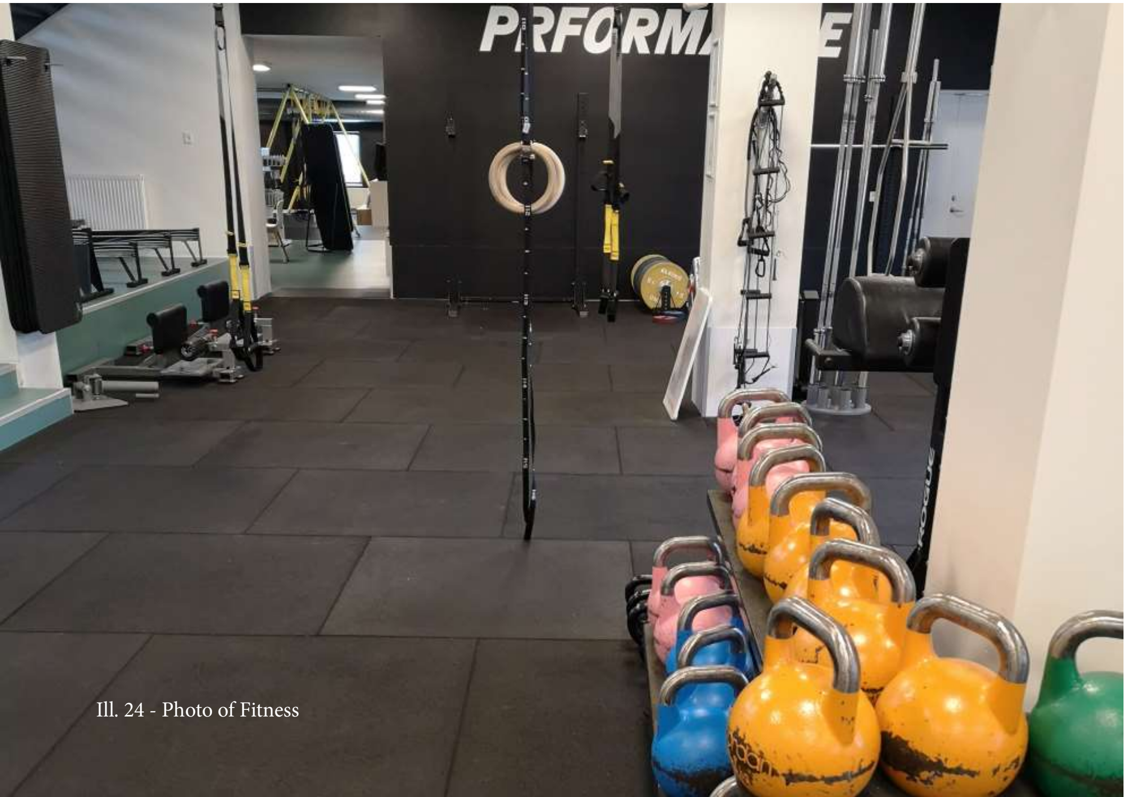
With the Platform being out at sea the amount of freedom to exercise is a limited, since it's not possible to strap on ones running shoes and go for a long run or go down to the local sports club or fitness centre. But with the rising increase in overweight and extreme overweight [danskernessundhed.dk], it is hoped to counteract or prevent this for the residents, by giving them the facilities to do physical activity within the community. By engaging with others in the community or alone while being encouraging the development of personal goals, these activity-based rooms can cultivate. The introduction of the activity-based functions brings along exercise and mobility along with social bonding which happens when doing rigorous training with others. Furthermore, it brings a degree of creativity when rethinking the way of exercising throughout an extended period in the attempt to reach once personal goals. The aim is to provide a space where people in the community can interact and compete while exercising through either fitness or group training and as a community keep up the motivation to continue using the facilities and keep a healthy level of personal fitness across the community.

CREATIVELY

As determined by the Maslow hierarchy of needs, the feeling of accomplishment and achieving one's full potential, which applies both at work and outside of it. Outside work it is expressed through more creative channels, such as arts and craftsmanship, which is used as relaxation or curiosity drove activity or merely a break from once daily life. Workshops act as spaces with special equipment for a variety of a specific craft, making flexible spaces that can be converted to facilitate the different crafts, that parts of the community want to partake in and thereby promoting the use of their free time. Thus, creating a common interest in the workshops to develop a culture of learning and helping each other with the goals set, be it in the strive to design a new chair or creating a painting. It also provides tools to enable the residents the tools needed to repair and maintain things both in the private residence and within the standard functions.

Ill. 22 - Photo of wood workshop

Ill. 23 - Photo of art worksshop



Ill. 24 - Photo of Fitness

Ill. 25 - Photo of yoga

// SUPPORTIVE FUNCTIONS

To be able to move function from land and out onto the water there needs to be a way to produce the resources that is needed to run housing, work and recreational activities, as well as what the waste product from the daily life of the building produces. Depending on the degree of connection to the traditional city infrastructure.

ELECTRICITY
Electricity is one of the easiest things to separate and create a local infrastructure to support the buildings since there's a range of renewable energy sources, that can supply the energy to a local storage unit. So that the building have a stable source of electricity, either if there's a diverse source of energy or the storage is large enough.

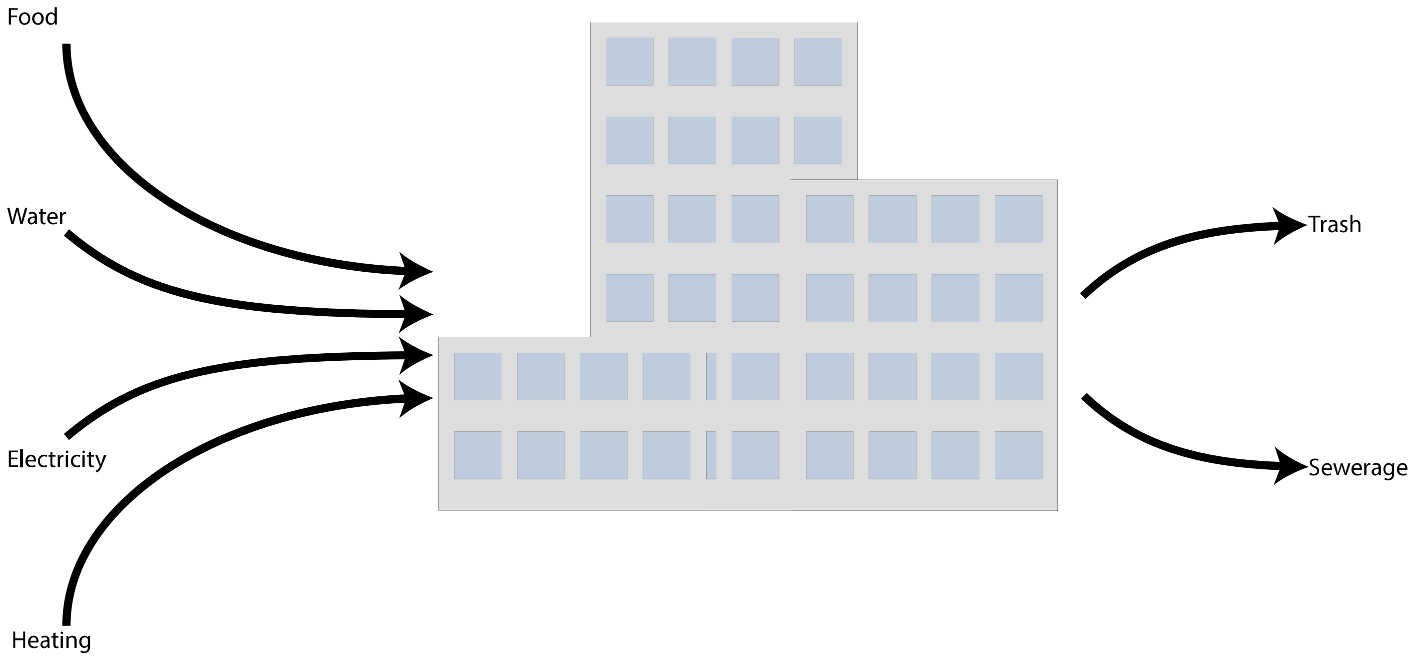
HEATING
Heating can be supplied through a few different ways, electricity can be converted to heating, solar energy can be used to heat water through solar collectors, or there can be an outside supply with district heating. If the heating supply comes from converting solar energy, there's normally a supportive supply since it's hard to store heated water for an extended period were there limited to no sun.

COOLING
Cooling can be supplied through mechanical cooling by converting electricity into the cold air and then distribute it through the mechanical ventilation, or there can construct a heat exchanger that draws from the outdoor water temperature to then use that as cooling for the building by pumping it around in a closed liquid system.

WATER
To provide clean water for all the functions requiring water within the buildings, there either need a supply from the city infrastructure to provide clean water or there needs to be constructed a local infrastructure of collecting rainwater and cleaning it. Before it's stored and ready to be used, its also possible to cleans seawater by removing the salt before cleaning it and storing it, but that's an expensive energy process so it should be avoided if possible.

FOOD
Food is the hardest thing to start supplying since there's a large number of different things that need to be cultivated to feed a community of people a varied diet. But its flexible in how the connection to the city needs to be since as long as it's possible to take a short trip to get food by boat it's not needed to provide that locally on the building. Resulting in that there can still be a separation from the coast while still being a supply of food.

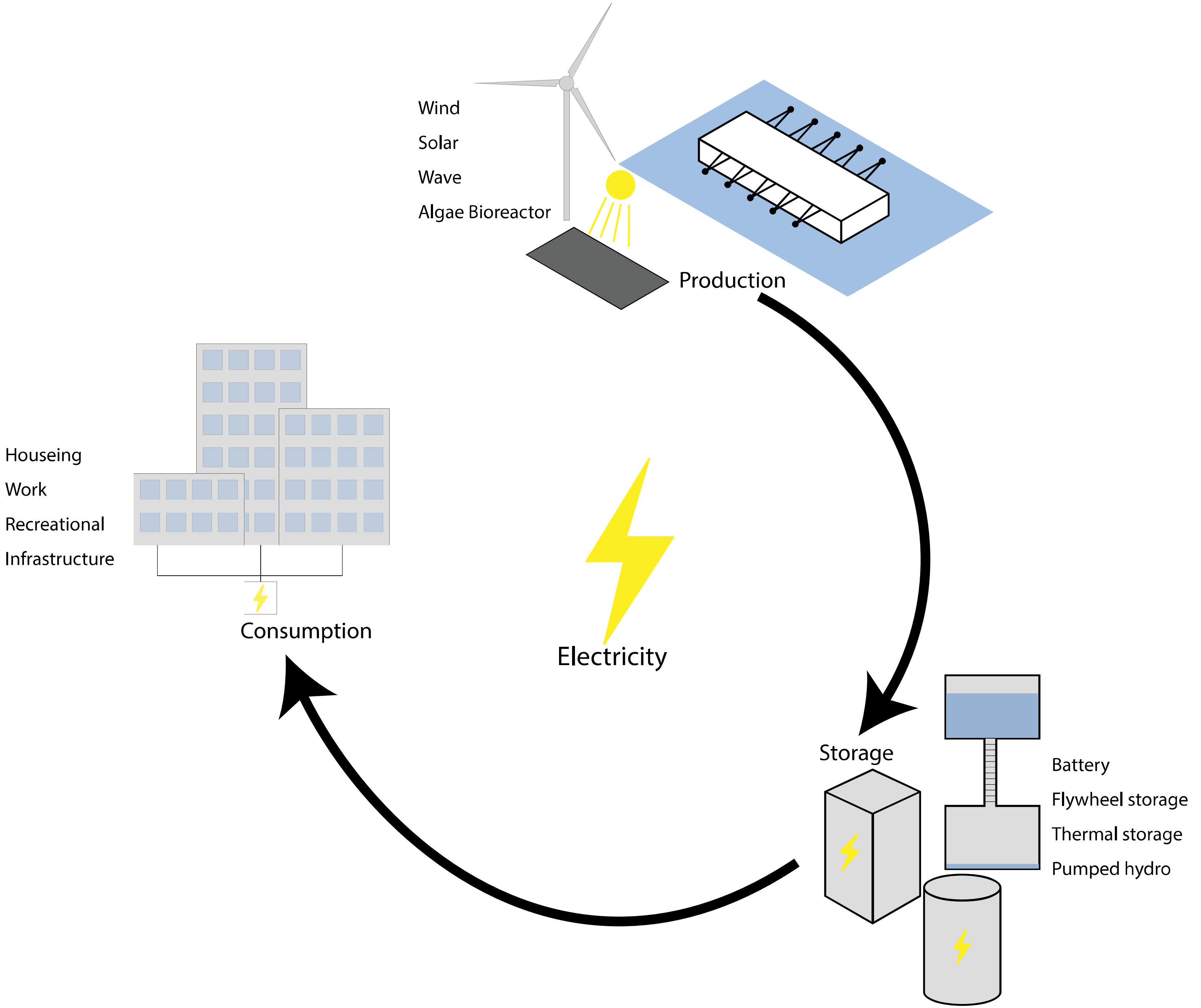
WASTE
To deal with the waste that's produced from the use of the building, where part of that is sewerage, and the other is trash. Sewerage is part of a large infrastructure that collects and cleans all the dirty water that is produced by buildings, and this entire infrastructure would need to be remodelled to handle the amount produced by the building, the same structure is present for trash with sorting it, and either recycling or properly disposed of.



Ill. 26 - Input and output from buildings

// ELECTRICITY AT SEA

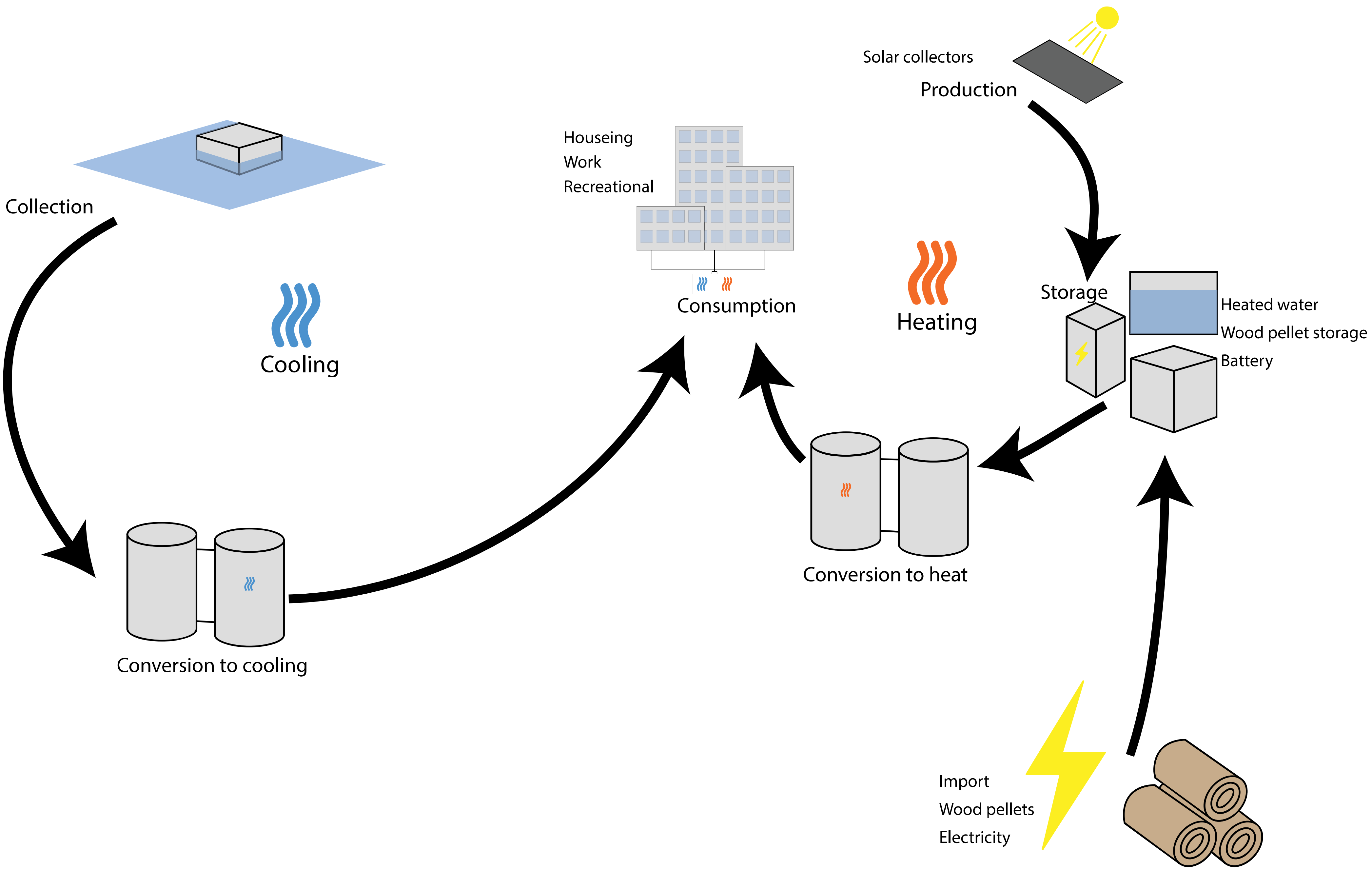
To produce electricity at sea, there a range of diffrent possible solutions for creating renewable energy that then needs to supply the infrastructure of the building complex and the buildings electricity consumption. To have a stable source of energy it needs to be either a large enough production, so that even if its at night or a still day that it produces energy to be running the entire building complex. Otherwise, there needs to be energy storage that collects surplus production that can then be released later when there a limited production. The electricity produced then runs the infrastructure and buildings consumption, to provide all the comforts that were present when living in a city on land.



Ill. 27 - Sustainable sources to providing electricity

// CLIMATE CONTROL AT SEA

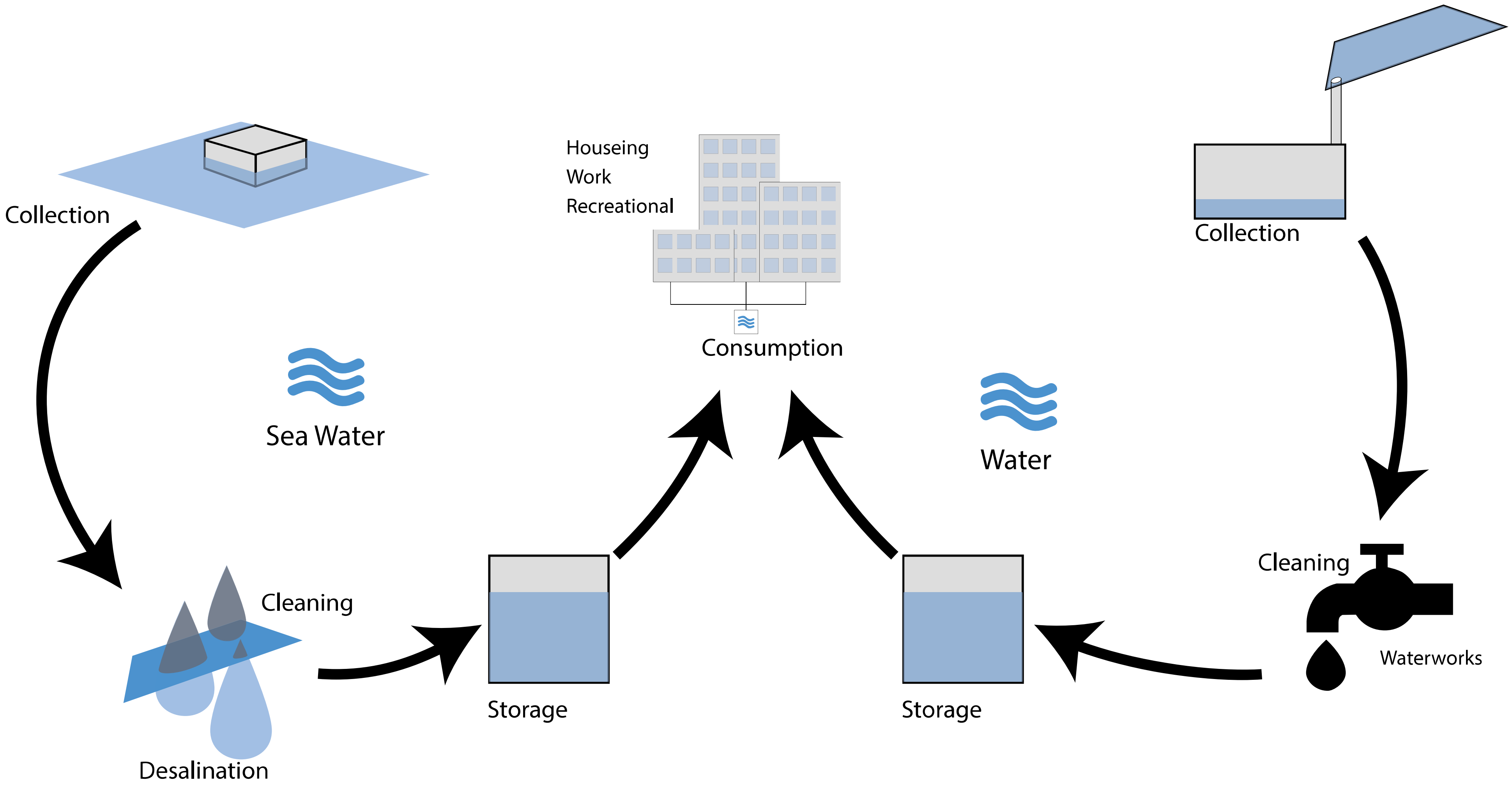
To provide heating and cooling at sea without consuming fossil fuel to provide a stable indoor climate. When breaking the two apart the cooling is solvable by utilising the sea water to draw in water and converting it into a closed system with a cooled down liquid that can then be pumped throughout the building complex to cool the buildings and infrastructure doing the summer period.
To heat the buildings in the heating season while using at least primarily renewable resources to do so. There are a few different solutions for what sources can be used to produce heating without burning fossil fuels. Solar heating can be used when there's sun out in the heating season but when the sun is not enough. There needs to be an alternative to supplying where heat pumps and wood pellets are both sustainable alternatives where both of requiring storage of either wood pellets or electricity that can then be converted into heating to supply the buildings with heat doing the heating season.



Ill. 28 - Sources for providing cooling and heating

// FRESH WATER AT SEA

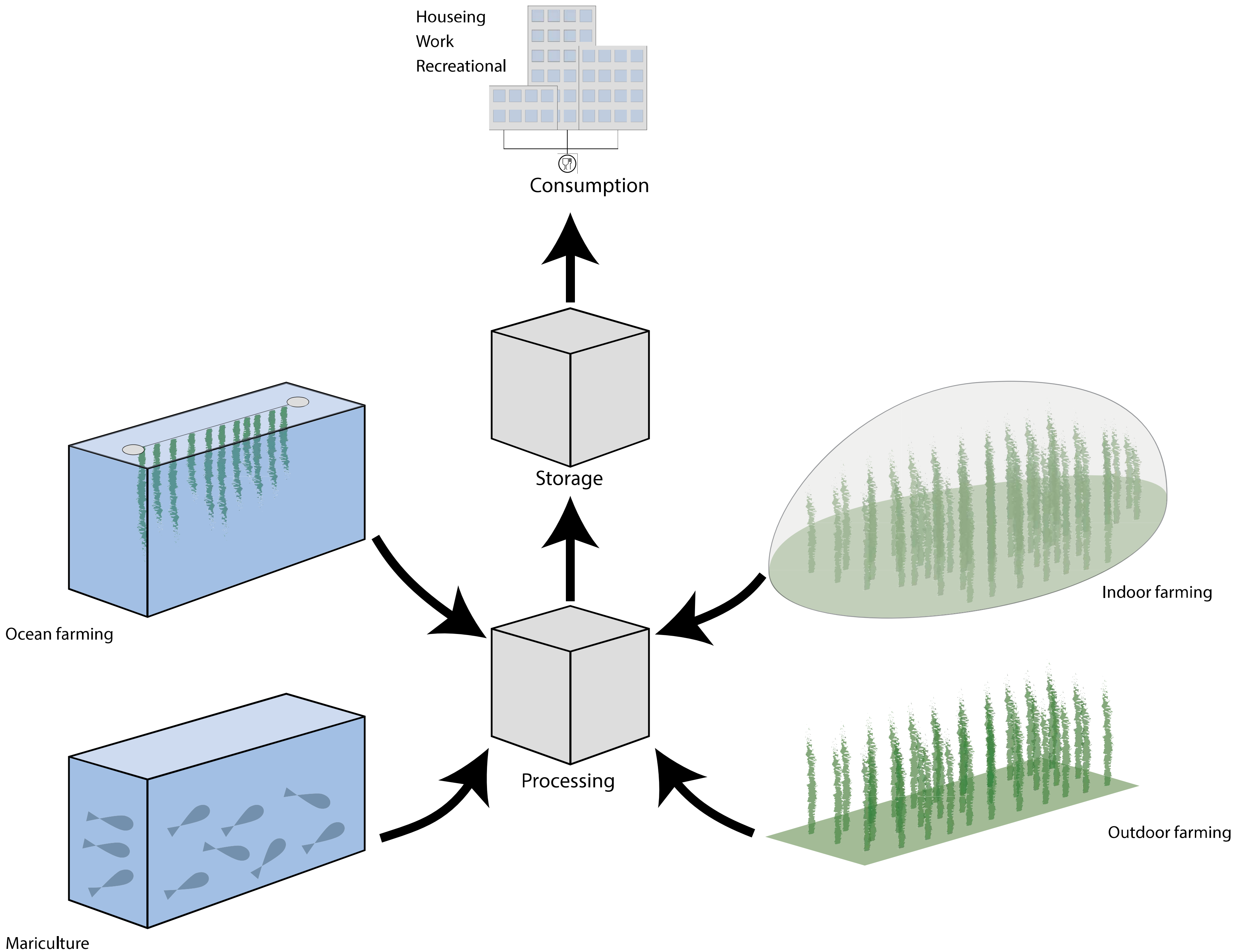
To provide clean water that can be used within the building complex, theres two options for collecting water that then need to be cleaned before it can be used within the buildings, either sea water can be collected, cleaned and having the salt removed. However, this is an expensive way, and it consumes a lot of energy to clean the salt water. The other option is to collect rainwater and then clean it before its stored waiting to be consumed this is a cheaper and less energy consuming way to provide clean water but there needs to be a large area and storage enough to keep water for dry periods so that the building complex don't run out of water.



Ill. 29 - Providing clean water

// PRODUCING FOOD AT SEA

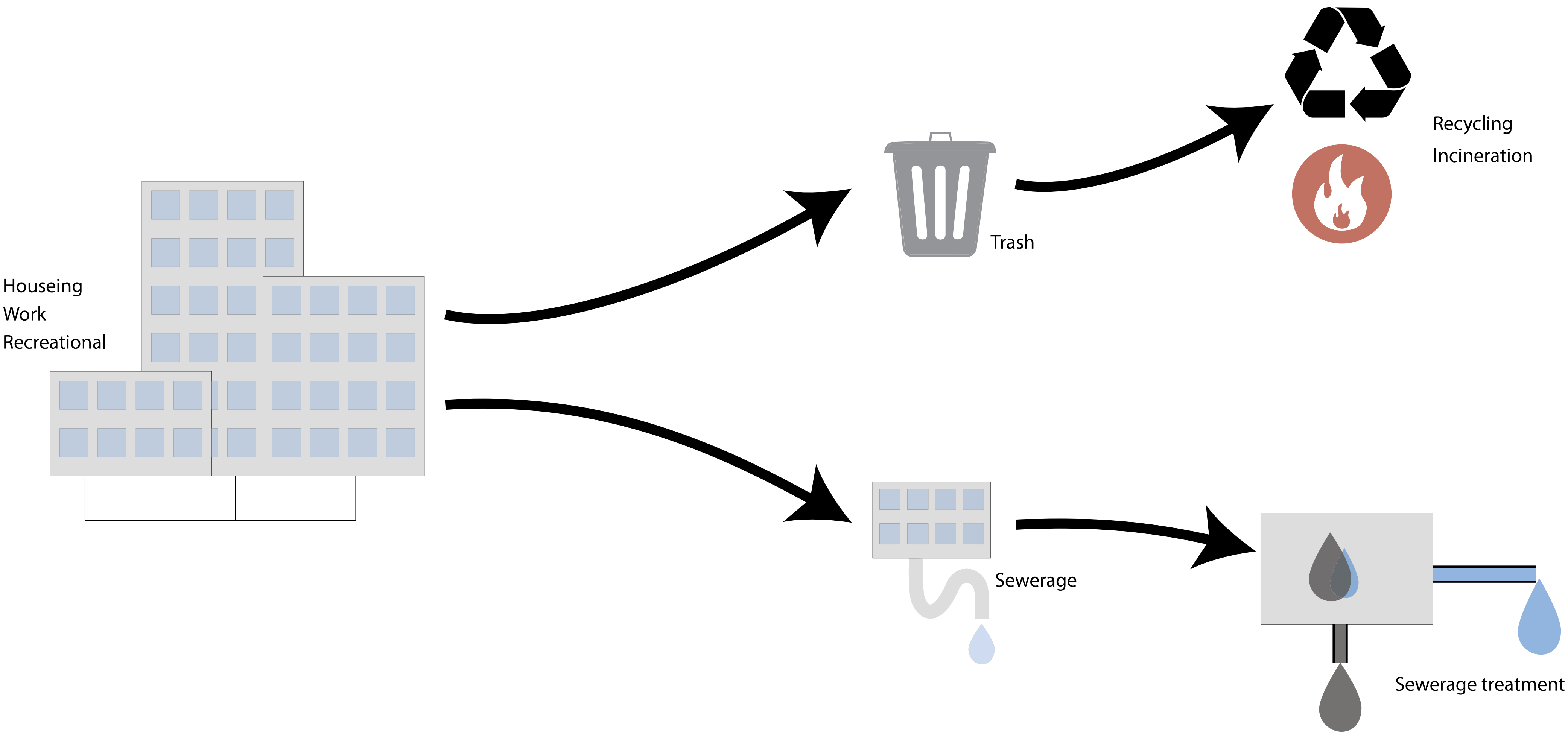
To supply food to the people living in the building complex, is gonna require a lot of space and work to plant, maintain, grow and harvest the diffrent types of food all year around. Theres a range of diffrent sources to get food from indside and outside farming and then ocean farming and mariculture, which creates a diverse production of food which is needed for sustaining a healthy diet for the population. Theres a lot of work required to sustain the production of food, but following the production theres not alot of work required, its primary storage and then preperation for it to be eaten.



Ill. 30 - Supplying food

// DISPOSING WASTE AT SEA

The two parts of waste that needs to be disposed of one is sewerage and the other is trash. To dispose of sewerage there needs to be a long process to gradually sort part out of the water and then, in the end, clean the water so that it can be let back out in the ocean or be used to for example watering plants. The parts of the sewerage that's sorted out in the process of cleaning the water needs to be either recycled or used to produce heat or electricity. When disposing of the trash, it needs to be sorted and then preferably recycled, used for compost or burned to produce heat or electricity.

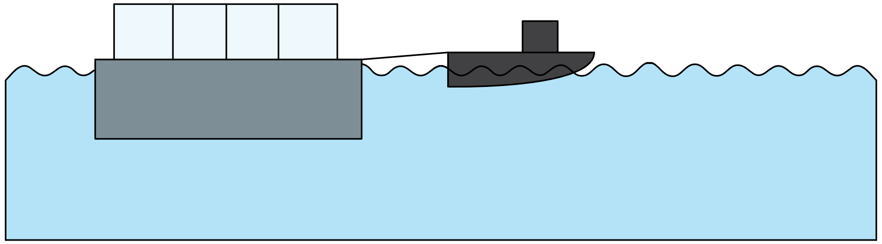


Ill. 31 - Handeling waste product from buildings

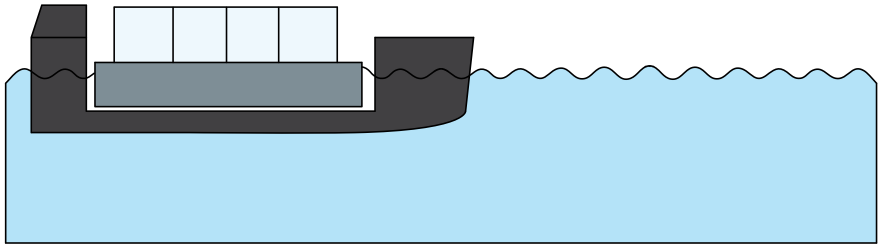
// CONSTRUCTION AND MOBILITY

To build a building thats floating on water, it can be constructed by building a partly submerged creating enougth boyancy to make it float, or on a platform which is carrying buildings through the same principle of buoyancy. To construct these buildings, it needs to be done in a controlled environment so it can be built either on land and transported into the ocean or be constructed in a drydock that then gets flooded, which then allows for it to be sailed out to where it is then anchored. The drydock has the most freedom with the construction of the buildings and platform since it's not limited to a certain scale since it can always be flooded and then dragged to its location to be anchored, whereas construction on land needs cranes and something for transporting it to the water.

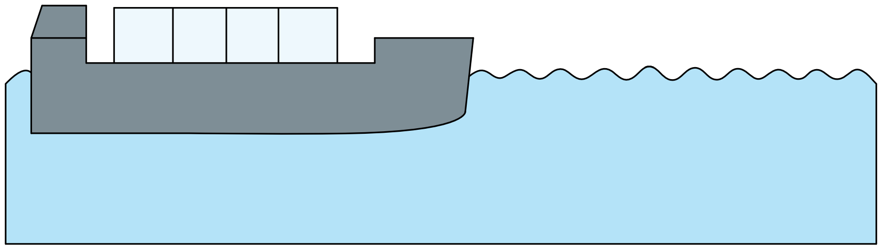
When transporting buildings on water there different solutions for doing so that brings different possibilities with each, towing the building make it quick and easy to move, but its hard to transport it across large open waters depending on how much height clearance the building have not to risk getting flooded during transport when its not in controlled waters. The same factors play in when looking at a self-propelled building other than it's quicker to begin moving but there a large amount of maintenance for keeping a motorised system functioning, compared to how rarely the whole building would probably be moved. The last option would be using a semi-submerged boat that lifts it out of the water and onto the boat, which then sails it to a location and then lowers it down again. This method of transporting the building is the most efficient for large open waters since it's lifted out and don't need to handle the ocean waves, which it is not built for. While for short distances on relatively still water, the other two methods are easier since it is not as large of operation to use while still being safe.



Ill. 32 - Tugboat towing the buildings



Ill. 33 - Simisubmerged boat perparing to transport the building



Ill. 34 - Selfpropelled building allways ready for transport

// CONCLUSION // SIZE AND DEPENDENCY

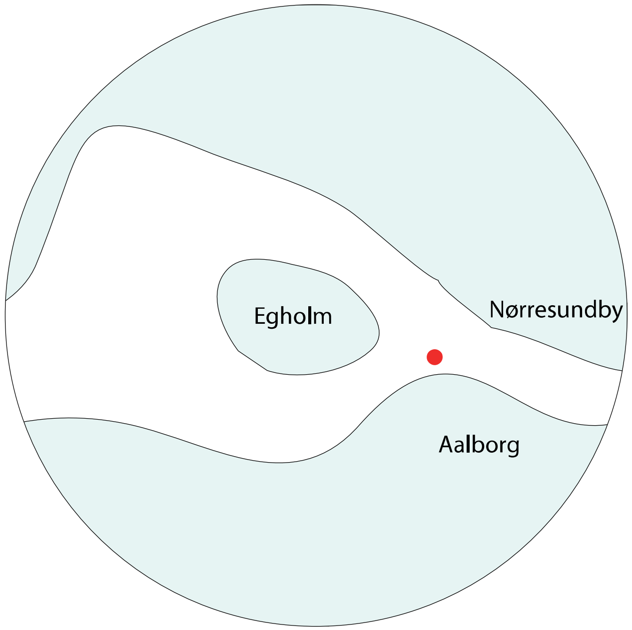
Concluding on the human needs and that the requirements of infrastructure those functions need to be able to move them out onto open water, influencing the size and the connection it has to the city and its infrastructure. The conclusion of how those factors influence the project lead to the building being dependent on the city infrastructure and having a limited size. With housing being the function chosen since its the most independent function which is easy to separate from the city. While it still supplies people to the city and not drawing people away and out to the platform, which would be the case if it had been recreational activity or offices.
The housing needs to be coupled to the city infrastructure but supplies electricity to cover its use, but simultaneously uses the electricity grid to stabilise it across the whole year due to the high production in the summer season and low production the winter period.

SITE

// SITE

With the site being just off the edge of Limfjorden in the western part of Aalborg. The water runs either west or east so theres regularity to the movement of the water and since the water is shallow, then even on days with harsh winds the water is still calm. With water being the immediate close context with the more distant context being a view of Egholm, Nørresundby, while its bridged connection to Aalborg through Vestre Fjordpark which provides access to outdoor recreational activity.
The site is close to Skudehavnen and Marina Fjordparken, which allows for the use of boats and other water-based transportation to get back and forth from the residents as an alternative to biking or walking to work.
The site's proximity to the city of Aalborg makes it easy to be connected to the range of different infrastructure, which is needed to support the residents with the things needed for daily life.

The site is chosen due to its proximity to a city that can provide infrastructure while there is outdoor recreation nearby, giving the residents with the possibility to both use those facilities but the water as well to provide free time activity. With the location so close to Egholm, it is within proximity to nature that can be easily accessed, while the city is still close by for the residents to go into and work, shop and provide food.



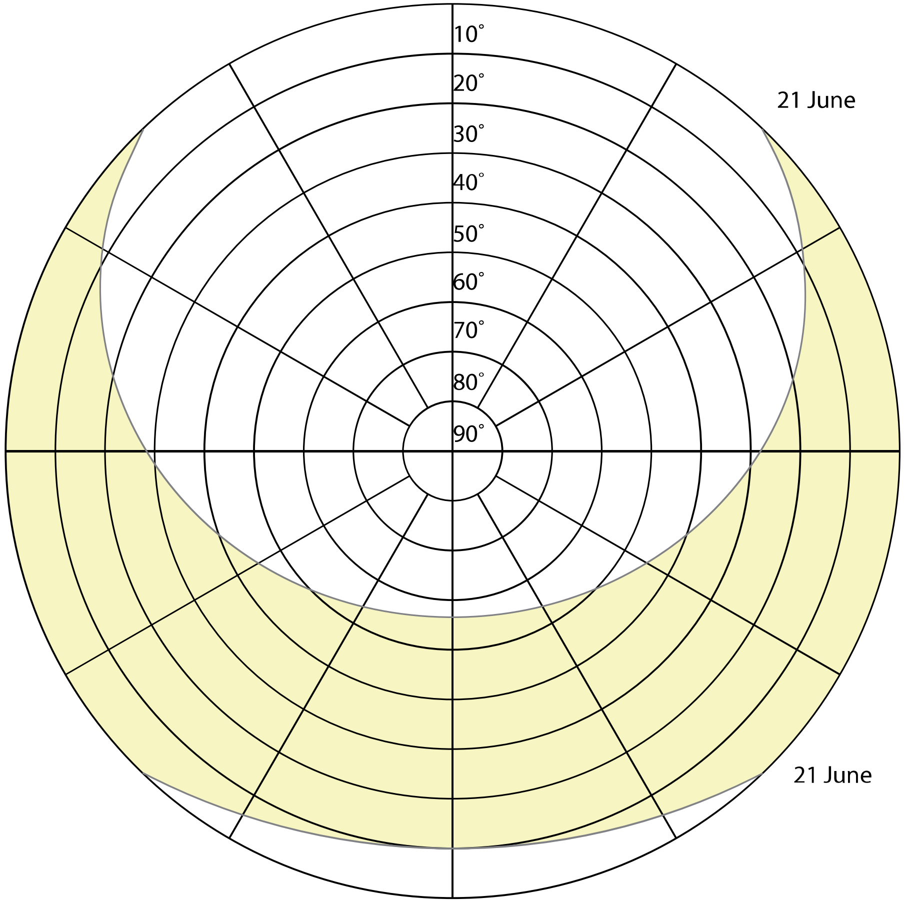
Ill. 35 - Diagram site location

Ill. 36 - Photo of the site 1

Ill. 37 - Photo of the site 2

// SUN

With the location of the site at open water, there aren't any building shading for the sun so the suns direction gives a pretty complete picture of the direct sun on the site, which will only be influenced by the built environment on site. That creates a great opportunity to use solar energy since the weather is the only thing blocking it and reducing its output. That can somewhat be negated by having storing electricity in the grid, which serves as an energy source for the winter time or a surplus of PVs to have enough to produce energy during the winter time when the sun is lower in the sky.

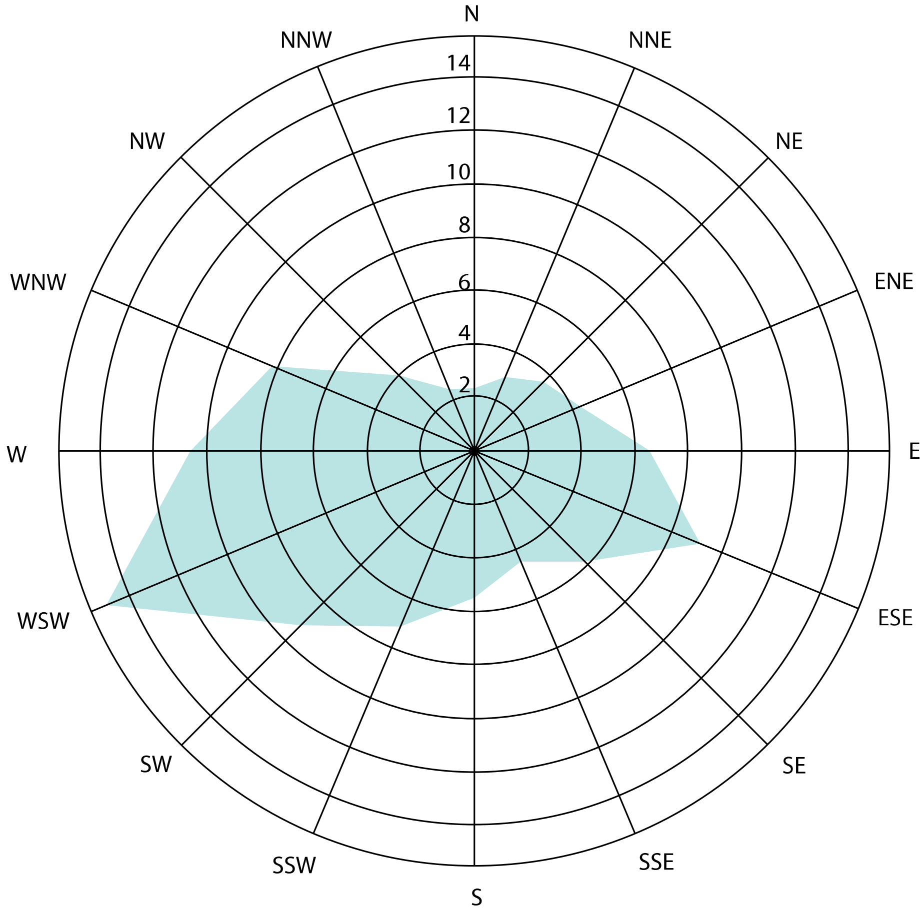


Ill. 38 - Sun diagram

// WIND

A wind rose is used in order of determine the predominent wind direction, however this is only accurate when you have a large open space, cause the air flow through a city or around multiple obstacles is hard to predict. But with the site being on Limefjorden the wind rose gives a somewhat accurate picture of how the wind behaves in that area, especially from the two primary directions of east and west.

The wind rose gives a picture of how the wind is every year with all data points plotted in, so it doesn't account for fluctuations which occurs doing the different seasons. This emphasises the most efficient sides to make the inlet of the natural ventilation on, which is used in the warm months while using mechanical ventilation in the cold months to create a hybrid ventilation system for the buildings



Ill. 39 - Diagram - Annual wind on the site

// ROOM PROGRAM

		Amount	Area	Total area	Roomheight	Natural	Mechanical	Heated	Daylight
Housing type 1	Type 1	4	96	384					
	Entre	1	4	4	2.5+	●	●	●	●
	Kitchen/dinning	1	17	17	2.5+	●	●	●	●
	Living room	1	19	19	2.5+	●	●	●	●
	Stair/hallway	1	16	16	2.5	●	●	●	●
	Bathroom	1	5	5	2.5	○	●	●	○
	Bedroom	1	11	11	2.5	○	●	●	●
	Free room	1	14	14	2.5	○	●	●	●
	Technical room	1	3	3	2.5	○	●	●	○
	Winter garden	1	7	7	2.5+	●	○	○	●
Housing type 2	Type 2	4	93	372					
	Entre	1	4	4	2.5+	●	●	●	●
	Kitchen/dinning	1	16	16	2.5+	●	●	●	●
	Living room	1	17	17	2.5+	●	●	●	●
	Stair/hallway	1	14	14	2.5	●	●	●	●
	Bathroom	1	5	5	2.5	○	●	●	○
	Bedroom	1	11	11	2.5	○	●	●	●
	Free room	1	16	16	2.5	○	●	●	●
	Technical room	1	3	3	2.5	○	●	●	○
	Winter garden	1	7	7	2.5+	●	○	○	●
Housing type 3	Type 3	3	89	267					
	Entre	1	4	4	2.5+	●	●	●	●
	Kitchen/dinning	1	15	15	2.5+	●	●	●	●
	Living room	1	17	17	2.5+	●	●	●	●
	Stair/hallway	1	13	13	2.5	●	●	●	●
	Bathroom	1	5	5	2.5	○	●	●	○
	Bedroom	1	11	11	2.5	○	●	●	●
	Free room	1	14	14	2.5	○	●	●	●
	Technical room	1	3	3	2.5	○	●	●	○
	Winter garden	1	7	7	2.5+	●	○	○	●
		Houses	M2						
	Total	11	1023						

Ill. 40 - Room program

// SENCE OF PLACE

Due to the site being off the coast there's only the water to relate to in the close context and then the coast beyond that, which makes it hard to create a connection to anything due to it being mostly uniform all the way around. So the impact this has on the way of building the platform is to make it, so there's always a connection to the water, resulting in the platform being of a size where the buildings have a relation to the sea. So that it's not so big that some buildings are hidden away from the outside and lose the connection with the water, the focus of the buildings should be to have a view of the sea towards the outsides of the community as well as a connection with the rest of the built environment.

When considering the history of how humans have been living on sea throughout history, there have been long traditions for working with wood and steel to create boats due to its lightweight comparative to its strength, and the ability to be worked into a streamlined shape to make it easy to sail. There can be made references to that with the choice of material but since it's not made to sail but rather be stable while laying still in the water while containing a sizable open volume. A heavy material that keeps water out would be advantageous for at least the part of the building which meets the water to lower its centre of gravity and be durable for long periods.

// DESIGN PARAMETERS

PRIMARY GENERATOR
FLOATATION

Creating a building which is separated from land while still relying on its infrastructure to facilitate all the functions necessary for living, while having a connection to the water, without risking getting flooded when the water rises or when under pressure from extreme weather.

BUILDINGS

Creating buildings which facilitate fulfilment of the human needs for safety, community and self-actualisation, while simultaneously being physically removed from healthy society as an exploration to move buildings out onto the water.

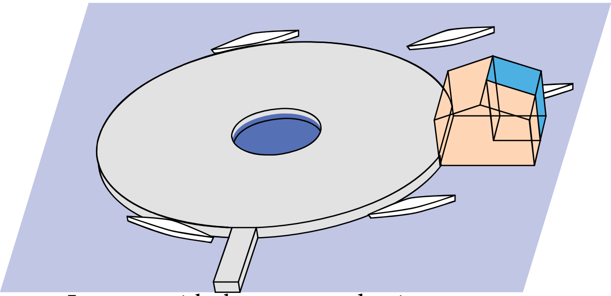
SECONDARY GENERATORS

- Designing a sustainable building complex
- Interacting with the water while both are getting to the building and when inside it.
- Integrate the material properties (tactile acoustic visual, etc.) into the shaping of the atmosphere of housing.
- Facilitate an indoor environment with a healthy atmospheric and thermal climate with proper ventilation.
- Creating functional and comfortable architecture on the water.
- Central access space for housing to facilitate an environment where people meet each other.

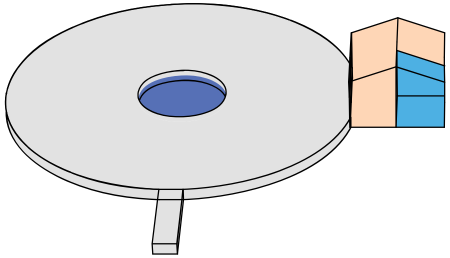
PRESENTATION

// VISION

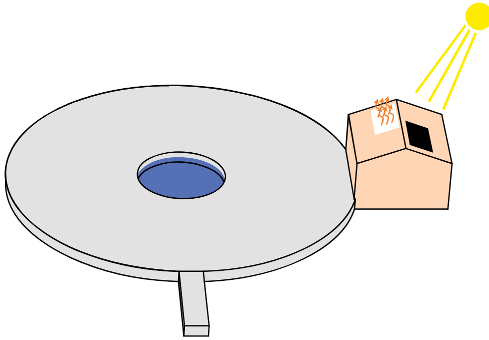
To create a sustainable community, where the built environment is adapted to being on water so that it can utilize a cities infrastructure while floating on water, to prevent it from being endangered by rising water levels and an increasing frequency of floodings.



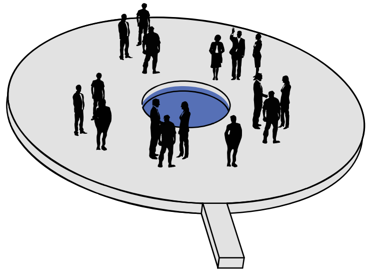
Interact with the water so that it can be used as a recreational space.



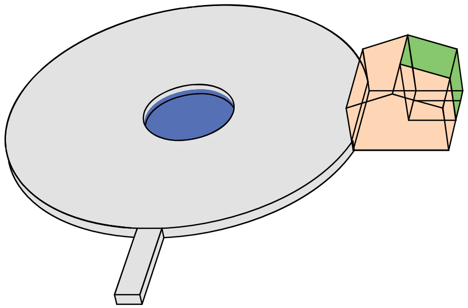
Provide private outdoor spaces for all the residents.



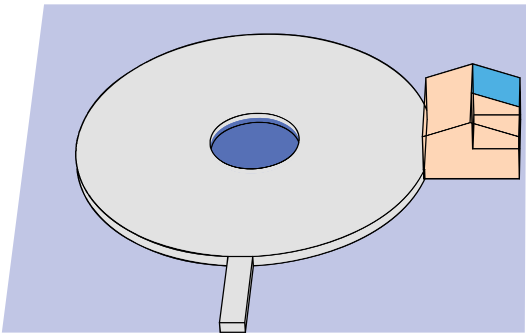
Integrate passive and active strategies.



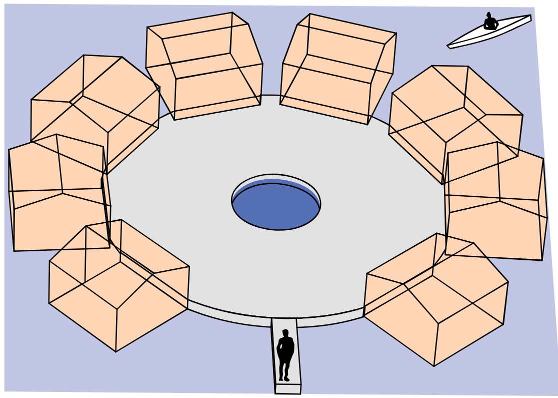
Facilitate the interactions between the residents



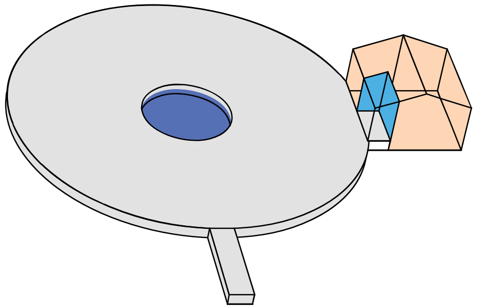
Articulate an outdoor space which allows for growing plants all year around



Design for integrateing water into the residents and the resident into the water.



Respecting the human scale both when approach-ing the site from the water aswell as from the path.

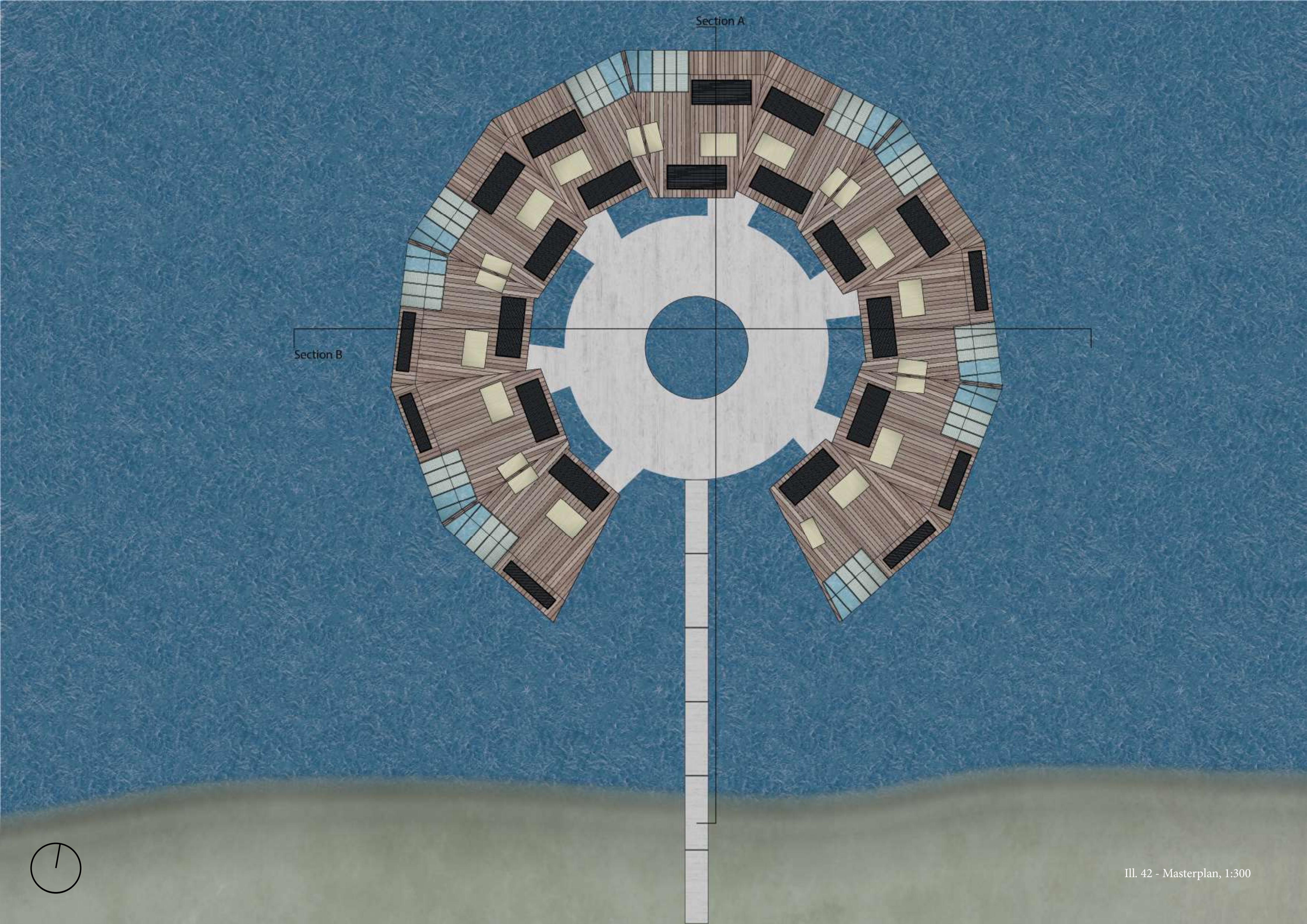


Protected entrance when entering the residents

Ill. 41 - Design parameters

// AQUATECTURE

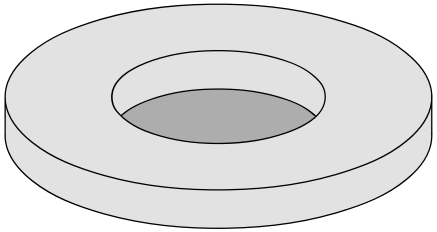
The building complex is positioned near the edge of Limfjorden within the city limits of Aalborg, reimaging the way of living in a changing environment affected by the advancement of climatic deviations resulting in rising sea levels. Aquatecture focuses on the interpretation of societies way of living near open waters, this has been the cornerstone for the forming of cities in Denmark, along with a majority of larger settlements across the globe. Beforehand this has been influenced by infrastructure but has in modern days expanded to a phenological relationship and has become a part of the city.
By expanding the city onto the water, not by constructing a pillar foundation where the structure roots below the surface creating a stable base in the ocean floor, Aquatecture emphases on buoyant foundation floating above the predicted rises in water levels. Simultaneously the weight of the building generates stability from wind and movement atop the water, leaving it only to require an anchor to stay in place. The building itself strives to create an interior space that facilitates modern living without sacrificing the comforts of living on land but instead replaces it with the additional function of being able to use the water as an integrated part of the home, offering the users an individual connection to the open waters through the winter-gardens. During the winter periods, these can be closed off for the user to use the area to grow plants.
The housing complex encloses a shared space for the residents to interact with one another and socialise while also connecting the housing complex with the mainland, though a longer path for the residents to freely use.



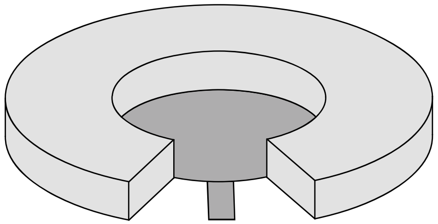
Ill. 42 - Masterplan, 1:300

// AQUATECTURE

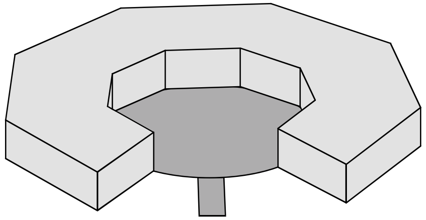
The concept behind Aquatecture, attempts on building an environment at sea that creates a small community, in connection to a mainland city — forming a protected environment for the residents to live in with a focus on providing privacy for the residents both when people get to the residents from the central space and when getting to the housing from the water. The internal space is connected to land to provide easy access to and from the building complex and generates a transition from the public place of the city to the semi-private space shaped between the households, into the private spaces of the individual residential homes.
Despite going into a new context and making a building that is placed in this unique context, it should also act as a catalyst for the future development of settlements. For people moving out onto the water creating a new way of living in a connection to the water, that has been treated as something to be controlled by meticulously moving it around instead of living in connection to it.



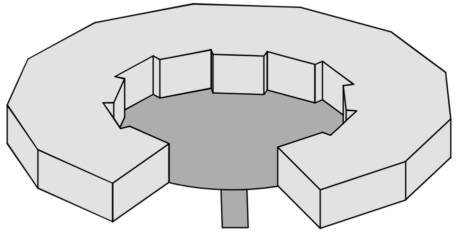
Protected space from wind, where the residents can enter their housing units



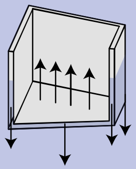
Breaking it up to create an entrance towards the coast and away from the dominant wind direction.



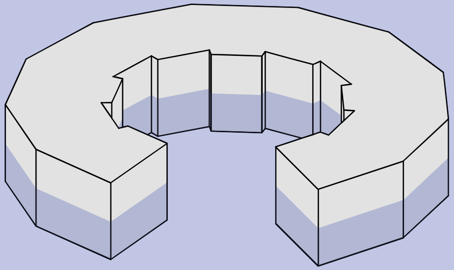
Dividing the facade into individual units on both interior and exterior facade



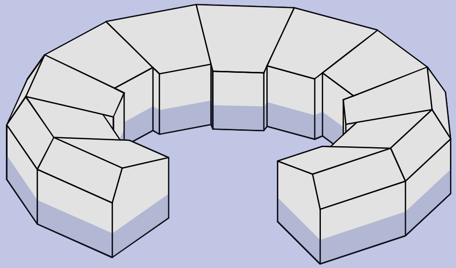
Breaking the interior facade up to not have one large flat facade



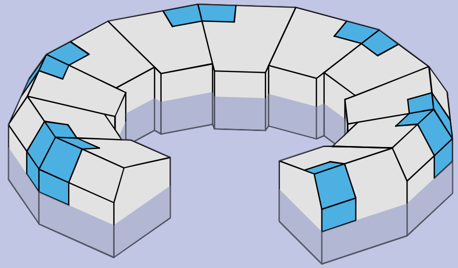
Making it float



Creating stability while floating while also having it leveled to make entering to residents easy.

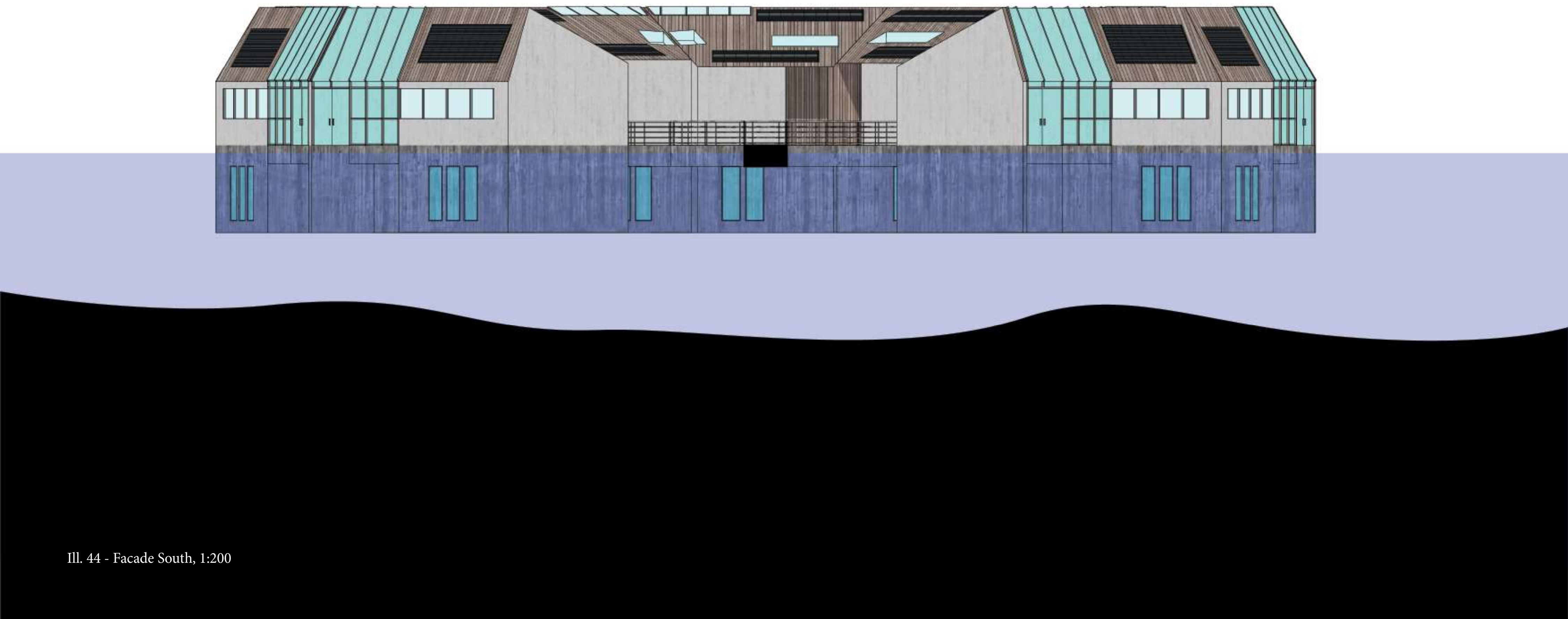


Sloped roof to allow for water to run of the roof and make space for photovoltics.

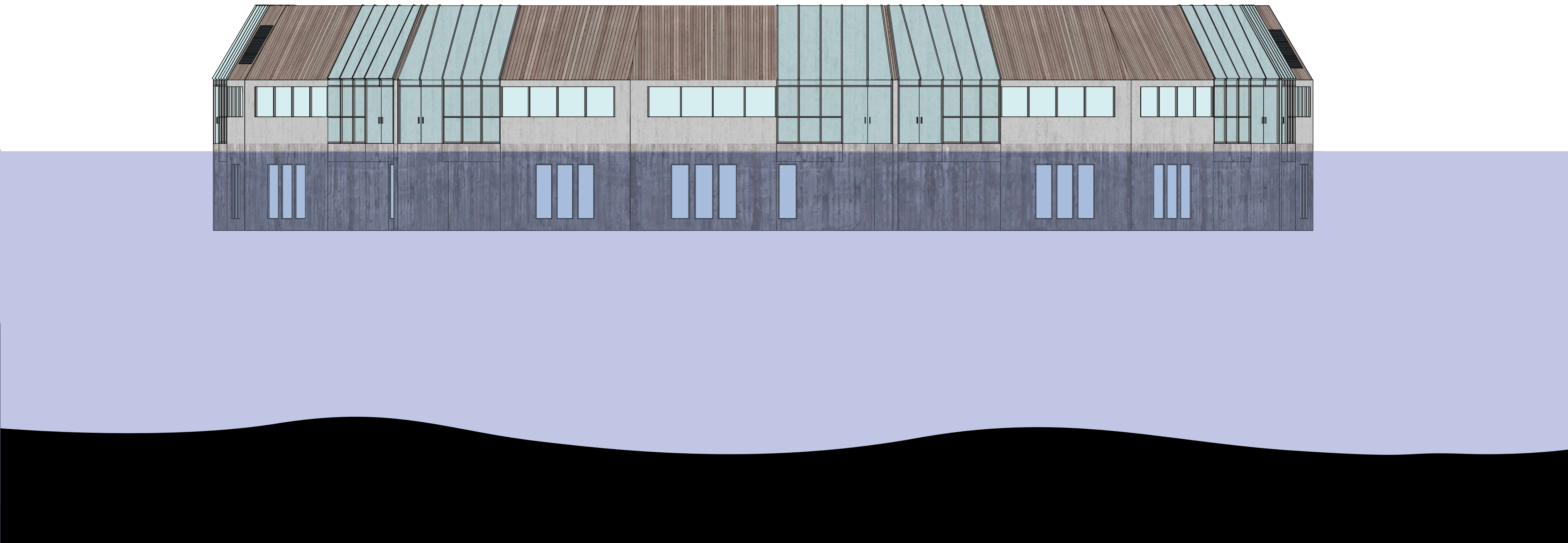


Integrate the water into the residents and allow for plantings in a simi outdoor protected space all year around.

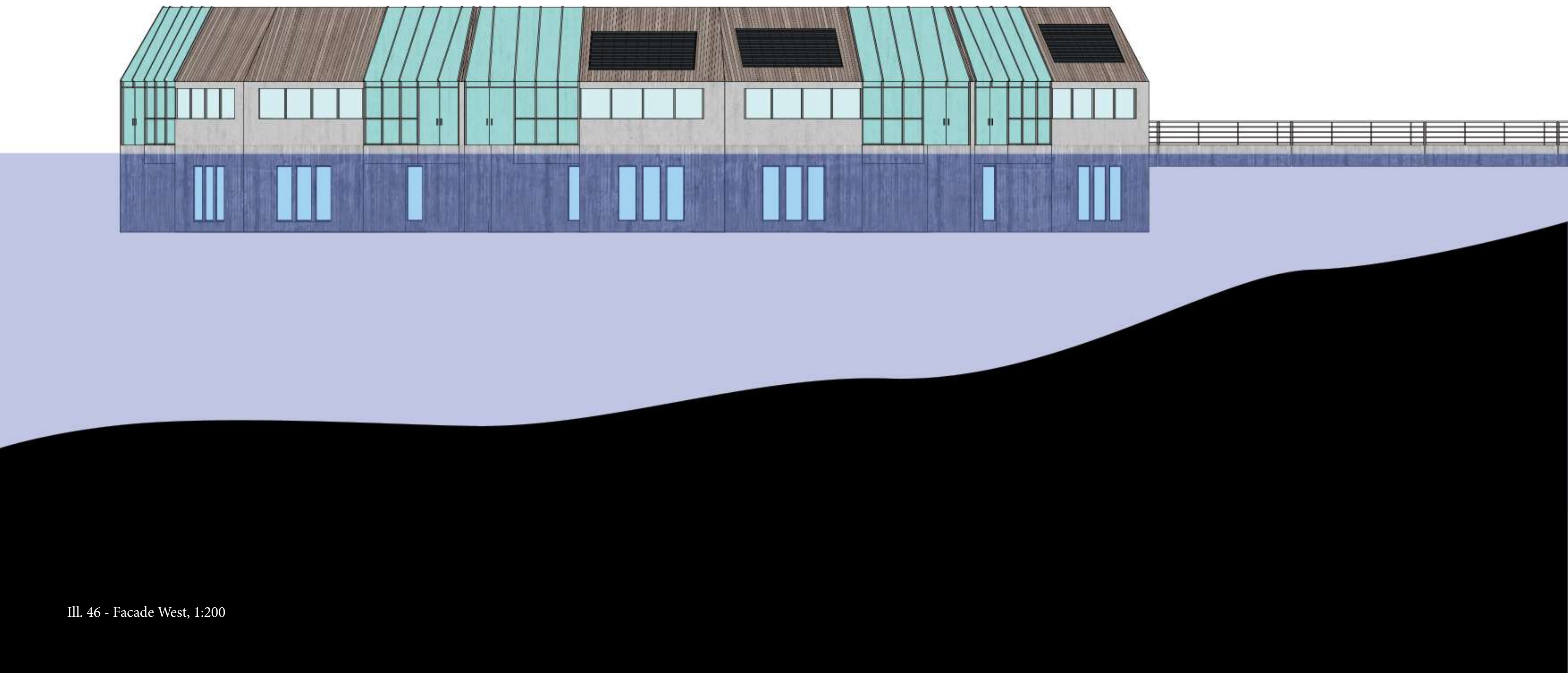
Ill. 43 - Concept diagram



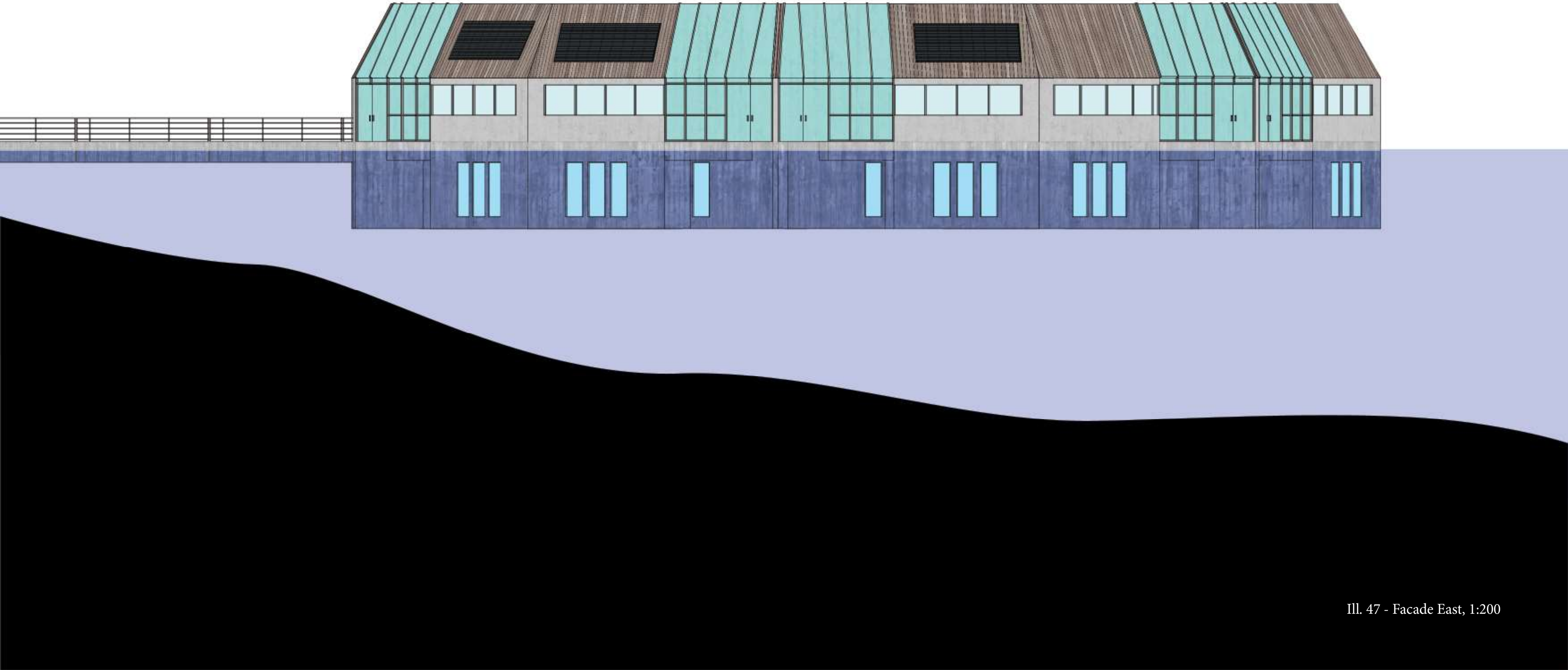
Ill. 44 - Facade South, 1:200



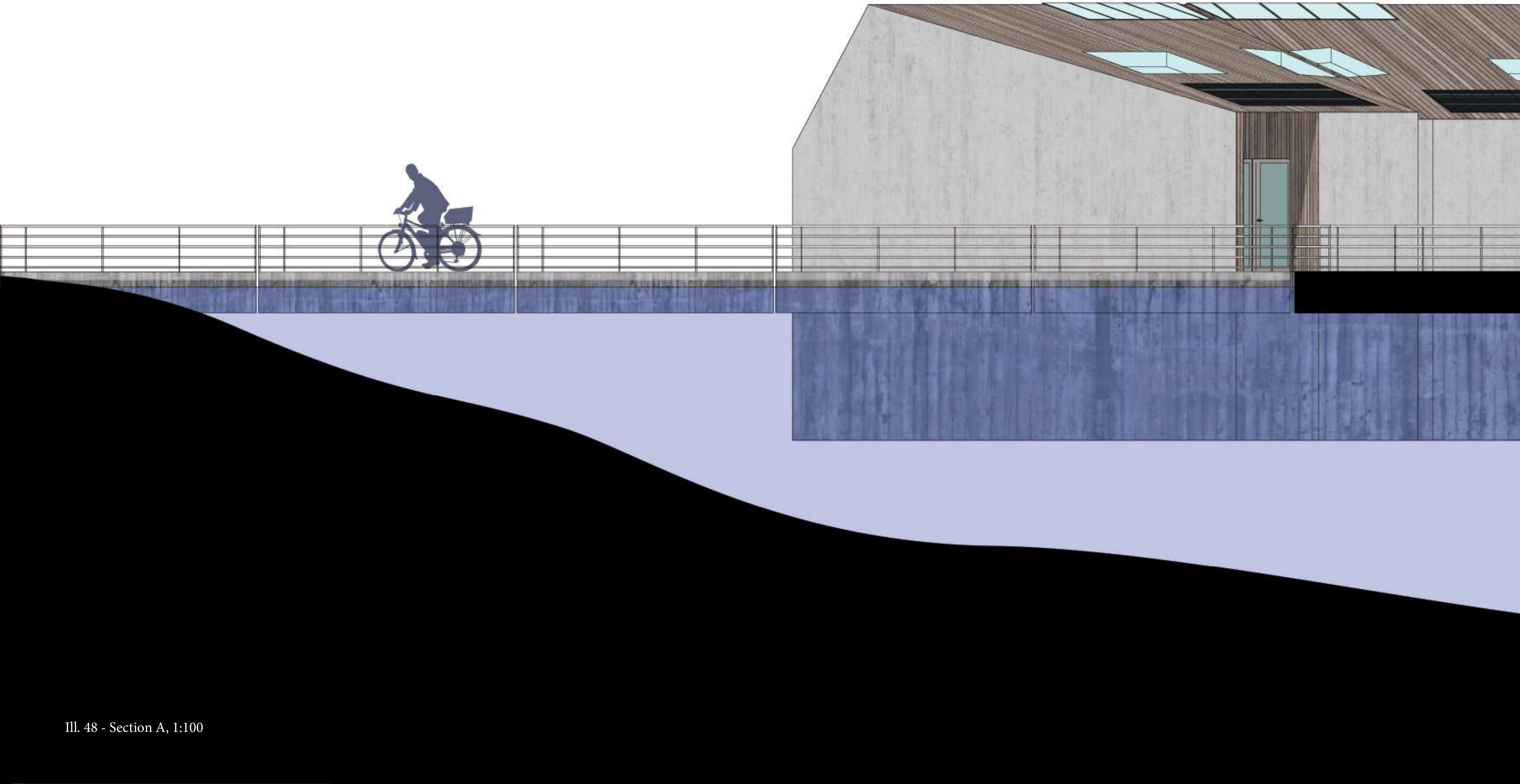
Ill. 45 - Facade North, 1:200



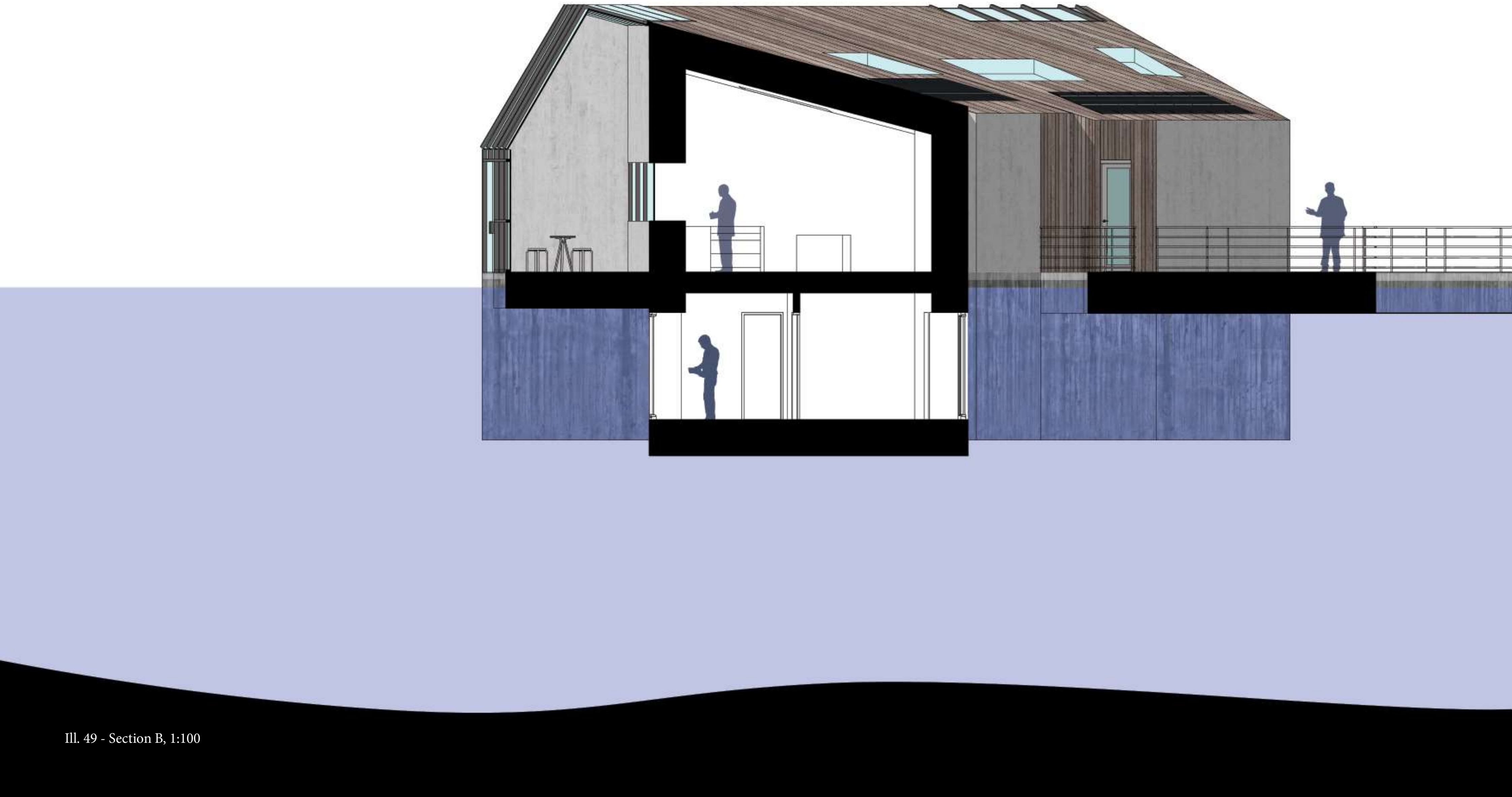
Ill. 46 - Facade West, 1:200



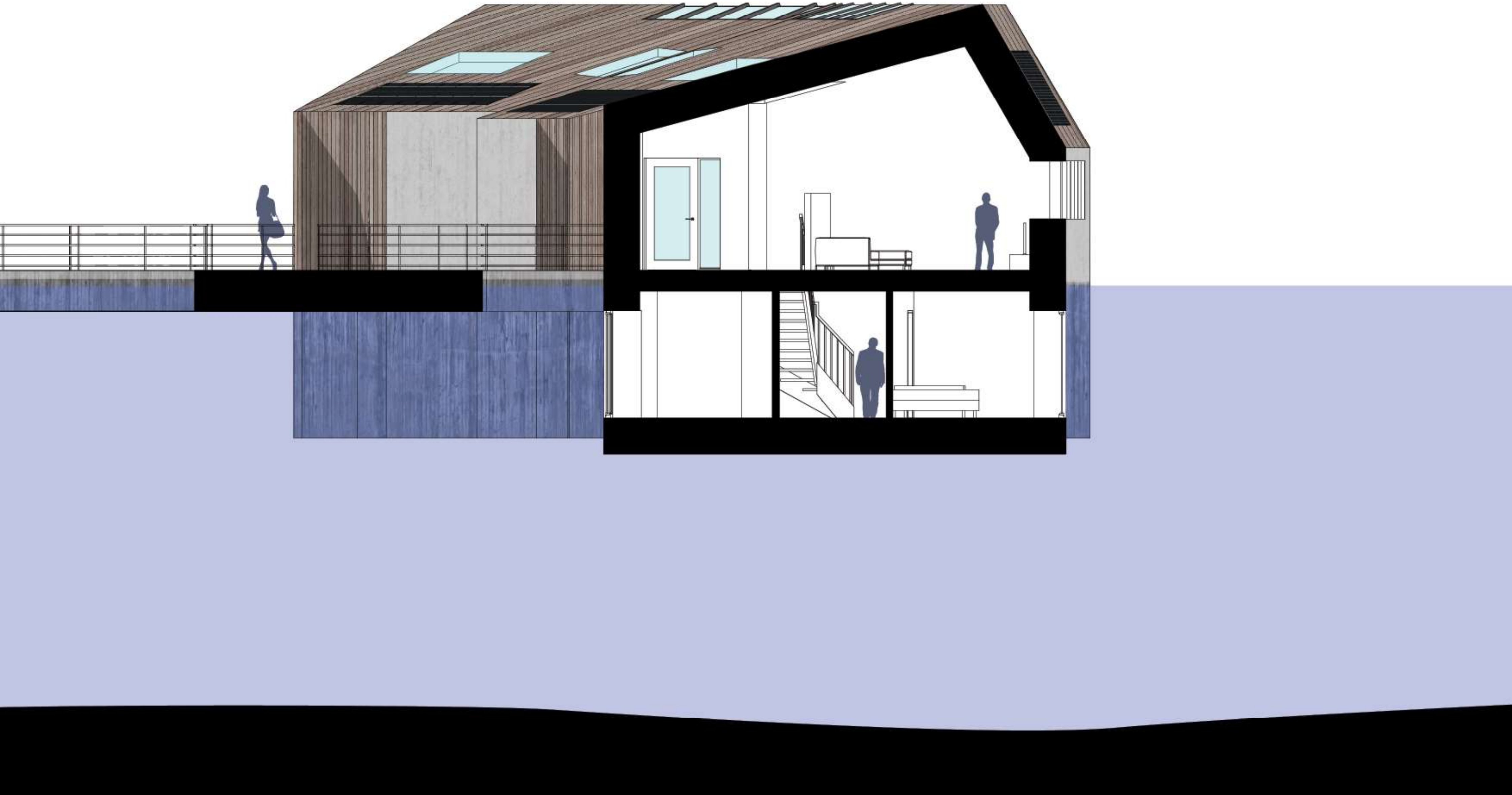
Ill. 47 - Facade East, 1:200

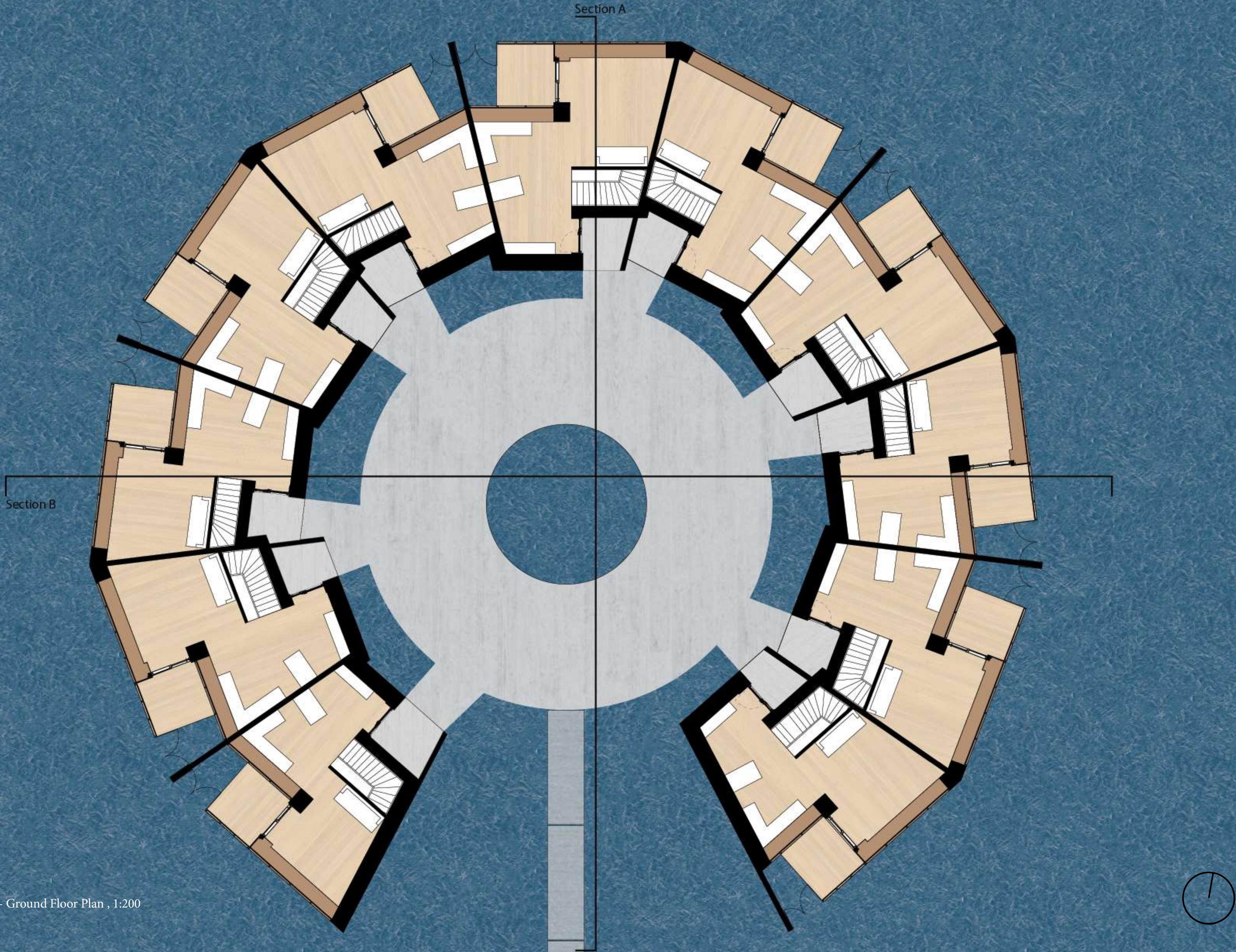


Ill. 48 - Section A, 1:100

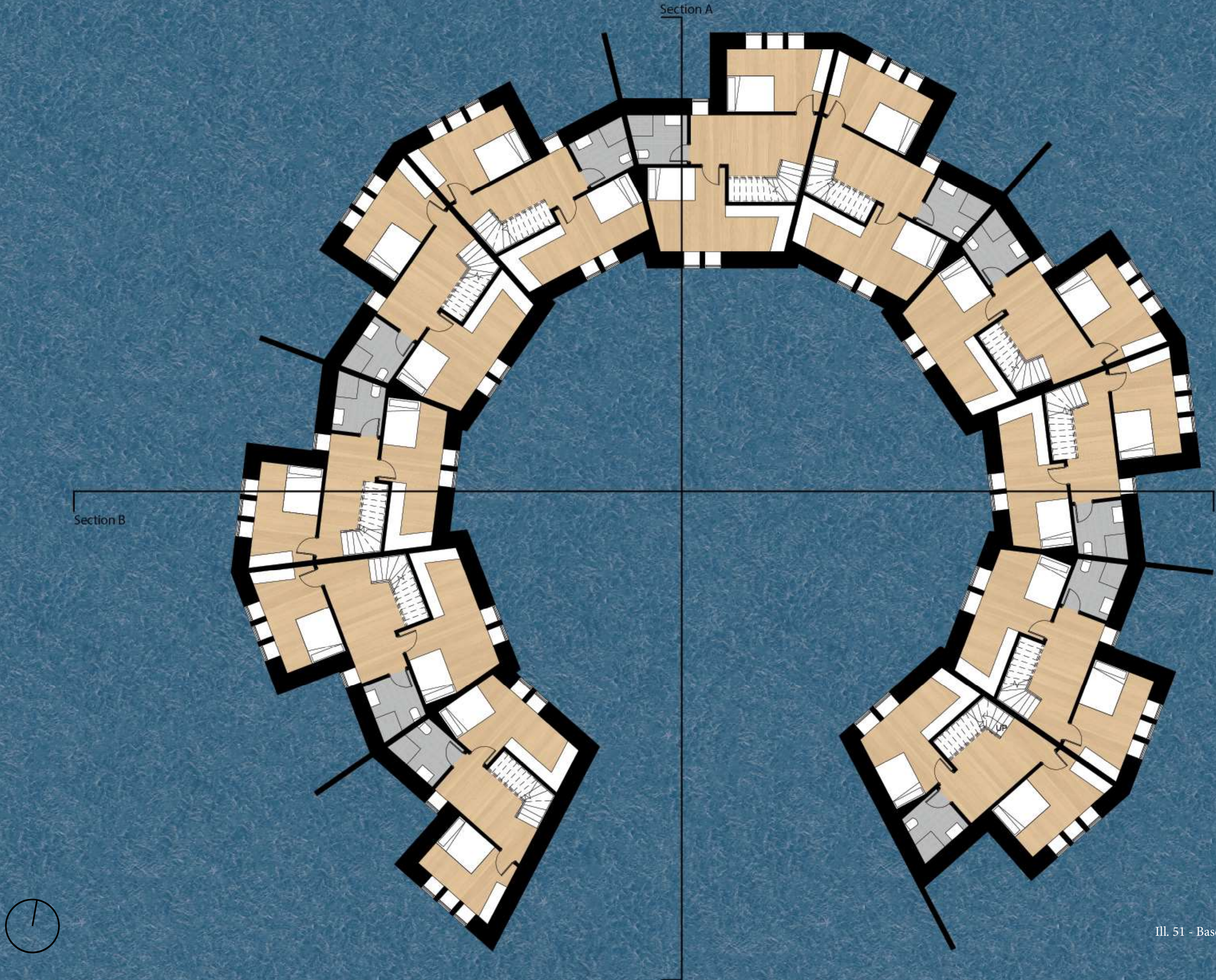


Ill. 49 - Section B, 1:100





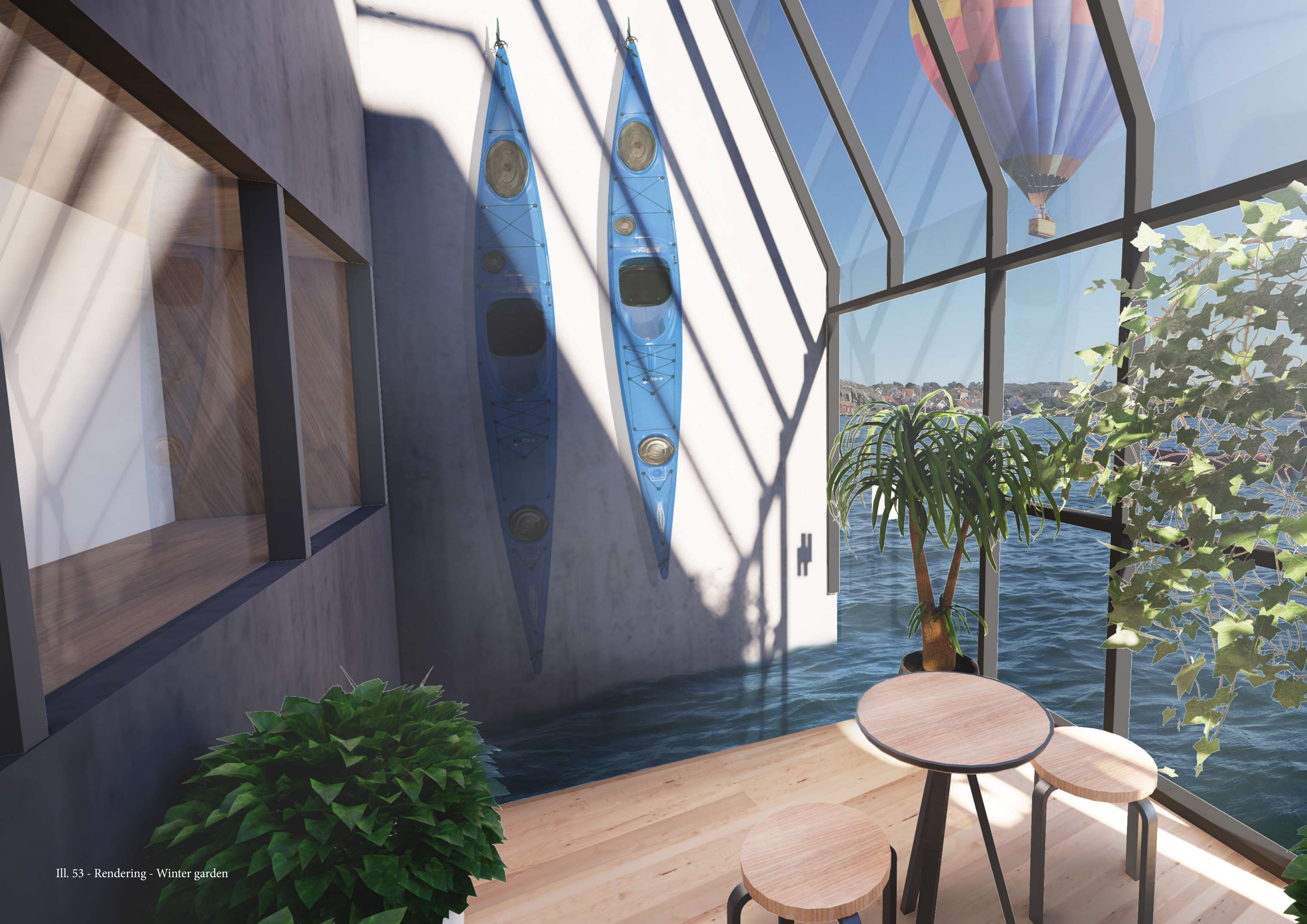
Ill. 50 - Ground Floor Plan , 1:200



Ill. 51 - Basement Plan , 1:200

The internal space between the housing functions as an access-way to the housing and connects it to the mainland, the connection to the mainland opens up and creates space for the residents to use to socialise with each other and meet when entering and leaving the houses as well as providing a space to spend once leisure time outdoors. Since the internal space is enclosed and people spend time and come and go there the entrances to the houses are covered and open on perpendicular to that so there isn't a clear view of the individual houses.

Ill. 52 - Rendering - Internal courtyard


Ill. 53 - Rendering - Winter garden

Ill. 54 - Ground floor plan single unit

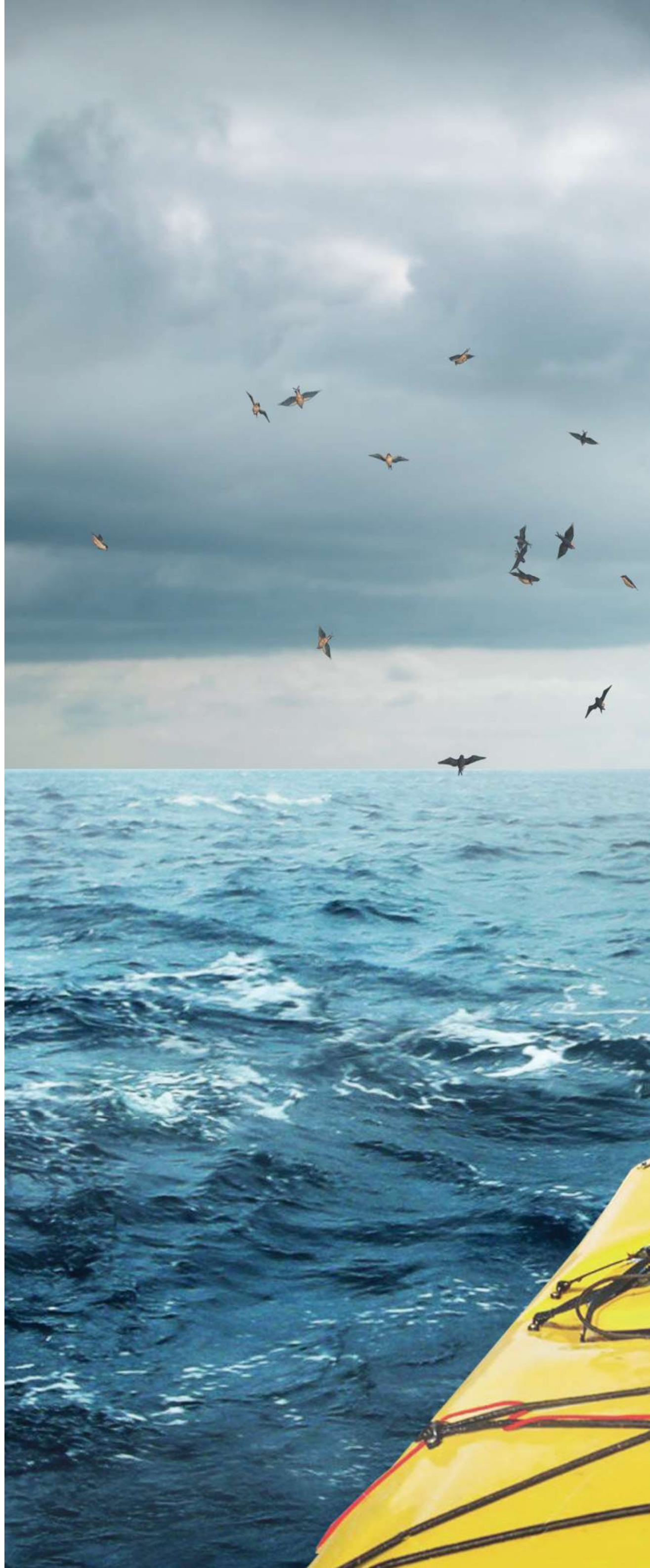
Ill. 55 - Rendering - Bedroom

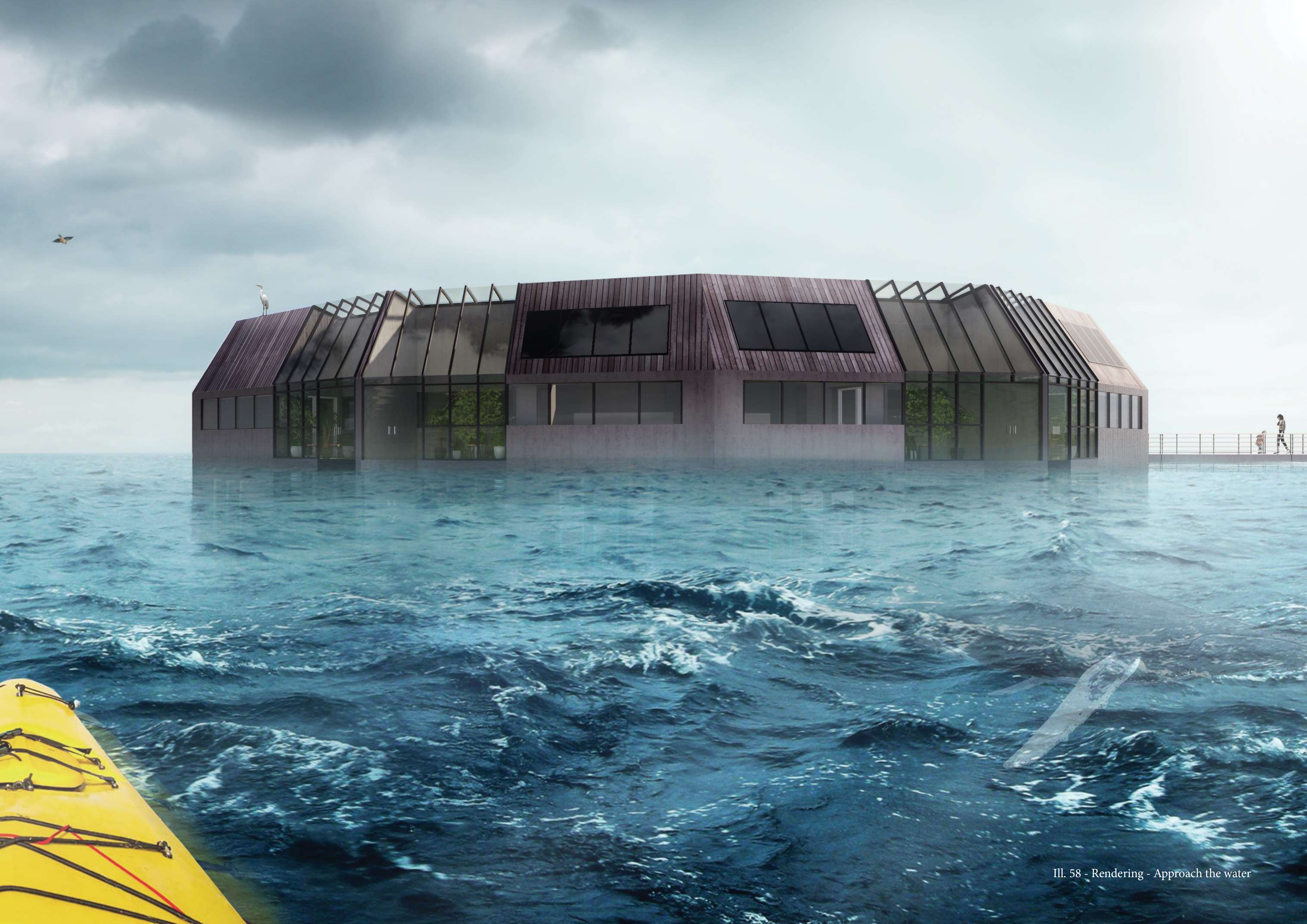
Ill. 56 - Basement plan single unit

When approaching the site from the mainland the facade is closed off so that visitor and residents cant look into the residents at the gabels. But it then opens both outwards and inwards towards the common space. The common space then leads into the covered entrances to the different houses before entering them. The outwards facing facade faces away from the path so that there is no clear view of the two houses that face the most towards the path to provide privacy to the residents living in them.

Ill. 57 - Rendering - Approach from land

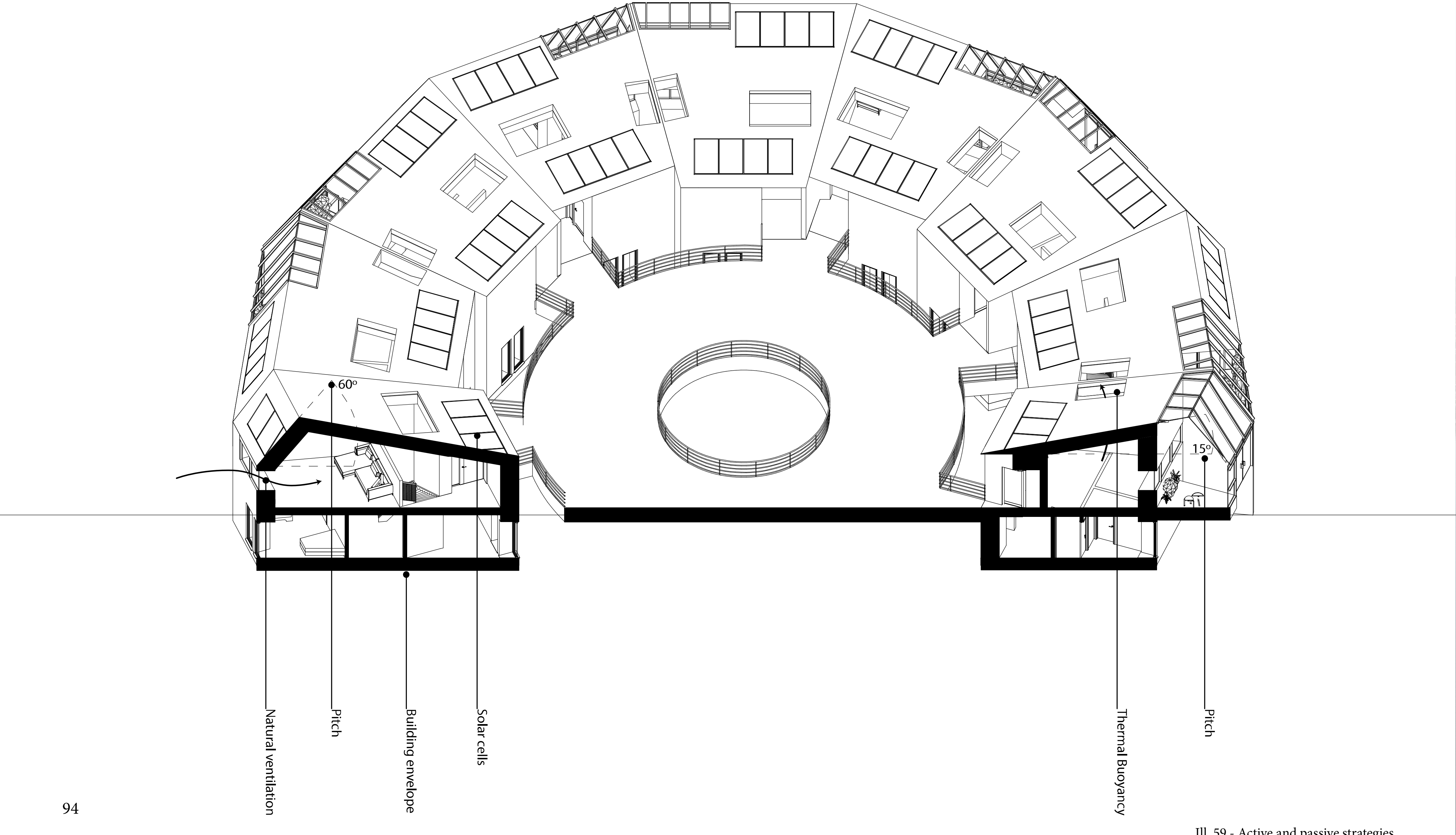
The approach from the water brings you to your own housing unit or to the internal space between the housing where in both places, it is possible to dock and store small boats.
With the water being a part of the housing, this allows for the water being used as an active part of the dwelling. The tenants are given the possibility to sail directly to and from the house, which makes it easy also to use the water as a recreational place. There is a wide range of possibilities depending on interests of the residents be it fishing, sailing, swimming or something else entirely, but with the easy access to the water, it can become a part of the daily life for the residents.
There aren't any floor to ceiling windows towards the water since that would impact the privacy within the houses since people sailing by could look into the housing, so the windows are raised to that at least while in a boat it's not possible to look directly into the houses





Ill. 58 - Rendering - Approach the water

// PASSIVE AND ACTIVE STRATEGIES



Ill. 59 - Active and passive strategies

Ill. 60 - Rendering - Multiple complexes in city context

// ENERGY AND INDOOR CLIMATE

BE15

Energy frame	KWh/m² pr· year	District heating	Electricity
BE15	28.1	0.8	2.5
BE20	22.9	0.6	1.8

Contributions to energy demand

Heating Demand		25.8
EL for building operation		0.9
Excessive in rooms		0.0
Primary energy	25.8 x 0.6 + 0.9 x 1.8 + 0.0	17.1
With Solar PV's		-2.1

Housing unit // West Orientated

Heat balance

Loss kWh

Transmission	-354
Ventilation	-2688
Venting	-7208
Infiltration	-1889

Gains kWh

Heating	4116
Equipment	876
Lighting	254
People	1334
Solar Radiation	5492

Thermal and Atmospheric Comfort

(Kitchen, Dinning and Lving room)

Air Change	4	h^{-1}
Co2 Level	453	ppm
Hours <20	21	
Hours >21	8612	
Hours >27	49	
Hours >28	14	

ENERGY DEMAND

To determine the energy demand of the housing complex and reach the energy frame set down by the Building regulation 2018, which sets a goal for the buildings energy consumption by 2020 as 20 kWh/m² per year, which is calculated in Be15. The building is partially submerged and partly above water, which poses a critical situation for the calculation of the buildings transmission loss which the program can't quite calculate. The temperature for the underwater part of the building is therefore set to be against a surface which is 10 deg across the year as an average of the water temperature year round while the part of the building above water is set to interact with the air as normal. Though a building envelope with a low U-value, which is airtight, the energy frame is reached with an energy consumption of 17.1 kWh/m² per year of primary energy. Furthermore, solar PVs are implemented to the different roofing surfaces, but since the roofscape is so varied they are places with various efficiency, but within the Be15 it is placed as direction, which is a little below average to ensure that it produces enough energy to cover the yearly consumption of the housing. The total energy demand, including PVs, is -2.1 kWh/m² per year with 110 m² of solar PVs.

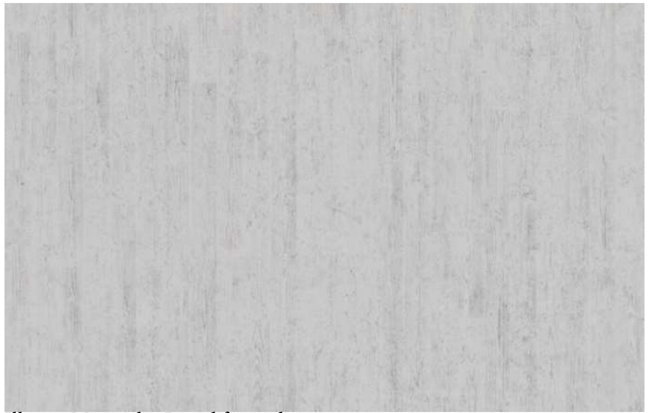
SOLAR PVS

The calculations within BE15 for solar PVs bases the buildings energy demand on heating, ventilation, cooling and domestic hot water. However, there is additional energy consumption for appliances, which are not taken into account within the BE15 calculation, so part of that is covered by the additional energy production, while the rest is covered by the electrical grid to which the building is connected.

INDOOR CLIMATE

To have a building categorised as a zero energy building it needs to uphold the standards for indoor climate to ensure comfort for the residents, part of the indoor climate is simulated with BSIM for the different units that are orientated north, west and southwest. BSIM simulate the indoor climate, so it's used to provide thermal climate to look at overheating within the upper floor of the housing, which contains the kitchen, dining and living room. To verify that the indoor climate is below the limits for overheating where there can be no more than 100 hours above 27 degrees and 25 hours above 28 degrees. The other aspect of comfort is the atmospheric comfort, which has the upper limit for CO2 pollution set to 850 ppm. The last aspect of indoor climate that have been tested is visual comfort, where Velux Daylight Simulator has been used to test the natural lighting of the rooms, where the minimum requirements is 300 lux or more for at least half the floor area, which if the 300 lux is converted to daylight factor gives 3 % [Bygnings regimented, 2018].
The Bsim and Velux DaylightSimulator simulations demonstrate a good indoor climate in regards to the atmospheric and thermal environment, in which the user can be comfortable all year around.

// MATERIALITY


Ill. 63 - Material - Board formed concrete

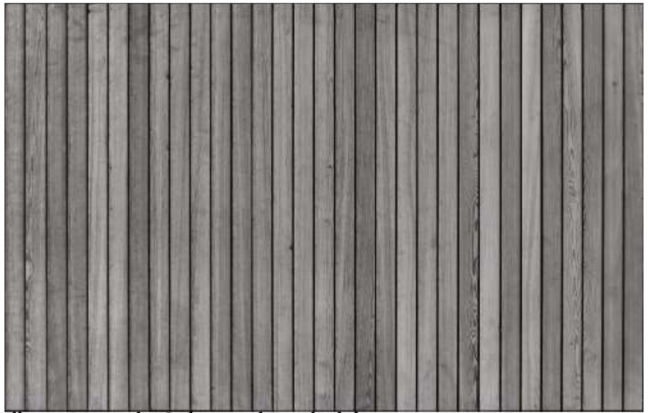

Ill. 62 - Material - Board formed concrete partly through the patina process


Ill. 61 - Material - Board formed concrete further through the patina process

The material that's used for the exterior facades is chosen for their expression and the way that they patina and deteriorate over time since the environment the building is in a wet environment, which is hard on the materials. The high amount of moisture in the air, as well as part of the building being submerged cause a constant interaction with the water speeding up the process of deterioration, which has a large influence on what materials are suited to be used in the situations.
Concrete is chosen for the material which is submerged as well as transitioning out of the water since it's often used in this environment, which is a testament to is durability under those harsh circumstances. But also due to its way of changing over time as patina takes effect on its surface. The colour of the concrete darkens, and the prominence of the texture strengthens, to utilise this change in appearance there chosen a board formed concrete since it brings extra texture to the concrete. That then becomes more visible over time.
Another Reason for going with concrete is its the weight which gives the building its overall stability since it lowers the centre of gravity and gives it a mass so that it is not influenced by weather and or people moving around, which if it was light could influence the proprioception senses of the humans living in the building.

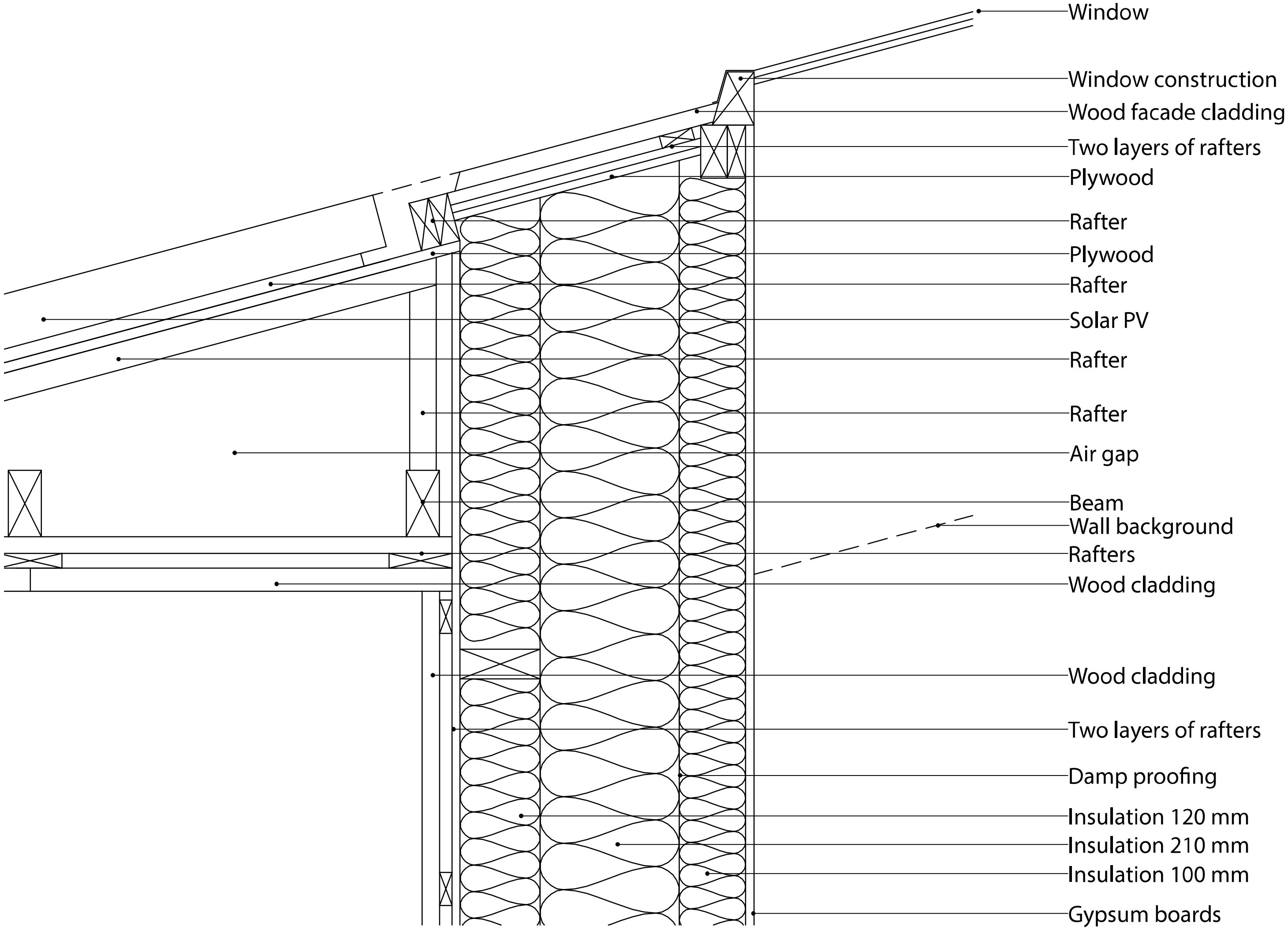

Ill. 64 - Material - Cedar wood


Ill. 65 - Material - Cedar wood partly through patina process

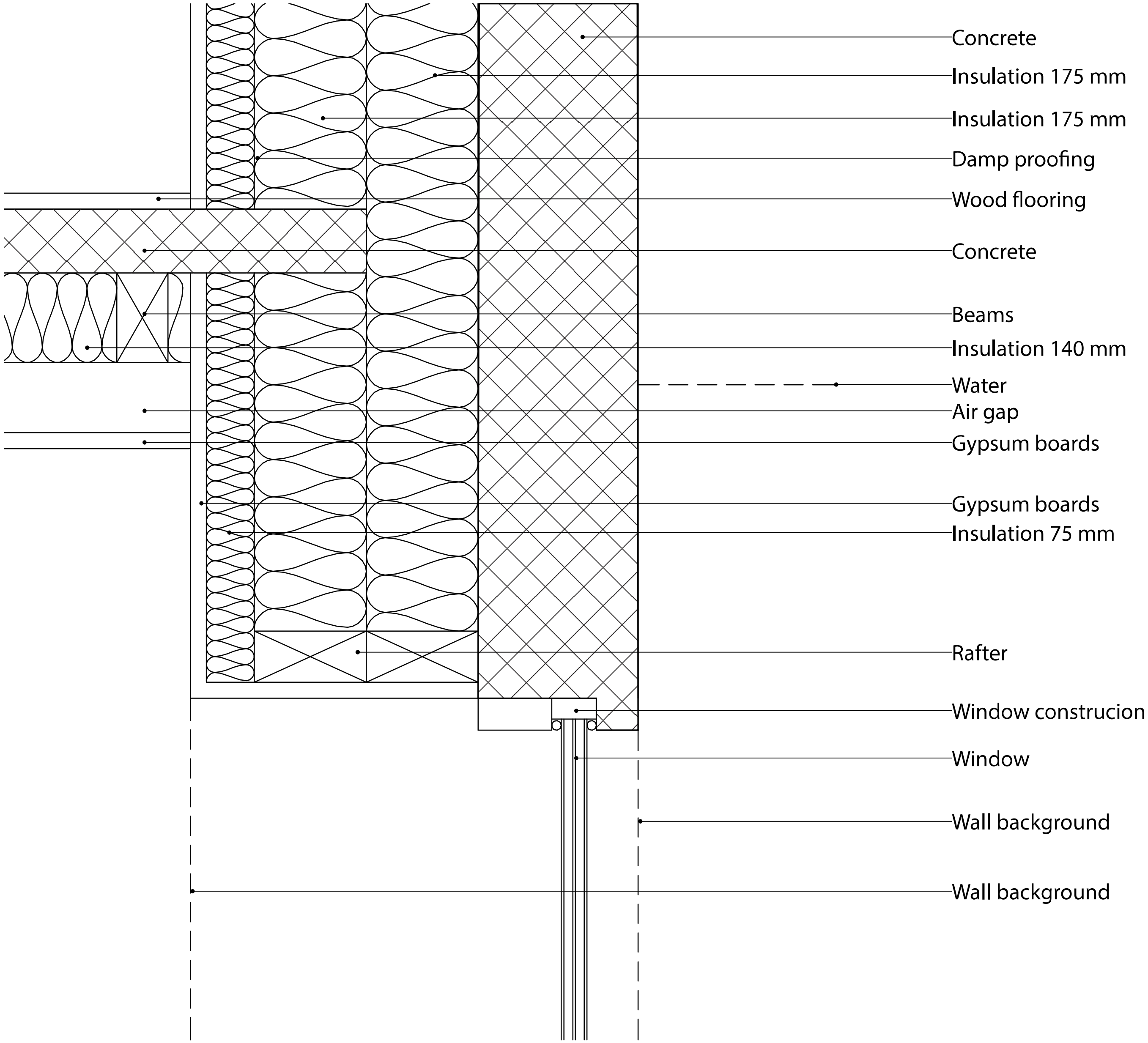

Ill. 66 - Material - Cedar wood Finished the patina process

Wood is chosen for the roofing, to stand in contrast to the concrete and since it has a long lifetime, even in harsh environments. The type of wood chosen is western red cedar wood due to its resilience against the climate and the weather, where it have a documented lifetime of 50 years. But even with its long lifetime, it goes from its initial look to the finished patina after a few years of being exposed to rain and sun, but if it gets treated before it gets mounted to the façade, the facade will keep its colour for a prolonged period. It is there for decided to treat the wood before putting it up so that it holds is colours. The wood remains its warm yellow-reddish colour for an extended period before it becomes a gradually more silver grey colour. The pattern of cladding also matches the verticality of the pattern that is imprinted into the concrete by the wooden boards that are used to make board-formed concrete.

// DETAIL DRAWINGS

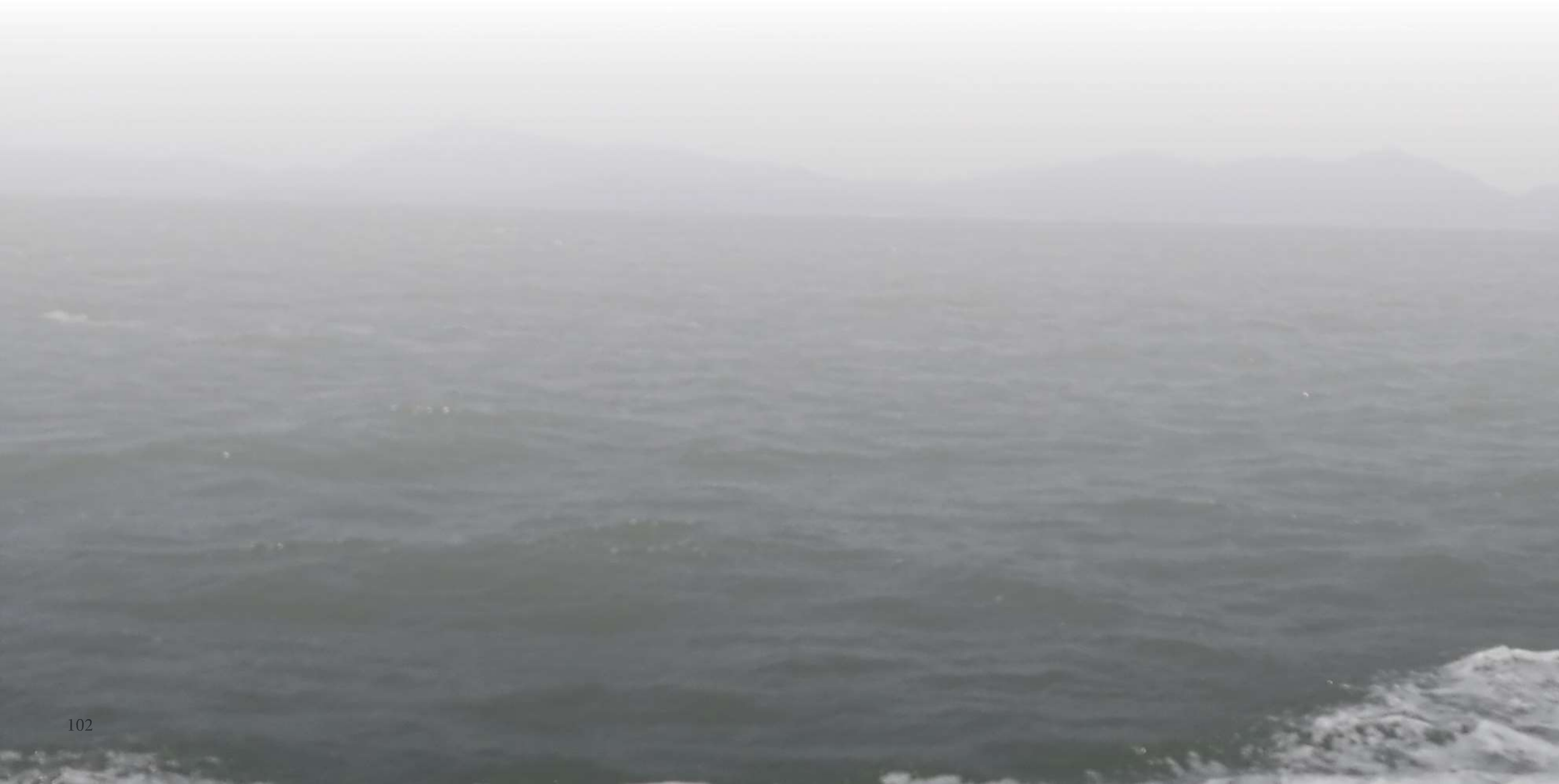


Ill. 67 - 1:10 Detail drawing wall, skylight and solar pvs

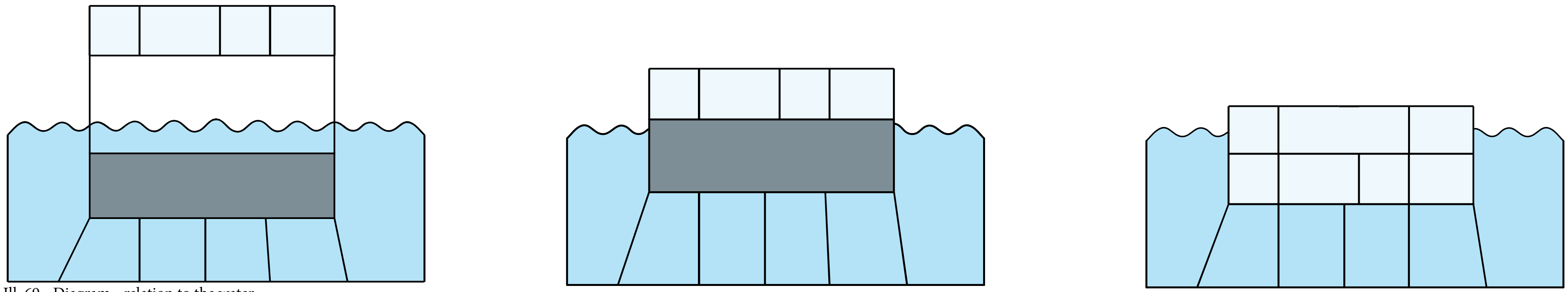


Ill. 68 - 1:10 Detail wall, window and floor

SKETCHING PHASE



// WORKSHOP // INITIAL SECTIONS & PLAN

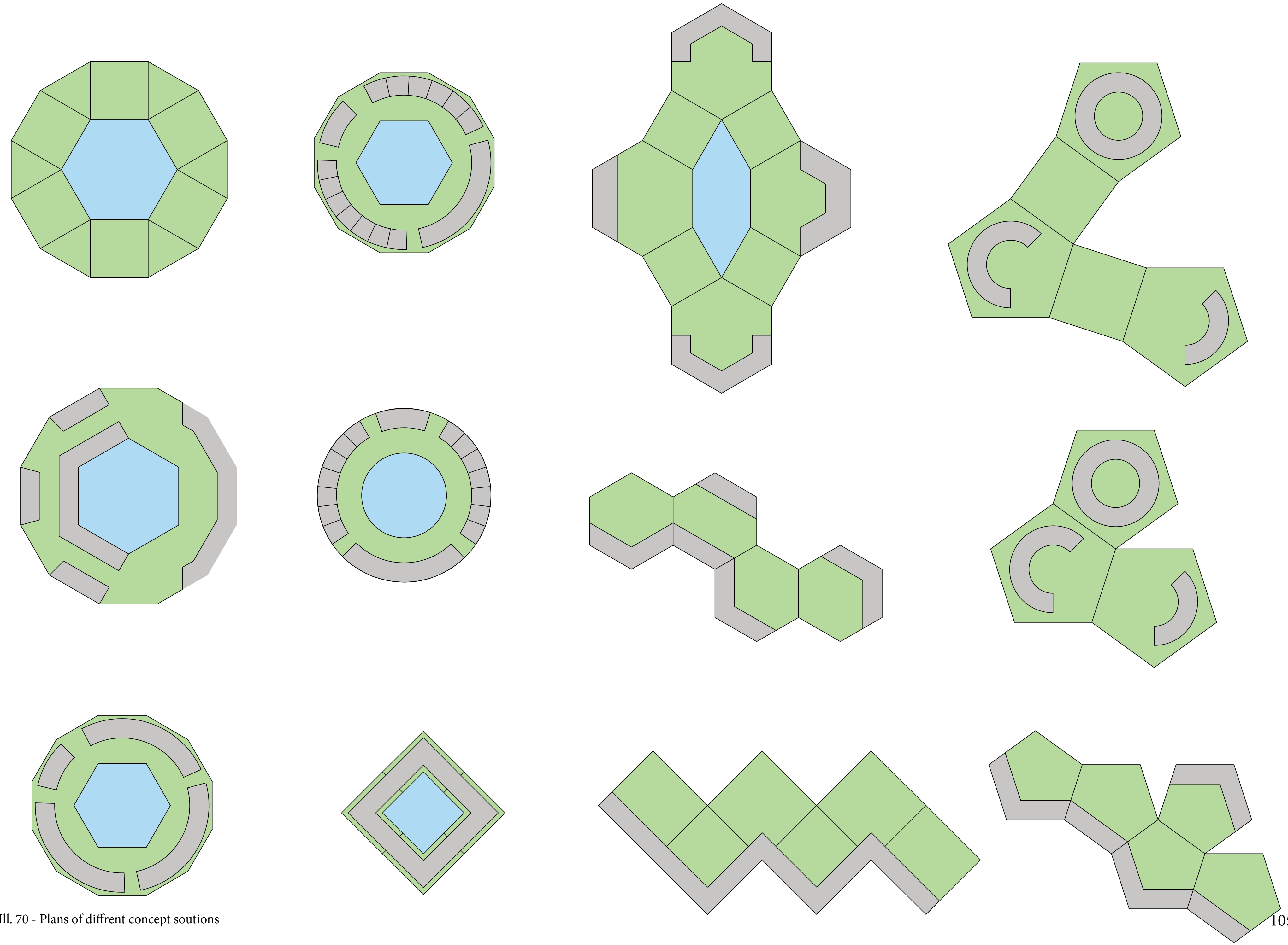


Ill. 69 - Diagram - relation to the water

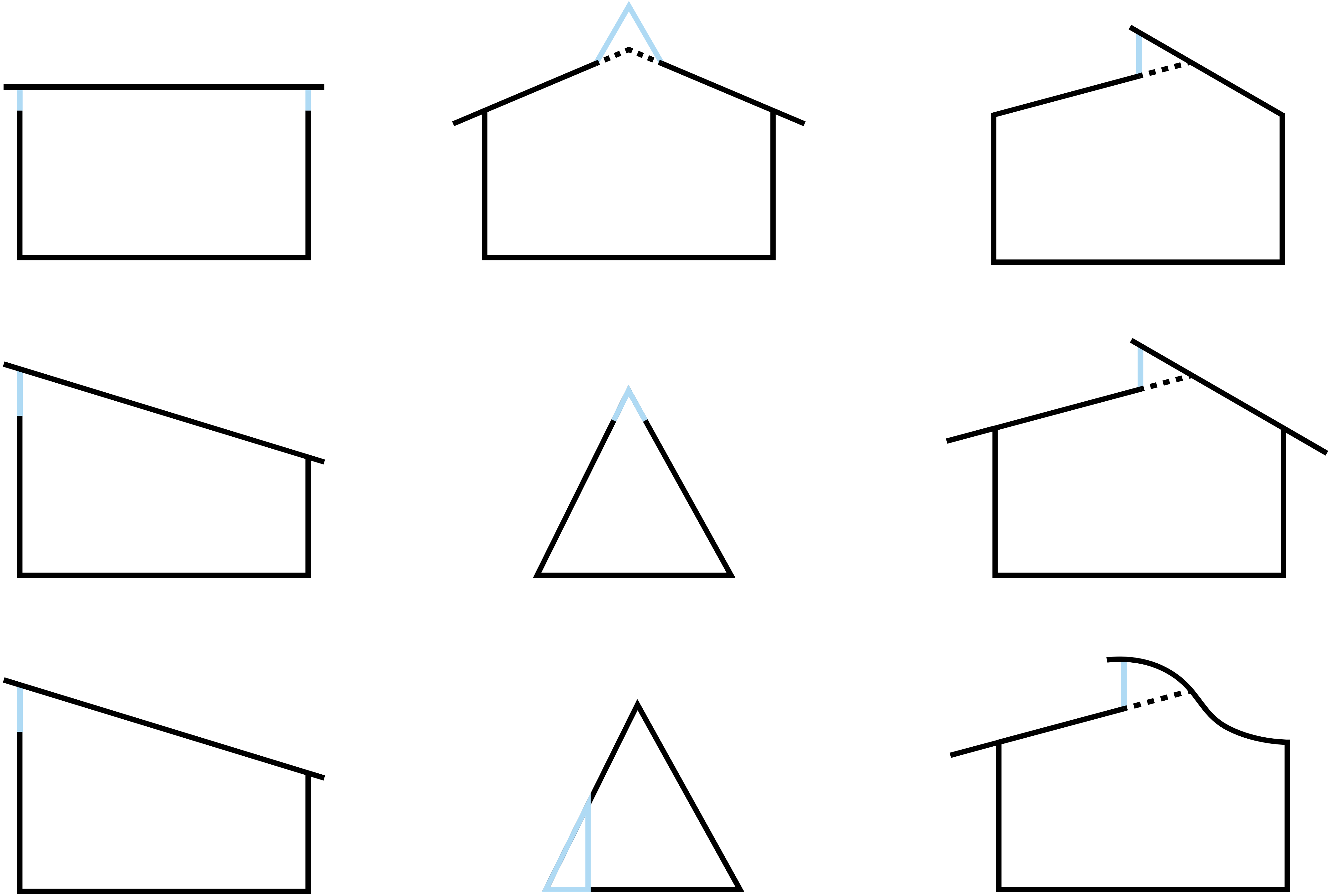
Before initiaing the first workshop, theres looked at three diffrent ways of floating and interacting with the water. Those three create a foundation, for which the sketching in the workshop can be focused around, while still allowing for freedom and variations within the different iterations.
These three concepts for floating are then sketched on top of to find a plan layouts, to find an initial base to start the thought process for what's needed to create a comfortable place to live on the water. The workshop with plans and sections is continued alongside the other workshops until the final concept is selected so there's constant development on the overall plan and the more specific plan solutions for the functions.

The three concepts are as shown in the diagrams above: raised above the water, leveled with the water, partly or entirely submerged.
The raised above the water, functions of the same principle of an oil rig, with large bunkers that creates buoyancy, which makes the buildings able to be lifted out of the water, but makes it hard to get to and from the building, the flipside of that it creates safety from rough seas.
The concept of building levelled with water relies on the buoyancy of the platform, which the buildings are situated upon. With its close connection to the water, it's easy to access the buildings and platform from either a boat or a floating path leading directly to land.

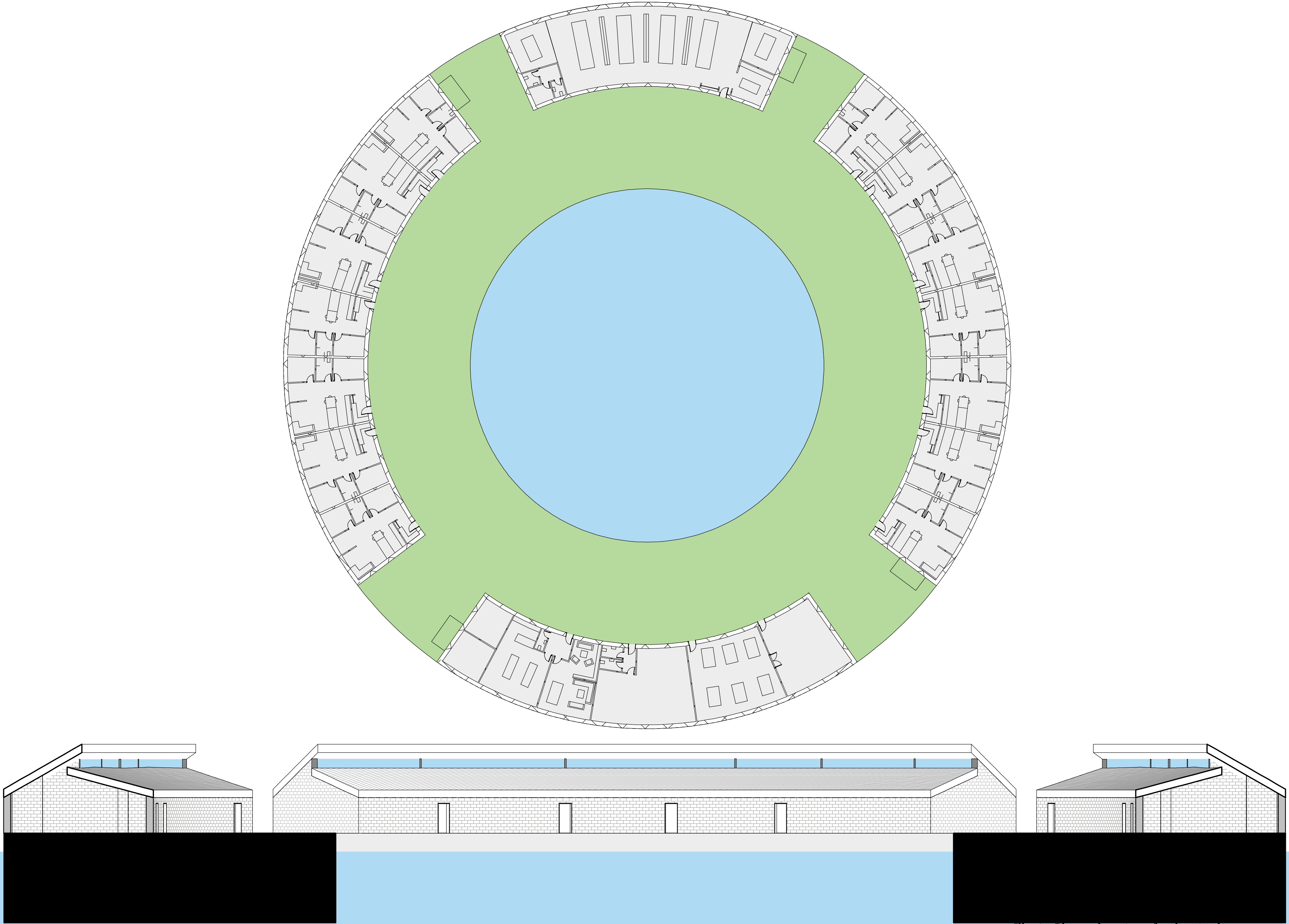
This way of building on the water is susceptible to rough seas, so there needs to be protected, or it needs to be placed in safe waters. The platform can be used for supporting functions, and technical equipment that doesn't need natural light or are used often.
The last concept is submerged or partly submerged, works of largely the same principle as being level with water but instead utilises the built environment underneath the water for additional square meters, which then balances the buoyancy out so that the building is at the required level so that the openings are free of water getting in.



Ill. 70 - Plans of diffrent concept soutions

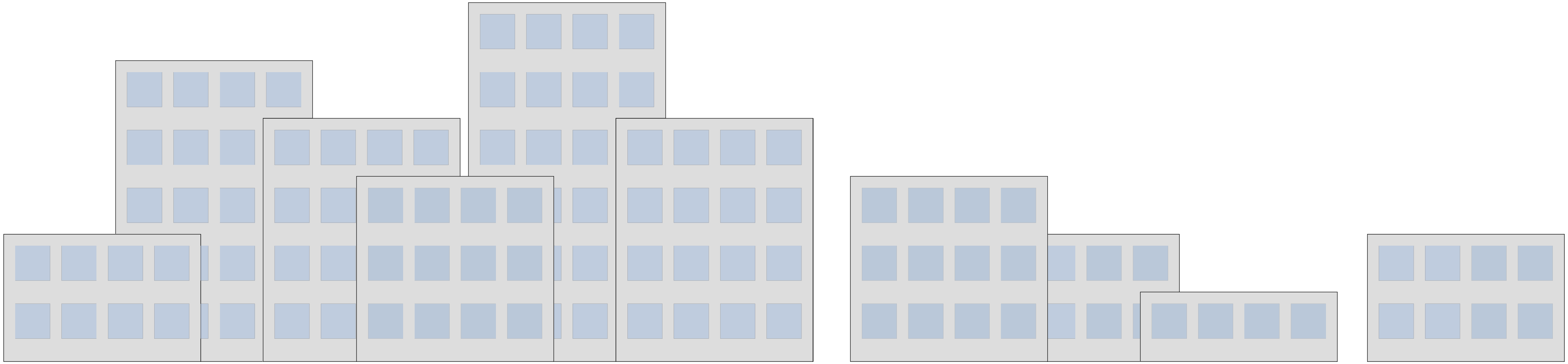


Ill. 71 - Sections of diffrent roofing soutions



Ill. 72 - Plan and section of early mixed use concept

// WORKSHOP // SIZE AND DEPENDENCY

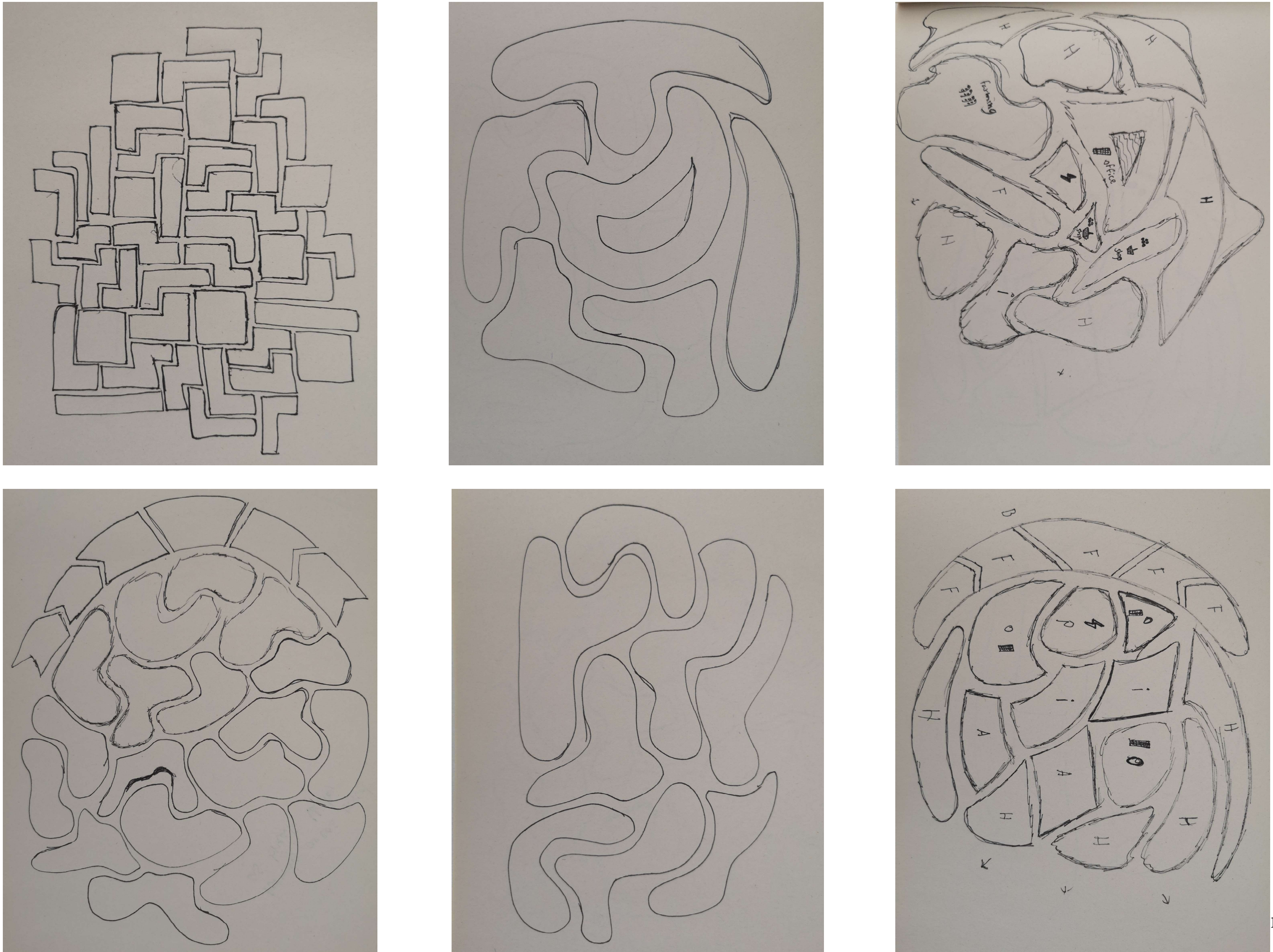


Ill. 73 - Diffrent project scales

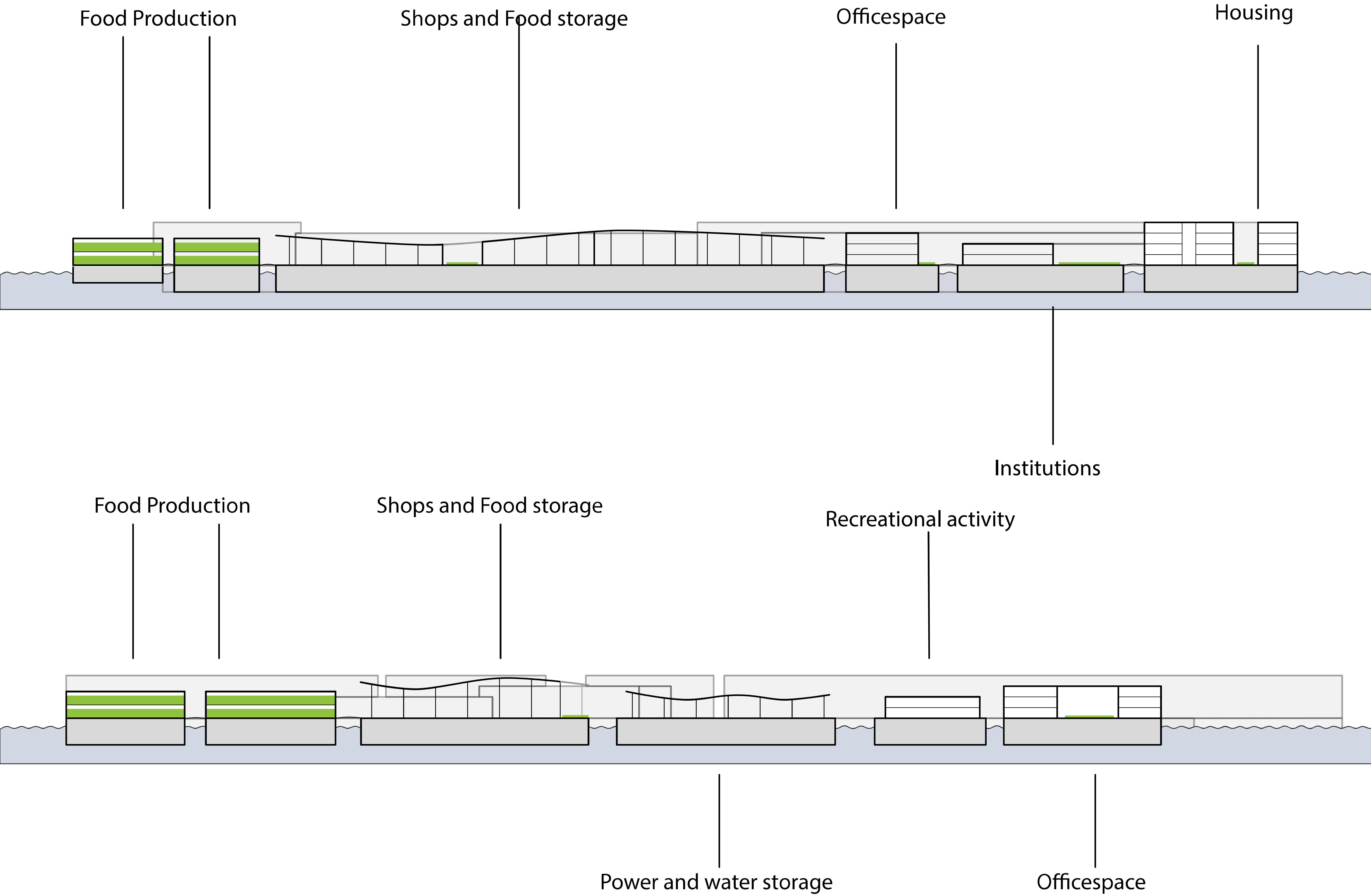
Following the first initial workshop, which starts the thought process for what needs and considerations are required to produce a holistic concept for building on water. Doing the first workshop, it became apparent that it is needed to determine its relation to the coast and the infrastructure which is on the site and which parts it is reliant on from the city. Where it depends on the size what infrastructure is practical to have on the site and which it's reliant on from the city so there are set up different scenarios to determine the scale and what infrastructure should be present on the site and the scale of the site. Those scales being a city scale which has all the infrastructure needed, a village size which has parts of the infrastructure and all the functions, and housing complex that is just housing and none of the infrastructure on site

The city scale idea includes all the necessary infrastructure from the production of food and water to the removal of waste product all done locally, which results in it being independent so that it can sail around without a connection to the mainland and mainland infrastructure. Since that amount of infrastructure is present and produced for a certain amount of people and building its possible to make it entirely sustainable with its production and consumption of resources.
A village scale project where the different functions are present at the site with recreational activity as well as living and workspace. A part of the infrastructure required to run it is present as well, but it still requires a connection to a cities infrastructure, for sewerage and handling of trash as well as the production of food.

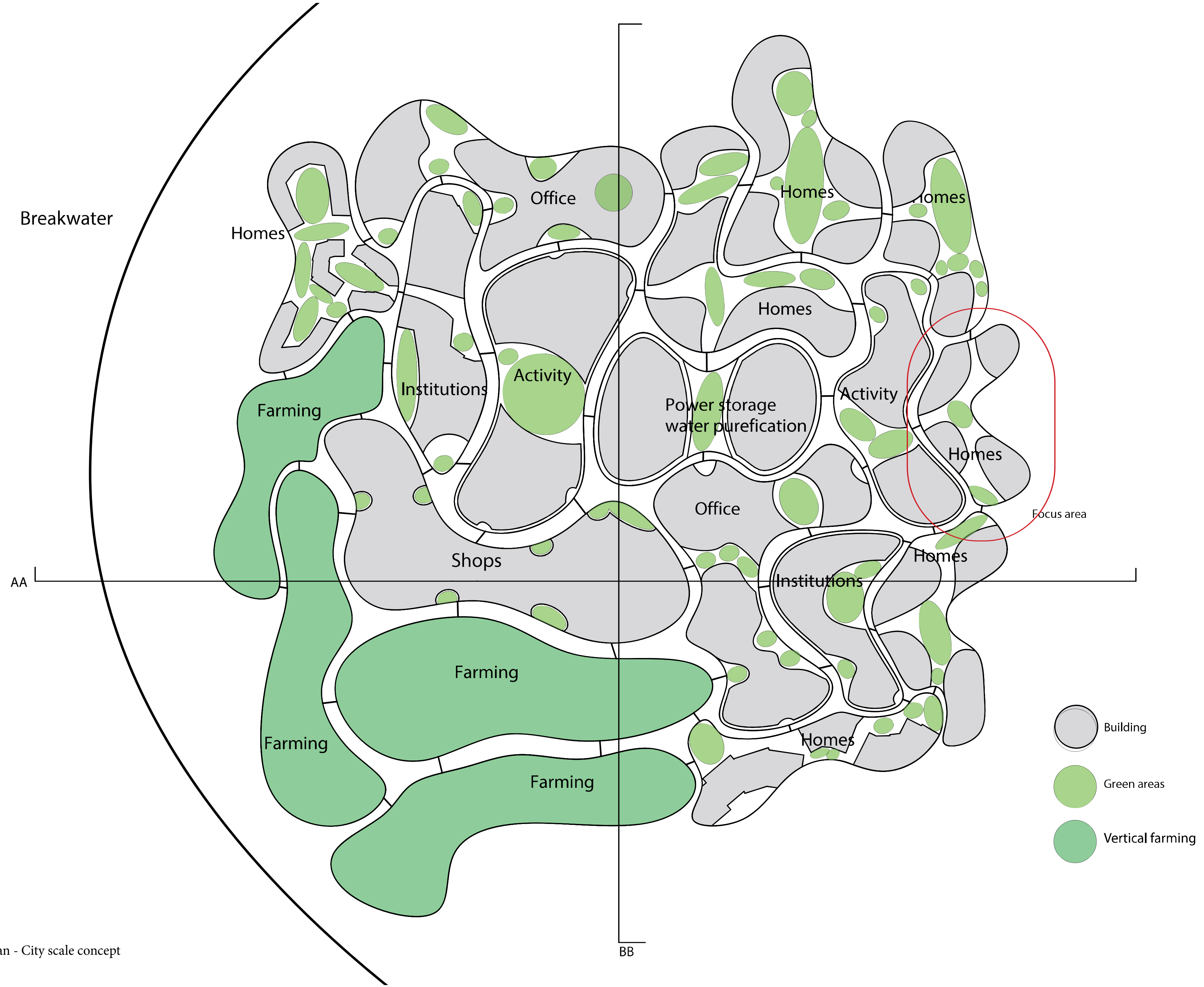
So it needs to stay in a location coupled to that infrastructure, but it would be possible to live there with only needing to go to the city for acquiring food.
Lastly, on the scale of size and dependency is a housing complex where it's reliant on all the infrastructure of a city as well as for its functions of work and recreational activity.



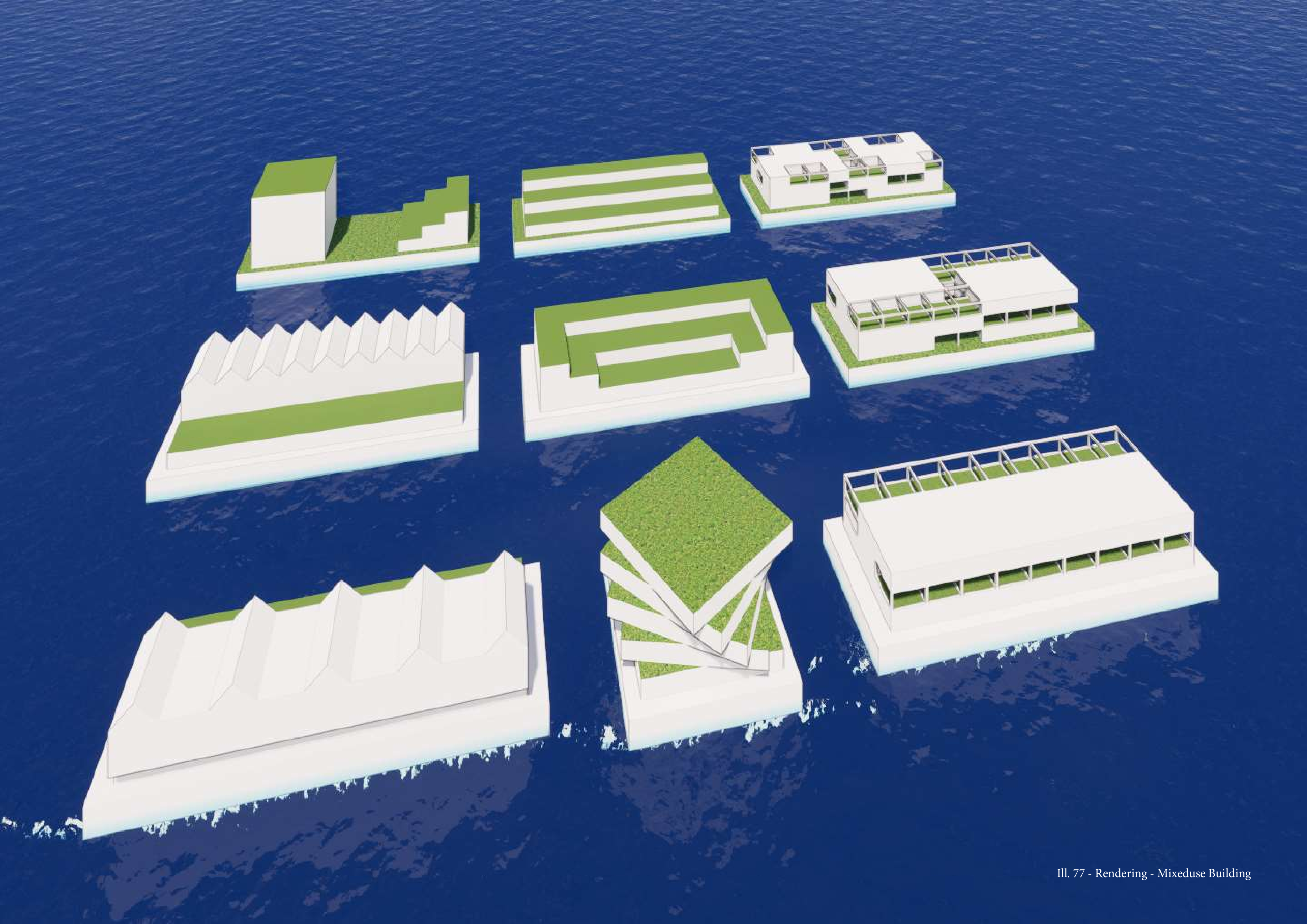
Ill. 74 - Plans - Difrent city scale concepts



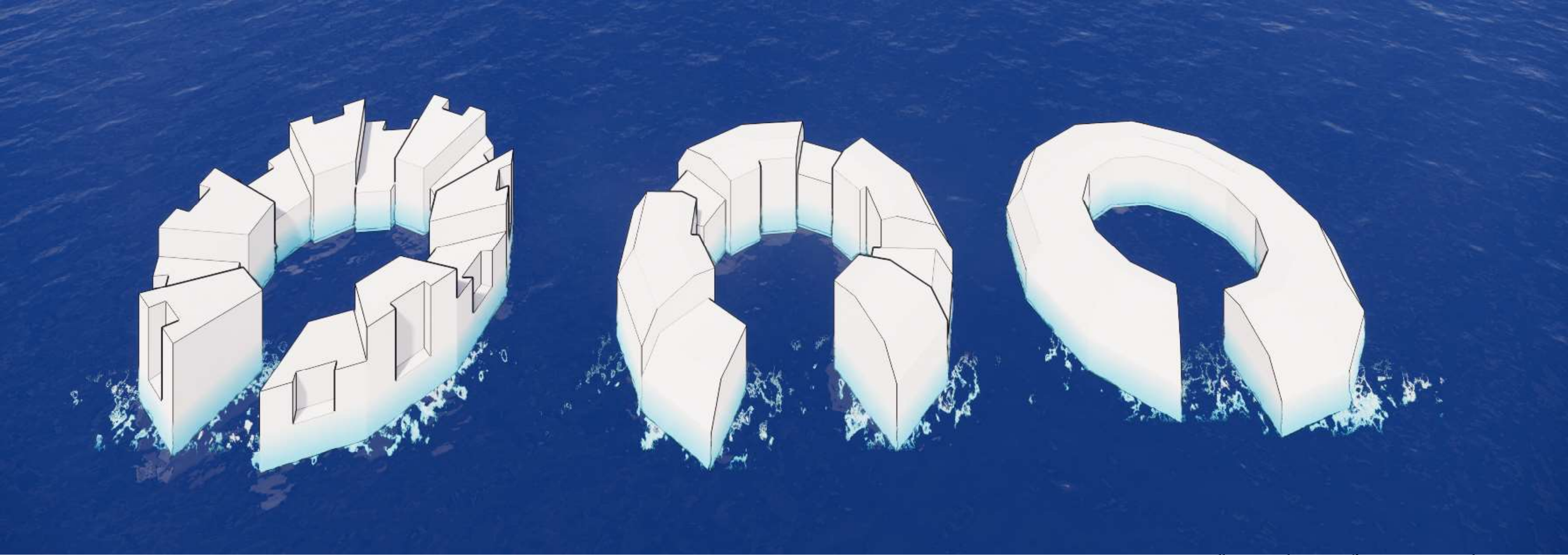
Ill. 75 - Section - City scale concept



Ill. 76 - Plan - City scale concept



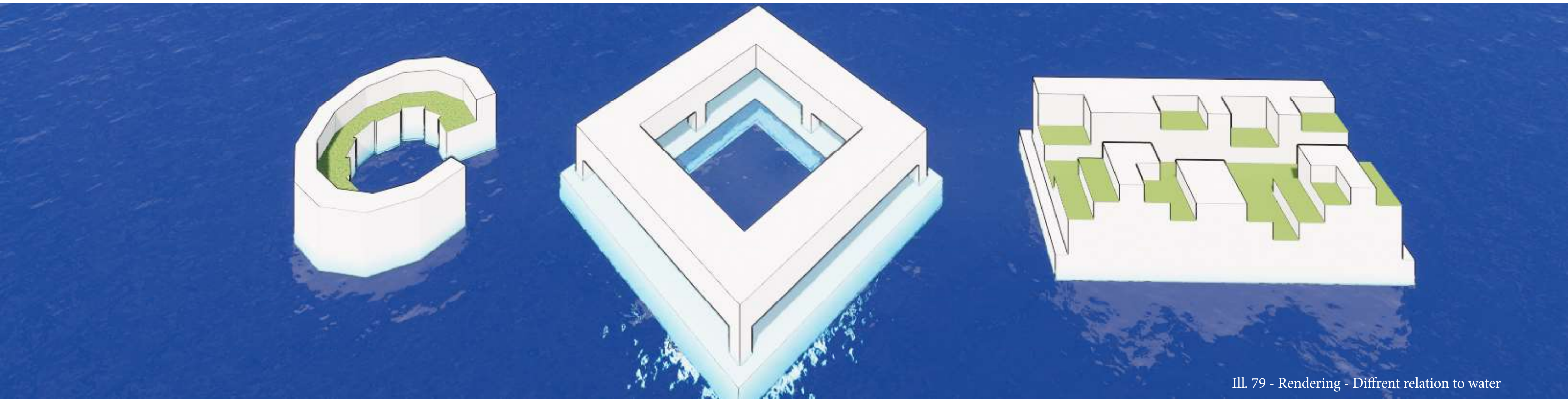
Ill. 77 - Rendering - Mixeduse Building



Ill. 78 - Rendering - Diffrent Housing complexes

When considering the requirement for infrastructure which comes from the different sizes and amount of dependency, along with the project size so that it doesn't move more towards the urban project instead of an architectural project. This lead to the choice being between a housing complex or a project that combines housing, work and recreational activity within the project. There are chosen a small housing project to facilitate further interaction with the water instead of doing a large platform with space for different functions and the additional infrastructure. The small project suits an early exploration into building housing on the water that then in the future can be developed into floating cities, which is self-sustainable for either extended periods if not permanently.

// WORKSHOP // HOUSING COMPLEX

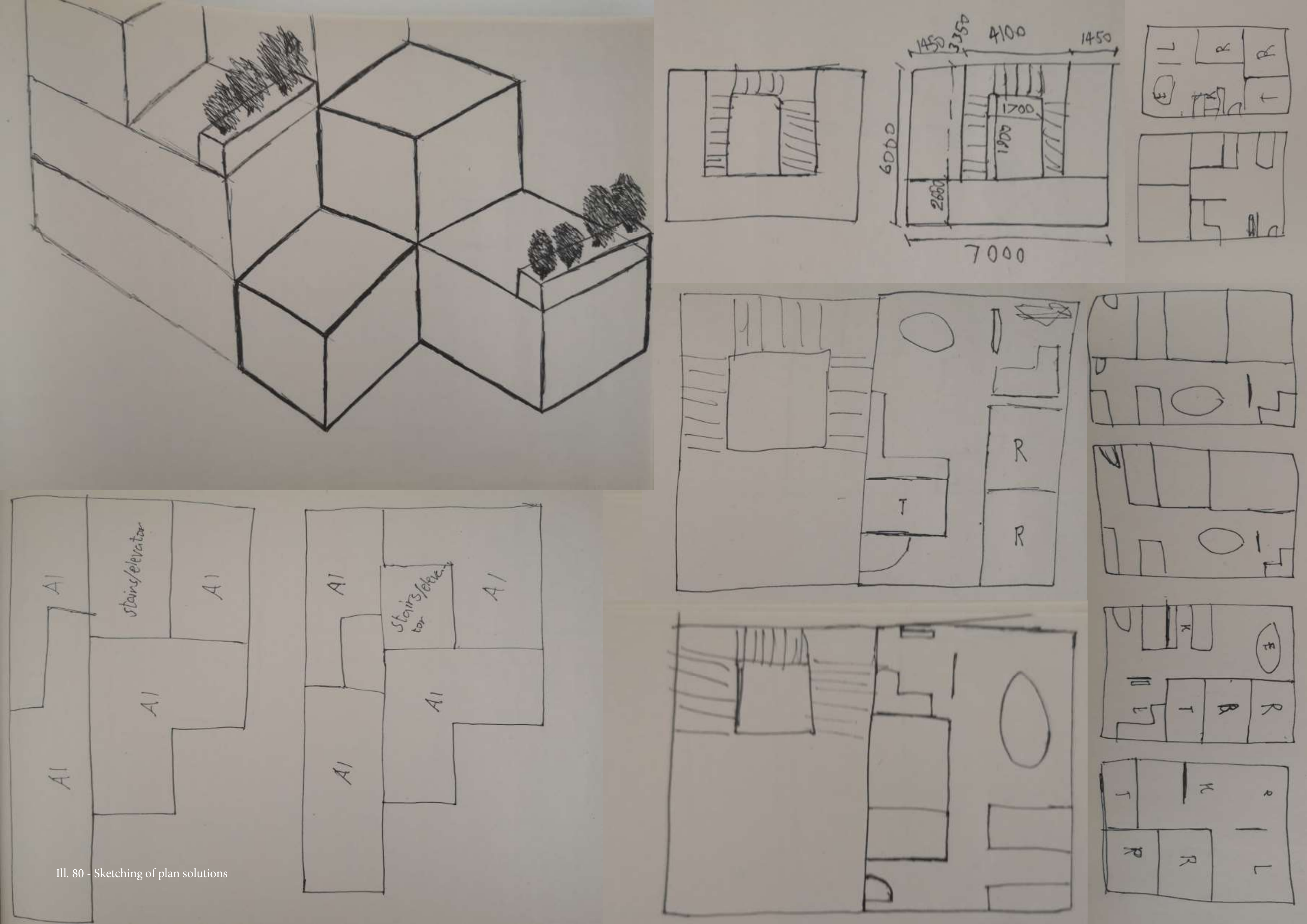


Ill. 79 - Rendering - Diffrent relation to water

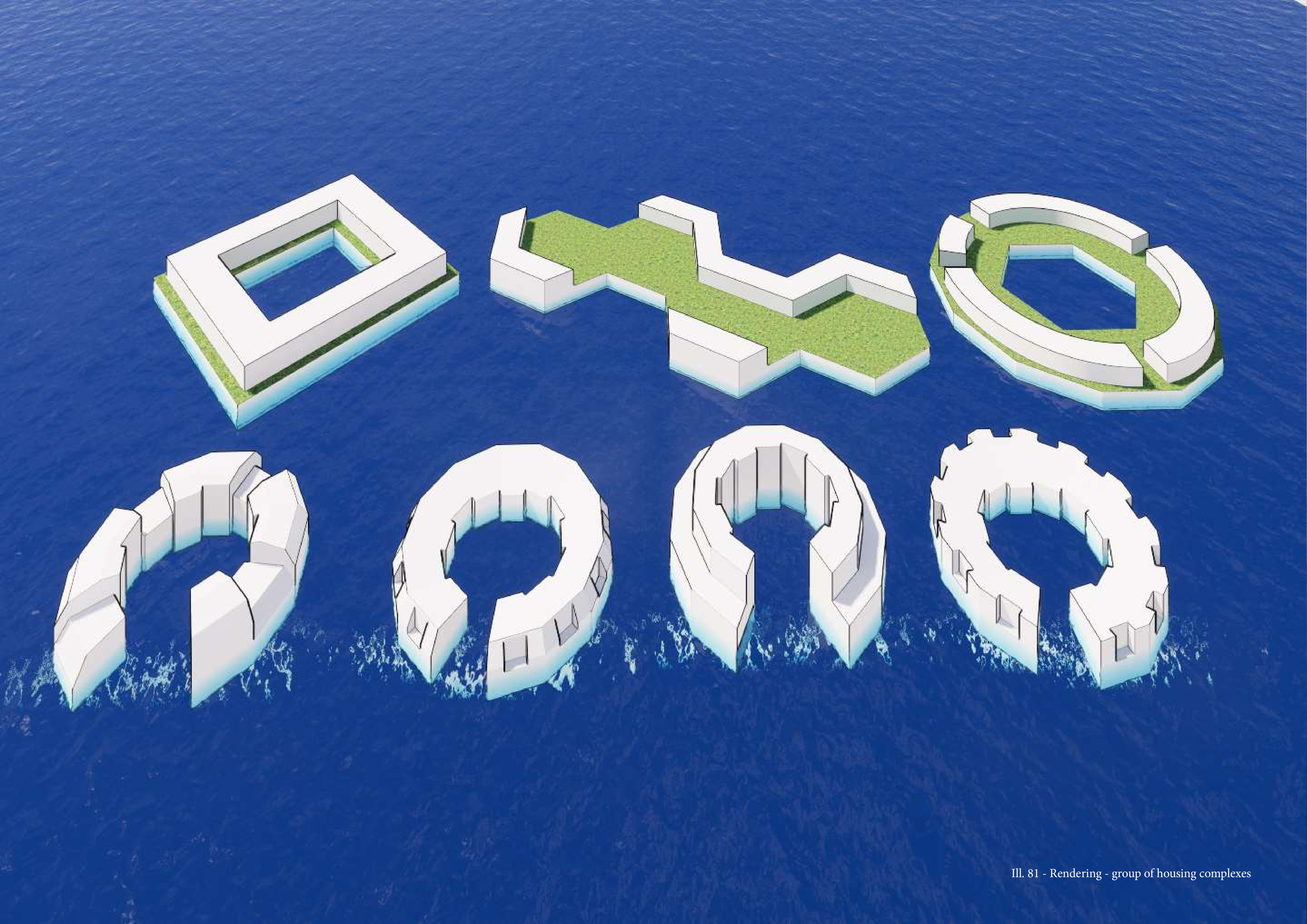
For the third workshop after finding the size and the dependency in connection to the mainland city infrastructure. To find the final concept for how to facilitate housing on water. Where after several iterations trends started emerging of protected internal space and a close connection with the water, be it by having a partly submerged or levelled with the water building, where the water adds value to the architecture. So that the building is related to the environment that the building is built and placed in, this also emphasises creating an architecture were removing it from the water and placing on a plot in a city gives the residents the same qualities but with a different view to the outside of the residents.

To further explore the development of the concept of a housing complex and to build on top of the development of plans and sections, was exploring some of the concepts as volume studies and developing them along with how interior plans would take shape within the overall shaping of the different concepts. This has been done with the help of different tools with both sketchings but also more comprehensive tools such as rhino and Revit for drawing up a three-dimensional space that can then be explored with depictions and live rendering when moving through space.
The quality of the different ideas was valued for their fulfilment of the primary and secondary generators

While designing the layout of the units with consideration to the methodology of integrated energy design to at least the extent that it's possible when part of the building submerged it eliminates some possibilities for natural ventilation the possibility to have another fire escape other than the staircase. These are considerations that need to be included when valuing it up against the qualities gained from having a platform which lifts the building out of the water and therefore allows for natural ventilation and providing the option with an additional fire escape route.



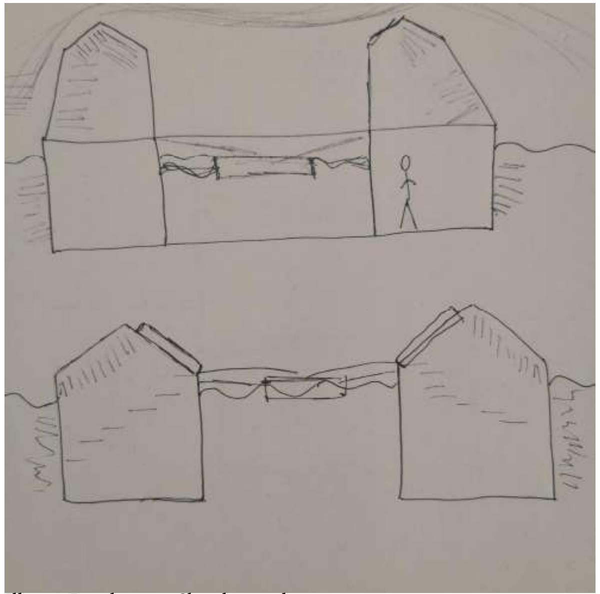
Ill. 80 - Sketching of plan solutions

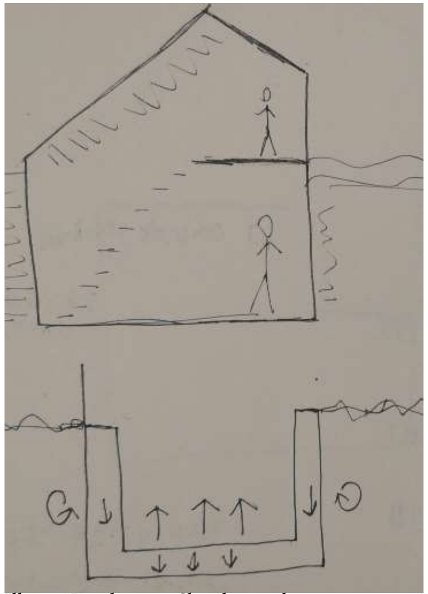


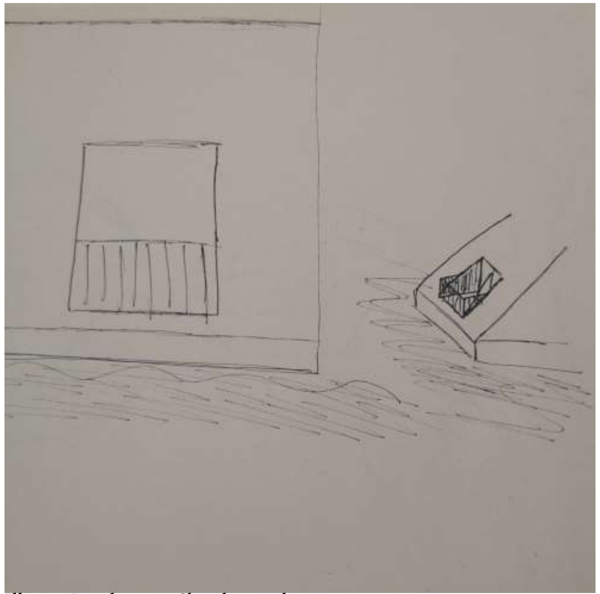
Ill. 81 - Rendering - group of housing complexes

Ill. 82 - Rendering - Housing complex

// WORKSHOP // RELATING TO WATER


Ill. 83 - Rendering - Sketching relation to water 1


Ill. 84 - Rendering - Sketching relation to water 2


Ill. 85 - Rendering - Sketching relation to water 3

The fourth workshop aims to investigate the relationship between the building and the water, to look at the different scenarios of how water can be used as a function in the housing. The water also interacts with the building from the outside through the principle of buoyancy where the volume of the building and the mass determines how deep the building lays in the water so a consideration for the materials since that the primary influence on the overall weight of the building. The opposite side of the heavyweight is the problem of stability if there's lightweight since it's then more susceptible for waves and wind, resulting in an uncomfortable indoor climate due to disturbance of the proprioception scenes.

Ill. 86 - Rendering - Sketching relation to water 4

Ill. 87 - Rendering - Relation to water 1

Ill. 88 - Rendering - Relation to water 2

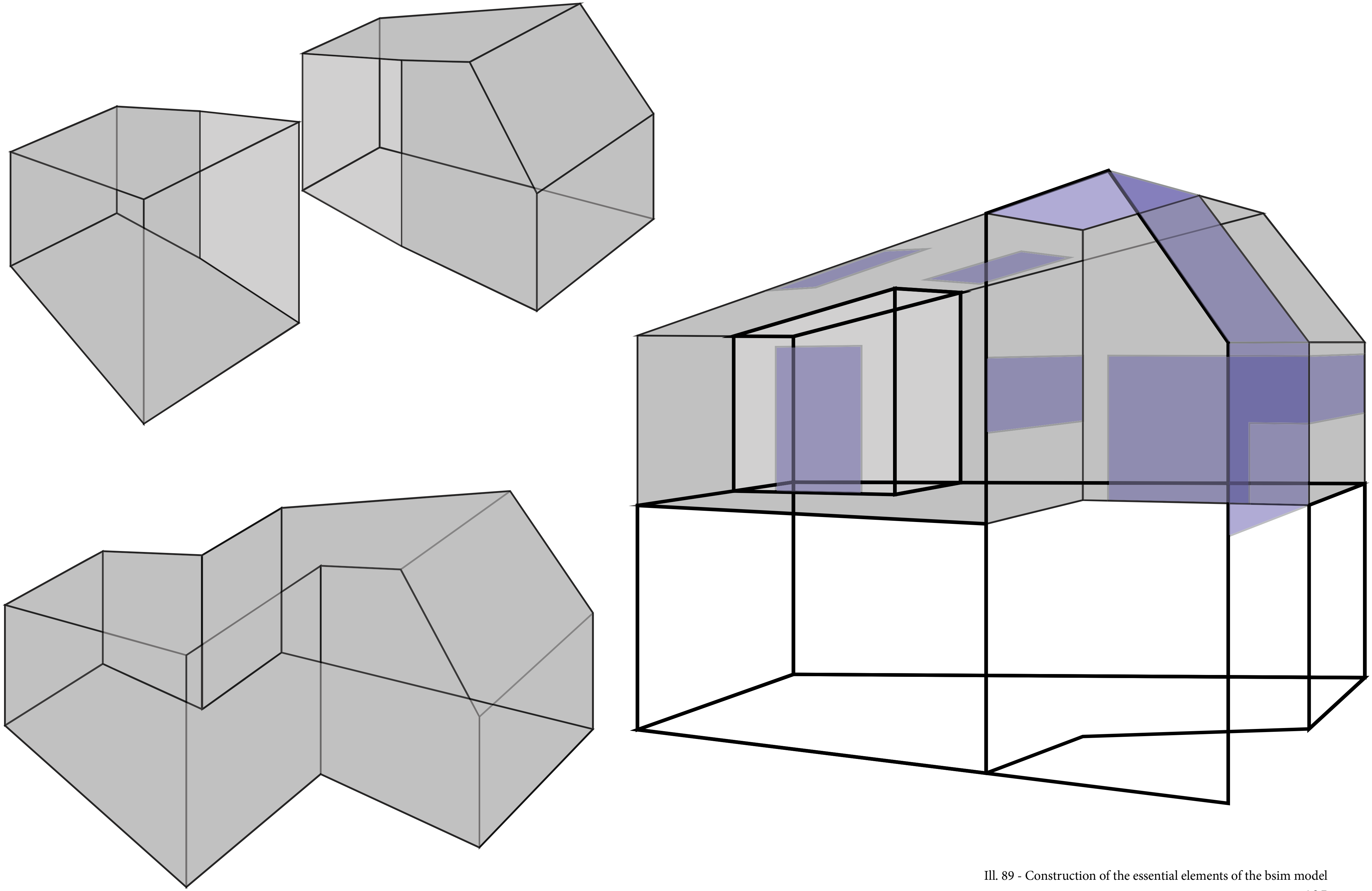
SYNTHESIS

// WORKSHOP // INDOOR CLIMATE

In the fifth workshop, the focus is to determine the right dimensions of windows and their placement, in a balance between thermal, atmospheric and visual comfort, which is tested in an analysis of windows through Bsim simulations that shows overheating hours, Velux Visualiser illustrates the daylight factor. The natural ventilation is calculated within Bsim based on the window openings and the weather data that are included in the BSIM calculation model.

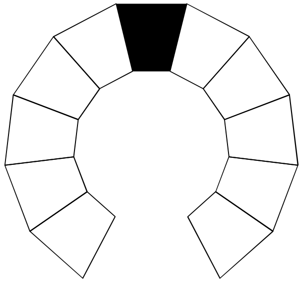
BSIM is a simulation tool for the indoor climate within a simple geometry where all walls can see each other so to create the room that is suspected to be most susceptible to overheating, which in this project is the entire top floor of the building. When creating a model of the top floor, the model needs to be split into two rooms. While then being allowed to share air between the two to simulate an approximation of one large room this way of building simple geometry leads to some differences from how it would perform in reality, but the main parameters are the volume of the room and the direction and size of windows.

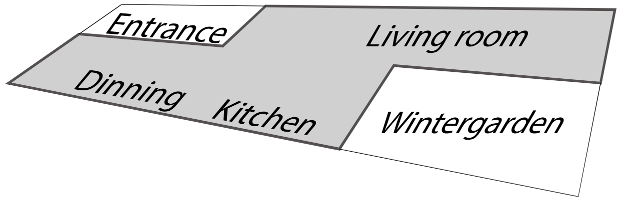
Velux Visualizer as a calculation tool, there a selected set of material that is given predefined values, so the daylight simulation is based on that material selection. While there is a lack of the correct material for the context since it doesn't have the capability for placing water as the material that surrounds the building, so there's chosen another reflective material but it doesn't have the same properties water would realistically have for reflection, transparency and absorption. That then also removes the possibility to calculate the daylight for the bottom floor since its underwater, so that part of the housing is designed with windows to be able to look out underwater but with the primary lighting being artificial.

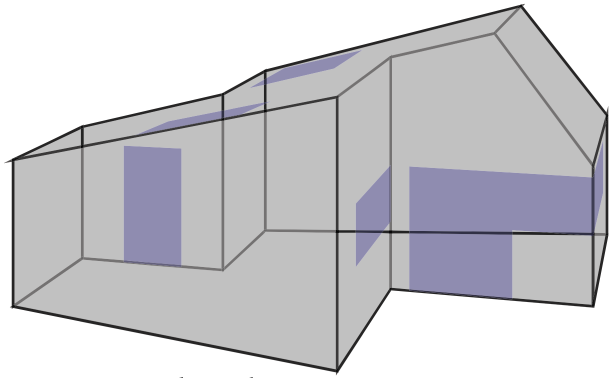


Ill. 89 - Construction of the essential elements of the bsim model

Ill. 90 - Diffrent window configurations 1 - Oriented north



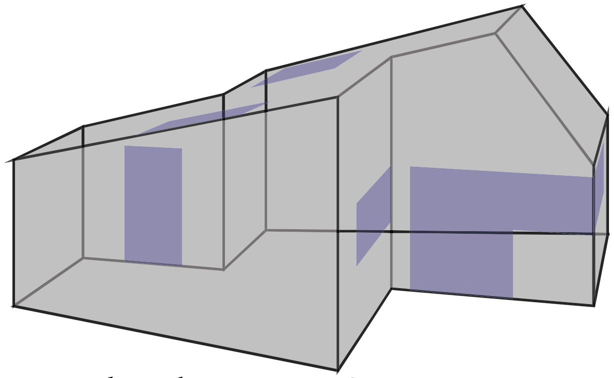




Windows - lavE | Opening nat. vent.
Roof: 2x1, 2.5x1.6 | 00 %
Entrance: 2x1.5
Kitchen: 1x3.5 | 00 %
Living room: 1x3.5 | 00 %
Wintergarden: 2.1x1.6, 1x1

Overheating
With the primary amount of windows facing north this housing unit is the least susceptible to overheating which is also reflected in the numbers of hours above 27 and 28 degrees 69 hours > 27 deg and 10 hours > 28 degrees

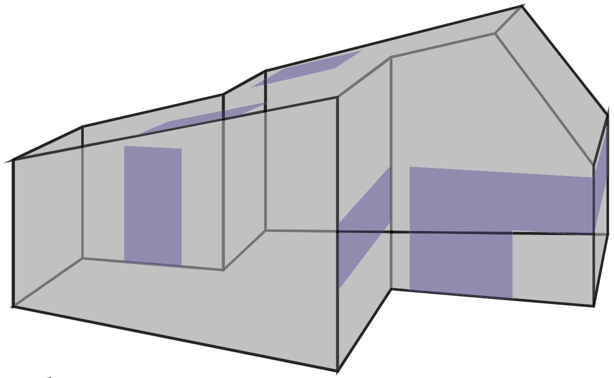
Daylight
With a reference plane 90 centimetre above the floor for the calculation model resulting in 2.5 % in the entrance 6 % daylight in the kitchen and dining area and 5.5 % in the living room.



Windows - lavE | Opening nat. vent.
Roof: 2x1, 2.5x1.6 | 10 %
Entrance: 2x1.5 | 10 %
Kitchen: 1x4.5
Living room: 1x4.5 | 10 %
Wintergarden: 2.1x1.6, 1x1

Overheating
With the addition of natural ventilation to the housing unit, lowers it further underneath the limit of 100 hours > 27 degrees and 25 hours > 28 degrees, with natural ventilation it reduces it to 4 hours > 27 degrees

Daylight
The amount of daylight is the same as in the previous iteration with 2.5 % in the entrance 6 % daylight in the kitchen and dining area and 5.5 % in the living room.

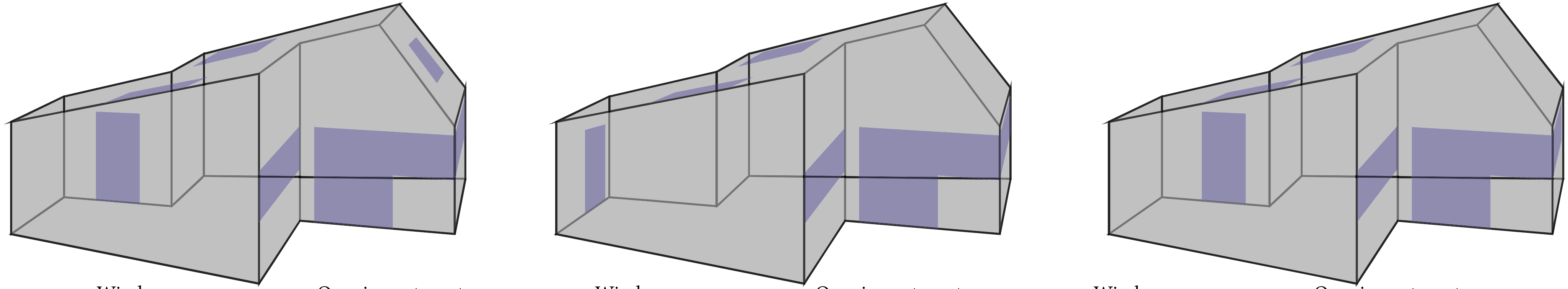


Windows - LavE | Opening nat. vent.
Roof: 2x1, 2.5x1.6 | 10 %
Entrance: 2x1.5
Kitchen: 1x4.5 | 00 %
Living room: 1x4.5 | 00 %
Wintergarden: 2.1x1.6, 1x1

Overheating
With widening the windows in the kitchen and living room to create a panoramic window spanning the facade. While using buoyancy for natural ventilation through the roof leading to 59 hours > 27 degrees and 16 hours > above 28 degrees

Daylight
The wide windows provide a steady amount of light within the rooms without dark corners integrated with the skylight for natural ventilation and light deep into the rooms, results in 3% light in the entrance and 6.5% in the kitchen, dining and living room

Ill. 91 - Diffrent window configurations 2 - Oriented north



Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6, 2x2	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
The fourth iteration of adding a window to the side of the roof facing north, using cross ventilation between the wall towards the north and the roof window to reduce overheating with 38 hours > 27 degrees and 8 hours > 28 degrees

Daylight
With the additional skylight in the living room, the daylight factor in there goes up to 9.4% and the dining room and kitchen go up to 6.9%, while the entrance stays at 3% daylight.

Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 1x2	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
The fifth iteration is replacing the roof window from the previous, with a roof window above the entrance to allow light in from the roof instead of through a glass door. resulting in 37 hours > 27 degrees and 8 hours > 28 degrees

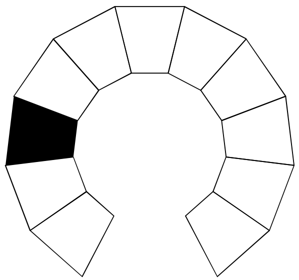
Daylight
With the addition of a window allowing light into the entrance instead of having the door being the source of light there, brings more light into that area with 4% while still having 6.5% in the kitchen, dining and living room.

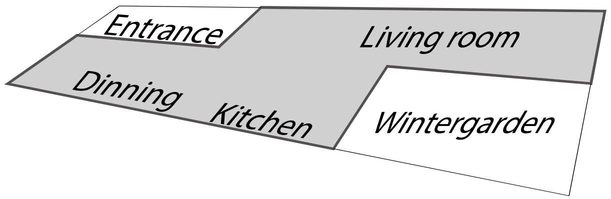
Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

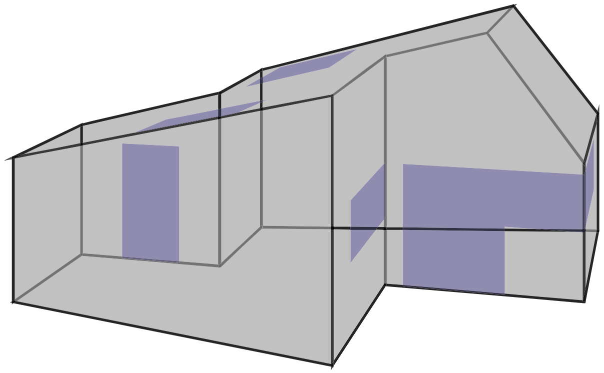
Overheating
As an iteration on top of the third iteration were adding natural ventilation to the kitchen and living room window resulting in 21 hours > 27 degrees and 4 hours > 28 degrees

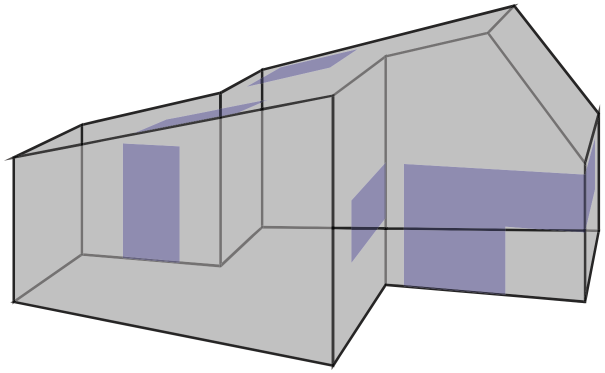
Daylight
Brings the same amount of daylight as the third iteration

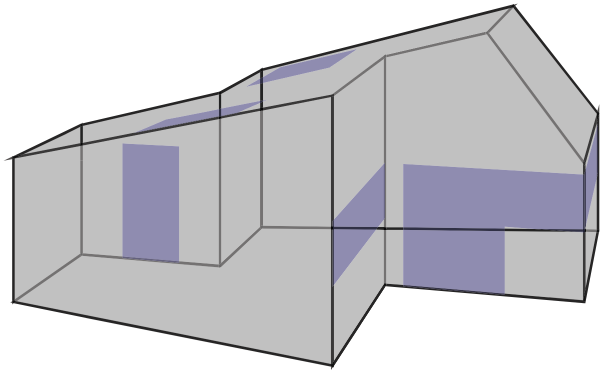
Ill. 92 - Diffrent window configurations 1 - Oriented due west











Windows - lavE	Opening nat. vent.
Roof: 2x1, 2.5x1.6	00 %
Entrance: 2x1.5	
Kitchen: 1x3.5	00 %
Living room: 1x3.5	00 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
With the primary amount of windows facing west this housing unit is amongst the most susceptible to overheating which is also reflected in the numbers of hours above 27 and 28 degrees with 161 hours > 27 deg and 59 hours > 28 degrees

Daylight
With a reference plane 90 centimetre above the floor for the calculation model resulting in 2.5 % in the entrance 6 % daylight in the kitchen and dining area and 5.5 % in the living room.

Windows - lavE	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	10 %
Kitchen: 1x4.5	
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
With addition of natural ventilation to the housing unit, lowers it underneath the limit of 100 hours > 27 degrees and 25 hours > 28 degrees, with natural ventilation it reduces it to 14 hours > 27 degrees

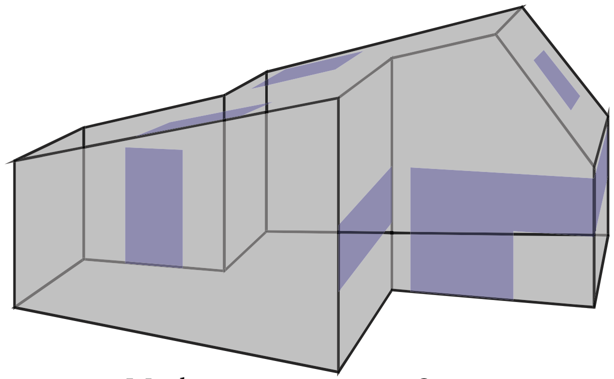
Daylight
The amount of daylight is the same as in the previous iteration with 2.5 % in the entrance 6 % daylight in the kitchen and dinning area and 5.5 % in the living room.

Windows - LavE	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	00 %
Living room: 1x4.5	00 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
With widening the windows in the kitchen and living room to create a panoramic window spanning the facade. While using buoyancy for natural ventilation through the roof leading to 106 hours > 27 degrees and 43 hours > above 28 degrees

Daylight
The wide windows provide a steady amount of light within the rooms without dark corners integrated with the skylight for natural ventilation and light deep into the rooms, results in 3% light in the entrance and 6.5% in the kitchen, dining and living room

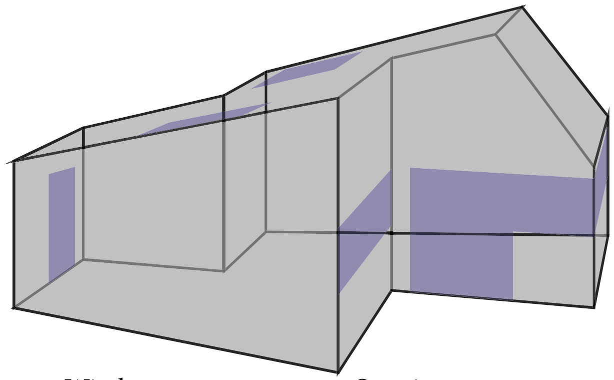
Ill. 93 - Diffrent window configurations 2 - Oriented due west



Windows | Opening nat. vent.
Roof: 2x1, 2.5x1.6, 2x2 | 10 %
Entrance: 2x1.5
Kitchen: 1x4.5 | 10 %
Living room: 1x4.5 | 10 %
Wintergarden: 2.1x1.6, 1x1

Overheating
The fourth iteration of adding a window to the side of the roof facing west, using cross ventilation between the wall towards the west and the roof window to reduce overheating with 117 hours > 27 degrees and 40 hours > 28 degrees

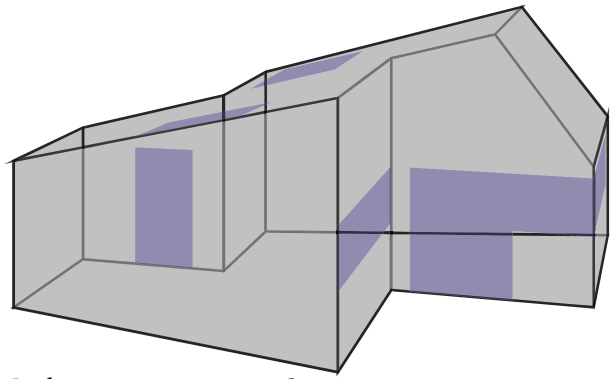
Daylight
With the additional skylight in the living room, the daylight factor in there goes up to 9.4% and the dining room and kitchen goes up to 6.9%, while the entrance stays at 3% daylight.



Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 1x2	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
The fifth iteration is replacing the roof window from the previous, with a roof window above the entrance to allow light in from the roof instead of through a glass door. resulting in 61 hours > 27 degrees and 18 hours > 28 degrees

Daylight
With the addition of a window allowing light into the entrance instead of having the door being the source of light there, brings more light into that area with 4% while still having 6.5% in the kitchen, dining and living room.

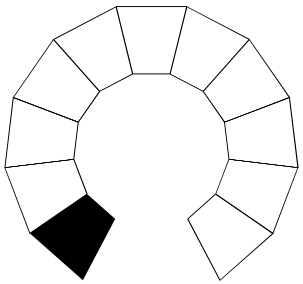


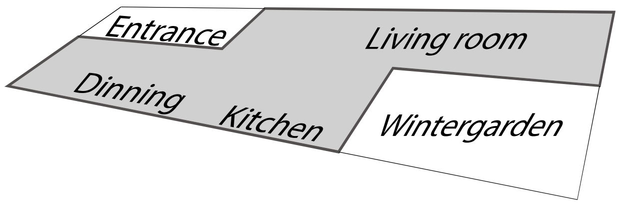
Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

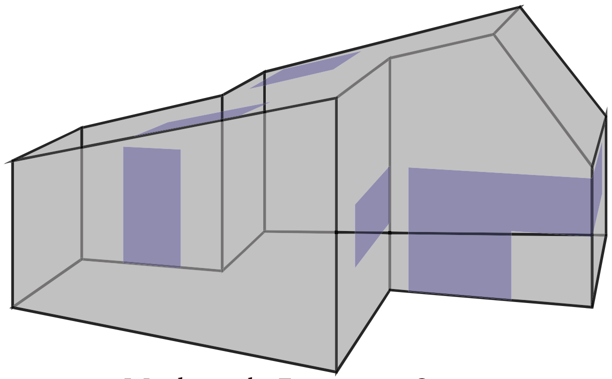
Overheating
As an iteration on top of the third iteration were adding natural ventilation to the kitchen and living room window resulting in 40 hours > 27 degrees and 10 hours > 28 degrees

Daylight
Brings the same amount of daylight as the third iteration

Ill. 94 - Diffrent window configurations 1 - Oriented south west 140 deg



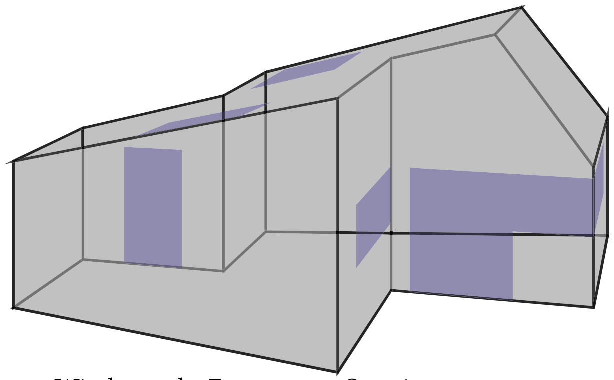




Windows - lavE	Opening nat. vent.
Roof: 2x1, 2.5x1.6	00 %
Entrance: 2x1.5	
Kitchen: 1x3.5	00 %
Living room: 1x3.5	00 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
With the primary amount of windows facing south-west this housing unit is amongst the most susceptible to overheating which is also reflected in the numbers of hours above 27 and 28 degrees with 101 hours > 27 deg and 31 hours > 28 degrees

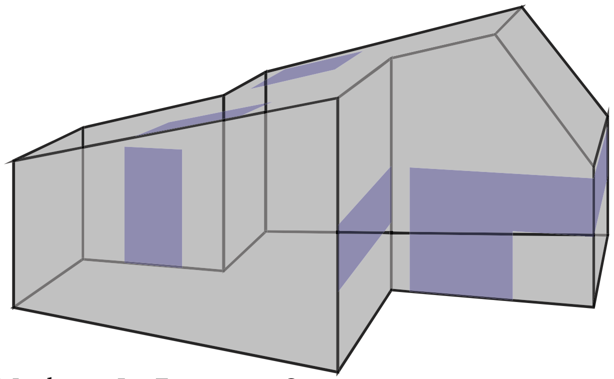
Daylight
With a reference plane 90 centimetre above the floor for the calculation model resulting in 2.5 % in the entrance 6 % daylight in the kitchen and dining area and 5.5 % in the living room.



Windows - lavE	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	10 %
Kitchen: 1x4.5	
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
With the addition of natural ventilation to the housing unit, lowers it underneath the limit of 100 hours > 27 degrees and 25 hours > 28 degrees, with natural ventilation it reduces it to 12 hours > 27 degrees

Daylight
The amount of daylight is the same as in the previous iteration with 2.5 % in the entrance 6 % daylight in the kitchen and dining area and 5.5 % in the living room.

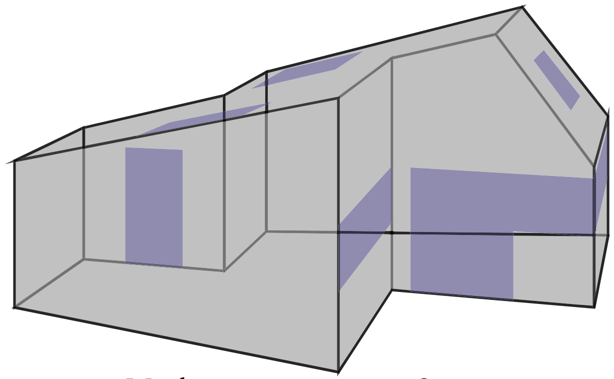


Windows - LavE	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	00 %
Living room: 1x4.5	00 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
With widening the windows in the kitchen and living room to create a panoramic window spanning the facade. While using buoyancy for natural ventilation through the roof leading to 59 hours > 27 degrees and 19 hours > above 28 degrees

Daylight
The wide windows provide a steady amount of light within the rooms without dark corners integrated with the skylight for natural ventilation and light deep into the rooms, results in 3% light in the entrance and 6.5% in the kitchen, dining and living room

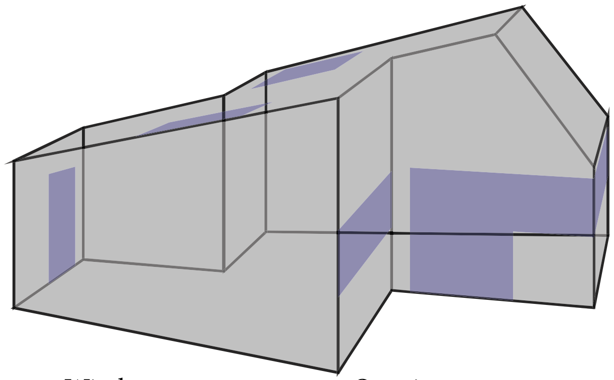
Ill. 95 - Diffrent window configurations 2 - Oriented south west 140 deg



Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6, 2x2	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
The fourth iteration of adding a window to the side of the roof facing south-west, using cross ventilation between the wall towards the south-west and the roof window to reduce overheating with 117 hours > 27 degrees and 40 hours > 28 degrees

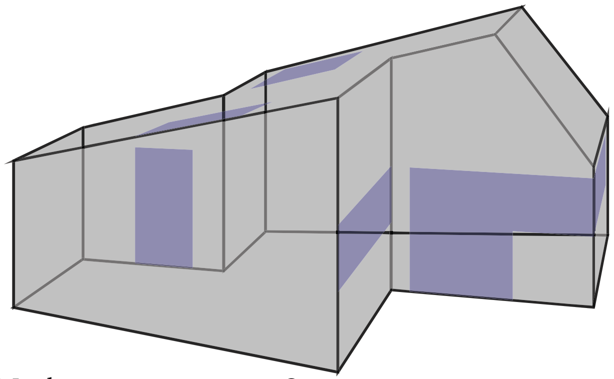
Daylight
With the additional skylight in the living room, the daylight factor in there goes up to 9.4% and the dining room and kitchen goes up to 6.9%, while the entrance stays at 3% daylight.



Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 1x2	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
The fifth iteration is replacing the roof window from the previous, with a roof window above the entrance to allow light in from the roof instead of through a glass door. resulting in 61 hours > 27 degrees and 18 hours > 28 degrees

Daylight
With the addition of a window allowing light into the entrance instead of having the door being the source of light there, brings more light into that area with 4% while still having 6.5% in the kitchen, dining and living room.



Windows	Opening nat. vent.
Roof: 2x1, 2.5x1.6	10 %
Entrance: 2x1.5	
Kitchen: 1x4.5	10 %
Living room: 1x4.5	10 %
Wintergarden: 2.1x1.6, 1x1	

Overheating
As an iteration on top of the third iteration, were adding natural ventilation to the kitchen and living room window resulting in 40 hours > 27 degrees and 10 hours > 28 degrees

Daylight
Brings the same amount of daylight as the third iteration

EPILOGUE

// CONCLUSION

In Limfjorden off the coast lies a new innovative architecture that deals with the coming climate changes by creating a floating housing complex that through buoyancy deals with rising water level – a sustainable building built following the zero energy standards for housing and gives it a new take on the relation between living and the water.

The housing offers a holistic and sustainable way of dealing with climate change in areas exposed to flooding's whether they are permanent or recurring in the future. That is done through working with the volume and mass of the building to make it float at a level so that the door is being safely above water so that it never gets flooded.

For housing, it is desired to work with both environmental and social sustainability and find a balance between the two. In several cases, the design must prioritise one above the other. However, they are both present in the design with an emphasis on environmental sustainability since the project deals with the consequences of climate change is valued slightly higher than social sustainability.

Environmental sustainability has through this master thesis been explored within the aspects of creating a zero energy building with a primary focus on passive strategies to lower the buildings energy consumptions so that the amount of energy needed to be covered by active strategies is reduced.

The housing units brings the residents close to the water with the bottom floor being underwater with a view to the outside but also the top floor where the entrance leads into the social space created for the residents to socialise between each other and leading the residents onto the mainland and into the city. While the other end of the residents open up towards the water with a panoramic view out but raised above the floor and the water, so it's not as easy to look in if sailing by in a small boat while at least sitting down.

Towards the water, there a view through the winter garden for part of the panoramic view which allows for access to the water from within the individual resident and includes that as a part of the housing creating a connection with the water that's different from the bottom floor.

Dealing with increasing water levels due to climate change by making the building itself float works but only to a degree, cause even if it the housing doesn't get flooded if the city to which it is connected to would get flooded. When this happens, it could impact the infrastructure connected to the complex, but also the opportunity to utilize the functions that it is dependant on ashore, which could be work, shopping or recreational activity.

The solution works best for periodical flooding, but since the complex is floating its possible to transport it to another city that could be further inland or a city at sea where the same or new residents could then reuse it. The possibility of in principle recycle the whole building just by moving it without having to deconstruct and recycle the materials bring an exciting prospect for the sustainability of the building if maintained in good condition.

By applying the strategies mentioned, the scheme of building on water meets the design criteria set forth while creating a zero-energy building that makes for a sustainable alternative to living on land without sacrificing modern living standards or losing privacy be people sailing in proximity to the housing complex. By producing a design that introduces safety from some climate change into residential functions, it can act as a catalyst for the future development of project similar to it or on a scale that would be more similar to a traditional city, by applying some of the principles outlined in this master thesis.

// REFLECTION

Aquatecture does not fit into a defined typology, but the building program is like that of housing complexes built on land but in a different context. This meant that the aspect of typology needed to be explored in the process of coming up with a design for the master thesis along with a concept for how to construct buildings on the water. The relation between the building and water have been redefined doing the process of the sketching where along with the size of the project changed how independent it could be about a city's infrastructure. This posed a challenge since building a sustainable build that was adapted to being placed on the water either needed to be independent of traditional infrastructure. To create a self-sustainable city that could be placed separately from a city or a small project which could be functioning in connection with a cities infrastructure to utilise its functions and infrastructure while being floating on water.

While dealing with the issue of climate change and the impact, this will have on the future on a variable timescale, to cities and the amount that the water level will rise in a particular place alone is a complex issue. That has had to be figured out, and the prediction for the changes depending on who is asked and on what time scale, one looks at has a lot of variables involved in what the impact on the coming climate changes and their impact on the world. The Thesis has brushed over climate change lightly with only looking at a small amount of research which has been done into that subject and summarizing the impact that it could have on the globe. But Even with the limited research into the topic, it seems the consensus for the future is that most coastal cities will come under some degree of threat and that it is therefore needed to be acted upon not to be overwhelmed by the consequences of climate change.

Sustainability has been a critical driving force since even if addressing the climate changes by translating to water-based architecture that makes floating as a response to the rising water levels. That is ongoing the building should not keep adding pollution to its environment and worsening the extent of climate change, by continuously polluting the environment the result of that is that the building is aimed at a zero-energy building. To fully express the intention of the design and to persuade the residents and the viewers externally of its potential, to handle climate changes locally while not contributing to it in a broader, more global context. The materiality in a sustainable context should have played a more significant role in the project where it's not chosen for primarily aesthetic aspects while its carbon footprint hasn't influenced the choice — but instead assessing the element of pollution under the materials life cycle from raw material to being disposed of. To make the building itself sustainable instead of only having a sustainable operation of the building.

While environmental sustainable have been hard to handle as an aspect of the project, social sustainability has been more consistent since the goal and perception of that for a housing complex is pretty consistent. With that, there is a need for a social space that the residents that create interaction with between the people with a volume that gives it an amount of intimacy so that it doesn't become so large that it makes it a space that not comfortable to use. While still providing the residents with privacy while they are within their residents, The addition of a winter garden that serves as a private garden to the residents and gives them access to the water from their residents gives them the possibility to use the water as a part of their residents.

With sustainability has been a key driver in the project, continually needing choosing, to determine what's the most important within the definition of sustainability, which is defined in this master thesis. To determine what is most important for a specific design issue, be it ventilation, glass area, daylight, volume or the materials used.

As the constant evaluations between architectural and technical considerations throughout the projects, which at times posed huge challenges, when including the two aspects into making a holistic building that's both comfortable and brings quality to the residents living there. When looking at the decisions that stem from technical and architectural considerations, it seems only to have enhanced the project by drawing from the strengths of both those aspects, within choices, iterations and modifications, under the design process and synthesis towards the design that is presented in the master thesis.
With the project having been drawn primarily digitally with the only analogue tool in the design process has been sketching by hand. The media of modelling have been left out; it is hard to anticipate the impact it would have had on the project, if this media had been used heavily within the design process, instead of substituting it with live rendering. While live rendering also gives a sense of how things are when you can interact with the building there are is an aspect of seeing everything through a screen that loses part of the information compared to sitting down with a model. The process of working with models instead of solely digital modelling could as an example have helped get the project into a direction faster without spending an extended amount of time on testing out which scale and independents it should have from mainland infrastructure. To have a built environment that adds to the way humans live in a world where climate changes are seemingly escalating.

// REFERENCES

Moelven 2019, Canadisk cedertræ, Viewed 17 May 2019, <https://www.moelven.com/dk/produkter-og-ydelser/canadisk-cedertra/>.

Bygnings relglementet 2018, Dagslys, Viewed 18 May 2019, <http://bygningsreglementet.dk/Tekniske-bestemmelser/18/Krav/379_381>

Steemers, K. (2015). 'Architecture for Well-being and Health', Daylight & Architecture, 23 (July), 1-22

Stoewen D. L. (2016). Wellness at work: Building healthy workplaces. The Canadian veterinary journal = La revue veterinaire canadienne, 57(11), 1188-1190.

Danskernes sundhed, physical activity <Viewed 10 February 2019> http://danskernessundhed.dk/

Wework, Office environment <Viewed 15 February> https://www.wework.com/mission

Bejder, A., Knudstrup, M-A., Jensen, R. And Katic, I. (2014). Zero Energy Buildings - Design principles and Built examples for Detached houses. Denmark: SBI forlag.

Ir. Karina C, Ir. Bart R, Arch. Barbara Z and Dr Ir. Rutger G. (2013) Seasteading Implementation Plan. DeltaSync BV.

Pallasmaa, H. (2012). The eyes of the skin. Chichester: Wiley Academy.

Kongebro, S. (2012). Design med viden. Copenhagen: Henning Larsen Architects, pp.14-17.

Edwards, B., 2010. Rough Guide to Sustainability. London: RIBA Publishing

Yiftachel, O., Hedgcock, D., 1993 Urban social Sustainability: The planning of an Australian city. Cities, 10(2), p. 140

Kibert, C.J., 2016. Sustainable Construction: Green Building Design and Delivery. Hoboken, New Jersey: John Wiley & Sons

Zhong, Y., Wu, P. 2015 Economic sustainability, environmental sustainability and constructability indicators related to concrete- and steel project. Journal of cleaner production 108(12), pp. 748-756

Knudstrup, M.-A., 2004. Integrated Design Process in Broblem-Based Learning. In The Aalborg PBL Model: Progress, Diversity and Challenges. Aalborg University press

United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248.

USGCRP, 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp, doi:

AMAP, 2017. Snow, Water, Ice and Permafrost in the Arctic (SWIPA) 2017. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 269 pp.

Maslow's Hierarchy, Maslow's Hierarchy of needs <viewed 22 may 2019>, https://www.simplypsychology.org/maslow.html

DMI weather, Weather <viewed 22 may 2019>,Dmi.dk

Max Roser and Esteban Ortiz-Ospina (2019) - "Global Extreme Poverty". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/extreme-poverty' [Online Resource]

(Mimura, Nobuo. "Sea-level rise caused by climate change and its implications for society" Proceedings of the Japan Academy. Series B, Physical and biological sciences vol. 89,7 (2013): 281-301.)

// ILLUSTRATIONS

APPENDIX

// BSIM

Options | Moisture | Simulation | HeatBalance | Parameters | Tables

2018 | Month | Hours | ThermalZone13445

ThermalZor	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	4116.49	353.84	275.42	292.52	666.03	553.27	371.05	173.76	230.16	419.26	150.15	273.87	357.18
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	-1888.97	-244.00	-224.21	-267.08	-158.81	-116.33	-87.42	-59.61	-56.28	-82.19	-145.71	-204.94	-242.40
qVenting	-7208.90	0.00	0.00	0.00	-1561.94	-1581.58	-1186.04	-940.60	-934.06	-1004.68	0.00	0.00	0.00
qSunRad	5491.66	74.45	173.14	395.26	669.77	819.25	816.99	907.00	735.62	471.69	267.89	99.88	60.72
qPeople	1334.40	112.00	102.40	113.60	110.40	112.00	110.40	113.60	112.00	112.00	112.00	108.80	115.20
qEquipmen	876.00	74.40	67.20	74.40	72.00	74.40	72.00	74.40	74.40	72.00	74.40	72.00	74.40
qLighting	254.30	0.00	0.00	0.00	44.60	39.80	38.00	37.70	43.20	51.00	0.00	0.00	0.00
qTransmiss	-353.80	-193.05	-214.86	-276.04	301.07	299.08	86.33	-15.89	37.63	160.33	-173.30	-176.36	-188.74
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	-2687.90	-177.63	-179.08	-332.66	-162.61	-206.33	-233.36	-297.17	-255.03	-209.00	-285.42	-173.25	-176.36
Sum	-66.73	0.00	-0.00	-0.00	-19.49	-6.44	-12.06	-6.81	-12.34	-9.59	-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(°(	22.5	22.0	22.2	22.8	21.9	22.3	22.6	23.5	23.3	22.3	22.7	22.1	22.0
AirChange(/	4.0	1.5	1.5	2.1	4.8	6.4	6.1	7.1	7.2	5.9	1.9	1.5	1.5
Rel. Moistur	37.5	25.3	25.1	21.9	31.6	39.6	49.0	54.9	53.6	49.8	41.8	30.9	26.8
Co2(ppm)	452.7	485.0	483.8	470.2	464.9	435.2	421.5	398.7	394.8	432.1	473.8	484.3	488.2
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0.1	0.1	0.3	0.3	0.5	0.6
Hours > 21	8612	744	672	744	647	689	712	743	741	712	744	720	744
Hours > 27	49	0	0	0	0	0	2	35	12	0	0	0	0
Hours > 28	14	0	0	0	0	0	0	12	2	0	0	0	0
Hours < 20	21	0	0	0	12	5	2	0	0	2	0	0	0
FanPow	1235.34	77.59	73.97	119.60	81.10	101.35	115.06	159.24	149.54	99.54	105.44	75.31	77.59
HtRec	5810.02	756.93	732.73	1243.53	486.10	309.11	188.95	74.45	65.46	157.67	432.18	611.06	751.83
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	1.37	0.00	0.00	0.00	1.13	0.13	0.09	0.00	0.00	0.02	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	1375.65	53.53	16.95	0.00	322.70	283.08	187.11	82.52	121.03	222.34	0.57	29.94	55.88
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
CentCoolinc	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
CentCoolinc	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

Ill. 96 - Bsim For the final model orientated due west

Options | Moisture | Simulation | HeatBalance | Parameters | Tables

2018 | Month | Hours | (House)

(House)	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	4087.22	327.44	265.60	292.52	660.60	561.65	404.60	211.56	254.03	378.49	149.31	251.12	330.29
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	-1902.39	-245.15	-226.89	-270.81	-159.02	-116.10	-86.71	-57.34	-56.23	-82.86	-150.50	-207.52	-243.26
qVenting	-7053.75	0.00	0.00	0.00	-1534.97	-1516.08	-1164.87	-913.39	-919.17	-1005.28	0.00	0.00	0.00
qSunRad	5797.98	149.86	264.56	496.52	667.68	735.26	713.96	769.60	701.72	563.83	420.58	188.95	125.46
qPeople	1334.40	112.00	102.40	113.60	110.40	112.00	110.40	113.60	112.00	112.00	112.00	108.80	115.20
qEquipmen	876.00	74.40	67.20	74.40	72.00	74.40	72.00	74.40	74.40	72.00	74.40	72.00	74.40
qLighting	253.90	0.00	0.00	0.00	44.80	39.70	37.50	37.60	43.20	51.10	0.00	0.00	0.00
qTransmiss	-455.77	-214.18	-233.27	-286.28	280.50	297.90	122.86	9.35	42.01	126.59	-197.59	-195.96	-207.71
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	-2979.09	-204.36	-239.61	-419.95	-160.55	-195.77	-214.66	-247.92	-254.23	-222.06	-408.20	-217.39	-194.38
Sum	-41.51	0.00	0.00	0.00	-18.56	-7.03	-4.92	-2.53	-2.26	-6.19	-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(°(	22.6	22.1	22.5	23.2	21.9	22.2	22.5	23.3	23.3	22.4	23.2	22.4	22.1
AirChange(/	4.0	1.6	1.8	2.4	4.8	6.3	6.4	6.9	6.8	5.7	2.3	1.6	1.5
Rel. Moistur	37.3	25.1	24.6	21.2	31.7	39.6	49.4	55.6	53.6	49.4	40.4	30.3	26.6
Co2(ppm)	450.9	482.2	478.8	459.2	469.9	441.7	427.3	395.6	393.4	436.3	457.8	481.8	486.7
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0.1	0.1	0.2	0.3	0.5	0.6
Hours > 21	-	-	-	-	-	-	-	-	-	-	-	-	-
Hours > 27	-	-	-	-	-	-	-	-	-	-	-	-	-
Hours > 28	-	-	-	-	-	-	-	-	-	-	-	-	-
Hours < 20	-	-	-	-	-	-	-	-	-	-	-	-	-
FanPow	1304.25	84.61	89.13	138.51	79.99	97.68	109.32	148.13	150.28	102.56	135.14	86.42	82.46
HtRec	6476.37	825.13	881.35	1456.84	481.20	304.03	187.18	70.48	65.76	157.26	554.79	688.20	804.14
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	1.02	0.00	0.00	0.00	0.83	0.17	0.01	0.00	0.00	0.01	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	1356.13	35.93	10.40	0.00	319.07	288.67	209.49	107.72	136.95	195.16	0.01	14.77	37.96
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

Ill. 97 - Bsim For the final model orientated 140 degrees south-west

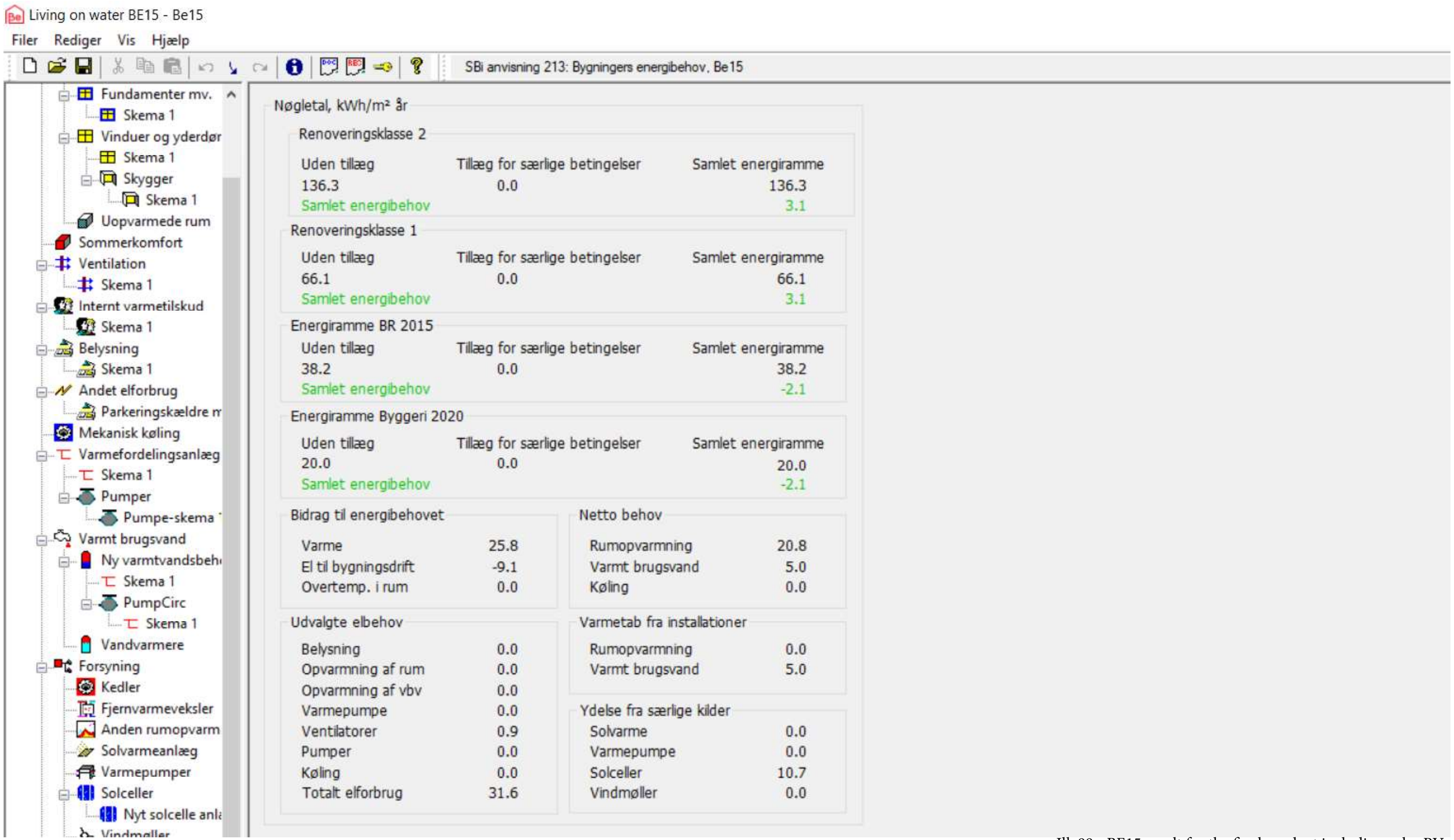
Options | Moisture | Simulation | HeatBalance | Parameters | Tables

2018 | Month | Hours | ThermalZone13445

ThermalZor	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	4333.74	354.51	277.98	292.58	685.19	572.90	391.42	219.47	294.77	459.86	150.92	276.17	357.96
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	-1880.28	-243.95	-223.79	-265.68	-159.34	-116.12	-86.93	-56.92	-54.08	-81.63	-144.71	-204.79	-242.35
qVenting	-6880.48	0.00	0.00	0.00	-1443.40	-1457.52	-1185.78	-879.98	-922.96	-990.83	0.00	0.00	0.00
qSunRad	4547.66	71.32	154.19	337.27	522.61	678.96	708.19	721.74	583.29	394.33	224.89	93.16	57.71
qPeople	1334.40	112.00	102.40	113.60	110.40	112.00	110.40	113.60	112.00	112.00	112.00	108.80	115.20
qEquipmen	876.00	74.40	67.20	74.40	72.00	74.40	72.00	74.40	74.40	72.00	74.40	72.00	74.40
qLighting	251.50	0.00	0.00	0.00	44.70	39.10	36.30	37.10	43.10	51.20	0.00	0.00	0.00
qTransmiss	-200.46	-190.86	-208.51	-268.48	319.28	261.52	174.23	8.31	67.28	161.99	-165.15	-173.31	-186.76
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	-2449.91	-177.42	-169.47	-283.69	-162.72	-191.45	-223.59	-242.95	-208.39	-189.68	-252.35	-172.03	-176.16
Sum	-67.83	-0.00	0.00	0.00	-11.29	-26.21	-3.76	-5.23	-10.58	-10.76	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(°(	22.4	22.0	22.2	22.7	21.9	22.2	22.6	23.2	23.0	22.3	22.6	22.1	22.0
AirChange(/	3.8	1.5	1.5	1.9	4.5	6.0	6.2	6.6	7.2	5.6	1.8	1.5	1.5
Rel. Moistur	37.7	25.3	25.2	22.2	31.6	39.6	49.1	55.8	54.4	49.8	42.1	30.9	26.8
Co2(ppm)	456.3	485.0	485.3	476.0	472.1	443.7	425.1	398.0	398.0	442.7	477.6	484.4	488.2
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0.1	0.1	0.3	0.3	0.5	0.6
Hours > 21	8643	744	672	744	661	714	703	740	742	715	744	720	744
Hours > 27	21	0	0	0	0	0	0	15	6	0	0	0	0
Hours > 28	4	0	0	0	0	0	0	4	0	0	0	0	0
Hours < 20	9	0	0	0	4	3	1	1	0	0	0	0	0
FanPow	1169.10	77.59	71.33	105.59	80.48	95.98	112.35	147.53	136.92	92.86	95.80	75.09	77.59
HtRec	5556.82	756.91	702.80	1091.08	477.42	301.50	189.19	70.38	60.29	153.32	392.95	609.13	751.83
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	0.71	0.00	0.00	0.00	0.51	0.15	0.05	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	1520.48	53.98	18.65	0.05	335.47	296.16	200.71	112.99	164.11	249.40	1.08	31.47	56.40
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
CentCoolinc	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
CentCoolinc	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

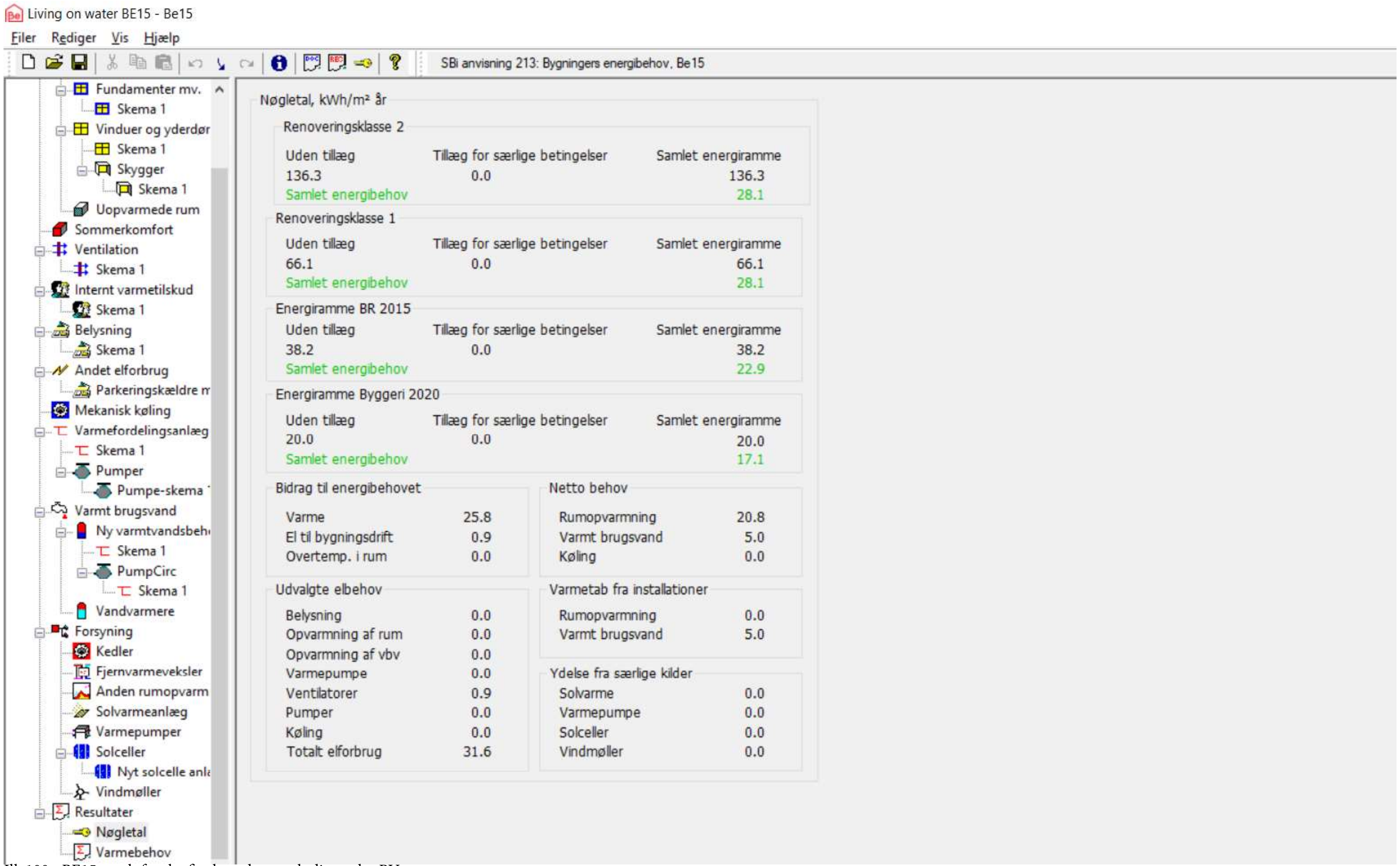
Ill. 98 - Bsim For the final model orientated due north

// BE15 WITH SOLAR PVS



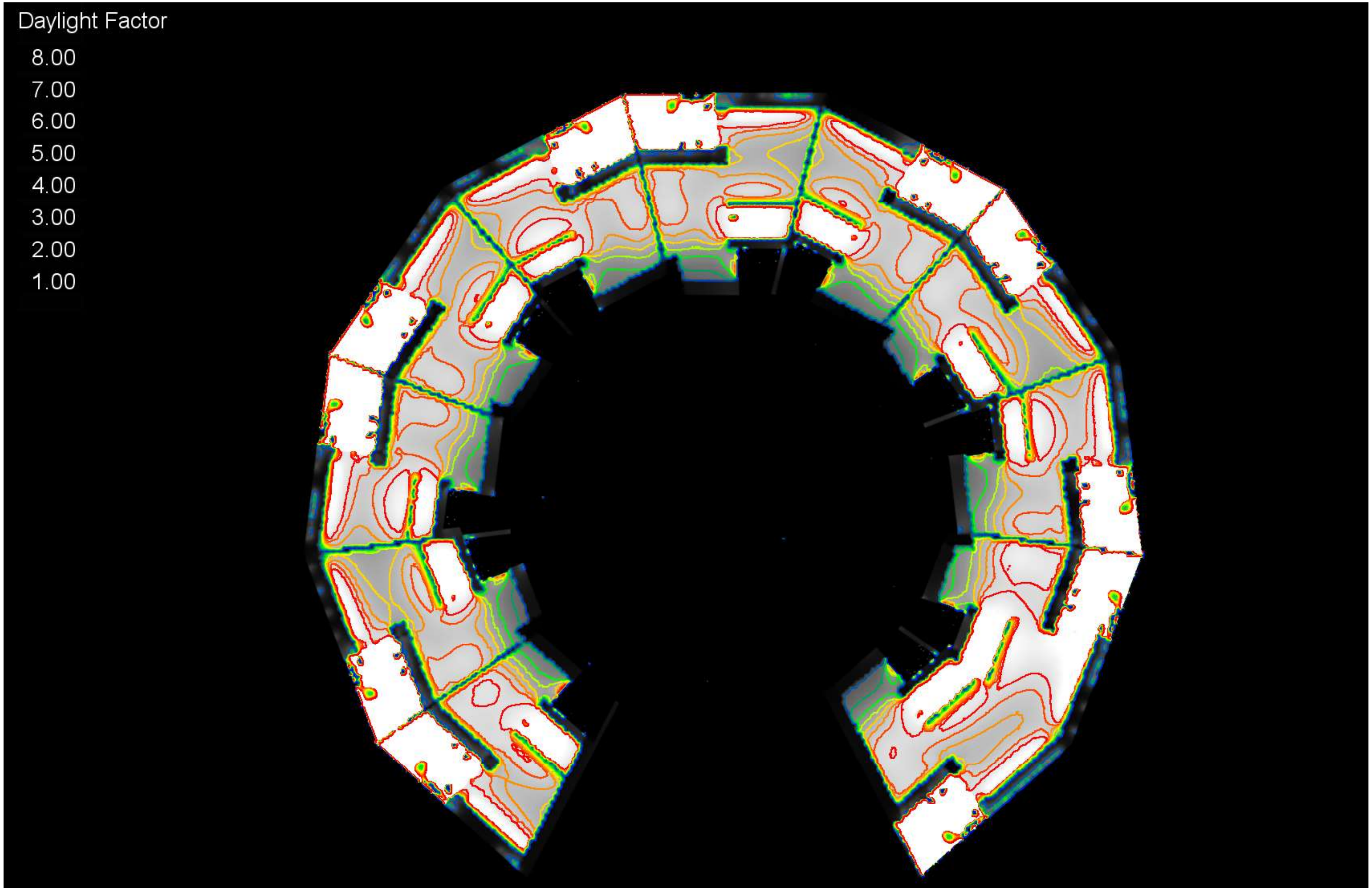
Ill. 99 - BE15 result for the final product including solar PVs

// BE15 WITHOUT SOLAR PVS



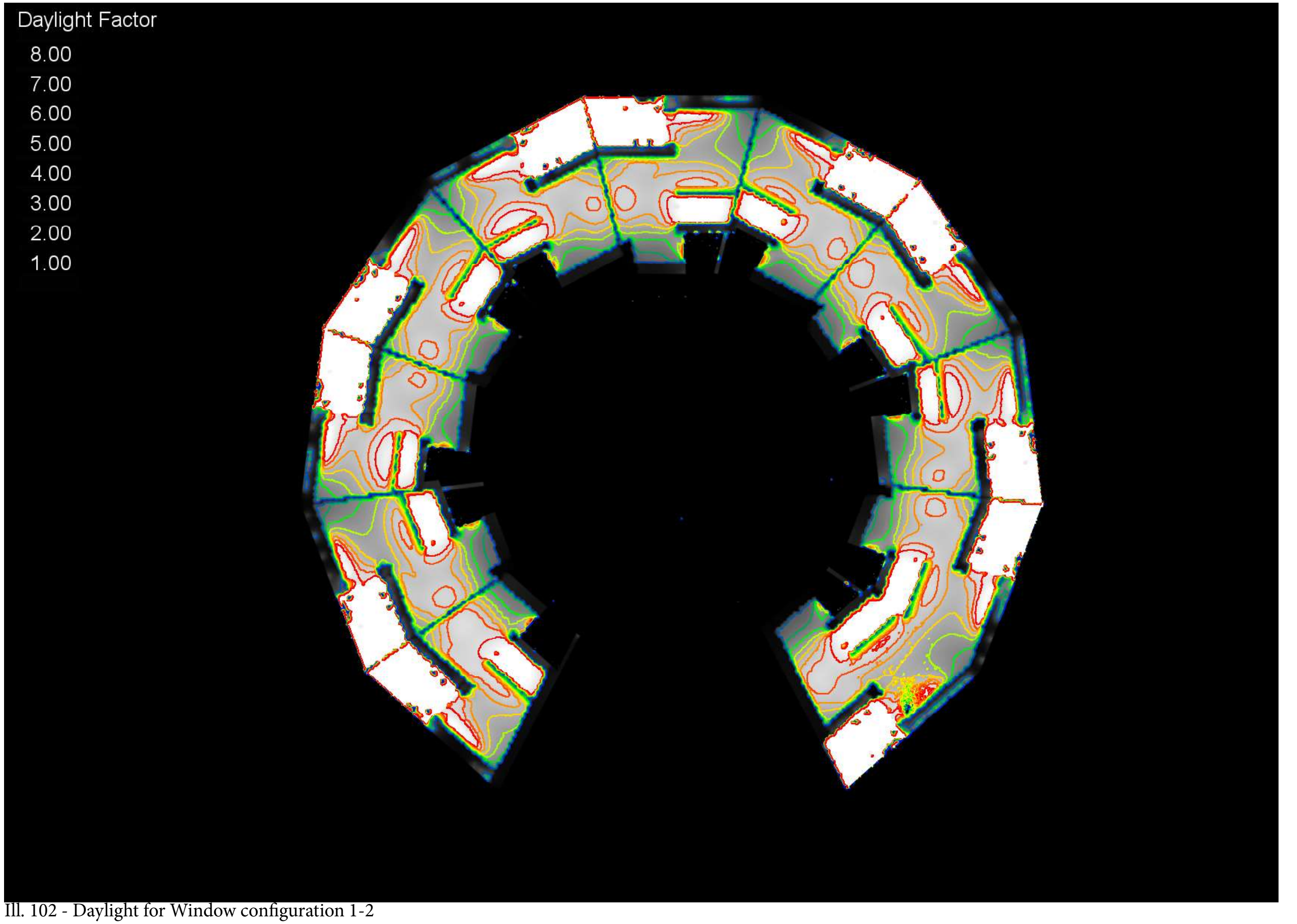
Ill. 100 - BE15 result for the final product excluding solar PVs

// DAYLIGHT

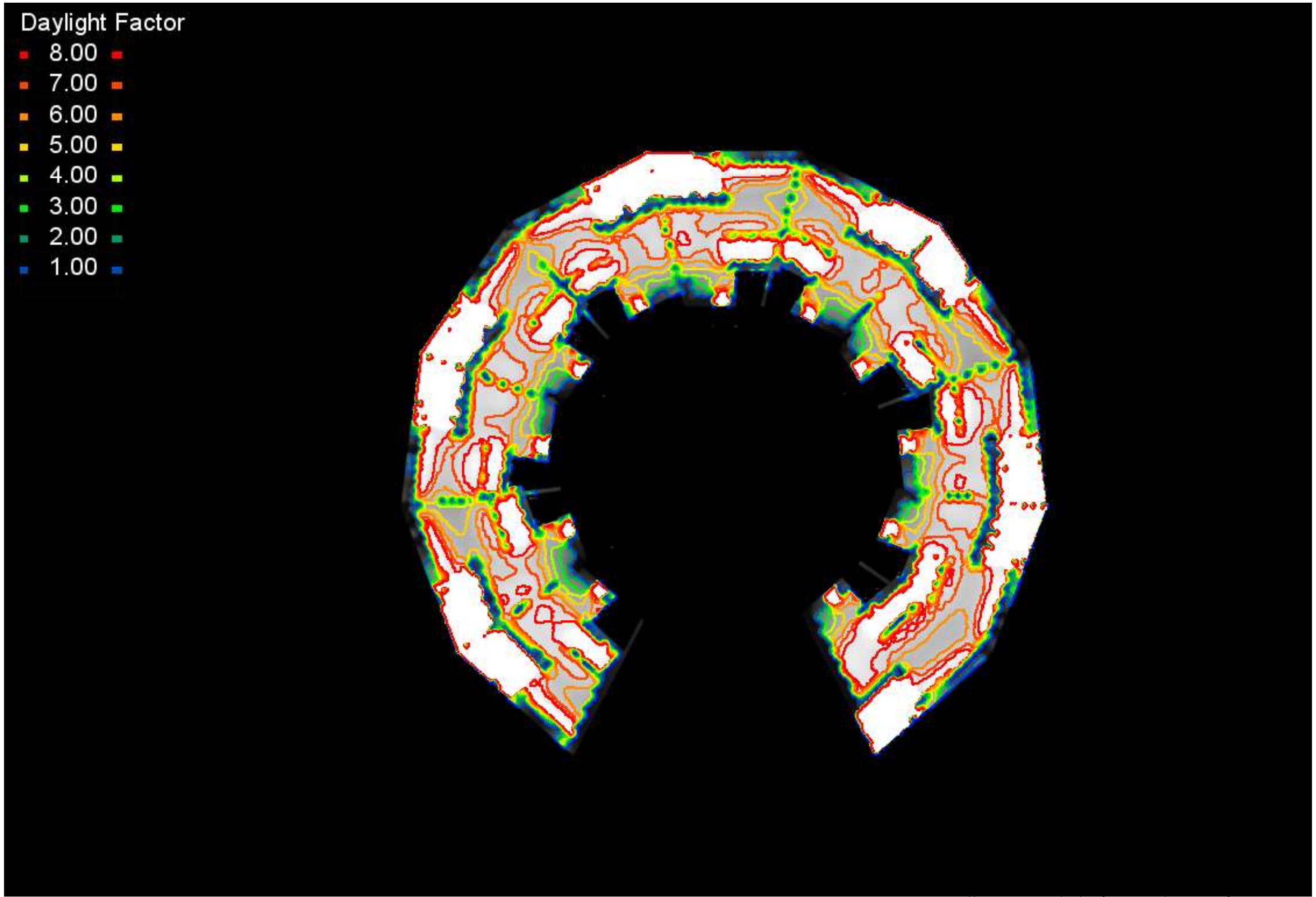


Ill. 101 - Daylight for Window configuration 3-6

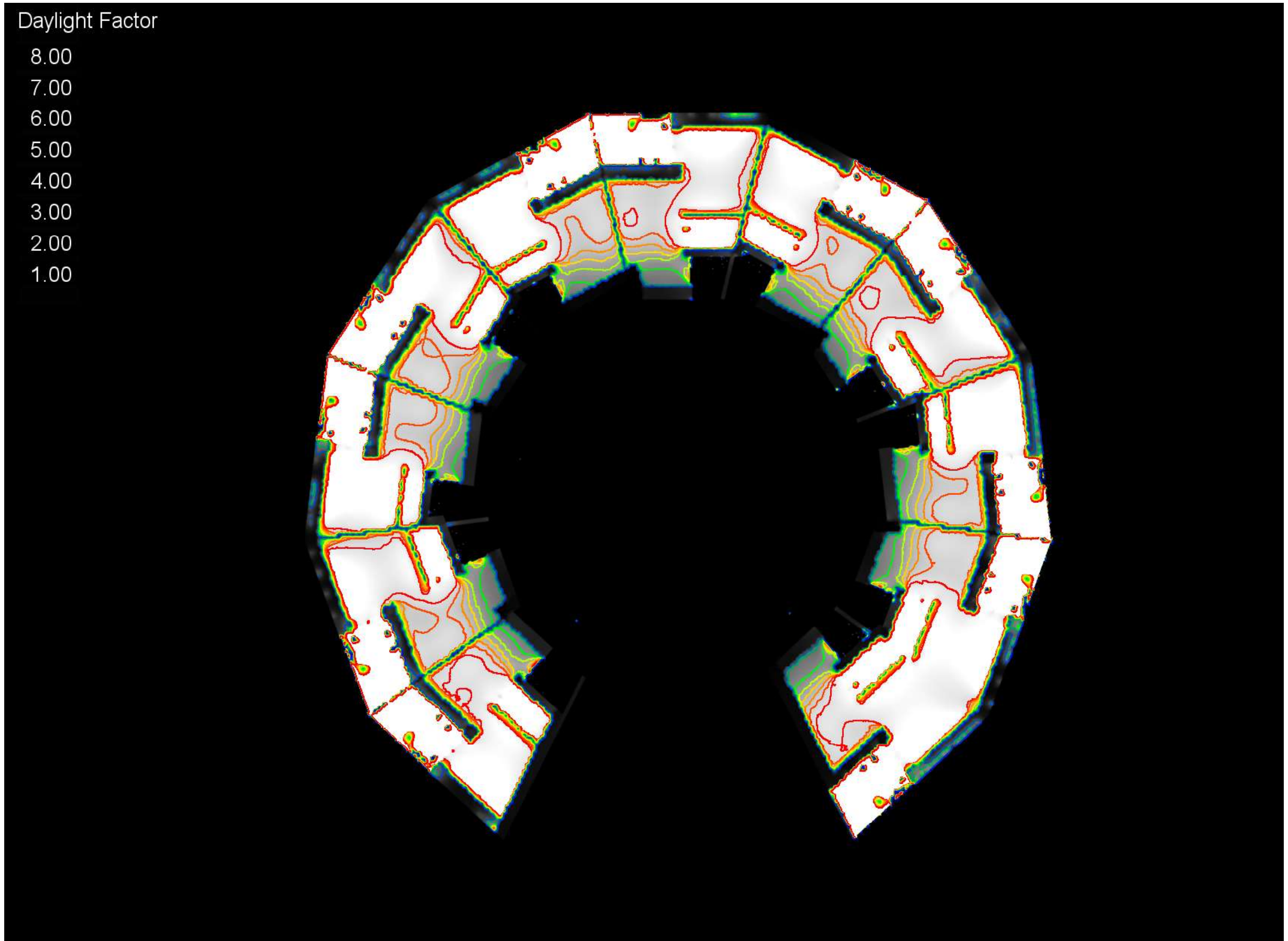
// DAYLIGHT PROCESS



Ill. 102 - Daylight for Window configuration 1-2

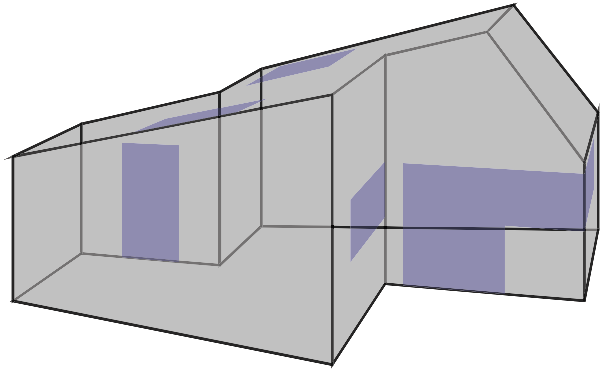


Ill. 103 - Daylight for Window configuration 5

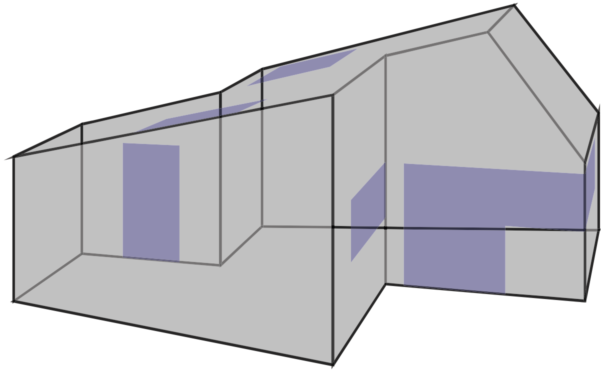


Ill. 104 - Daylight for Window configuration 4

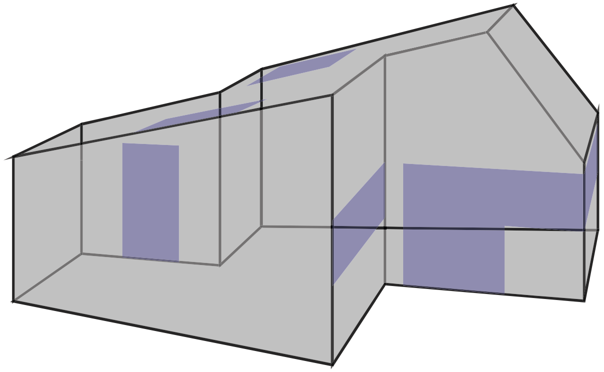
// WINDOW CONFIGURATIONS



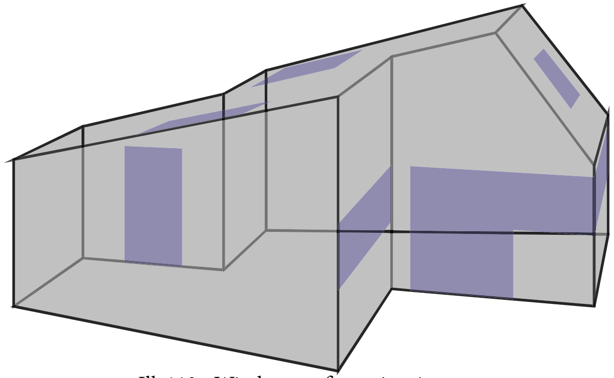
Ill. 106 - Window configuration 1



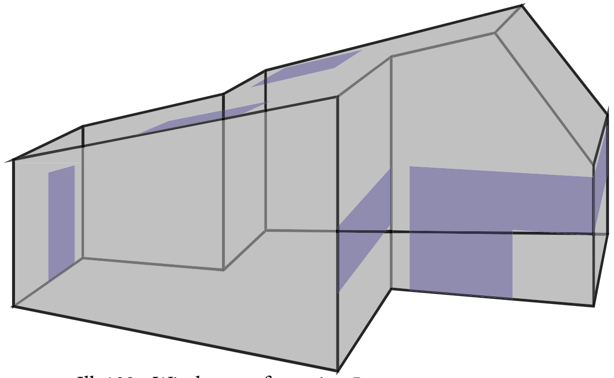
Ill. 105 - Window configuration 2



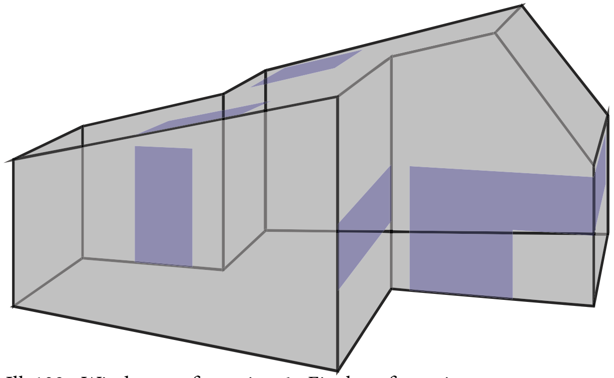
Ill. 107 - Window configuration 3



Ill. 110 - Window configuration 4



Ill. 109 - Window configuration 5



Ill. 108 - Window configuration 6 - Final configuration

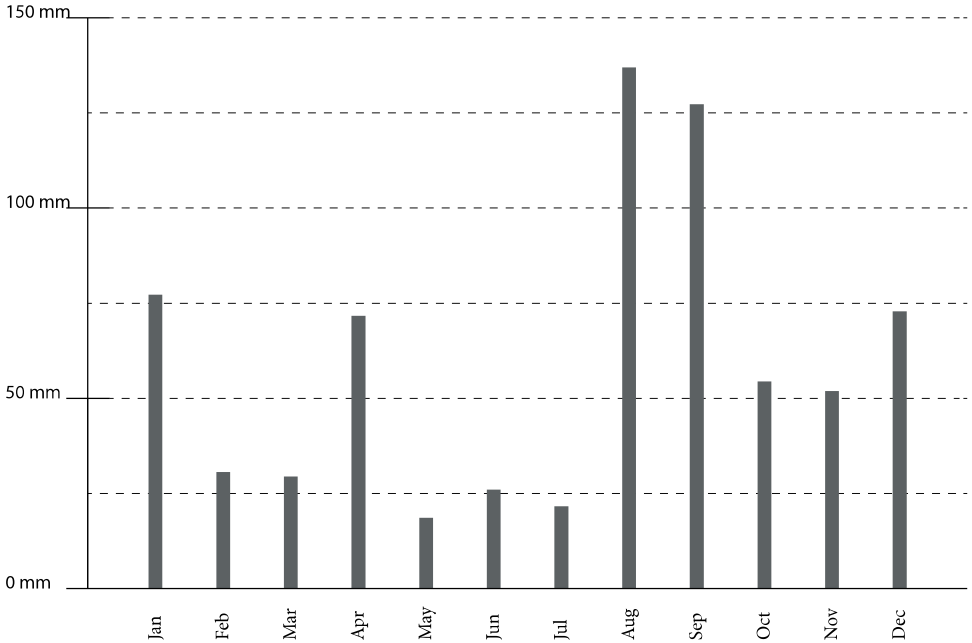
// VENTILATION HANDCALCULATION

ventilation need calculated for olf	Area m2	Roomheight m	Volume m3	People load Amount	Pollution pr. person olf	total pollution from people olf	Pollution pr m2 from building materials olf/m2	Total material pollution olf
First floor	40.0	3.4	136.0	4	1	4	0.10	4.00
*its calculated for a maximum of 15% dissatisfaction. Herby its read as experiences air quality for a gives 1 decipol aflæses den oplevede luftkvalitet til at give 1 decipol (GKB s.41)								
ventilation need calculated for CO2	Area m2	Roomheight m	Volume m3	People load Amount	Activity level pr. pers. met	Pollution pr. person m^3/h	q=Total people load m3/h	Air stream (VL) (m3/h) q/c-ci
First floor	40.0	3.4	136.0	4	1.20	0.0204	0.0816	204

Ventilation need calculated for olf	Pollusion in total olf	*Air stream VL l/s	Air stream VL m^3/s	Air change n h^-1	Air Stream VL L/s / m^3
First floor	8.00	80.00	0.08	2.12	0.588235294
Ventilation need calculated for CO2	Air change n (h^-1) VL/VR				
First floor	1.50				

Ill. 111 - Ventilation Amount hand calculation

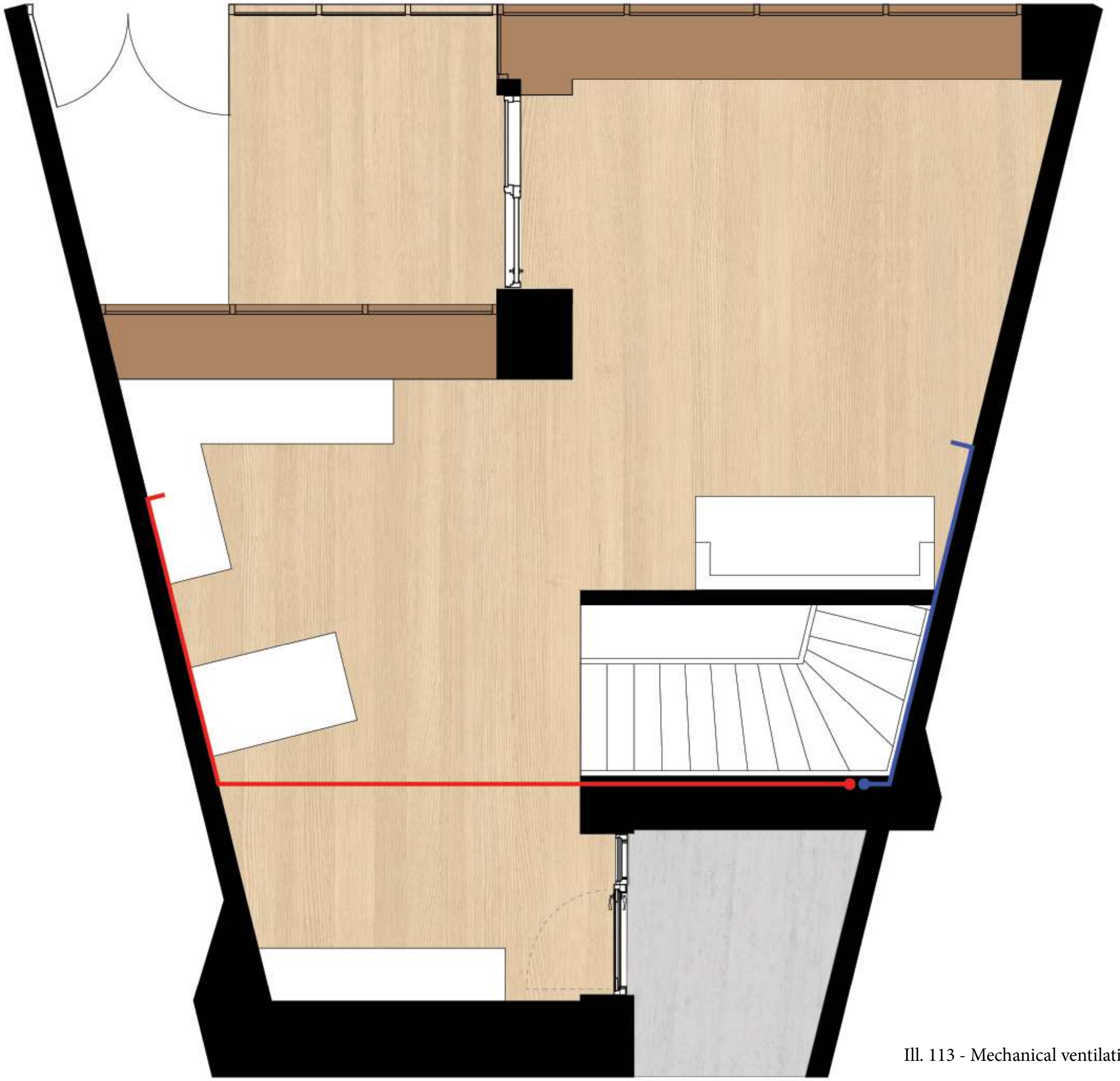
// PERCIPITATION



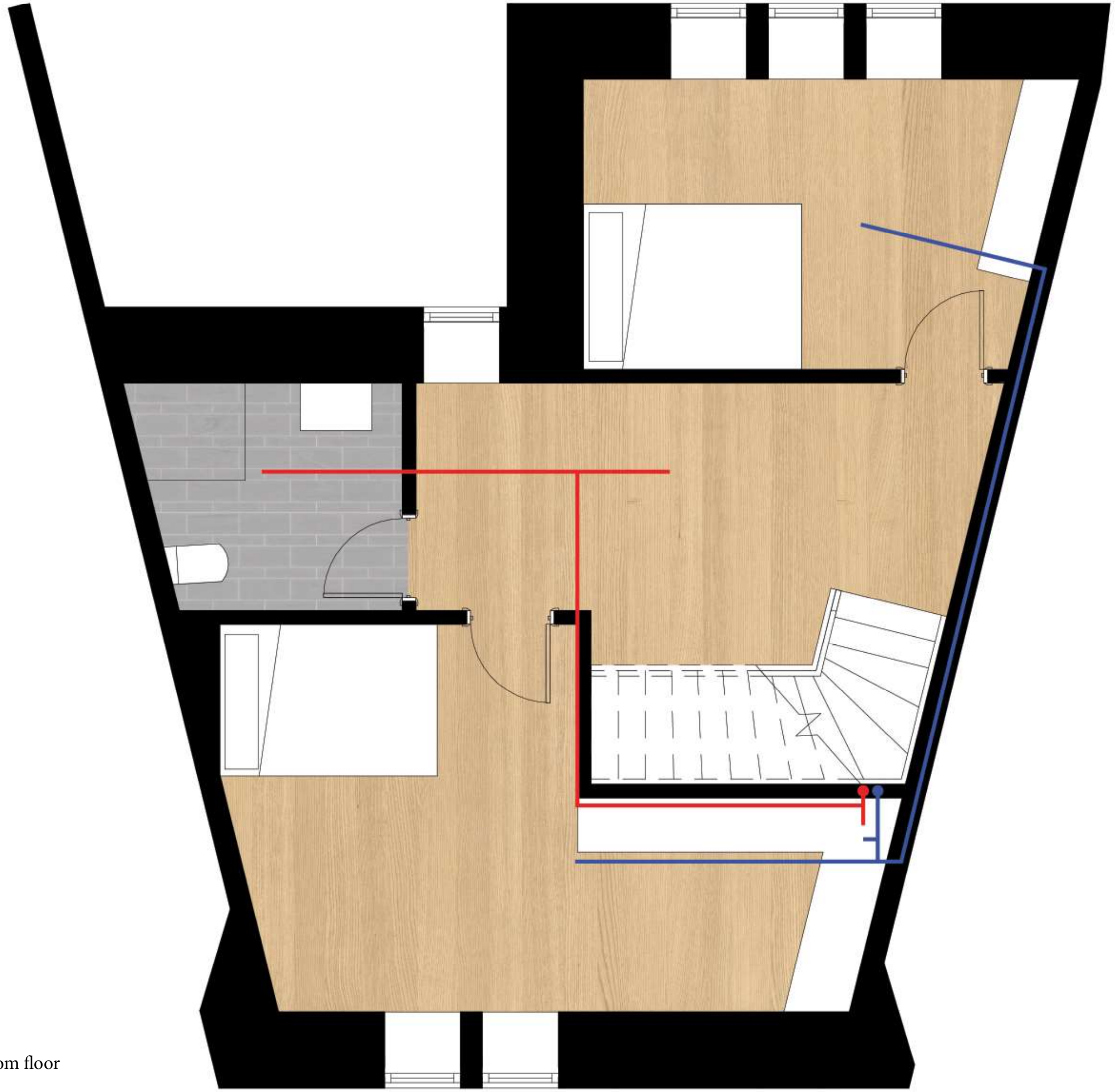
The presented data for precipitation for Aalborg is the data presented by DMI, which was collected for 2018.
In itself doesn't pose a problem on the site, since it can easily be lead away from the roof and the outdoor areas and into the fjord. To get an idea of the precipitation across a year weather data for 2018 has been looked at to get the idea of the rain across the year to then later be compared to the amount of water used by each resident. This is done to determine the amount of area and storage of fresh water there need to be on the site to supply the site's resident with water without running out. The year 2018 was chosen since it was a year with a rough period with limited rain, to be prepared for bad scenarios that could influence the site in the future so that it is not needed to have the ability to convert seawater to freshwater by installing a desalination device. So since there is not a fresh water supply from the outside, there needs to be a large storage unit with the possibility to let out water to the ocean to compensate between periods with large amounts of water and periods of dry weather.

Ill. 112 - Percipitation

// MECHANICAL VENTILATION



Ill. 113 - Mechanical ventilation top floor



Ill. 114 - Mechanical ventilation bottom floor