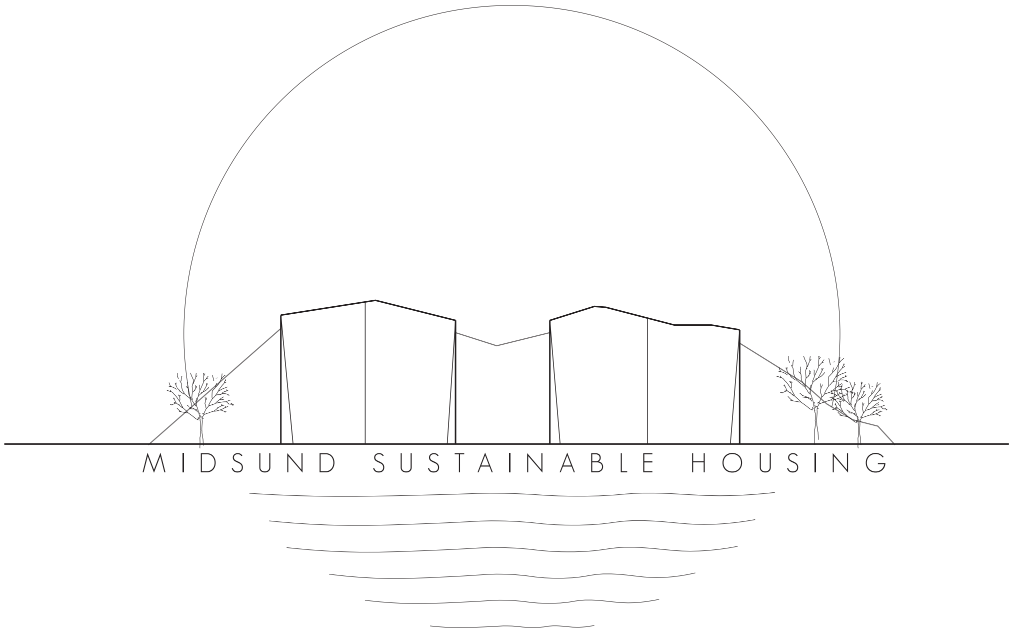

AAU MSc04 ARK 2018 - May 2018
Master Thesis - Midsund Sustainable Housing - Sustainability - Aalborg University - Gr. 02
Crystal Khodeida - Gestur Egill Johannsson - Ole Allin Egebæk

MIDSUND SUSTAINABLE HOUSING

Title:	*Midsund Sustainable Housing*
About	*Semesterproject, MSc04 Arch* *Department of Architecture & Design* *Aalborg University*
Authors:	*Stud. Msc. Eng. Architecture:* *Crystal Khodeido* *Gestur Egil Johannsson* *Ole Allin Egebæk*
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Ole Allin Egebæk

ABSTRACT

This booklet presents the multidisciplinary development of a sustainable housing complex, situated on the harbourfront of Midsund, on the west coast of Norway.

The project originated in collaboration with a local Norwegian construction firm, Røberg Bygg A/S, seeking to build on a newly planned building site. The project has aimed to conceive an architectural, sustainable and feasible project, focused on enhanced life quality, through the utilization of natural resources on the site. These resources have been a design catalyst for forming a harmonious project, with relation to the surrounding context.

Furthermore, analysis of energy consumption and indoor environmental qualities has been conducted, through several design iterations and verification of the final design. These analyses are made in BE18 and Bsim.

CONTENT

ILL. 7. 1

MOTIVATION

The motivation for choosing this particular project for the thesis was, above all, based on the tremendous opportunity of designing an actual project, situated on an attractive site with beautiful surroundings. The authenticity of the project amplifies the motivation factor of developing a great project. Furthermore, the project offers a great insight into the professional environment of the building industry, where many stakeholders are involved, and where economics play a crucial factor.


Camping

01 PROGRAMME INTRODUCTION

ILL. 9. 1

PROJECT LOCATION

ILL. 10.1

ILL. 10.2

NORWAY

The project is located in Midsund, a small city on the island Otrøya in the county of Møre and Romsdal, Norway, Scandinavia, marked with the red circle (see ILL. .1).

MØRE & ROMSDAL COUNTY

Otrøya, marked in the circle (see ILL. .2), is the largest island in Midsund municipality in Møre and Romsdal county, in the western part of Norway. The total size of the island is 75,5km2 and has around 1600 inhabitants of which 78% is living in Midsund. [thorsnæs, 2015]

ILL. 11.1

ILL. 11.2

OTRØYA

Midsund is located with direct access to a narrow inlet, between Otrøya and Midøya, and is well sheltered. These conditions have made Midsund an attractive area for living, dating all the way back to the stone age. [Idékonkurranse om utvikling av Midsund sentrum, 2013] The city of Midsund is marked on the air-photo above.

MIDSUND

Midsund developed around its harbor, where a shipyard for steamships and industrial fishing boosted the establishment. The industry, new institutions, and commercial businesses laid the ground for the bridge to Midøy and Ny Skule in the late 1960s and underline the importance of the city, as the center of Midsund Municipality. [Idékonkurranse om utvikling av Midsund sentrum, 2013] The illustration (see ILL. .2) marks the location of the site.

READERS GUIDE

This project booklet is divided into main chapters, equivalent to those of the integrated design process. Throughout the chronological presentation of the design process, new information will be presented as it is investigated, simulated or received from the different stakeholders – this forms the basis for the following iterations.

Referencing is in accordance to the Harvard referencing method, with all references listed in the back of the booklet.

PROBLEM STATEMENT

How to design an attractive and sustainable housing project, with architectural qualities, as a local landmark, that contributes to Midsund city and creates a coherence to the surrounding nature, while utilizing and enhancing the natural resources as a catalyst for life quality and social interaction between inhabitants and guests - all this while simultaneously considering and balancing the interest of the stakeholders within the project?

ILL. 14.1

PROJECT FOCUS

As this project is made as a design proposal for an actual apartment development in Midsund, Norway, a significant focus during the development of the design has been to follow the applicable legislation and regulations, from the local plan, and the wishes from the building owner and local real estate agent.

From this, the focus of this project has been to develop an apartment complex, with a high architectural quality, inspired by a Nordic architectural approach and how this can contribute to creating well-being for the users.

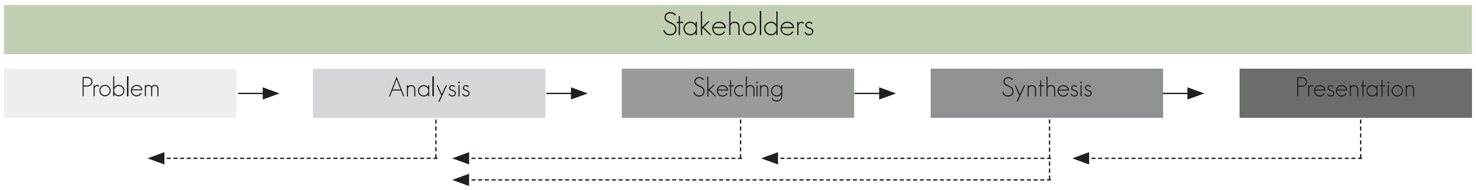
As a catalyst to create these qualities, different measures, described in the following part, have been taken to capture and enhance the spirit and atmosphere of the place, while aiming to pass on aspects of it, to a more modern, and currently missing part of Midsund.

With the desire of making a place specific apartment project, a focal point of the project has been local materiality and building tradition, and how to utilize this in a strong contemporary architectural concept derived from the majestic context.

While conducting BE18 Energy calculations and Bsim indoor environmental simulations, adequate weather files for the simulations were not available, and this might cause slightly inconsistent results. To comment on this issue, average temperatures and wind data for Denmark and Molde have been compared. This comparison shows that the building plot in Norway has a lower annual average temperature, of 6.8°C [Dmi.dk, 2018], compared to Denmarks 8.3°C [Dmi.dk, 2018]. The climatic differences could result in the indoor temperatures being lower, and the energy consumption being higher than the results of the analysis in the report shows. Subsequently, the dominant wind direction and the average velocity varies, with a slightly lower velocity in Molde than in Denmark. [meteoblue, 2018] This could cause problems when coping with overheating, but due to the lower average temperature at the site, this might even out the results a bit. Which is why the focus in this project has been the process of the simulations more than the actual results, however, it is important to state this issue is only present in the BE18 and Bsim simulation results. Weather data can be found in the Climate comparison chapter in Appendix.

Additionally, the energy frame for the project has been reevaluated based on new knowledge and wishes from the building owner, as the initial idea was to create a zero-energy building. Investigations, presented in the booklet shows, the motivation for making a ZEB are shallow when considering available energy sources, held against the price for establishing and maintaining a ZEB. Therefore, the focus has changed, from zero-energy to a building reaching the requirements for a low energy building, both reaching Danish and Norwegian standards.

METHODOLOGY



Identifying and specifying the problem statement in the project.

Analysing and researching e.g. site, future plans, user criteria, technical and construction principles, energy goals and relevant theory.

Generating solutions and ideas different problems within the project; architectural, technical, sustainable, construction etc.

Development and integration of ideas chosen from sketching phase are being merged to a holistic project proposal.

The project proposal is presented with graphic material, text, technical drawings and 3D- or physical models.

ILL. 16.1

The project is based on the iterative methodology of The Integrated Design Process (IDP) developed by professor Mary-Ann Knudstrup at Aalborg University. The objective of the methodology is to ensure a holistic design approach, combining knowledge from architecture and engineering to solve complex design problems. One can say that the methodology considers both the measurable and the unmeasurable elements of design. By integrating aesthetics, functionality, technical and environmental aspects in an iterative dynamic process comprised by five phases, where the designer travels back and forth between the various phases throughout the process, ultimately optimizing the quality of the finished product. [Knudstrup, 2004]

Throughout the Bachelor's and Master's programme at Aalborg University (AAU), the projects have solely been academic, where the primary constraints have been the learning goals from the various semesters, as well the general legislation and regulations. However, in this projects, several additional restrictions have been added, consisting of the multiple stakeholders in the project. These stakeholders consist of the building contractor, real estate agency, the authorities, external expert groups as well as potential buyers, but the fundamental difference lies in the reality of the economy, as the project has to make sense financially, presenting an unfamiliar territory for the students at AAU.

ILL. 17.1

1. Problem phase
The project is introduced with a brief, followed by a problem constructed for the project. The brief is the platform for the project and must be exact and comprehensible. By introducing the problem statement, the entire outset begins.

2. Analysis phase
Between the problem statement and the analysis phase, relevant analysis is processed to investigate the interest of the project. Site analysis is considered, including topology, infrastructure, climate, and functions of the site. Relevant theory, such as Nordic architecture, sustainability, well-being, energy in Norway, future plans for Midsund, users, case studies, materials, etc. restrictions are investigated.

3. Sketching phase
In extension to the analysis phase, ideas and thoughts are developed with the previous knowledge, gained during the analysis phase. At this point, proposals are established through sections, plans, elevations, physical models, 3D, and hand drawings. More measurable and digital (3D) methods are introduced later in the process, where specific details such as envelope thickness, size of windows and materials are introduced to achieve an understanding of energy consumptions. Furthermore, observations of the site in connection with a phenomenological approach are expressed in connection with a trip to the site.

4. Synthesis phase
More detailed concepts arrive in this phase to provide an integrated design, were the chosen design are optimized concerning detailed construction- and sustainable solutions. Relevant aspects such as engineering, functionality, and aesthetics are merged and used as a focal point to allow the project to take form.

5. Presentation phase
The technical, aesthetical and functional qualities are presented, as an outcome of the previous phases. It is crucial that the introduced material is understandable and precise for the reader.

02 PROGRAMME THEORY

ILL. 19. 1

PROGRAM PROSPECT

The first part of the program is a collection of theory, concerning qualities and tendencies in Nordic architecture and essential qualities for well-being in a sustainable perspective. This part further elaborates on sustainability in a greater perspective, including DGBN, descriptions, and cases of passive houses and zero energy buildings, energy requirements and available sources in Norway.

The second part of the program, digs into an analysis of the site, available functions, and resources present in the context and the climatic conditions, both in a macro and a micro scale.

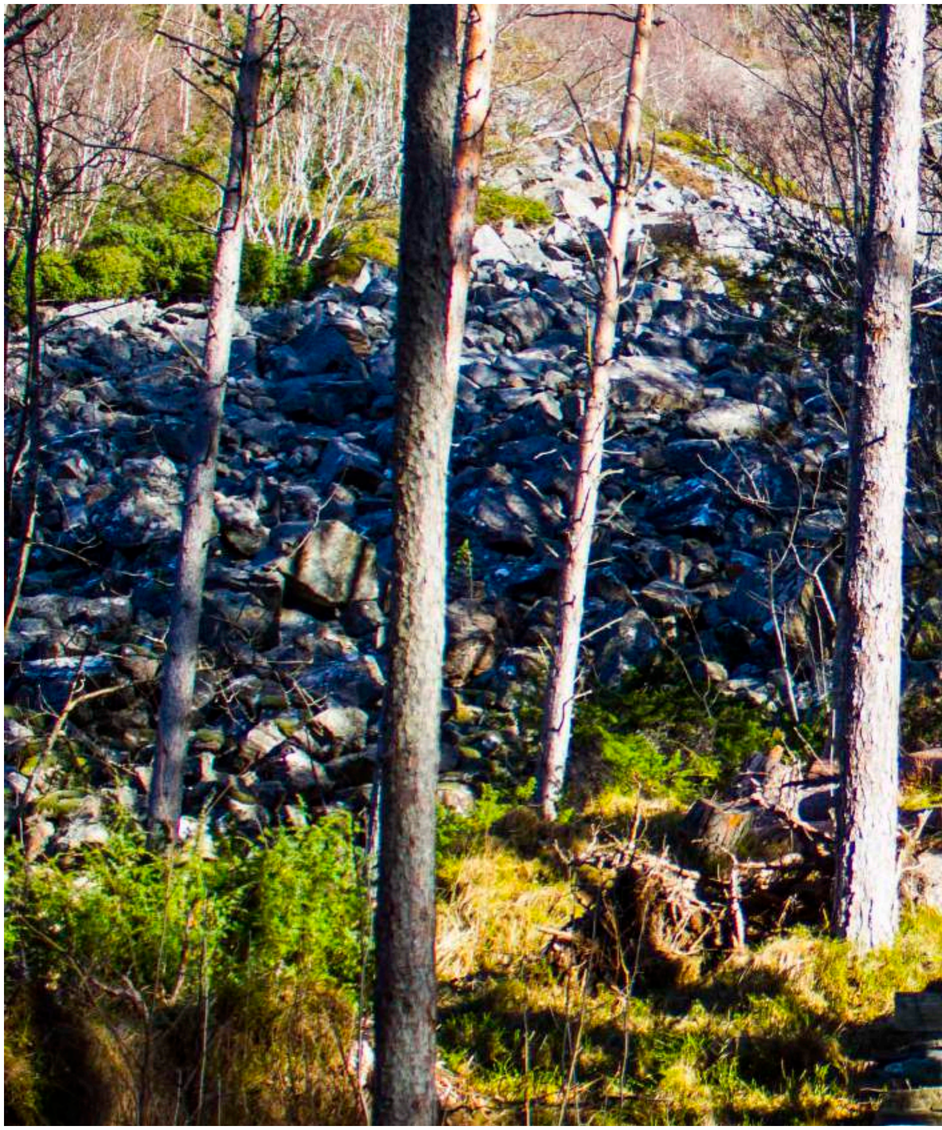
Furthermore, the third and final part of the program revolves around the spatial, technical and functional requirements to the building and restrictions from the local plan.

At the end of the program, a number of design criteria have been created, to sum up, elements within the program that functions as inspirational design catalysts and parameters for later evaluation of the project.

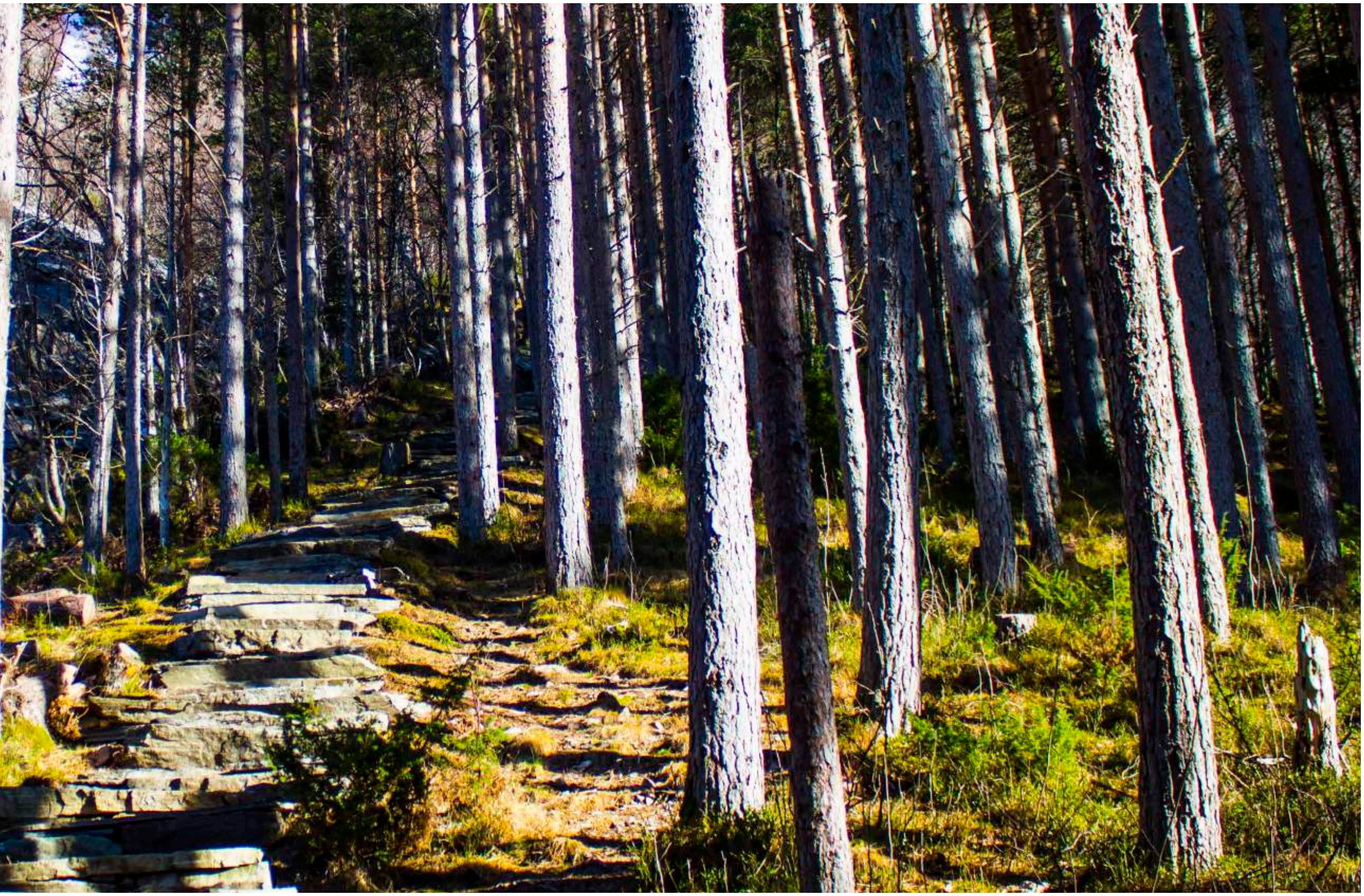
ILL. 21. 1

NORDIC ARCHITECTURE QUALITY

This investigation of Nordic Architecture, is made to gain a deeper understanding on how to create an architectural dwelling project that respects and captures the surroundings in a Nordic context. Peter MacKeith, professor in contemporary Finnish and Nordic architecture [Kjeldsen, K. m. fl., 2012], refers to the Nordic architecture as a natural product raising from the native soil of the surroundings, expressing the essence of the location, utilizing and communicating the language of the natural resources within the site; "[...] An architecture of the true North, so shaped by climate, light (and its absence), material resources, and our sublime perceptions of the arctic latitudes as to constitute its own regional construct." [Kjeldsen, K. m. fl., 2012] Kenneth Frampton, additionally mentions the topography of a given area, as another natural resource for the Nordic Architecture. [Tostrup, 2006] The use of the natural resources, to emphasizes the attention to the context is similar to the approach of "Genius Loci", a theory developed by Christian Norberg-Schultz, who was a Norwegian architecture theorist. [denstoredanske, 2016] In Norberg-Shultz's "Genius Loci" he, states the importance of allowing one to open up and listen to the spirit of the place as an objective thing; "it is the way it is, whether we like it or not, and will reveal its secrets and its riches if we ourselves open up and listen to its spirit". [Norberg-Schultz, C. 1991] Furthermore, Norberg-Shultz mentions the traditional Norwegian wood architecture as if it; "had grown out of our nature and landscape", and how it was a; "place specific building tradition." [Kjeldsen, K. m. fl., 2012] This naturally leads the attention of this project towards utilizing the natural surrounding resources, both tangible resources, such as local materials and the Norwegian building tradition, as well as intangible, e.g. climate and light. When talking about the importance of light, Louis Kahn states; "Light gives all things their presence" [Frampton, 1995]. Natural light has a substantial influence on architecture within a Nordic context. The specific light conditions call for intelligent design solutions, to exploit and benefit from the ever-changing inclination of sunlight, throughout the year. Furthermore, there is a tendency for some architec-



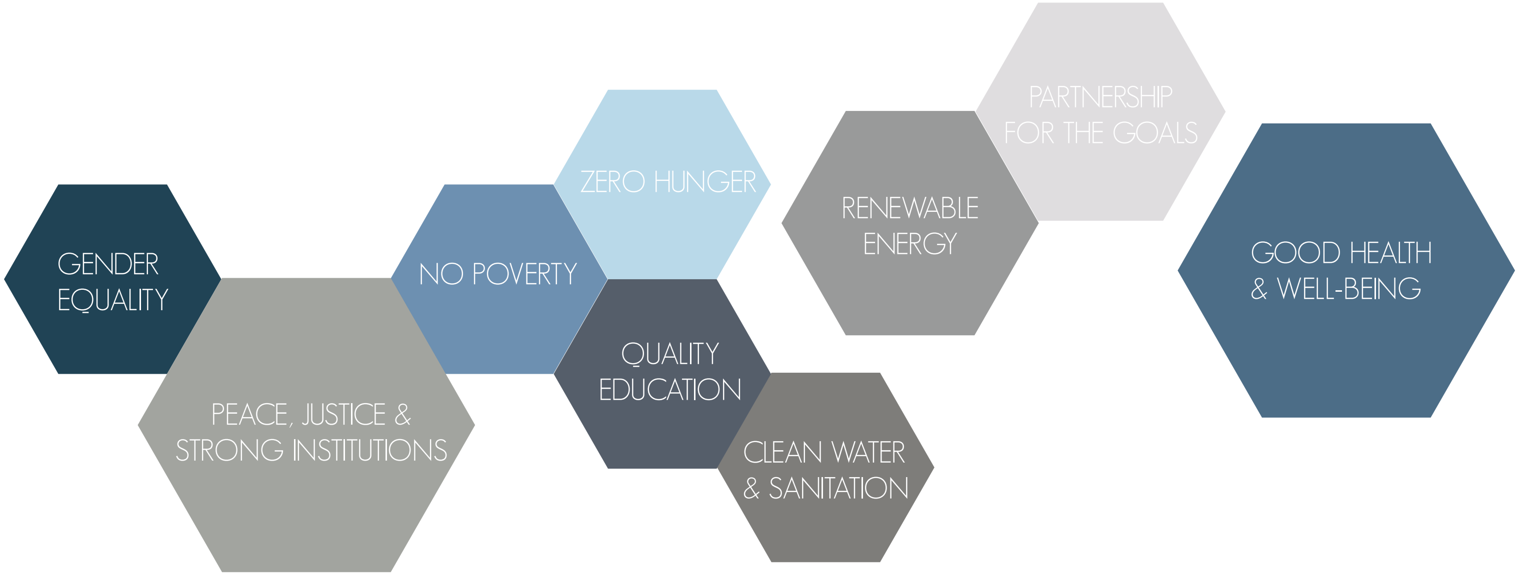
ture within the Nordic countries to reflect particular values within the respective countries' democratic, welfare societies. [Kjeldsen, K. m. fl., 2012] Nordic Architecture does not have a specific architectural style definition, but the general tendencies of imitating nature, relating to the context and its honest utilization of natural materials, for constructional, functional and aesthetical purposes [Kjeldsen, K. m. fl., 2012],


ILL. 23. 1

correspond with the fundamental ideas of a multi-tectonic approach which can further be translated into an integrated design project. This approach leads to the question on how this interpretation of Nordic architecture, an integrated and amplify architectural qualities, health, and well-being while establishing a genuine connection between the architecture, the resources present at the site and the inhabitants?

This project will revolve around the creation of intelligent design-solutions to accommodate the climatic conditions at the site, with a particular focus on light, wind, and precipitation. Furthermore, utilization of local materials for constructional, functional and aesthetical purposes, will be treated in a Nordic manner, to create an architecture that expresses the essence of the site and its resources.

SUSTAINABILITY

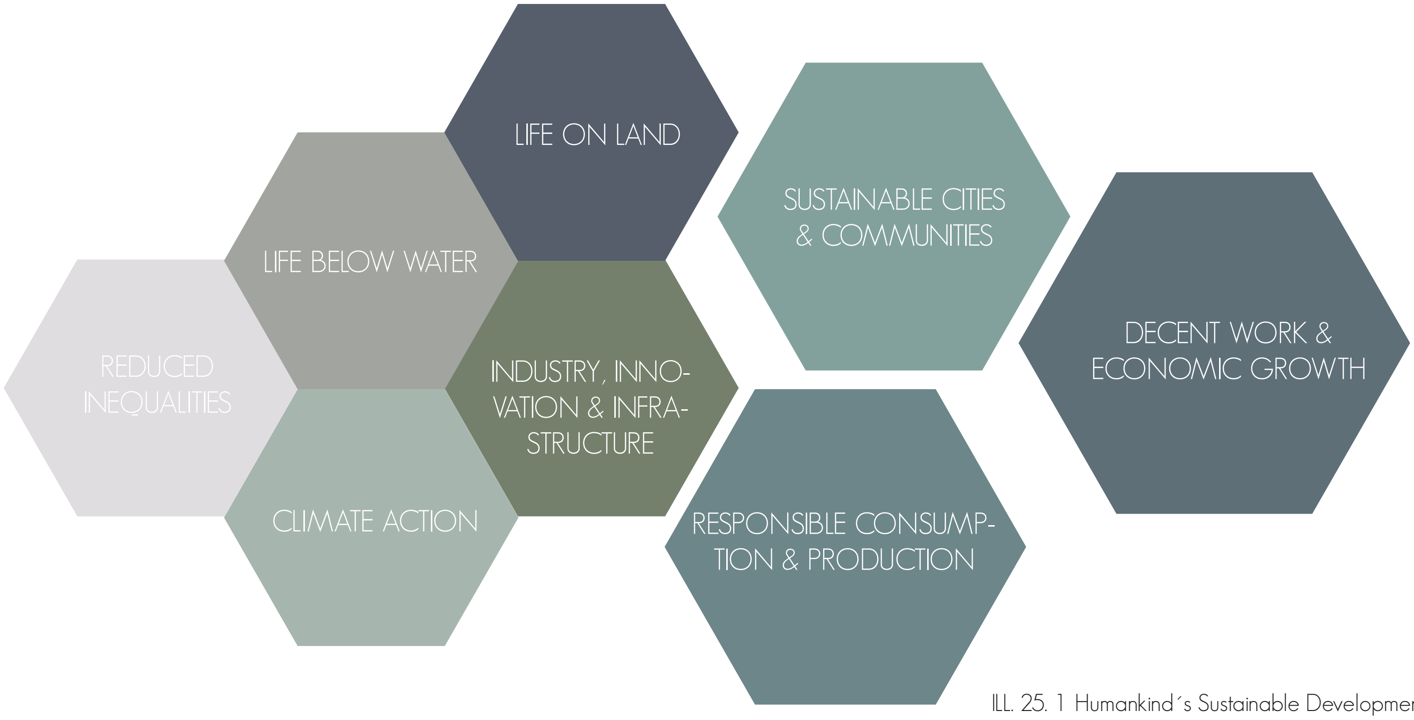


This chapter will use references, outline information and theory from several articles and mainly from an article written by A.D. Basiago (see [Basiago, A.D, 1998]). The initial text will briefly describe the history behind the development of sustainability, followed by framing sustainability in three subjects consisting economy, environment, and social aspects.

For approximately two centuries the subject of sustainability has been evolving throughout the discipline of economics. During the initial 1800's Thomas Malthus (an English political economist) created a debate as a result of his work, mentioning this subject, whether the planets finite natural resources were capable of continuing to contribute life support an extension to the increasing population. [Dixon, J. and Fallon, L. A. 1989]

In 1798 Malthus published "An Essay on the Principle of Population" where the central concept of Environmentalism is framed based on the prediction of a stern future. Due to the population growth in a exponential (1,2,4,8,16, etc.) progression while subsistence only grows in arithmetic (1,2,3,4,5, etc.) progression, resulting in starvation. [Eblen, R. and Eblen, R., 1994] Considering the crucial information Malthus presented, an absence of concern regarding the dilemma of resource depletion was still a reality, while the efficiency of resource use has generally been the bigger concern for economists. This lack of concern concerning pollution and resource scarcity has caused a poor development of models from economists. [Freeman, C, 1973]

As Basiago mentions in the paper, only during "recent decades a global concern has emerged about the non-renewability of natural resources as a factor limiting production and the threat to long-term economic growth caused by environmental destabilization and pollution." [Basiago, A.D, 1998, p. 146]. This attention towards the environment have lead economists back to the proposal by Malthus, whether "exponential growth in population and resource use, but only linear growth in technology and subsistence is bound to lead to a social catastrophe in a word, whether the contemporary course of economic development is 'sustainable'" [Basiago,



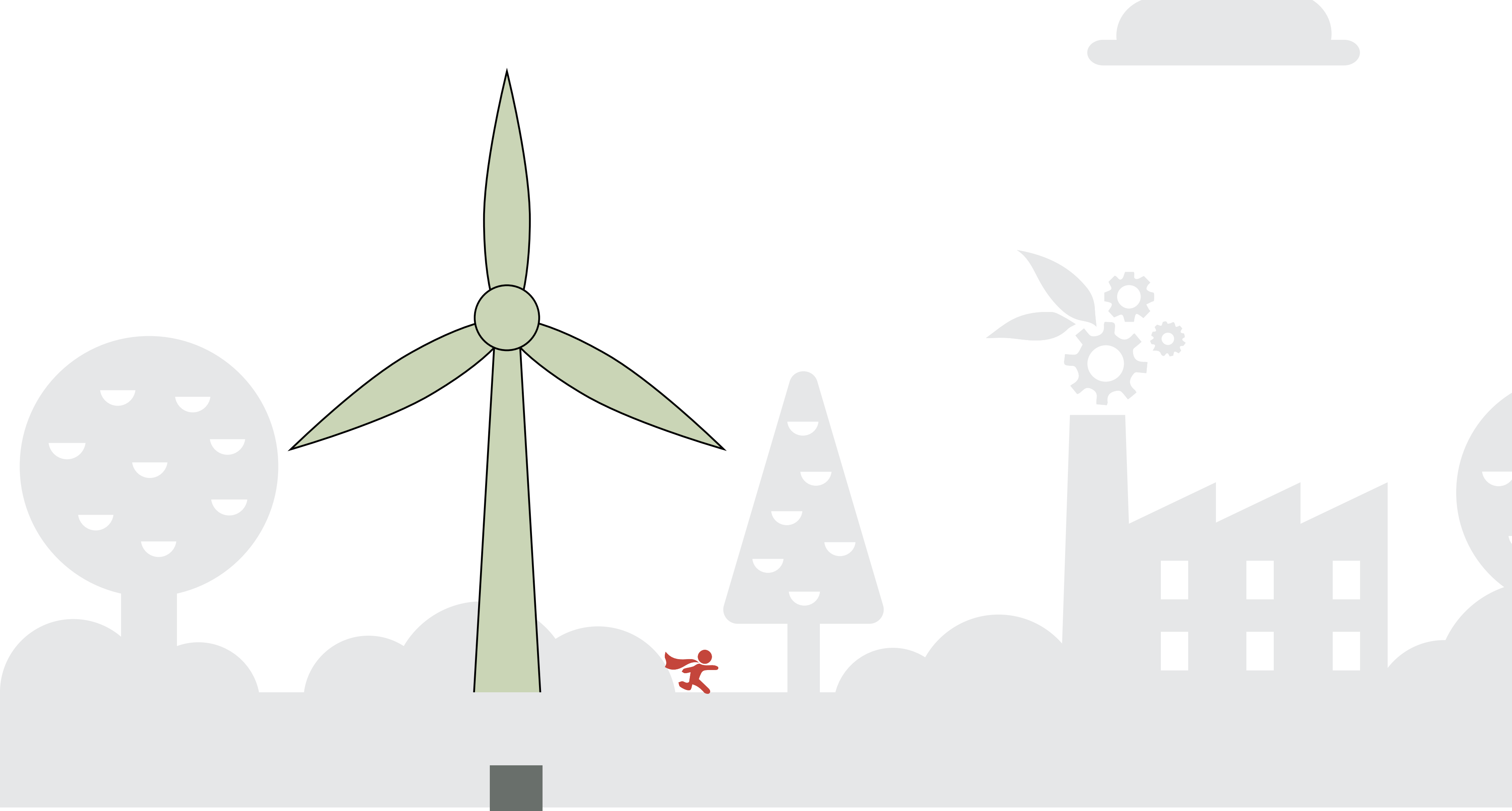
ILL. 25. 1 Humankind´s Sustainable Development goals (UN, 2018)

A.D, 1998, p. 146]. The harm towards the natural system caused by the industrial production, the matter of overpopulation, and the issues about non-renewable energy sources created together with the idea of having a sustainable society. These mentioned concerns were presented in the 1970-80's by Brown (Worldwatch Institute president). However, the phrase sustainable development was first introduced in the 80's during the UNEP (United Nations Environment Programme). [Eblen, R. and Eblen, R., 1994]

In 1987, a new call for sustainable development was established in relation to the World Commission on Environment and Development (WCED) chaired by Gro Harlem Brundtland, which led to the publishing of "Our common future" also known as the "Brundtland report." The idea behind the call was to protect the environment, alleviate poverty, and feed the world, which lead to new principles for sustainable development. The Brundtland Commission report describes the sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," which are principles still used until this day. [Basiago, A.D, 1998, p. 148]

In Rio de Janeiro in 1992, during a conference held by UN regarding Environment and Development (also known as Earth Summit), 120 nations signed five pacts of 'sustainable development' "as the overarching policy of the 21st century." [Basiago, A.D, 1998, p. 146]. 27 principles arrived during the "Rio Declaration on Environment and Development" which was seen and understood as the nation's responsibilities and rights to practice well-being and development. [Keating, 1993]. The declaration also established a framework of the sustainable development with Agenda 21 which was clarified as a blueprint which lies within "three conceptual pillars"; environmental-, social-, and economic sustainability [Kahn, M. 1995]

As Basiago mentions "only by 'integrating' and 'interlinking' economic, social and environmental 'sustainability' can negative synergies be arrested, positive synergies fostered, and real development encouraged."[Basiago, A.D, 1998, p. 150]



ENVIRONMENTAL

During a meeting in New York on September 25, 2015, the UN adopted a development agenda for sustainable development for both humans and the earth until 2030. These goals represent 17 different milestones which together must help eliminate hunger and poverty, reduce parallel inequalities, focus on education, create more peace, offer better working conditions and strengthened international partnership. The same good intentions also apply to sustainability, with a high focus on sustainability in terms of social, environmental and economic positive development. These parameters must together form development outcomes that will benefit our planet and our people. [Ohchr.org, 2018]
If the topic sustainability is pointed towards the building sector, the three notions Environment, Social and Economic sustainability can be concretized further. According to a report issued by the Green Building Council Denmark in connection with the Danish Sustainability Certificate DGNB, combining the three notions will result a more efficient building. [DGNB System Denmark. 2017]
A publication from Aalborg University indicates that the total amount of Denmark's energy consumption occurs from the building sector by approximately 40 % [Bejder, A. K., Knudstrup, M-A., Jensen, R. L., & Katic, I. 2014]. Research show's that the subject of sustainability is more than ever discussed by architect's, and that" in Denmark, the discussion about sustainability is mostly focused on the energy consumption during operation, which is reflected in the building regulations (Erhvervs- og byggestyrelsen)" [Petersen, M. D. 2010]. The concerns linked to the high energy-consumption coming from the building industry are facing changes due to the

ILL. 27. 1 *Sustainabiilty; Social, Environmental & Economic*

great amount of attention.
DGNB have established considerations and factors concerning environmental-, social and economic sustainability. [DGNB System Denmark. 2017]
Economic sustainability in the building industry considers the building cost during the entire lifespan including ensuing cost concerning the demolition of a building. To benefit further in economic sustainability, qualities such as flexibility and adaptability in will prevent an empty building, robust resources such as right materials (calculated regarding the lifespan) and robust solar screening (instead of free screening devices) and passive design strategies to reduce the need of technical devices. Qualities in social sustainability are accompanied with health (see the chapter about well-being for a more detailed description), user satisfaction and comfort. Measurable features have a significant impact on health such as adjusted air temperature, air quality, visual comfort (daylight), user control of devices (ventilation, temperature, light, etc.) Other significant social sustainable elements according to DGNB are safety, architectural qualities, integrated art, and accessibility. The environment is affected by the building sector on a large scale, not only during energy consumptions as mentioned earlier but also through the entire spectrum of the building phases. The buildings phases are initiated with the manufacturing of materials, the operation of the design, demolization and the utilization of materials. This process is known as lifecycle assessment (LCA), which estimates the environmental impacts caused by a building. [DGNB System Denmark. 2017] In the chapter DGNB selected features is described.

WELL-BEING

When we are dealing with the topic well-being in connection to dwellings, we are entering a huge spectrum within the notion itself. When we say well-being, do we then talk about single parameter as we already know, for instance, comfortable humidity and temperature within our homes, or are we facing a much more holistic approach, where we now are considering health and well-being in a much larger scale?
The real question is, how do we define health and well-being and how do we implement this in architecture?

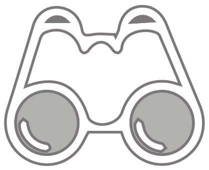
This chapter is based on a paper (literature review) written by Koen Steemers where several published articles and evidence-based information are provided, to outline how architecture can influence the health and well-being of our society. [The Daylight Site | Daylighting research, architecture, practice and education, 2018] Relevant studies will be investigated more in-depth. The first section of this chapter will focus on the definition of health and well-being, where the last part will provide information regarding how to use the achieved information in architecture.

The National Health Service in England (NHS) estimated that since 1948, the life expectancy for the population in the United Kingdom has improved with 12 years which is caused by a medical improvement. [The Daylight Site | Daylighting research, architecture, practice and education, 2018] Even though that the numbers of the increased life expectancy since 1948 have expanded, the society are facing an aging population, chronic diseases, obesity and higher consumer expectations. [Chief Medical Officer 2009]

One of the worlds largest organizations (World Health Organization) emphasizes that one of the principle´s of the constitution regarding health is that 'health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.'. [World Health Organization, 2018] This statement from WHO is a principle and definition of health, where we now are dealing with the relationship between medical, psychological and social factors and not as the absence of ill-health. The World Health Organization also mentions that "Whether people are healthy or not, is determined by their circumstances and environment." [World Health Organization 2018] which is a clear message about the understanding of the quality of our physical environment, and by implementing this mindset, the pressure on the health services can be decreased.

A report published by Commission for Architecture and the Built Environment (CABE) is introducing the idea of strategic designing "healthy places." It is mentioned that "good health is determined not simply by access to medical care, but by a range of factors, some of which are closely related to the quality of the physical environment.". [The Daylight Site | Daylighting research, architecture, practice and education, 2018] The considerable influence that architecture has towards a holistic approach within health are crucial to be aware of, and as architects, this kind of knowledge is essential to include and considered in architecture to constitute right design solutions to provide long-term solutions. [CABE, 2009]
As Steemers mentions in his paper "The notion of well-being consists of two key elements: feeling good and functioning well." [The Daylight Site | Daylighting research, architecture, practice and education, 2018]
Another report on our mental health and well-being have been published by The Government office for Science. This report includes evidence that defines the "five ways to well-being." These are more practical and objective characteristics that we more easily can apply to the built environment. The five ways; connect, keep active, take notice, keep learning and give, have been associated with positive mental health and have shown to be influenced by physical design characteristics mental capital and wellbeing. [Foresight, 2008]. The "five ways to well-being" are briefly introduced with keywords for each notion in the following text.

Take notice

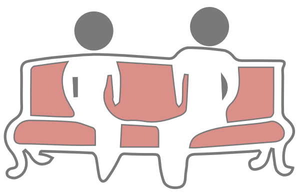


By being thoughtful, aware and in general to stop and to take notice of something, depressions, stress, and anxiety can be affected and lowered. [Chambers, R., Gullone, E., & Allen, N. 2009]. A study resulted that "diverse types of open space (combining green as well as hard landscaping) and a higher relative proportion of public to private space is also associated with increased reported mindfulness." [The Daylight Site | Daylighting research, architecture, practice and education, 2018]

Keep learning

To keep learning "parameters include a home that is clean and uncluttered appears safe for play and is not dark or monotonous." [The Daylight Site | Daylighting research, architecture, practice and education, 2018] Based on the interaction level, orientation and the distance of "seating concerning others will influence the level of interaction and dialogue." An example of this could be to place seatings in a circle, which will force more eye contact and thereby lead to more conversation. [The Daylight Site | Daylighting research, architecture, practice and education, 2018]

Connect

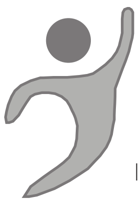


Social connections can be a supporting element in relation to well-being and physical health. Social relationships can be initiated by; having a conversation with other human beings. To support this type of strategy, simply by placing a bench and designing stop spaces in the urban context can be a reason to build a dialog with others. Common areas within a building such as green gardens or workshop spaces can collect individuals to support a network. [Foresight, 2008]

Give

Moving away from a self-centered mindset and instead attempting a pro-social behavior by helping others volunteering contributes to better life qualities such as happiness. [Plagnol, A., & Huppert, F. 2010)] Self-reported altruistic behavior is more prevalent in neighborhoods which incorporate space design related to "diversity, proximity, accessibility, and qualities." [Anderson, J. 2014]

Keep active



ILL. 29. 1

Its proved by studies that physically activity can reduce chronical diseases and mental ill-health, by introducing intentional design strategies, people can be encouraged to move more. [Krogh, J., Nordentoft, M., Sterne, J., & Lawlor, D. 2011] A significant approach would be to apply a pedestrian-friendly space, such as keeping low traffic and rate to produce a considerable activity level. Another strategy is to form a route around a building with a combination of a positive experience by, e.g., adding a green path. Movement inside a building could be achieved by implementing different levels and stairs, and in general to separate functions from each other to stimulate higher activity. [Bauman, A., & Bull, F. 2007]

INTRODUCTION TO DGNB

ILL. 30. 1

The ideas behind DGNB have their origin in the Brundtland-report from 1987 (also mentioned in sustainability chapter), that first stated ideas about responsibilities of sustainability and later from the Rio-declaration, published in 1993, where the concept of sustainability was divided into three pillars; Environmental, sociocultural and economic. [DGNB System Denmark. 2017]
DGNB is a voluntary agreement for classifying sustainable buildings. The classification is based on the European Building standards and creates a holistic evaluation of the primary qualities of the building; the process, the environment, the economy, sociocultural- and technical aspects and the site. The evaluation method is set up as an equation to evaluate the overall sustainability performance of the building, within the five main qualities and the 40 sub-qualities. This is to ensure that all sustainability strategies and solu-

- Thermal Comfort in Winter Thermal Comfort in Summer Indoor Air Quality
- Acoustic Comfort
- Visual Comfort
- User Influence on Building Operation
- Quality of Outdoor Spaces
- Safety and Security

- Accessibility
- Efficient Use of Floor Area
- Suitability for Conversion
- Public Access
- Cycling Convenience

- Design and Urban Planning Quality through Competition
- Integration of Public Art

- Comprehensive Project Definition
- Integrated Design Process
- Comprehensive Building Design
- Sustainable Aspects in Tender Phase
- Documentation for Facility Management
- Environmental Impact of Construction Site / Construction Process
- Prequalification of Contractors
- Construction Quality Assurance
- Systematic Commissioning

- Fire Prevention
- Indoor Acoustics and Sound Insulation
- Building Envelope Quality
- Ease of Cleaning and Maintenance
- Ease of Dismantling and Recycling

- Global Warming Potential
- Ozone Depletion Potential
- Photochemical Ozone Creation Potential
- Acidification Potential
- Eutrophication Potential

- Local Environmental Impact
- Sustainable Use of Resources / Wood

- Nonrenewable Primary Energy Demand
- Total Primary Energy Demand and Proportion of Renewable Primary Energy
- Drinking Water Demand and Volume of Waste Water
- Land Use

- Building-Related Life Cycle Costs
- Suitability for Third-Party Use

- Site Location Risks
- Site Location Conditions
- Public Image and Social Conditions
- Access to Transportation
- Access to Specific Use Facilities
- Connection to Utilities

tions, is made on a knowledge-based and well-considered basis. [DGNB System Denmark. 2017] When evaluating a project, the equation calculates overall to what extent, the project fulfills the requirements of DGNB. In Norway, the most commonly used evaluation method is BREEAM, which is also a non-government system, based on the three pillars of sustainability, divided further into multiple sub-criteria. A lot of the criteria in BREEAM is the same as the DGNB criteria, but the evaluation of the individual criteria and the overall certifications ranges a bit differently, where the single criteria of BREEAM is a bit less strict. [Anthony Provenzano Architects, 2013] Since both evaluation systems are applicable in Norway and the fact that the sustainability lessons at Aalborg University evolve around DGNB, this project will only use DGNB as a guideline to ensure a holistic approach to sustainability.

ZERO ENERGY BUILDING

Approximately 40% of the total energy consumption in Norway is caused by buildings and there is a great potential for decrease this number, mainly when focusing on new buildings, where energy efficiency can be integrated throughout the design process. [UngEnergi.no, 2018] A Zero Energy Building, also called ZEB, is a building with any given function, commercial, residential, etc., that has significantly reduced energy demands, through implimentation of passive strategies and furthermore balances its own demand with "low-cost, locally available, non-polluting, renewable sources" [Zero Energy Buildings: A Critical Look at the Definition, 2006]

Typical examples of renewable energy sources that can be integrated in a ZEB are; Photo Voltaic, Solar panels and heat pumps.

This does not mean that a ZEB has to even out the energy consumption while being off-grid. Due to the limitations of energy storage technologies present at this time, achieving ZEB autonomously would be very difficult. [Zero Energy Buildings: A Critical Look at the Definition, 2006]

There are multiple ways of defining the ZEB goals, according to wishes and demands of the different parties in the process, e.g. the building owner that usually cares about the energy cost, national organizations who focuses on primary energy on a national level, the building designer who is commonly interested in the site energy use, according to building requirements and finally those who are concerned about limiting pollution from energy production and construction on a global level. [Zero Energy Buildings: A Critical Look at the Definition, 2006]

The illustration displays the general concept of energy balance, in the different phases of the buildings life span.
In the following part some of the most common definitions are listed and shortly explained.

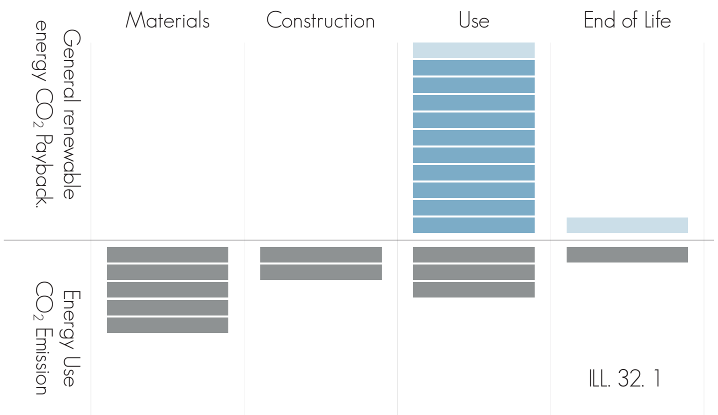
Net Zero Site Energy Building: "Produces at least as much energy as it uses in a year, when accounted for at the site" [Zero Energy Buildings: A Critical Look at the Definition, 2006]

Net Zero Source Energy Building: "Produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site" [Zero Energy Buildings: A Critical Look at the Definition, 2006]

Net Zero Energy Cost Building: "The amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year" [Zero Energy Buildings: A Critical Look at the Definition, 2006]

Net Zero Energy Emission Building: "Produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources" [Zero Energy Buildings: A Critical Look at the Definition, 2006]

Because the primary available energy source in Norway is hydro power (electricity) and the fact that a Site ZEB for an electric building is equivalent to a Source ZEB [Zero Energy Buildings: A Critical Look at the Definition, 2006], the aim, is to design a Net Zero Site Energy Building, with a special focus on heating and cooling solutions, due to the availability and easy access to renewable electricity in Norway.



ILL. 32. 1

ENERGY IN NORWAY

HYDRO POWER
129 TWh/yr
96%

THERMAL POWER
3,3 TWh/yr
2,5%

WIND POWER
1,9 TWh/yr
1,5%

ILL. 33. 1

TOTAL PRODUCTION:
134.200.000.000 kWh/year

The Norwegian government states that in 2016, 98% of the Norwegian electricity production comes from renewable energy sources. Hydropower is the most significant contributor, accounting for around 96% of the overall production, additionally Thermal- and wind power accounts for respectively 2,5% and 1,5%. The substantial contribution from hydropower began in the 1980s and have since then been the basis for Norwegian industry and the development of the welfare society. The amount of precipitation and the natural inflow of water from the mountains is vital to fill up reservoirs and generate flexibility in the power production. The production flexibility makes it possible to both export and import energy, depending on demand in Norway and the neighboring countries. [Energy Ministry Norway, 2018] As seen in the Project Location chapter, Midsund is not in close connection to any bigger city, which means that only electricity is available from the grid, while there is no access to district heating. Because of this, electricity covers 80% of the total energy consumption in Midsund and leaves a vast potential for utilization of heat pumps and solar thermal collectors, to cover internal heating and heat loss. This could lower the energy demand by 50-60% but would require waterborne heating systems in all residential and commercial buildings in Midsund. [Energi- og klimaplan Midsund kommune, 2012]

FEEDBACK BOX
BUILDINGOWNER

Primarily renewable energy sources in norway and dialogue with stakeholders, influenced the predefined energy consumption goals.

ENERGY REQUIREMENTS

Below is a comparison between the Norwegian and Danish energy demands for low energy houses. This text elaborates on the Norwegian energy requirements for low energy houses.

REQUIREMENTS FOR HEAT LOSS:
Allowed heat loss, through walls, roof, windows and doors, including air leaks and venting for a low energy dwelling block in Norway is 95 kWh/m^2 heated area pr. year. [Lovdata.no, 2018]

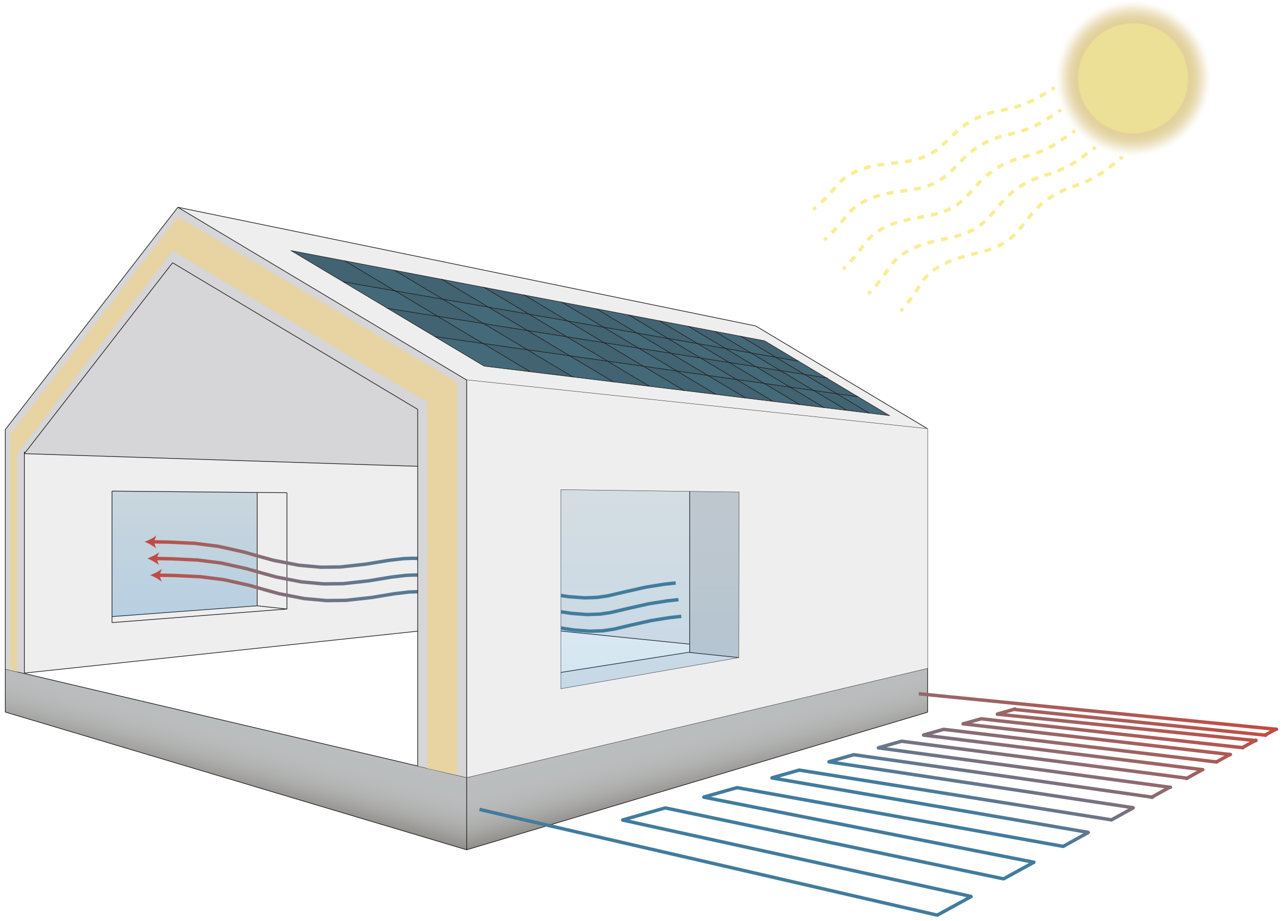
REQUIREMENTS FOR HEATING NEEDS:
The need for heating depends on the climate and the building size. For a low energy house larger than 250m2 the need for heating should be below 15kWh/m2/yr. The requirements are adjusted for dwellings less than 250m2, located where the yearly average temp. is below 6,8°C. [Lavenergiprogrammet, 2018]

REQUIREMENTS FOR ENERGY SUPPLY:
Heating of a passive house must be covered as much as possible by renewable sources, minimum 50%. The rest can be covered with electricity. [Lavenergiprogrammet, 2018]

REQUIREMENTS FOR BUILDING PARTS:
The requirements for building technical solutions and ventilation can be seen in the scheme below.

PASSIVE & ACTIVE STRATEGIES

When designing a zero-energy building, it is important to integrate energy optimized solutions throughout the whole process. Usually passive design strategies is integrated to decrease respectively heating and cooling demands and there by reach the general energy requirements, illustrated in the chapter regarding Energy Requirements. Then add active strategies to equal-out the remaining energy demand with renewable energy. The process of integrating passive strategies is to a large extend an exercise in balancing heating and cooling strategies, in order to achieve the best overall energy performance of the building - The building type and operation usually influence the choice of strategies. [Climate CoLab, 2018] The passive strategies can be divided into four overall categories, being;
Passive Heating can be achieved with a well-insulated building envelope to avoid unnecessary energy loss and a building design that utilizes the solar radiation and captures the internal heat gain. [Climate CoLab, 2018]
Passive ventilation, can be controlled by designing the building to enhance and take advantage of natural occurring air flow patterns, such as wind and buoyancy to cool the building with outdoor air. [Climate CoLab, 2018]
Passive Cooling is used to avoid overheating, either by controlling the solar gains with external shading, or by accumulating and removing internal heat gains, with thermal mass and natural ventilation. [Climate CoLab, 2018]
Daylighting control can be designed to minimize the electricity needed for artificial lighting, by ensuring a good distribution of natural daylight in the areas where light is needed. [Climate CoLab, 2018] Due to the climatic location and the building being residential, which mainly has night-time occupancy, is this project will tend to have a heating dominant energy profile. [Climate CoLab, 2018]
Active strategies are implementation of technology that produces renewable energy, either heating or electricity. The most commonly used technologies in Norway is; Photo voltaic panels, thermal solar collector panels and heat pumps, collecting either from ground heating or air. Furthermore, smart-systems can be used to control window opening, shading, heating and cooling in real time, so the building constantly adapts to the environment, for maximal efficiency. [Maddock, 2012]



ILL. 35. 1

	Roof	Walls	Foundation	Windows	Heat rec.	General:
NO	0,13W/m^{2}K	0,18W/m^{2}K 0,6L/s/m^2**	0,10W/m^{2}K	0,8W/m^{2}K	Min. 80% 1,5kW(m^3/s)	15+3.5(T-5)kWh/m^2/yr***
DK	500mm*	0,09W/m^{2}K 0,5L/s/m^2**	400mm*	0,8W/m^{2}K 22m^2/100m^2	No Min. 1kW(m^3/s)	20kWh/m^2/yr max. 120kWh/m^2

ILL. 35. 2

* Insulation ** Preassure test with 50Pa *** T=Yearly average temerature

Source: [Paroc.dk, 2018]
Source: [Greenmatch.dk, 2018]
Source: [Lovdata.no, 2018]

DEVELOPMENT PLANS

After a period with decreasing population, the curve flipped, and in 2013, the municipality of Midsund made an idea-competition for the development of Midsund city center, to make the area more attractive to live in and to attract more labor and competences in the future. [Idékonkurranse om utvikling av Midsund sentrum, 2013]

"The competition proposals must contribute to:

- Creating a more attractive and aesthetic city center, accessible for everybody.
- Developing a more functional and nice city center.
- Exploiting and expanding the waterfront more holistically.
- Ensure predictability for future builders.
- Better utilization of the water near building plots.
- Better cooperation between different actors."

Translated from norwegian. [Idékonkurranse om utvikling av Midsund sentrum, 2013]

The overall purpose of the competition was to receive a variety of proposals on how to develop the city more attractively and playfully, mainly focusing on the water near areas, both existing buildings, new developments and outdoor spaces. [Idékonkurranse om utvikling av Midsund sentrum, 2013]
The main road, Fv. Veg 668, creates a quite clear division in the area, with around 2000 cars pr. Day, however, the speed limit is restricted to 50km/h. This areal division, combined with the topographic conditions in Midsund enhances the importance of the water near areas and their influence on denser city development. The water near plots is partly private property and partly owned by the municipality, and there is a significant potential to develop both new and existing buildings in addition to the unbuilt areas between Tusenårsplassen and Midsund Marina. [Idékonkurranse om utvikling av Midsund sentrum, 2013] Specifically, for new building projects, the municipality of Midsund requested proposals for alternative use of available building plots, with significant architectural expressions that creates a relation between new and existing buildings and links the buildings with surrounding public spaces, preferably with pedestrian paths at the waterfront and while handling the issue of climate change, such as rising sea level. [Idékonkurranse om utvikling av Midsund sentrum, 2013] In addition to the architectural desires, the municipality has proposed to integrate parking solutions and right conditions for soft road users [Idékonkurranse om utvikling av Midsund sentrum, 2013], also mentioned in the section about Well-being.

The winning design proposal from Arkitektgruppen Cubus describes a vision to create a more physical contact with the waterfront, rather than the current visual connection and how there is a change in the function of the sea, going from primarily logistic to recreational purposes. There has been a focus on planning public spaces, pedestrian paths, for example a pontoon bridge, and bicycle roads close to residential areas to encourage the inhabitants to walk or bike and thereby decrease noise, areas needed for parking, ensure good air quality and improve chances of unplanned interaction between the inhabitants and visitors. [Arkitektgruppen Cubus, 2013] Cubus explains the importance of the characteristic landscape, Midsunds connection to both mountains and sea, and how these unique elements should be enhanced as the primary identity for new development in Midsund. According to the proposal, one way of utilizing and enhance these qualities could be by placing residential buildings, such as apartment complexes, at the waterfront, oriented towards west. This could attract new inhabitants to Midsund. [Arkitektgruppen Cubus, 2013] Cubus further elaborates on how these apartment complexes should strive to preserve a human scale and contain apartments varying in size to accommodate different user groups. However, the apartments should have a balcony to exploit the location and the view. The new developments should strive to incorporate vegetation as a mean to soften the quayside and generate both private and shared gardens. [Arkitektgruppen Cubus, 2013]

ILL. 37. 1

PROJECT INTEREST

The objective of the main of stakeholders in the project, Røberg Bygg AS and Lyngjabygg ANS, is to gain a short-term profit while minimizing the economic risk associated with the project. The intent is, therefore, to sell the majority part of the dwellings before initiating with the construction work, as should the potential buyers be able to buy the apartments upfront. The potential buyers are profoundly influenced by the market for a specific place, at a specific time, as a project has to be sellable for the right price for it to make sense economically, thus will the market be the most influential driver for the direction of a project.

The project site is one of the most attractive locations on the Island of Otrøya, situated at the harbor front of the city center of Midsund, close to shopping centers and health-care service. However, the purchase cost of the site is quite expensive for the area, and comes with a high additional cost concerning the groundwork, as approximately half of the site is currently under water. These factors alone will narrow down the user groups, as the potential buyers have to be able and willing to pay for the extra cost associated with the project.

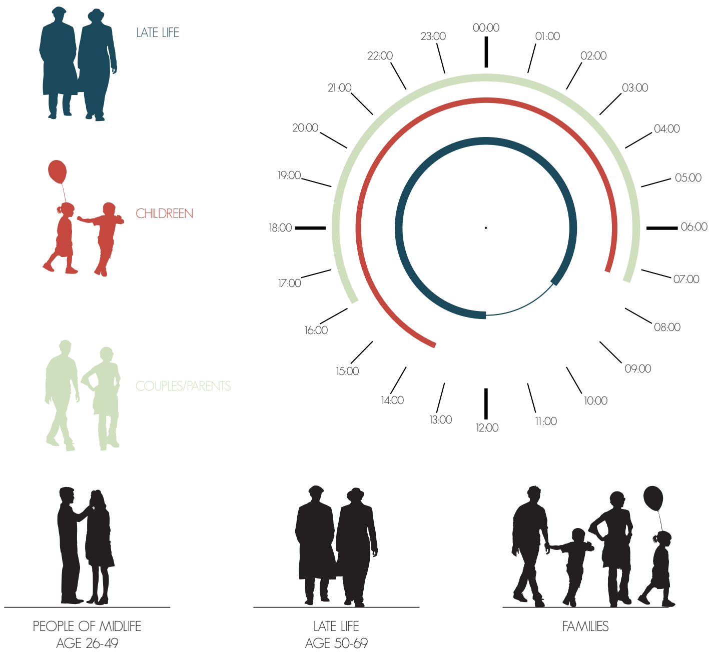
To form the framework for a successful, and sustainable building project, one of the first and most important steps is to evaluate the appropriate user groups, as the users will set the course and determine the direction of the project. The following chapter will focus on narrowing down the user groups, followed by an analysis of the user's needs and behavioral patterns.

To gain a better understanding of the potential buyers, a meeting was arranged with local real estate agent Kristine Gautvik-Dahl, to discuss the direction of the project. Kristine was enthusiastic about the project due to centrally placed, and attractive project site, expressing that there were a number of people in the Municipality looking to relocate from their single-family houses in the countryside to denser dwellings types in the city center. The central location provides short distances to shopping facilities, medical care as well as schools and kindergartens, making the dwellings particularly attractive for families with children. The dense dwelling types also provide better social opportunities, as well as lower maintenance, that would offer more spare time for the users. This combination makes the project highly attractive for both families and couples. She recommended targeting both couples and families above 30 years old, by offering a wide variety in the sizes of the dwellings, ranging from approximately 80 to 140 square meters. During the meeting, several criteria were established to accommodate the needs of the target group, which included two to four bedrooms, spacious private outdoor spaces, ranging from 15 to 30 square meters, as well an interior and external storage space for each apartment [Gauvik-Dahl, 2017]

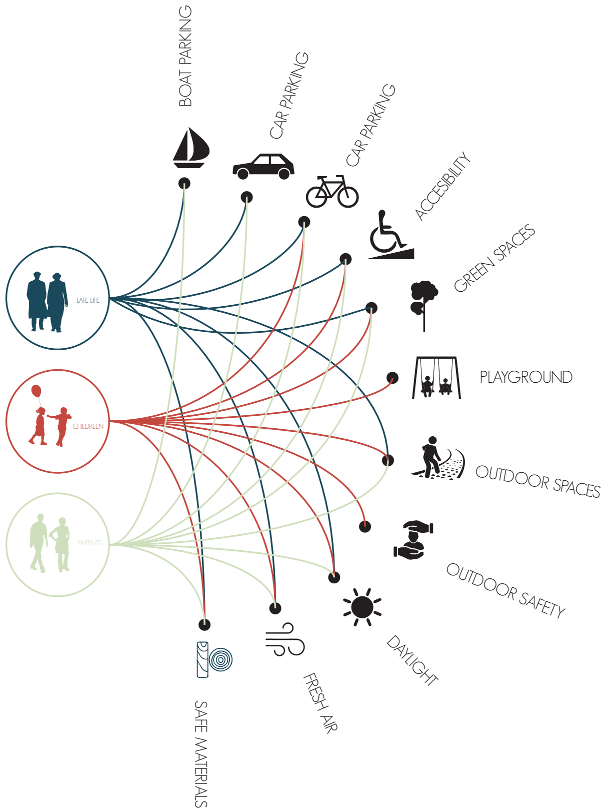
FAMILIES

In general, families have a busy lifestyle, where the parents are at work during the daily hours, while the children are in school or daycare. The members of the family, therefore, spend most of their time at home in the afternoon till evening and on weekends. To accommodate for this lifestyle, the common interior living spaces, as well as the private and shared outdoor spaces should all be oriented towards the afternoon and evening sun, for the families to get the most out of their dwellings.

To support social sustainability within the family units, particular emphasis should be put on the shared living spaces, providing them with a spacious and comfortable environment for social interaction. Regarding social sustainability within the family users of the housing complex, an attractive common outdoor space should be provided for the family typology, in particular, offering spaces for the various families to meet and interact with one another, to establish relationships and form a sense of community within the housing complex.



ILL. 39. 1



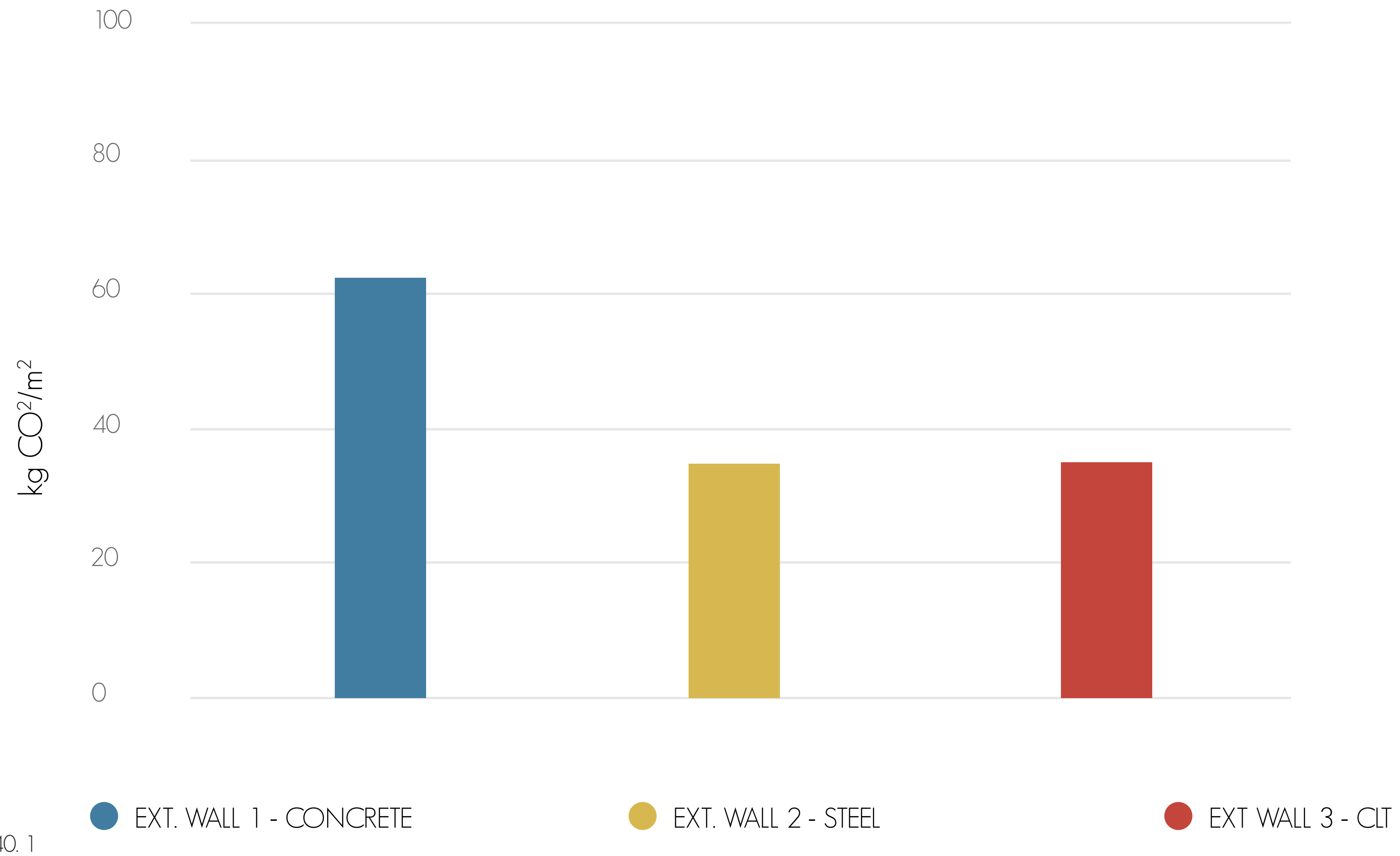
ILL. 39. 2

People in late life are often still active in the working environment. Many are, however, either retired or semi-retired, allowing more time to be spent at home (Ssb.no, 2018). It would, therefore, be valuable for the users to have common recreational spaces, where they can meet and socialize during the day, ultimately making them feel more connected and more alive (Moore, 2010). Some users may have declining health, which could eventually affect their mobility. Particular emphasis should, therefore, be put on assuring good accessibility.

COUPLES, MIDLIFE

Couples of midlife share a similar schedule as the family typology, as should the various spaces be oriented toward the afternoon and evening sun when the users are at home. For this typology, additional rooms should be provided in the case of future expansion.

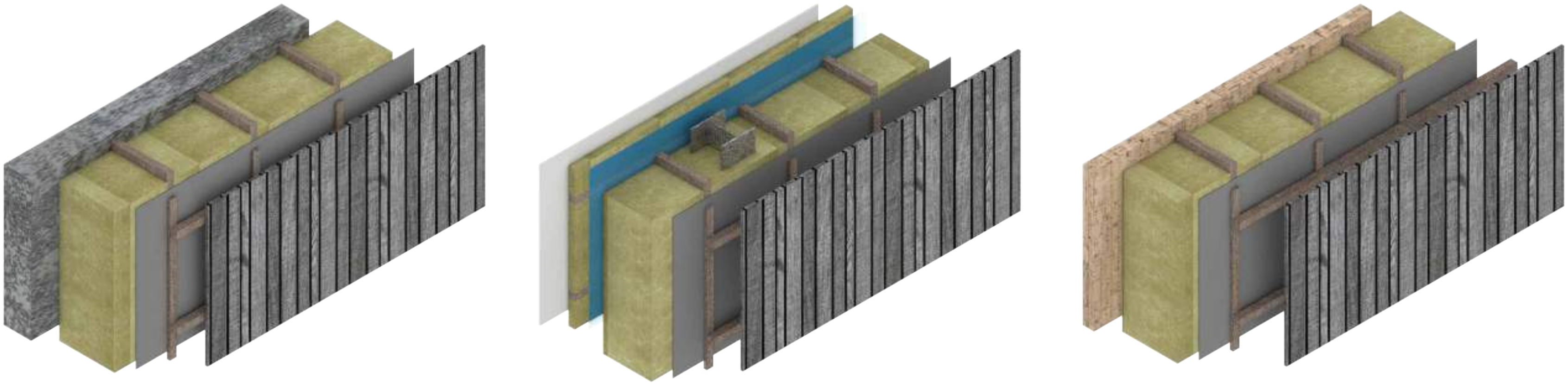
MATERIALS COMPARISON



ILL. 40. 1

ENVIRONMENTAL & ECONOMIC

To gain a better understanding of the environmental and economic impact of the most commonly used, load-bearing building materials, a comparison has been made for three different external walls, using the calculation tool LCA Bygg for the environmental impact. Whereas the cost calculation was based on unit prices given by the construction firm, Røberg Bygg (Hjalmarsson, 2018). As illustrated in (Ill. 43.1) the comparison shows that the concrete wall has the highest cost, as well as the highest environmental impact. The high emission of CO2 generated during the production, combined with the amount of material required of concrete as a load bearing structure, makes the concrete wall the least favorable of the three. The steel and Cross Laminated Timber (CLT) wall are quite similar in terms of cost and environmental impact. The steel wall has the least environmental impact of the three. This mostly due to the small quantity needed to construct a load-bearing structure. However, the CLT wall is more favorable because the load-bearing CLT can be also be used as an interior surface, and thereby exclude the cost of additional building layers.



	Concrete Construction:	Steel Construction:	CLT Construction:
Thickness (mm):	690	500	575
U-value(W/m^2K):	0,090	0,087	0,086
Mass (kg/m^2):	487,1	88,1	117,7
Thermal Capacity (kJ/K):	475,2	191	320,6
Price (NOK/m^2):	3161	2215,85	1967,5

ILL. 41. 1

WOOD

In recent years, the use of wood as a structural material for has had made a breakthrough with the building industry in Norway. The key to this significant growth is a result of new technological knowledge of Cross Laminated Timber (CLT), along with the increasing awareness of its environmental properties. Nowadays, many multi-story buildings in Norway are being built entirely of prefabricated, load-bearing CLT elements, whereas previously, concrete and steel have dominated as structural systems for multi-story buildings (Marius and Catherine, 2018). Wood is a natural material grown by the earth and offers several useful properties that can be utilized to obtain a sustainable and architectural environment, including acoustics, moisture, heat capacity and low weight, while also adding a certain warmness and tactility. In this section, there is a particular focus on wood but with a comparison of more traditional structural materials in the building industry such as concrete and steel. The first text in this chapter will treat the aesthetics of the materials, followed by the properties associated with the indoor environment. The environmental and economic impact concerning lifecycle assessment, energy, and the cost will be described in the final part of the chapter.

Aesthetics & Ambience

"I've never seen anybody walk into one of my buildings and hug a steel or a concrete column, but I've actually seen that happen in a wood building." [Green, 2018]

Just like humans, wood is provided with its own characteristics which give the material a unique identity. The age of the wood appears in the texture of the material with beautiful circles starting from the core of the wood and extending to the outer layer called growth rings. Simultaneously wood has various scent, color, texture, and luster depending on species. "It is the most humanly intimate of all materials. Man loves his association with it, likes to feel it under his hand, sympathetic to his touch and to his eye. Wood is universally beautiful to Man." [Wright 1975]

In architecture, architects often aim to trig feelings from humans, which is often demonstrated by the use of materials. Each material has its own features and can be exceptionally good at underlining the specific emotions the architects seek to evoke. For instance, wood was purposely used in the Swiss Pavilion Sound Box Hanover by Peter Zumpthor. The pavilion was a design with the intention to provide "a welcoming place to rest, a place to just be" [Etherington, 2018]. The pavilion was made out of Douglas pine and larch from Switzerland with use of 2800 m3 wood. The structure was formed purely from wood, without added nails or glue. However, steel cables were used to brace the beams. The pavilion evoked various senses arriving from the raw use of wood, such as the beautiful shades of each piece of wood, the feeling of thousands of individual cracks and knots, and an intense scent in the air providing the visitor with an experience of architecture full of life and taste. The pavilion was later taken down, and the wood was reused for other building projects [Etherington, 2018].

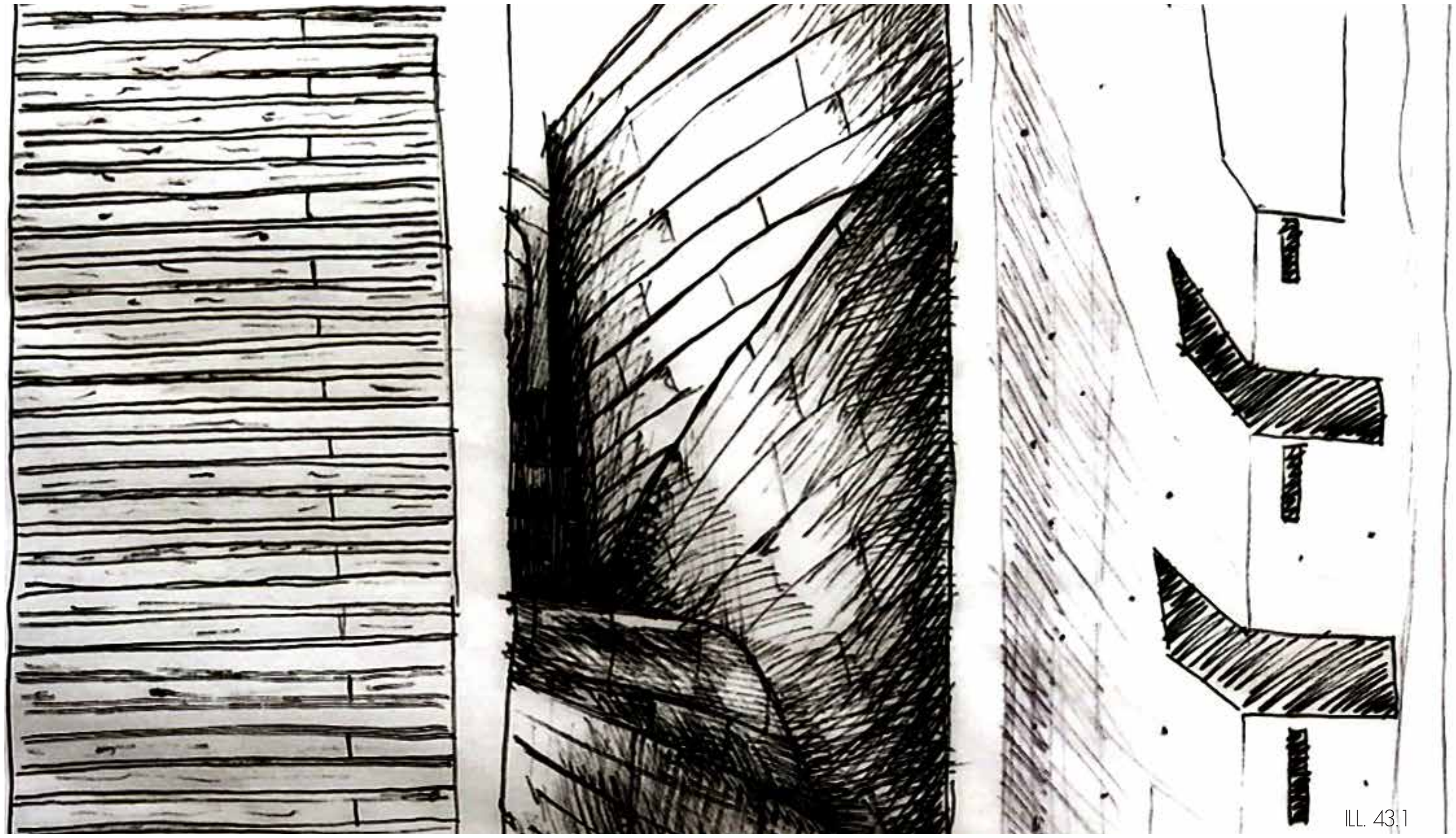
A project which has the opposite purpose is the Jewish Museum in Berlin designed by Daniel Libeskind. In this project, the cold and dead space created by massive grey concrete walls is utilized to demonstrate the sad history behind the world war II and to "express feelings of absence, emptiness, and invisibility" [ArchDaily, 2018].

Indoor Environment:

As previously mentioned in the well-being chapter "good health is determined not simply by access to medical care, but by a range of factors, some of which are closely related to the quality of the physical environment.". [Webarchive.nationalarchives.gov.uk, 2018]. These information adjoints to the fact that the physical environment profoundly relies on our indoor environment. The following chapter is an investigation of materials ability to contribute to the indoor environment.

Acoustics:

When sound moves in a space, the energy is partially ab-



ILL. 43.1

sorbed, reflected or transmitted when it makes contact with the materials surrounding the space. The degree to which the sound is reflected, absorbed or transmitted, is highly dependent on the material properties. Concrete and steel are materials with hard and impermeable surfaces, which form reflective barriers within a space. Wood is, on the other hand, a quite porous material, which allows it to absorb more energy when it makes contact with sound waves (Worre Foged, 2015). Comparing the materials in terms of shaping a comfortable indoor environment, the absorptive properties of wood could be used to contribute to a faster decay of sound, and thereby reduce the risk of unwanted noise.

THERMAL MASS

The simple explanation for thermal mass is the ability of a material to absorb and store heat. Thermal mass can be used to storing heat, and thereby avoid drastic temperature changes within an environment in case of sudden heat gains or losses. This phenomenon can lead to reduced energy consumption, as heat gained during the day can be stored and released at a later time. The materials ability to store heat depends on its density. Wood is relatively dense material, with a good heat capacity, but due to its porosity, the material has a low thermal conductivity, making it quite slow at responding to sudden heat gains or losses. Concrete can store a significant amount of heat due to its density, while a high thermal conductivity, making it an excellent material to store and respond to thermal changes during the daytime cycle [Termisk masse og klimatisering av bygninger, 2018].

03 CASE STUDIES

ILL. 45.2

CASE STUDIES - SNØHETTA - SVART HOTEL

Svart Hotel is designed by the Norwegian architecture office Snøhetta. Though the project is unbuilt, it is an innovative and ambitious attempt to create first-class sustainable architecture.

The hotel is located north of the arctic circle at the foot of the Svartisen glacier, in Norway and is the world's first certified Powerhouse hotel. [Snohetta.com, 2018]

"The term "Powerhouse" is used to describe so-called "plus house" buildings that are built by the Powerhouse collaboration. "Plus houses" are energy producing buildings that, in the course of a 60 year period, will generate more renewable energy than the total amount of energy that would be required to sustain daily operations and to build, produce materials and demolish the building." [Snohetta.com, 2018]

While being the world's first and northernmost Powerhouse building, it will have a yearly energy consumption approximately 85% lower than an equivalent hotel built after modern Norwegian building standards. [Snohetta.com, 2018]

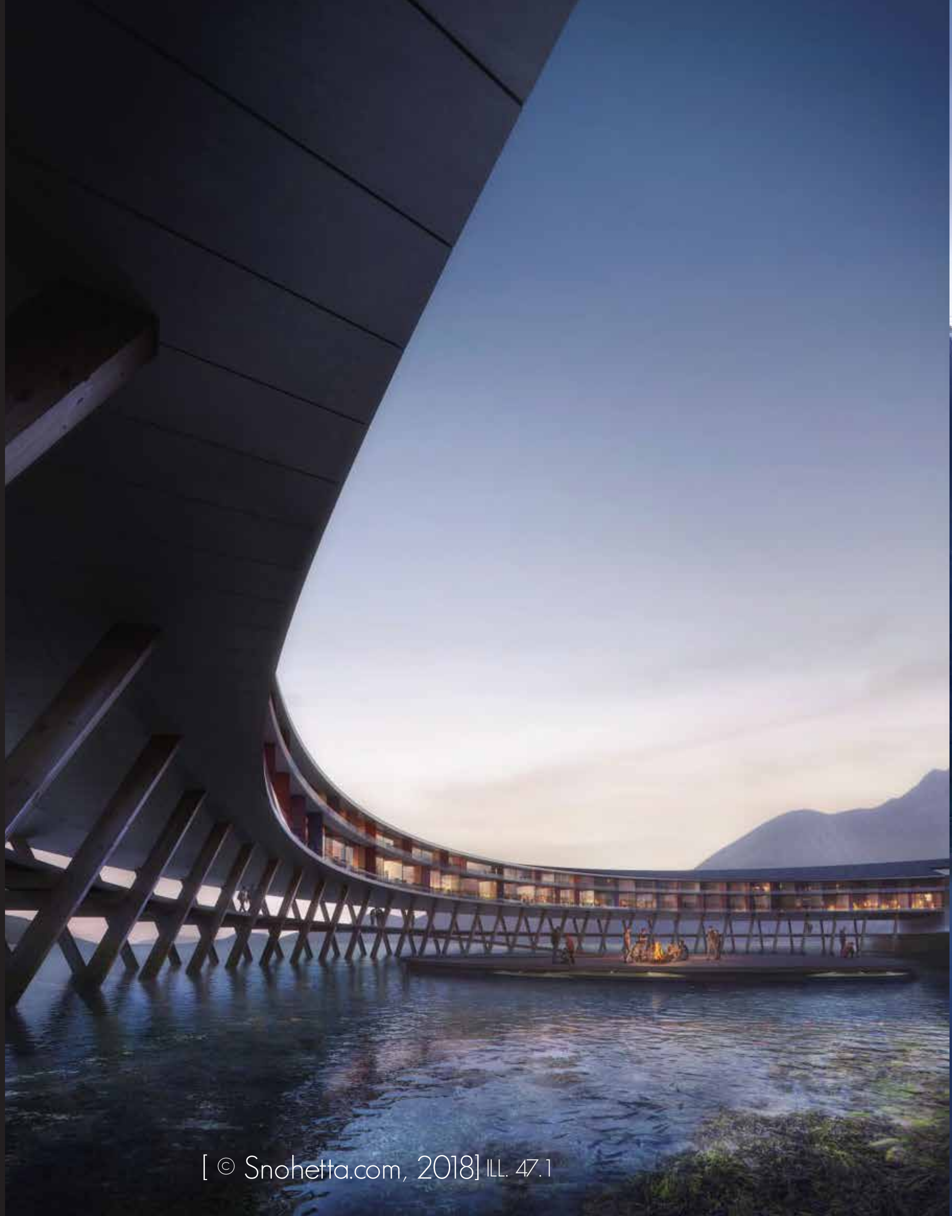
The Building is designed with a particular focus on the surroundings. With its circular shape deploying from the shoreline between the mountain and the fjord. This, to ensure a minimal foot-print, that could influence the "natural beauty and the fauna and flora of the site," [Snohetta.com, 2018] and with the construction elevating it from the site, as a reference to traditional Norwegian, wooden structures, used by fishermen. Furthermore, the structure and the shape contribute to an almost transparent appearance and an extraordinary panorama view in all directions. [Snohetta.com, 2018]

To reach the Powerhouse standard, an extensive study has been made on the solar radiation, present on the site, to ensure the best possible utilization of natural energy sources. Also, here the circular design proves useful, when "both hotel rooms, restaurants, and terraces are strategically placed to exploit the Sun's energy throughout the day and seasons." [Snohetta.com, 2018]

The whole roof of the hotel is covered with photovoltaic panels, to include the electric energy demand of the hotel, and because of the significant number of sunlight hours in the very northern environment, the annual energy production will be substantial. Regarding heating, the hotel utilizes geothermal wells and heat pumps. [Snohetta.com, 2018]

The terraces of the hotel are designed as a part of a passive strategy, to protect against overheating and a potential cooling demand during the summer, while giving maximum sunlight exposure to the glass facades, during the winter. [Snohetta.com, 2018]

All materials used in the design are carefully selected to have as little embodied energy as possible, meaning that steel and concrete as a structural material, have been avoided as much as possible, as they are quite energy-intensive materials. "The use of wood in construction and cladding minimizes the environmental impact of the building" [Snohetta.com, 2018]

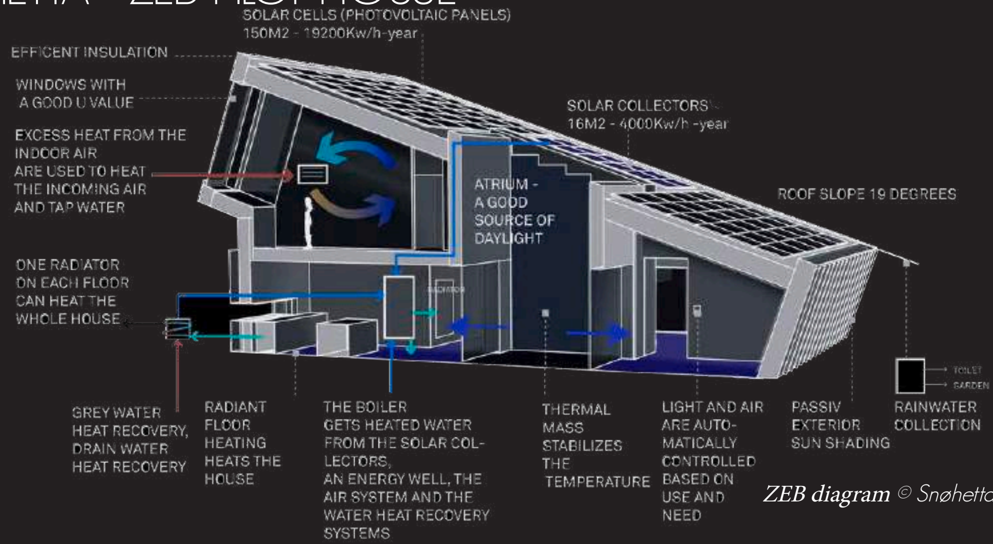

[© Snohetta.com, 2018] ILL. 47.1


[© Snohetta.com, 2018] ILL. 47.2


[© Snohetta.com, 2018] ILL. 47.3


[© Snohetta.com, 2018] ILL. 47.4

CASE STUDIES - SNØHETTA - ZEB PILOT HOUSE



ZEB diagram © Snøhetta ILL. 48.1

Referring back to the chapter Zero Energy Building, the building sector represent one of the highest energy-consuming industries in the world with 40 % and causes great impact on the environment. [UngEnergi.no, 2018] The awareness of this issue has led architects among others towards “a movement to create buildings that mitigate global warming and climate change”[World Barcelona]

A great example of a successful Zero Energy Building project is the family house “ZEB Pilot House” also recognized as the “Plus House Larvik” designed by Snøhetta in collaboration with, SINTEF, ZEB, Optimera and Brødrene Dahl and finished in 2014 in Larvik, Norway. The design is conducted with the principles of Zero Energy Building simultaneously with the surplus production of energy, to power an electric car, signifying that the house produces more energy than it consumes. The design is only dependent on renewable energy generated by solar-thermal and photovoltaic panels which are integrated into the building envelope. This design strategy is a vital step away from the use of fossil fuels, and a closer step towards a more sustainable future. With a roof slope of 19 degrees solar cells (photovoltaic panels) consisting of 150 m2 provides approximately 19200 kW/h-year to cover electricity consumptions. Solar collectors using 16m2 of the same sloped roof offers 4000 kW/h-year to contribute heat for air system and heated water.

This piece of architecture possesses numerous qualities, which for instance are expressed in the materials. The materials indicate a raw expression while analogous leaves a harmonious atmosphere as a result of calming and complementing colors. The materials are not only chosen on behave of the atmosphere but as well as the properties and technical qualities which contributes to a better indoor environment and air quality. The design has a modern expression due to sharp edges and the simple form, but simultaneously contains traditional materials which together express new technology with familiar materials. The house is cut into two pieces, however still provides the holistic sense due to the large openings, which contributes light and the visual connection. A beautiful light falls to the raw brick wall in contact with an industrial staircase and gives a desire to move further up to meet the light. [Snohetta.com, 2018]
The building is not only accomplished within its architecture but as well as for the sustainable manner. Passive strategies such as solar heat gain, thermal mass, and exterior shading are keywords for the project and should be investigated further during the design process.


[© Paal-André Schwital] ILL. 49.1


[© Bruce Damonte] ILL. 49.2


[© Bruce Damonte] ILL. 49.3

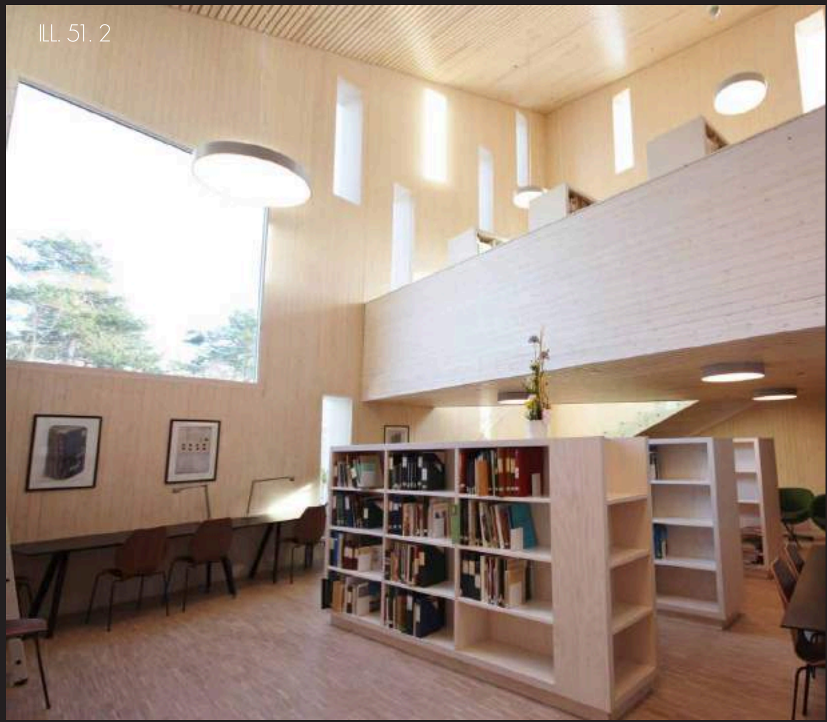
CASE STUDIES - NORWEGIAN ARCHITECTURE

Traditionally, the architecture in Norway had its basis in rationalism, has responded to the harsh climate, poverty and material restrictions. The houses were often placed on sloped terrains situated along the coastlines, overlooking the sea, and complied with a strict and functional geometrical shape, with a balanced constructional composition of materials. Traditionally, they were built in local stone, or with logs of local wood placed on a base of stone, separating the wood with the moisty ground and forming a strong foundation for high winds (Tostrup, 2006). The windows very typically narrow or nonexistent to reduce heat loss. Low pitched turf roofs were commonly used in Norway, providing a useful insulating layer to prevent heat loss, as well as forming a harmonious relationship with nature. Most houses in Norway had turf roofs until the beginning of the 18th century, where steeper slate roof gradually began to replace the turf roofs, especially in urban areas (Kamta, 2012). Slate roofs are especially beneficial for the Norwegian climatic conditions to shed snow and water more effectively, ultimately reducing the snow weight as well as the risk of water leakage. Exploring modern architecture in Norway, buildings with inspiration from nature can be found in Romsdal Museum (see picture below) placed in Molde, Norway. The Beautiful sharp roofs taking its inspiration in the Norwegian fjelds, and complete use of massive wood elements (see picture 3) stands in contrast of the street "Bygata" traditional houses dating back to the pre-war (see Picture 1). Another great example of a Norwegian piece of architecture is the single "red house" (see picture 4) found in the edge of Midsund city, Norway next to the fjord. The use of natural materials such as stone, wood and wild green roof compliments in surrounding nature.

A bit closer to the city Midsund, a flock of small houses is found at the line of water. The many colors are fighting for attention, yet the portion of houses stands in great harmony and underlies simplicity.

ILL. 50. 1


ILL. 51. 1


ILL. 51. 2

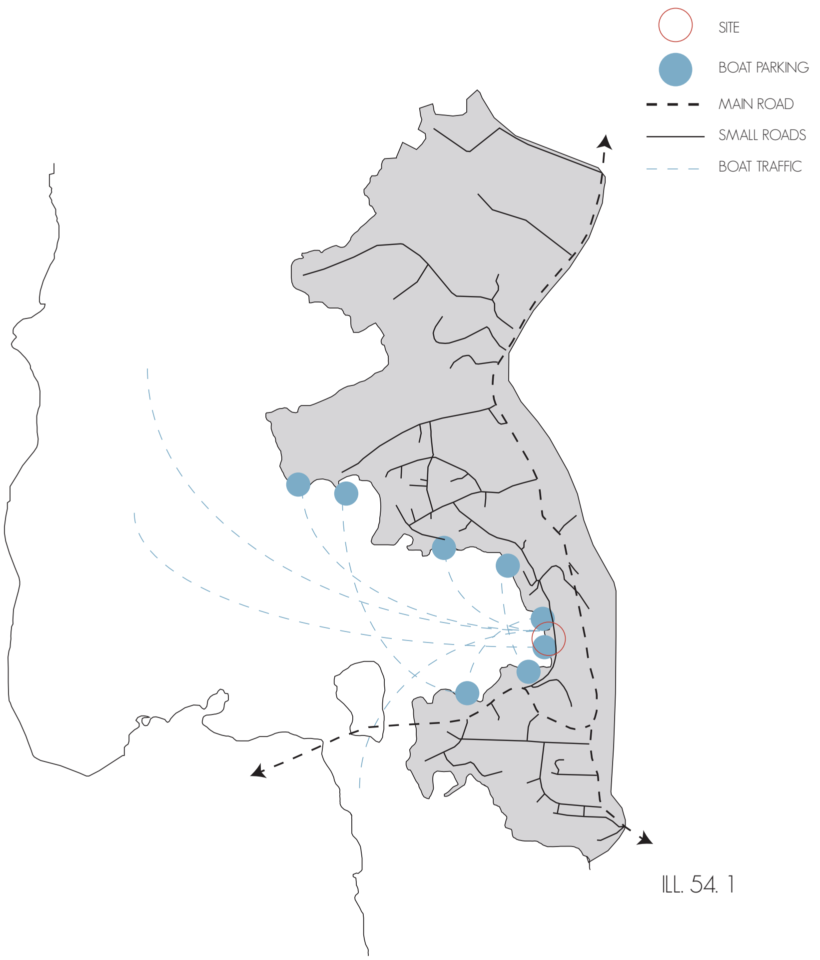

ILL. 51. 3

ILL. 51. 4

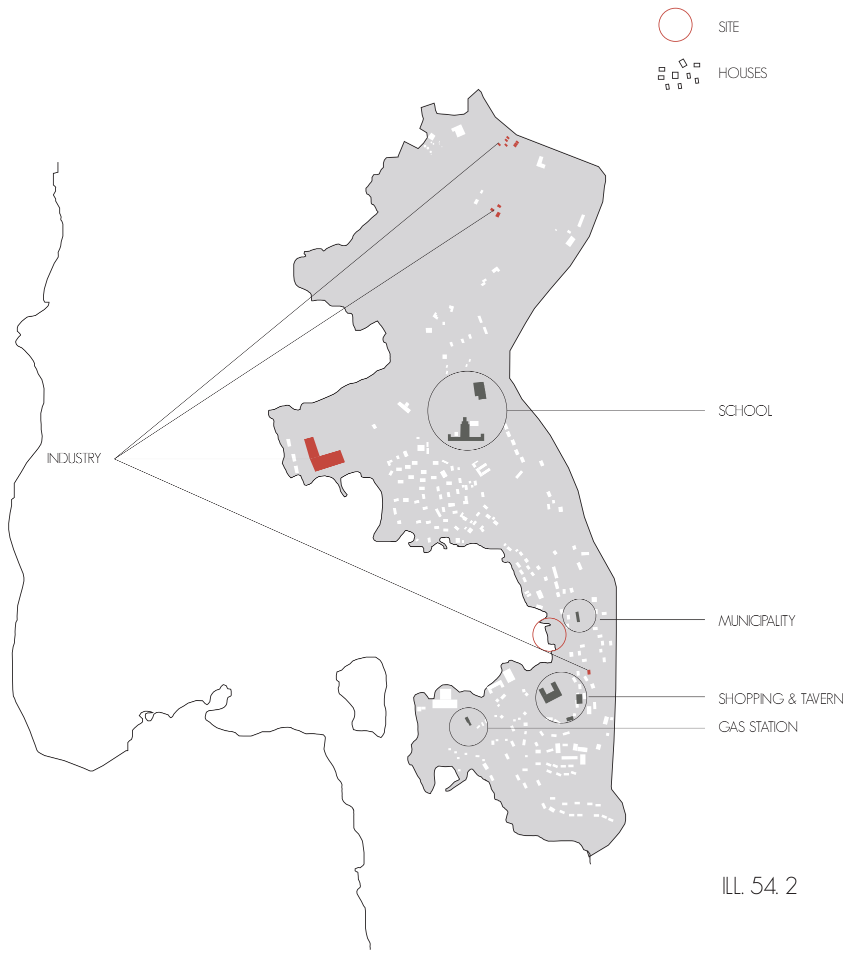
04 PROGRAMME SITE ANALYSIS

ILL. 53. 1

SITE ANALYSIS



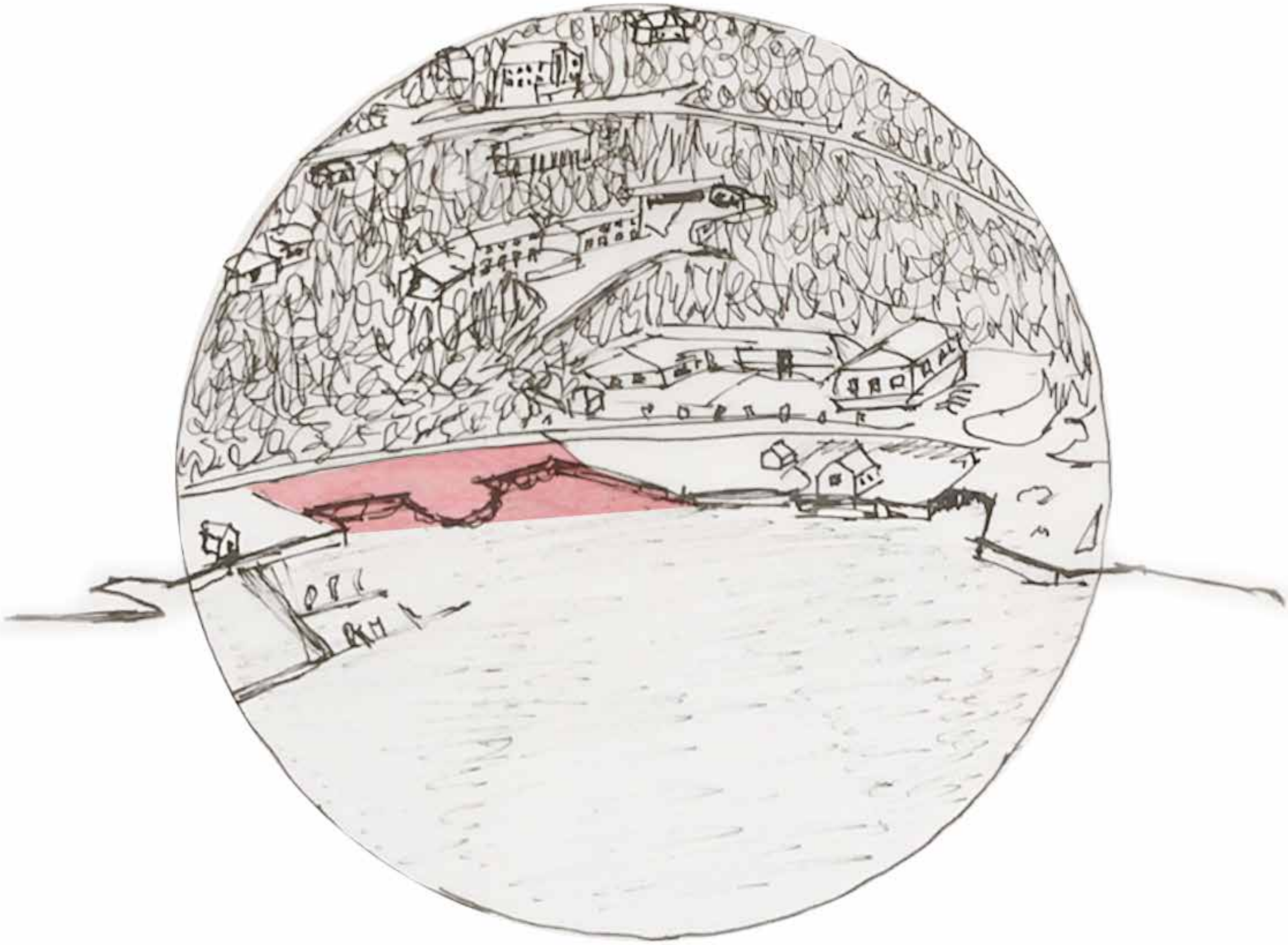
ILL. 54. 1



ILL. 54. 2

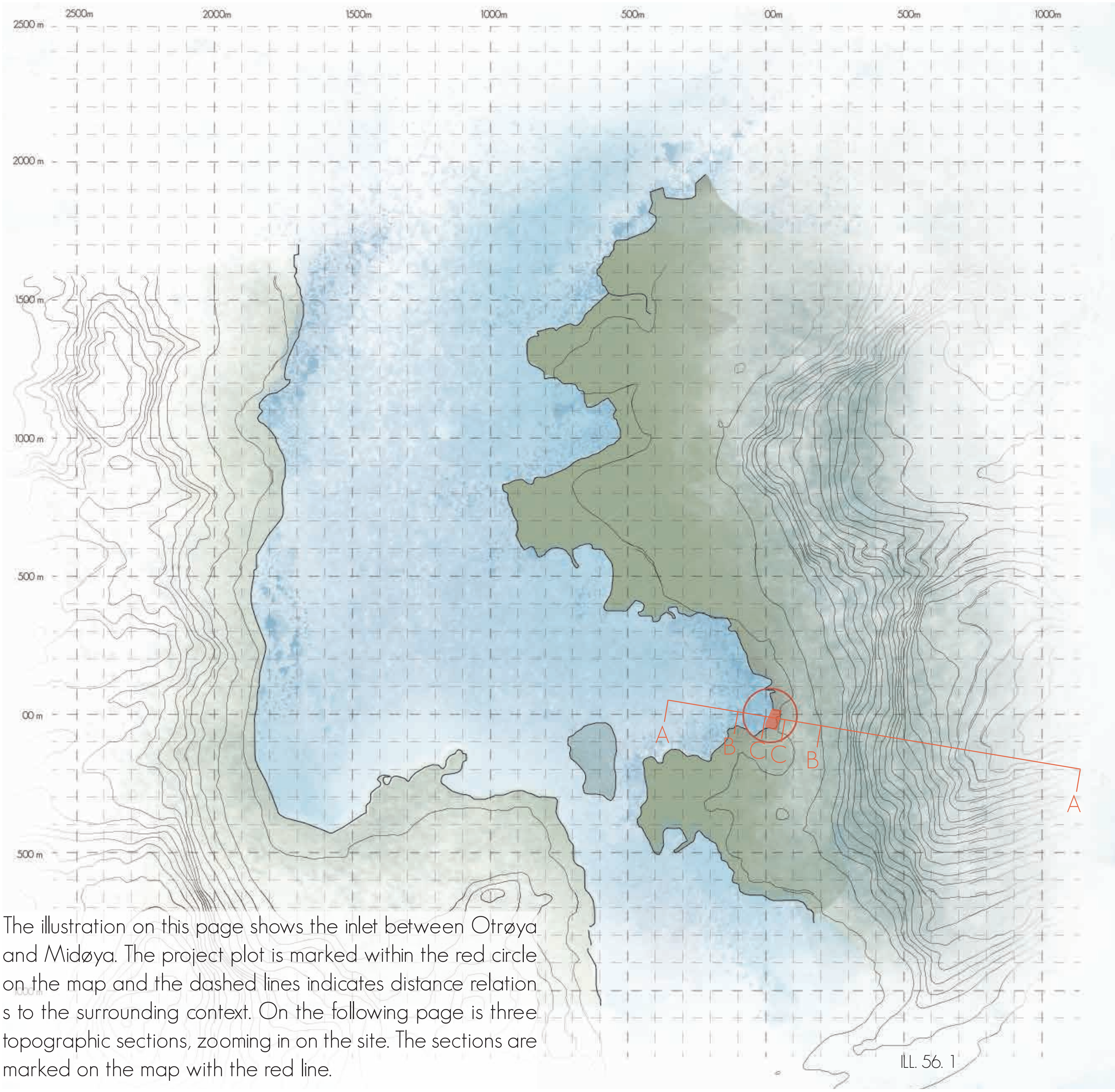
As mentioned earlier, the site is located on the island of Otrøya, causing many in the area using boats for transportation. A main road provides good connection from Otrøya to the nearby islands Midøya and Dryna. A lot of small roads are found primarily near residential areas; however there is a lack of smaller paths for bicyclists and pedestrians.

The site is located near shopping and general supply centers, providing easy access to the site. The island has few industrial areas, as well as one public primary school, where the majority of the area consists of single houses. The picture on the next page shows the site (marked red).



ILL. 55. 1 *Midsund - Site marked in red*

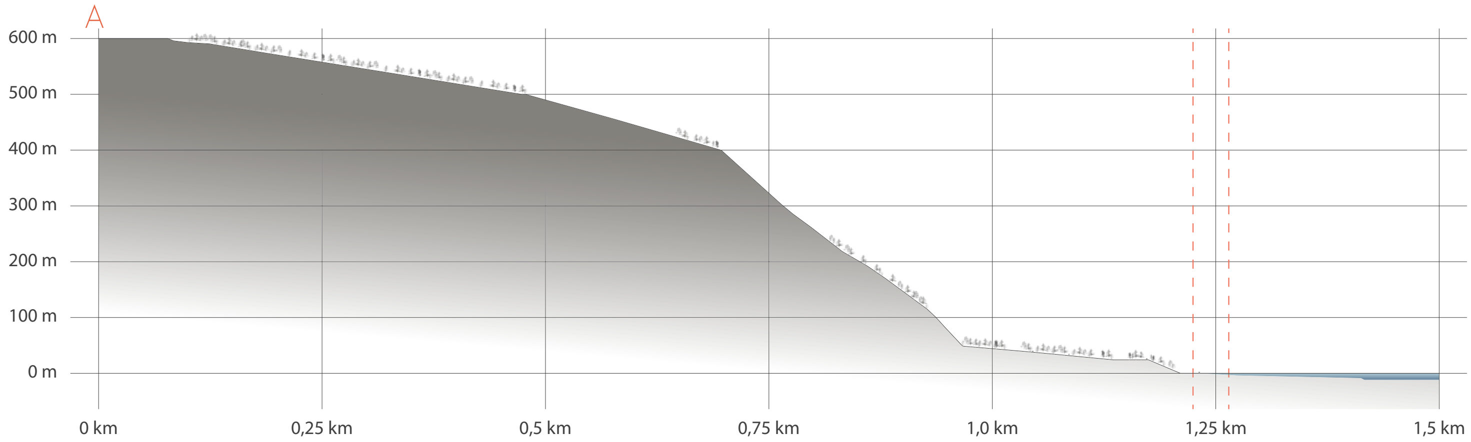
SITE ANALYSIS



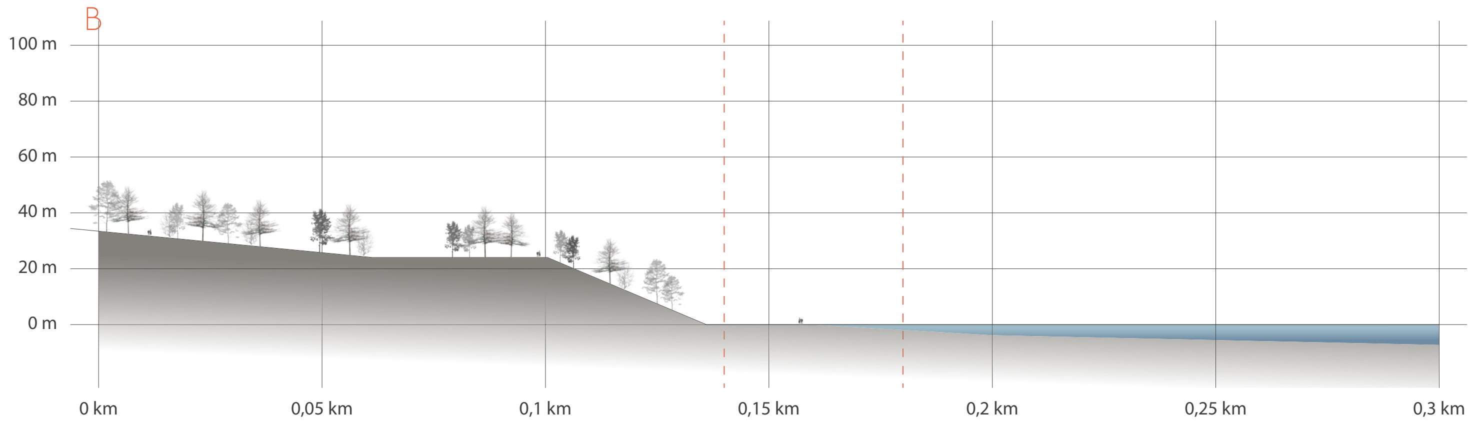
The illustration on this page shows the inlet between Otrøya and Midøya. The project plot is marked within the red circle on the map and the dashed lines indicates distance relation s to the surrounding context. On the following page is three topographic sections, zooming in on the site. The sections are marked on the map with the red line.

ILL. 56. 1

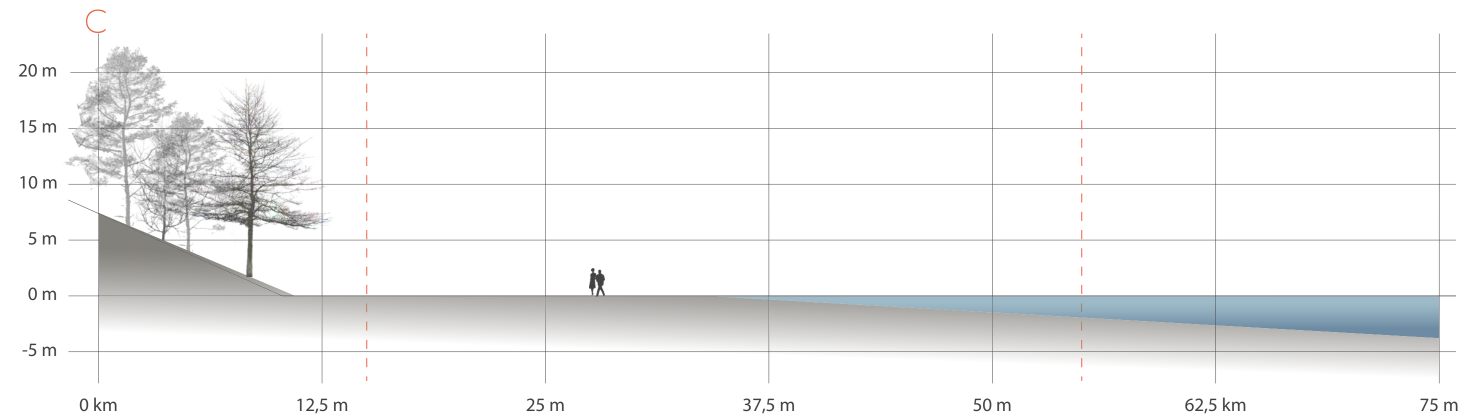
TOPOGRAPHIC SECTION



ILL. 57. 1

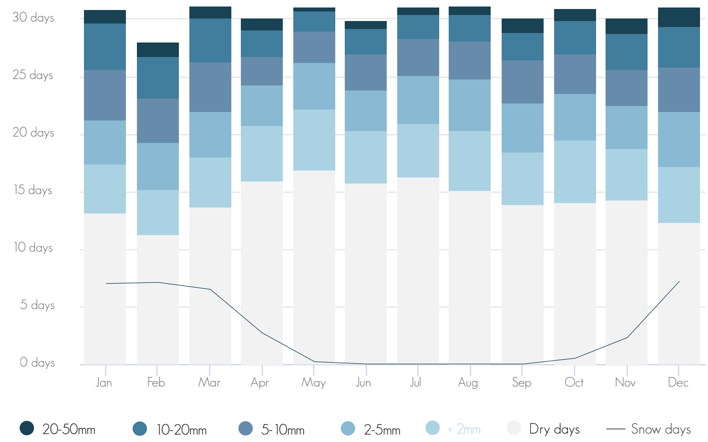


ILL. 57. 2

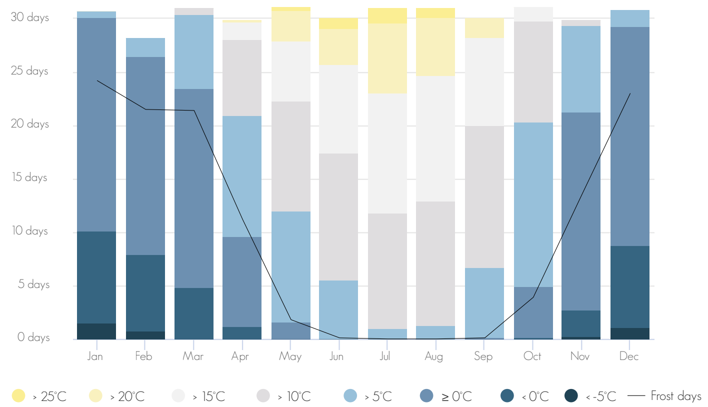


ILL. 57. 3

MACRO CLIMATE ANALYSIS

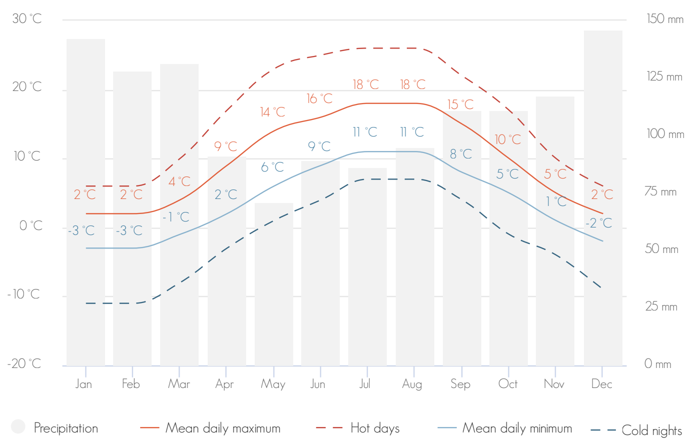


ILL. 58. 1

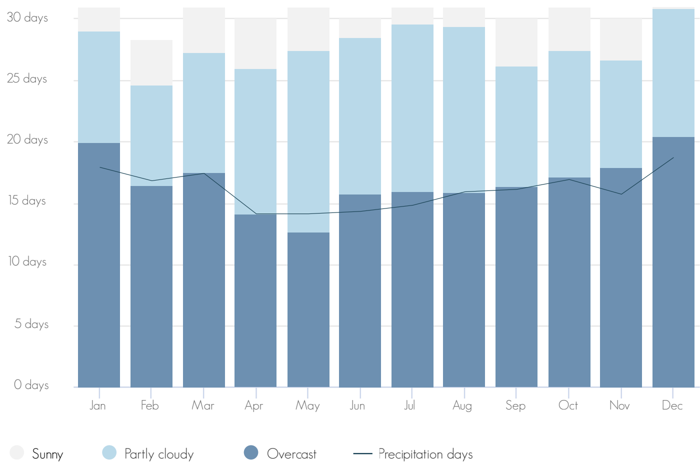


ILL. 58. 2

The following climatic analysis will be firstly describe the conditions of the macro climate in the region, providing a general impression of the climate at the site. The following analysis will go further into how the surrounding geography affects the local conditions of the micro climate. Throughout the analysis, observations are made regarding the project sites interaction with the climatic conditions, and how potential design strategies could be utilized to support a sustainable approach. The region of Møre and Romsdal is located far north in the Northern Hemisphere, just south of the Arctic Circle. However, the region has a relatively temperate climate due to its position on the west coast, as the North Atlantic Drift cools the air during summer and warms it during winter (Weather Online, 2018), resulting in an annual aver age temperature of 6,8°C (Climate-Data.org, 2018). For the warm season, lasting from June to September, the average



ILL. 59. 1

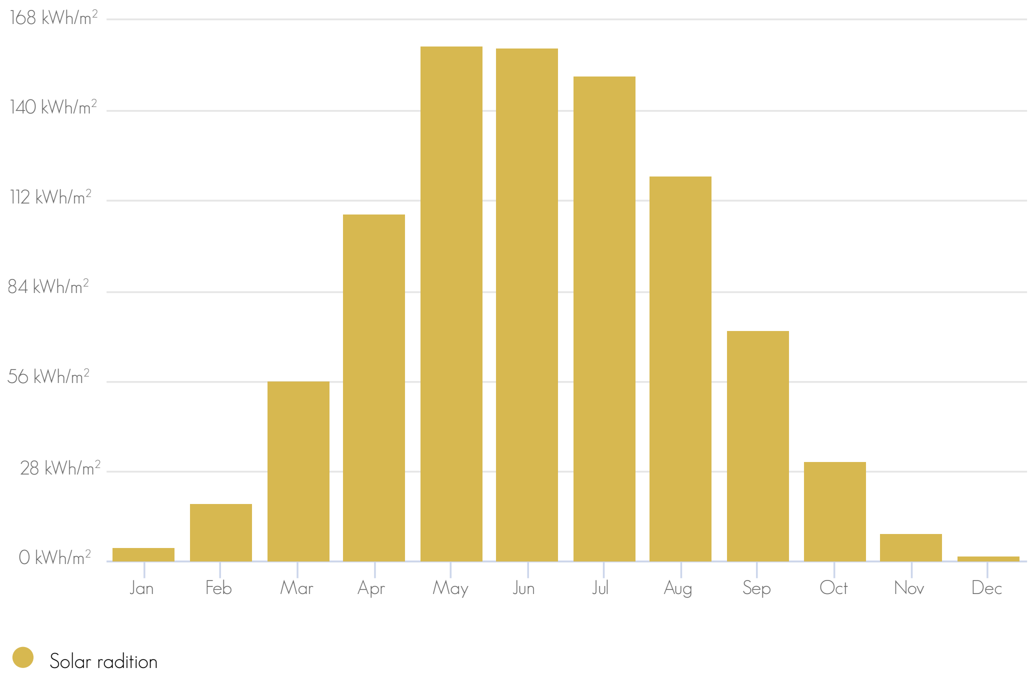


ILL. 59. 2

high temperature ranges from 16 to 18°C, while the average low, in the same period, ranges from 9 and 11°C. During the cold season, from mid November to February, the average high temperature ranges from 2 to 5°C, and an average low between 1 and -3°C (Meteoblue, 2018). These climatic conditions, generates a relatively strong potential for utilizing thermal buoyancy as a driving force for natural ventilation during summer, in order to enhance the thermal and atmospheric comfort inside the dwellings.

The outdoor temperature is, in general, significantly lower than the thermal comfort for humans throughout the majority part of the year, resulting in heat loss due to transmission and infiltration. As mentioned in the chapter about passive strategies, ensuring a well-insulated and airtight envelope is therefore crucial in order to minimize the total energy consumption for the dwellings

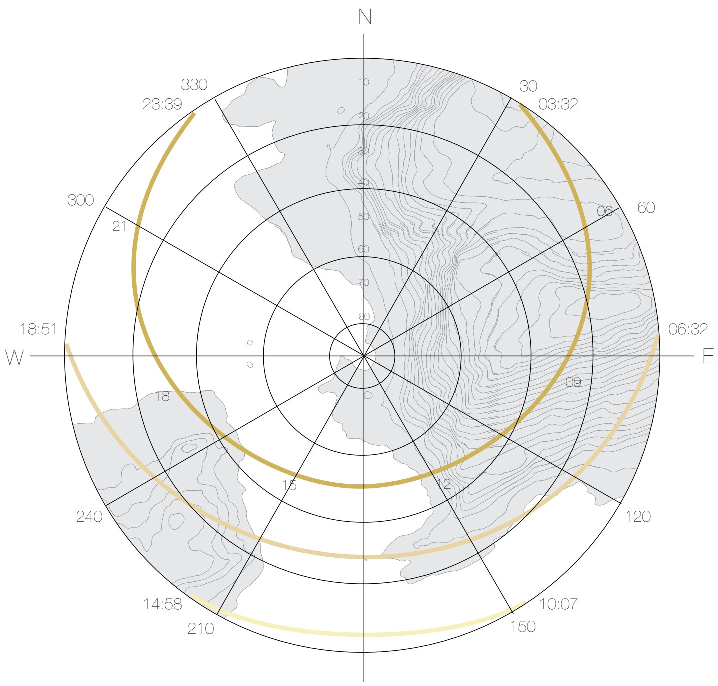
SOLAR RADIATION AND WIND



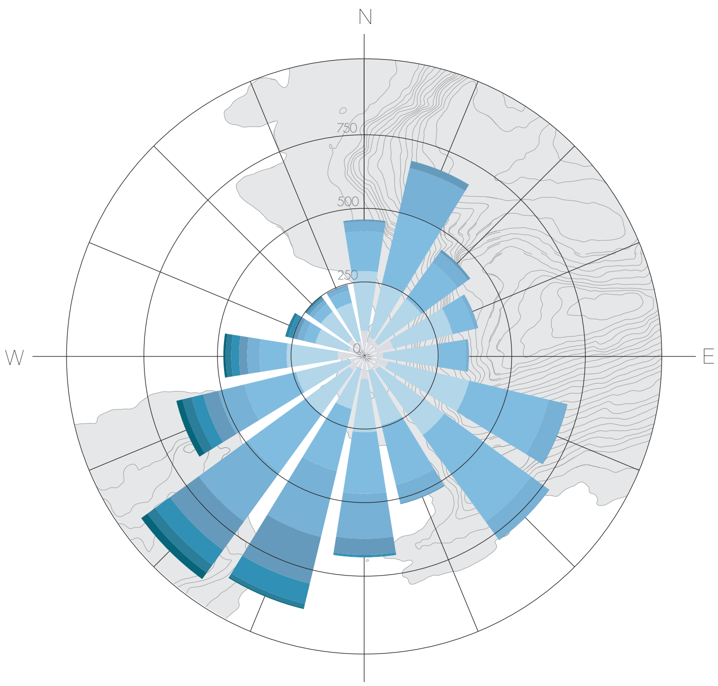
ILL. 60. 1

The high latitude of the project site in the Northern Hemisphere causes considerable variations of the daylight conditions throughout the year. As illustrated in the sun diagram, the sun rises high in the sky around the summer solstice, providing up to twenty hours of daylight. However, during winter, the conditions change drastically, resulting in short days, with only five hours of daylight at the winter solstice (Gaisma, 2018). During winter, the significant lack of daylight needs to be considered in order to optimize the daylight conditions, and while the strong presence of the sun during summer offers a vast potential for shaping well-lit spaces, overheating could become an issue.

The total monthly solar radiation in the region is relatively high from April to September, where the monthly average exceeds 100 kW/h/m2, reaching its peak in May when the average daily sky is clear. Throughout the rest of the year, the solar radiation is quite insignificant, and is almost nonexistent from November to February, resulting in a yearly total of 880 kWh pr. m2, approximately 20 percent lower than the annual average of Aalborg, Denmark (Gaisma, 2018).
The wind conditions in the region also vary throughout the year. The conditions are relatively calm from April to October, with an average wind speed of 2,5 meters per second, while the wind increases significantly from October to April



ILL. 61. 1

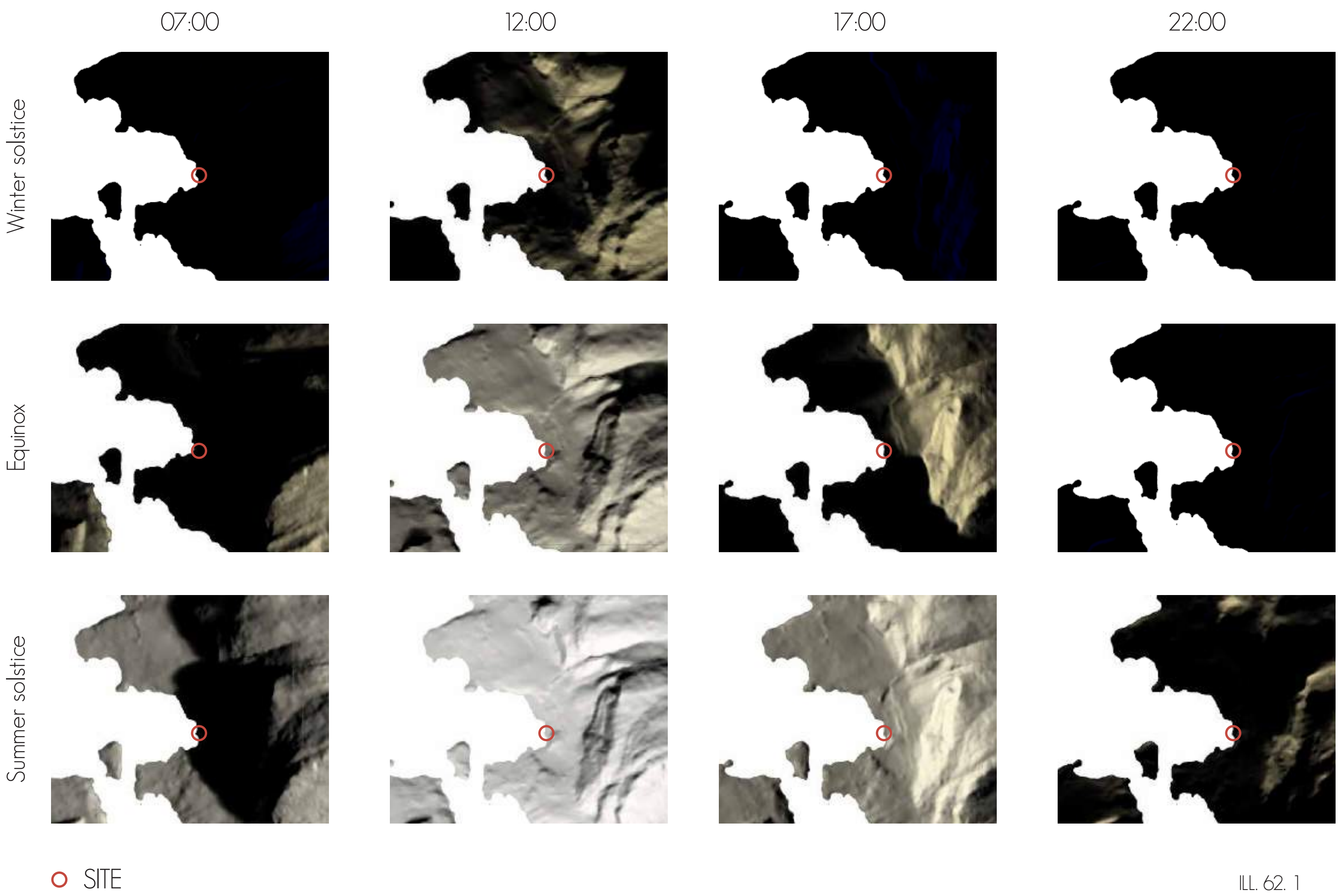


ILL. 61. 2

with an average of 5,1 meters per second. The predominant wind direction is south from September to April, while the direction is more balanced from April to September, but mainly west dominant (Weatherspark, 2018). However, according to project manager Johann Hjalmarsson, from Røberg Bygg As, the primary stakeholder in the project, strong winds occur mainly from North during winter (Hjalmarsson, 2018). From October to April, the strong winds from north and south should be carefully considered to provide comfortable and useful exterior spaces (Weatherspark, 2018). To draw advantage of these wind patterns, the wind forces could be utilized to enhance the interior comfort during summer by placing openings towards west, allowing wind to naturally ventilate, as well as cool down the building on warm days.

The annual yearly precipitation for the area is quite high, with a total of 1317 mm, usually occurring in the form of moderate rain or drizzle (Weatherspark, 2018). These conditions should be carefully considered to design useful outdoor spaces, that shelters from rain.

MICRO CLIMATE ANALYSIS - DIRECT SUNLIGHT

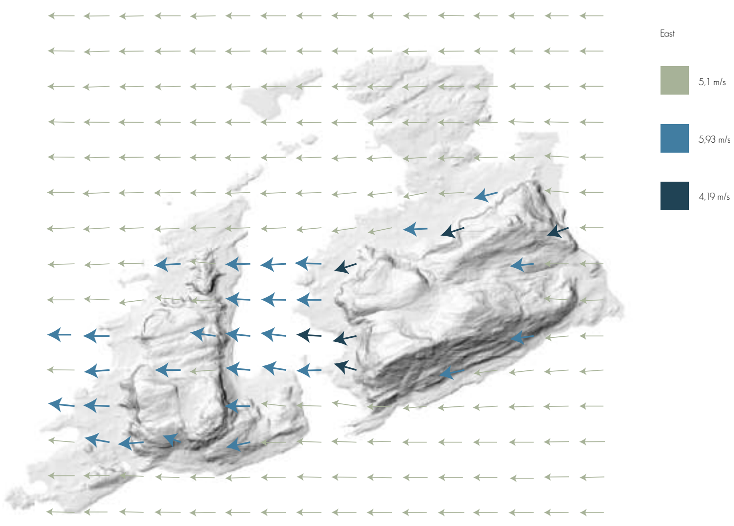


ILL. 62. 1

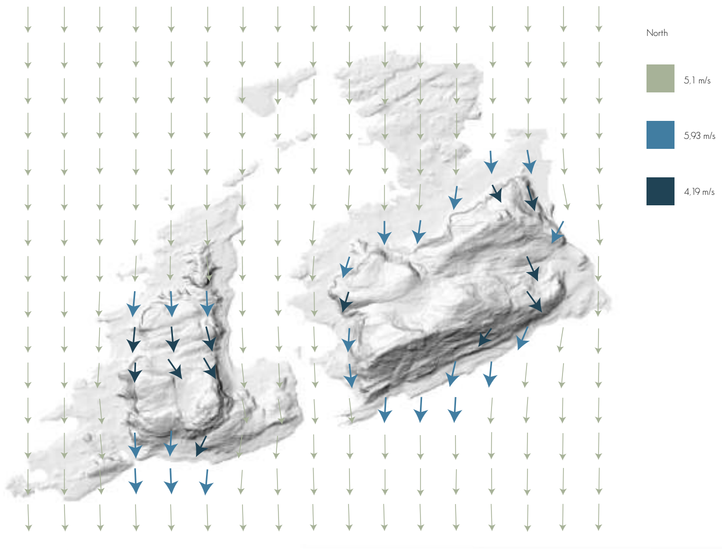
To gain a better understanding of how the surrounding context affects the microclimate of the project site, a simulation was conducted regarding the direct sunlight, excluding defuse light, and wind conditions. The mountains east and west of the site have a profound impact on the climatic conditions. The mountain east of the site casts shade on the area during morning hours throughout the whole year, as well as during the entire day at the winter solstice. For the majority part of the year, the mountain west of the site casts a shade on the site, as the sun sets behind the mountain west.

In conclusion, the optimal orientation for direct daylight throughout the year is available from southwest and west.

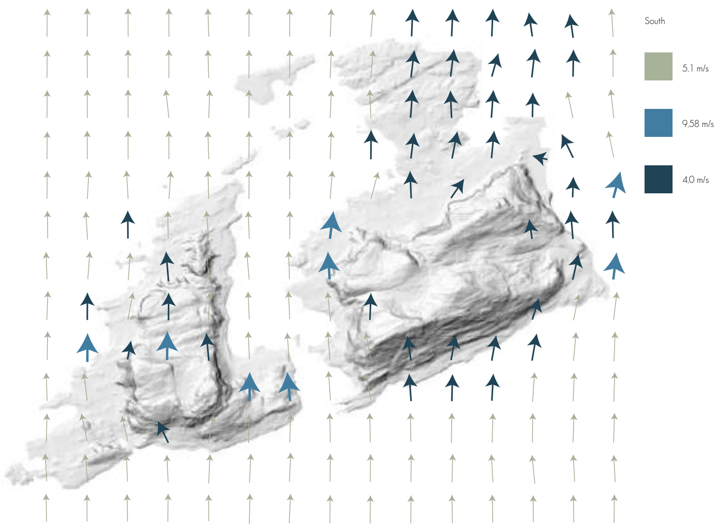
MICRO CLIMATE ANALYSIS - WIND



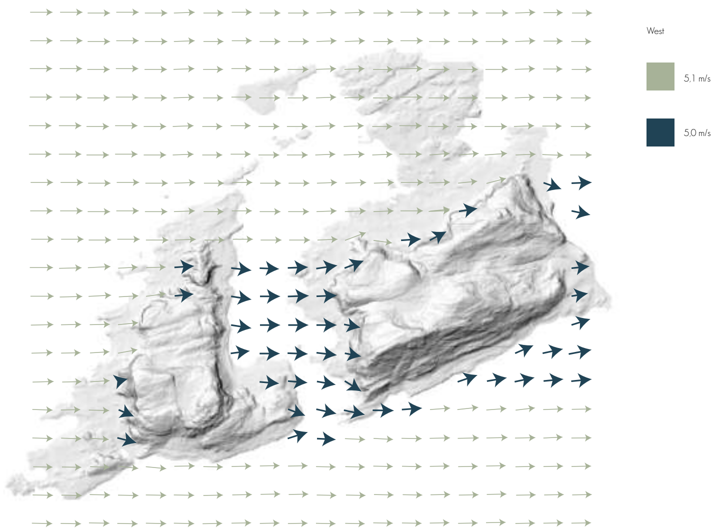
ILL. 63. 1



ILL. 63. 2

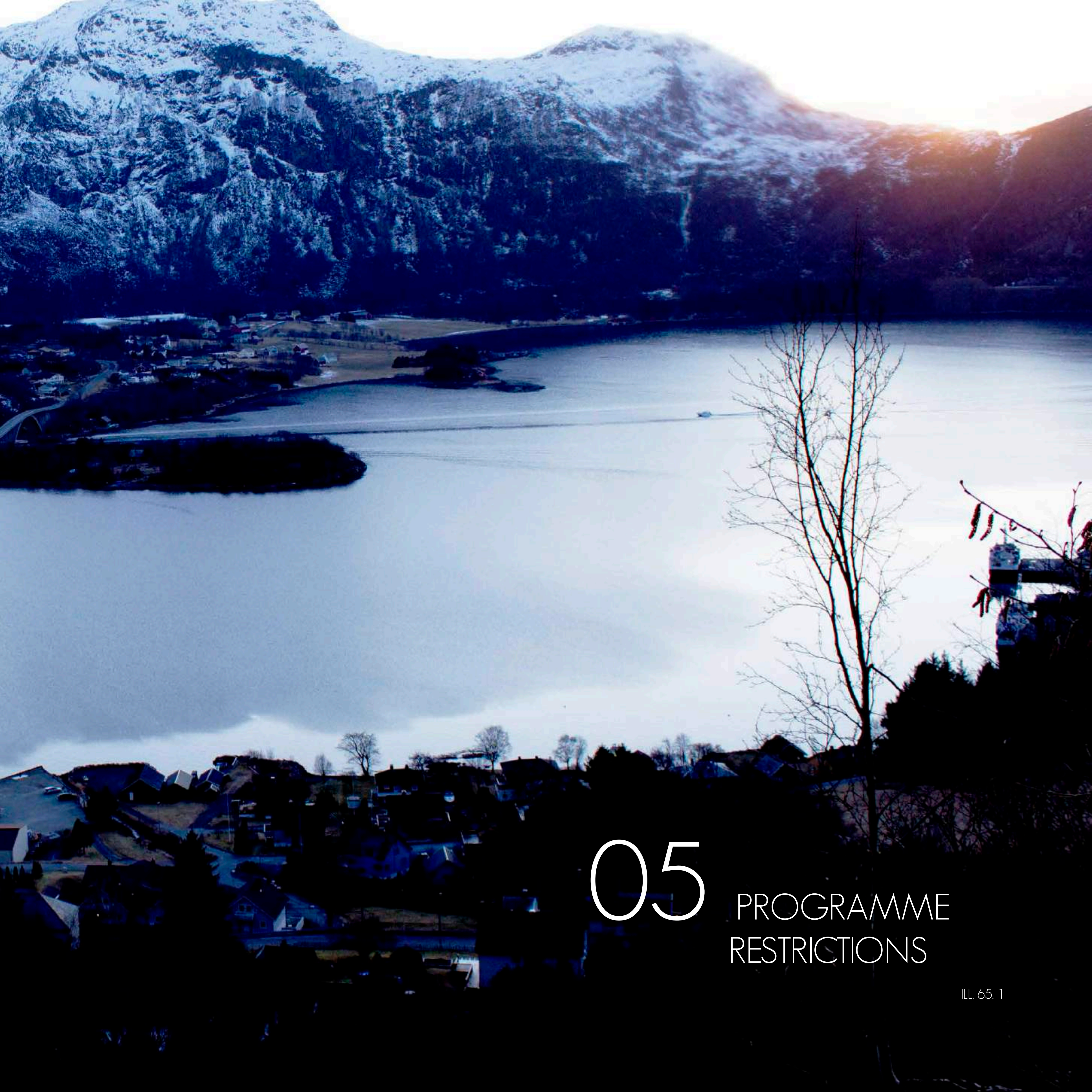


ILL. 63. 3



ILL. 63. 4

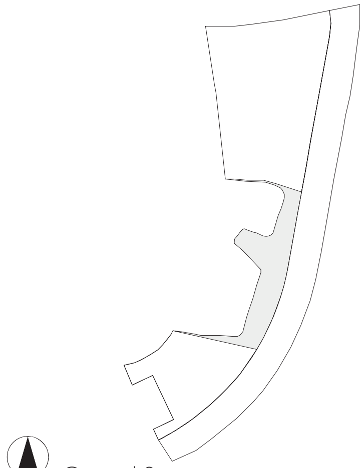
Regarding the wind conditions, the mountain east of the site shelters from strong winds directed from northeast and southeast. However, the site is quite open and exposed from the waterfront towards west and northwest, where the dominant winds are directed from during summer, could be used to ventilate and cool the dwellings naturally.



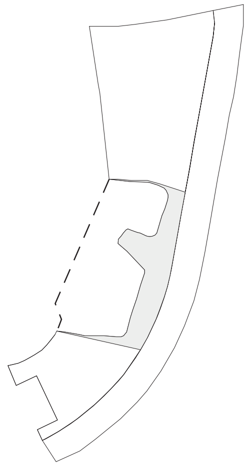
05 PROGRAMME RESTRICTIONS

ILL. 65. 1

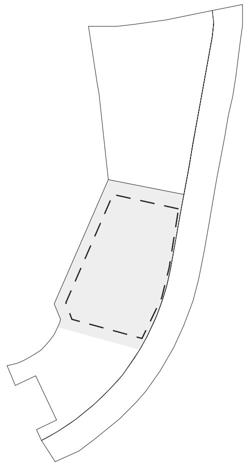
LOCAL PLAN & REGULATIONS



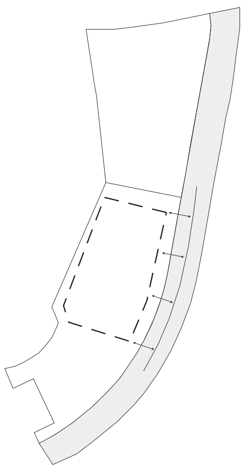
Original Site ILL. 66. 1



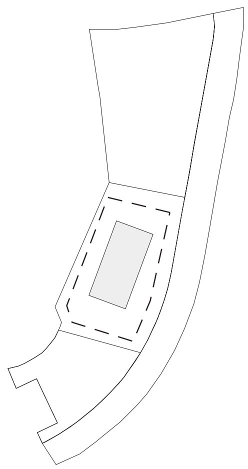
Potential site boarder ILL. 66. 2



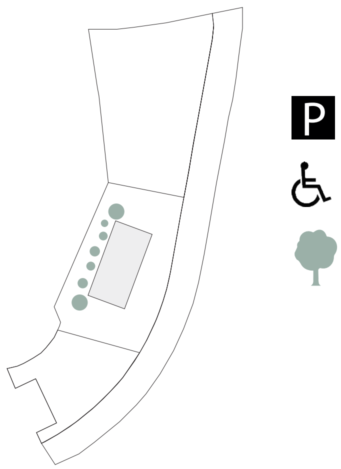
Building limit ILL. 66. 3



Min. 8m from building limit to road senter ILL. 66. 4



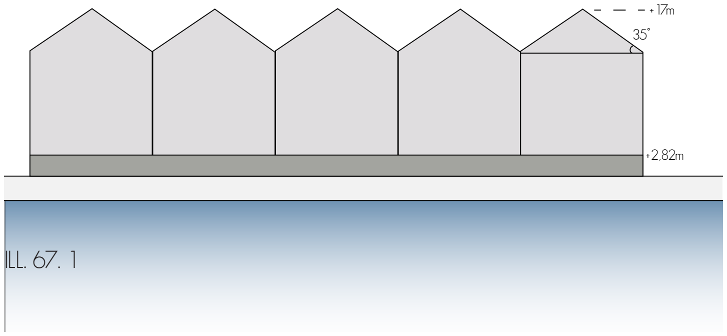
Max 40% built area (BYA) ILL. 66. 5



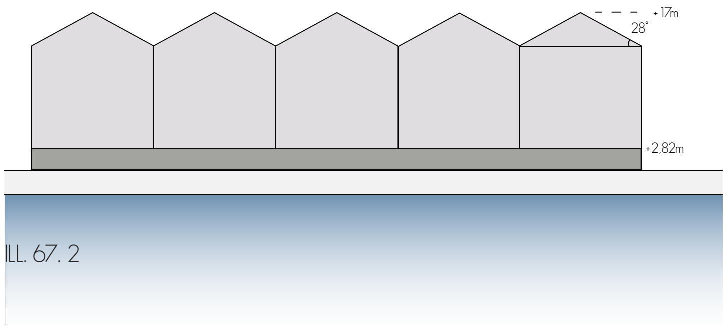
recuiremets for accessability, parking and green space ILL. 66. 6

A local plan for area of Midsundfjøra was published by the municipality of Midsund in 2014, based on the development plan as well as the winning proposal for the idea-competition for the city center of Midsund, both mentioned in the Development Plan chapter. The local plan states general requirements for the entire area, as well as specific requirements for the individual properties (Føresegner, 2014).

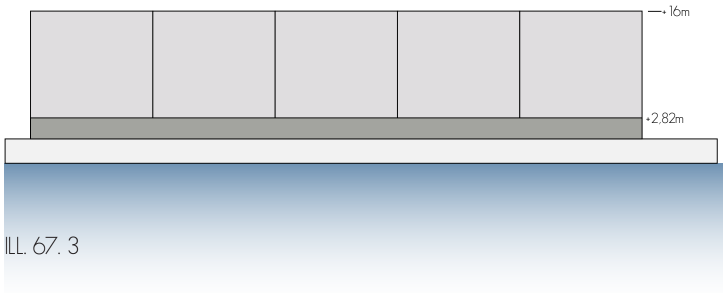
The general requirements include adapting to the rising sea level and minimize potential damage associated with floods, where all living spaces in new buildings must be positioned at least 2,82 meters above sea level. The local plan also clearly underlines the importance of ensuring accessibility for all, both regarding the outdoor spaces, but also for the dwellings themselves, where a minimum of 25 percent of the apartments has to fulfill the requirements for accessibility, according to the National Building Regulations, TEK. General requirements are also made for the common outdoor spaces, stating that the areas should be attractive, with plenty of daylight, and should provide a safe environment for children to play, to which each of the dwelling units shall resign 25m2.



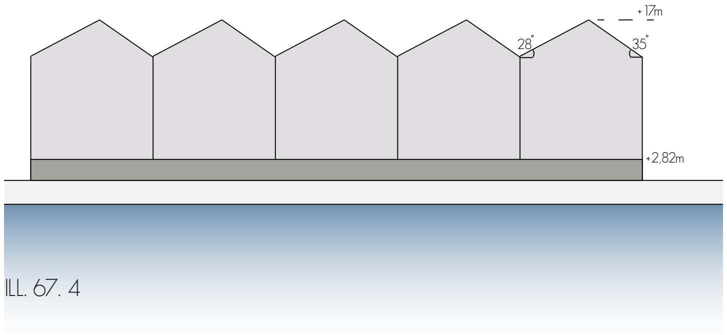
ILL. 67. 1



ILL. 67. 2



ILL. 67. 3

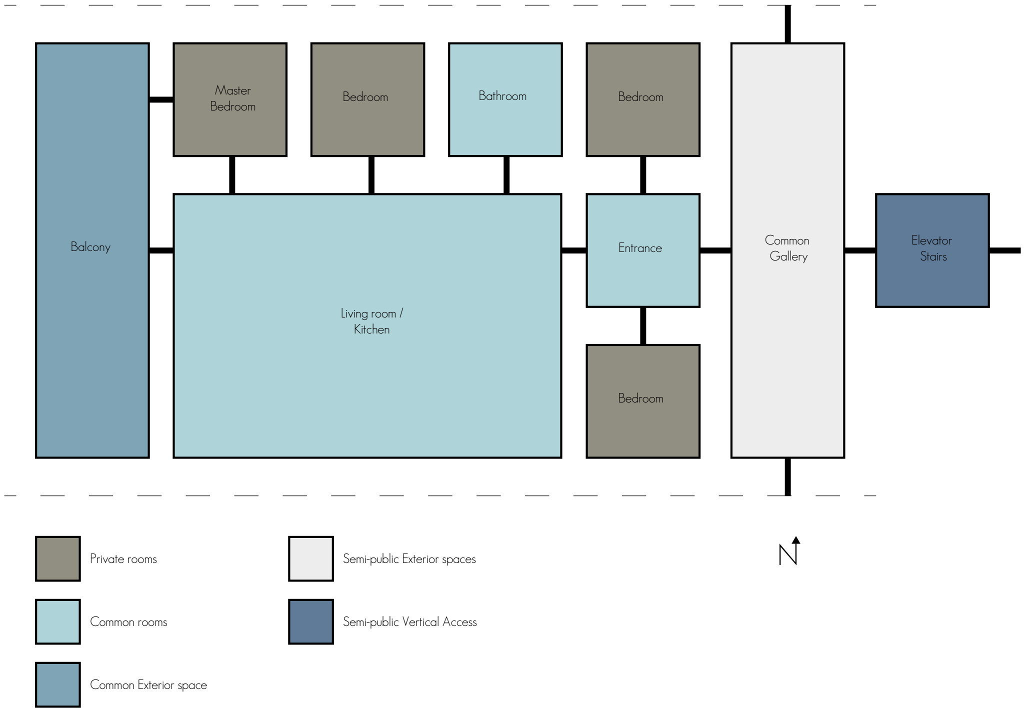


ILL. 67. 4

The dwellings shall be provided with a total of 1,5 parking spaces per unit, where 5 percent are facilitated for disabled. All building limits must be kept at a minimum distance of eight meters from municipal roads. (Føresegner, 2014).

For the property of the actual building plot, a specific requirement is made concerning the building type, the allowed footprint, the building height as well as the shape of the roofs. The property can be utilized for dense dwellings, with a maximum BYA (Build Area) of 40 percent. The height limit is defined as the vertical distance from the sea level to the highest point of the structures, where the allowed height is dependent on the shape of the roof. The designer has the option to form structures with flat roofs, with a height limit of 16 meters above sea level, or to shape east-west oriented pitched roofs, with an inclination between 28° and 35°, allowing the designer to increase the vertical distance to 17 meters above sea level.

SPATIAL AIMS & FLOW FOR APARTMENTS



ILL. 68. 1

	LARGE					MEDIUM					SMALL				
	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY
	[pc]	[m2]	[m2]	[m]	[pc]	[pc]	[m2]	[m2]	[m]	[pc]	[pc]	[m2]	[m2]	[m]	[pc]
Bedrooms	4	14	56	2,4 - 3	1,25	3	13	39	2,4 - 3	1,3	3	10	30	2,4 - 3	1,3
Kitchen	1	25	25	2,4 - 3	5	1	20	20	2,4 - 3	4	1	15	15	2,4 - 3	4
Living area	1	30	30	2,4 - 3	5	1	30	30	2,4 - 3	4	1	20	20	2,4 - 3	4
Bathroom	2	8	16	2,4 - 3	1	2	6	12	2,4 - 3	1	1	6	6	2,4 - 3	1
Entrance	1	4	4	2,4 - 3	2	1	3	3	2,4 - 3	2	1	3	3	2,4 - 3	2
Storage	1	5	5	2,4 - 3	-	1	4	4	2,4 - 3	-	1	4	4	2,4 - 3	-
Technical Space	1	3	3	2,4 - 3	-	1	3	3	2,4 - 3	2	1	2	2	2,4 - 3	-
Subtotal:			139	2,4 - 3	-			111					80		
Balcony	1	40	40	2,4 - 3	5	1	30	30	2,4 - 3	4	1	20	20	2,4 - 3	4
Parking	1,5	11	16,5	-	-	1,5	11	16,5	-	-	1,5	11	16,5	0	-
Exterior common area	1	25	25	-	5	1	25	25	-	4	1	25	25	0	4
Total unit area:			220,5					182,5					141,5		

ILL. 68. 2

PREDEFINED TECHNICAL AIMS FOR APARTMENTS

A room program has been established for the technical aims of the project. The room program is to be used as a guideline for the project throughout the design process, to ensure a comfortable and healthy indoor environment for the occupants. The aims are set to, at a minimum, correspond with the requirements of the Danish Building Regulations, as well as Danish Standard for Indoor Environment category 2. Here it is stated that the indoor temperatures cannot exceed 100 hours above 27 degrees and 25 hours above 28 degrees. The relative humidity should be kept within 30-65%. CO2 concentration must be below 850ppm with an average air change of 1,5/h. [DS/EN 15251, 2007]

	ORIENTATION	BUILDING CATEGORY 2					LIGHT				
Room Program	DIRECTION	ROOM TEMP. SUMMER	ROOM TEMP. WINTHER	CO2 CONC.	EXHAUST AIR FLOW	DAYLIGHT FACTOR	NATURAL LIGHT	ARTIFICIAL LIGHT	OPENINGS IN THE FACADE		
		[Celcius]	[Celcius]	[ppm]	[l/s]	[ppm]			0 openings	1 opening	2 openings
Bedrooms	East/north	23-26	20-25	850	-	2-5%	■	■	□	■	□
Kitchen	East/west	23-26	20-25	850	20	>5%	■	■	□	□	■
Living area	South/west	23-26	20-25	850	-	>5%	■	■	□	□	■
Bathroom	Variable	23-26	20-25	850	15	2-5%	□	■	–	–	–
Entrance	Variable	23-26	20-25	850	-	2-5%	□	■	–	–	–
Interior storage	-	>16	>16	-	-	-	□	■	–	–	–
External storage	-	-	-	-	-	-	□	■	–	–	–
Exterior common area/ balconies	South/west	-	-	-	-	-	■	■	–	–	–
Parking	-	-	-	-	0,2/m2	-	□	■	–	–	–

	VENTILATION		PASSIVE COOLING STRATEGIES			SOLAR RADIATION CONTROL				
Room Program	NATURAL	MECHANIC.	CROSS VENT.	SINGLE-SIDED	THERMAL BUOANCY	WINDOW AREA	WINDOW ORIENTATION		SHADING DEVICE	
	Manuel	Automatic	Two openings	One opening	Upwards	[%]	Morning	Evening	Permanent	Moveable
Bedrooms	■	■	□	■	□	15%	East	North	■	■
Kitchen	■	■	■	□	■	30%	East	West	■	■
Living area	■	■	■	□	■	50%	South	West	■	■
Bathroom	□	■	□	□	□	0%	–	–	□	□
Entrance	■	□	□	□	□	5%	–	–	□	□
Interior storage	–	–	–	–	–	–	–	–	–	–
External storage	–	–	–	–	–	–	–	–	–	–
Exterior common area/ balconies	–	–	–	–	–	–	–	–	–	–
Parking	□	■	–	–	–	–	–	–	–	–

ILL. 69. 1 The room program is based on DS/EN 15251, DS 474, BR18 and in addition to own preferences.

06 PROGRAMME DESIGN CRITERIA

ILL. 71. 1

VISION

The vision is to design an apartment complex rooted in sustainability with an integration of the three aspects, social, environmental and economic. The aim is to reach a low energy building, within a feasible cost limit, while simultaneously striving to enhance life quality for users by following the five ways of well-being. Additionally, the design should create a coherence to the surrounding nature by utilizing the natural material wood, in a Nordic architectural manner, for constructional, functional and aesthetical purposes. The building shall contribute to a vibrant atmosphere to the city center while attempting to position itself as a landmark.

DESIGN CRITERIA

- Use local materials (e.g., wood)

- Secureness of good indoor environment - thermal and atmospheric comfort helped by an application of passive & active initiatives

- Use robust materials

- All interior spaces should aim for natural daylight and exterior view and allow the exterior to become a part of the interior

- Enable social interactions between the users

- Microclimate – mountain

- Holistic integration of predefined goals for indoor environment and energy consumption

- Consider the five ways of well-being

- Consider the view from inside to outside

- Consider common outdoor green spaces

- Consider the local context

- Consider architecture that can provide good relations

- Proximity to the water

- Consider the connection between water and mountain

- Consider the user group

- Consider nature

- Low maintenance

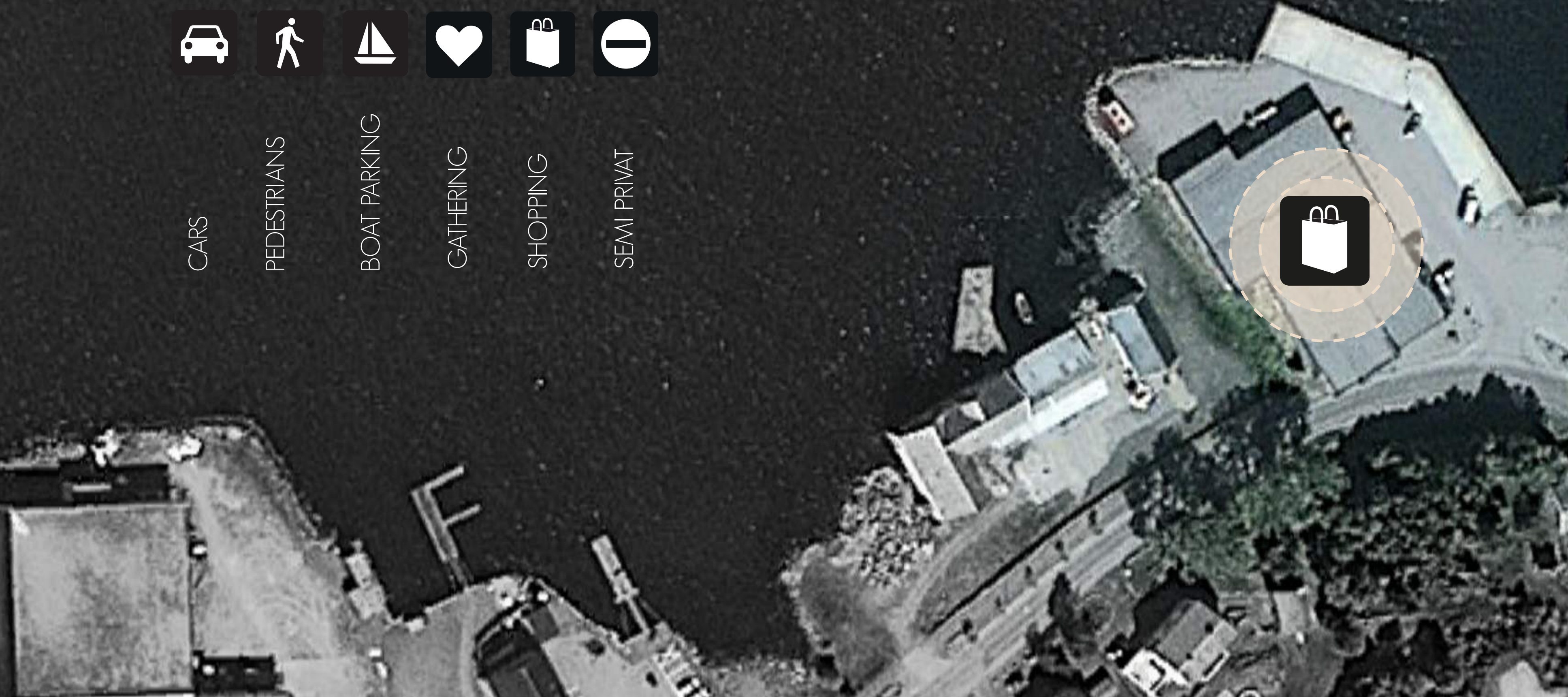
07 DESIGN PROCESS

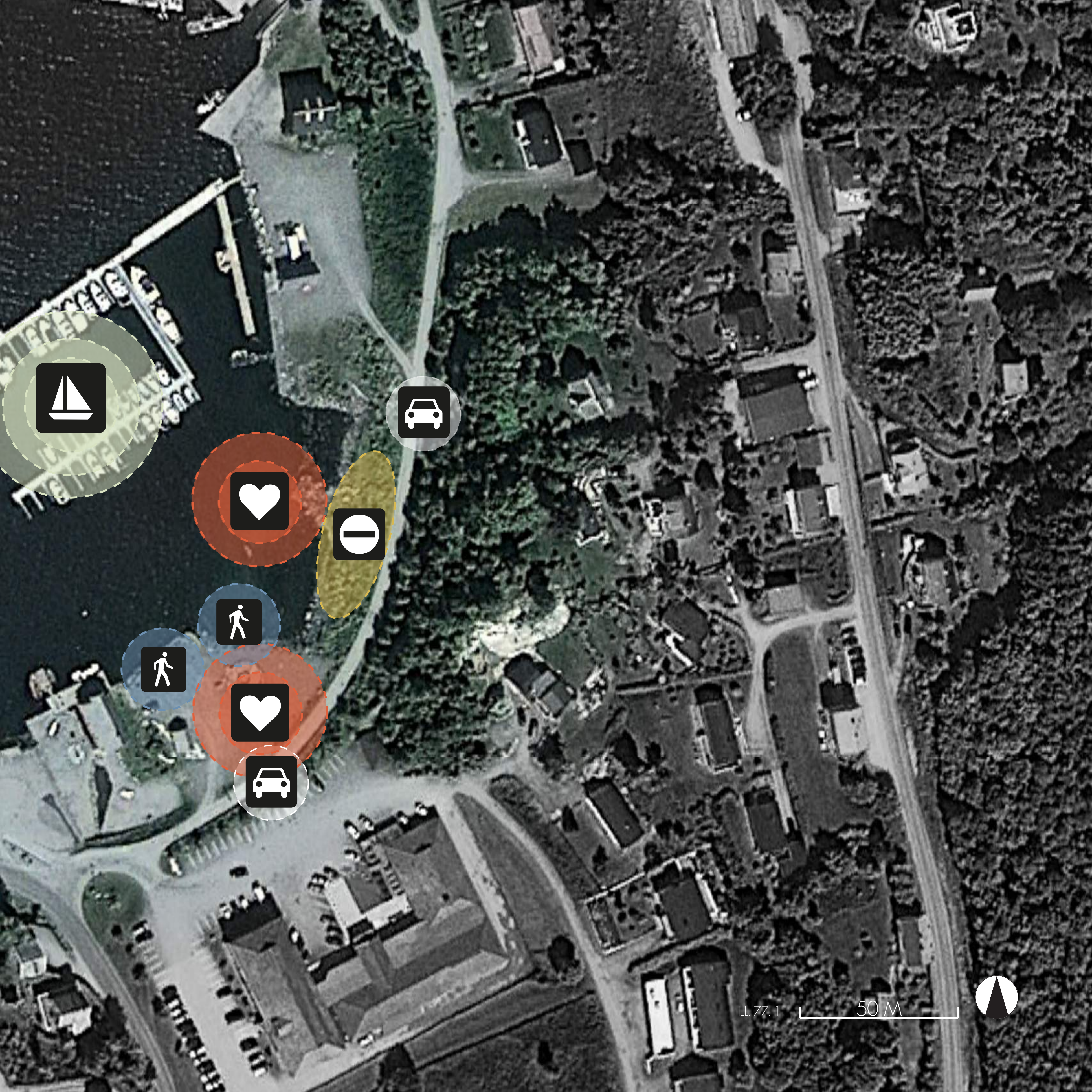
ILL. 75.1

INITIAL SITE CONSIDERATIONS

Initially, the design process, the site is considered in an overall perspective with the surrounding areas to form a holistic design approach from the early stages of the process. Considering the existing master plan of the area, activity occurs near shopping (southwest) and the marina area (northwest). The current connection between the frequently used areas takes place on the east part of the site, which indicates that the link should be maintained. As mentioned earlier in the development chapter, the goals for the future development in the area is to provide the waterfront with a future pontoon bridge, and therefore this element is sufficient to connect the two areas.

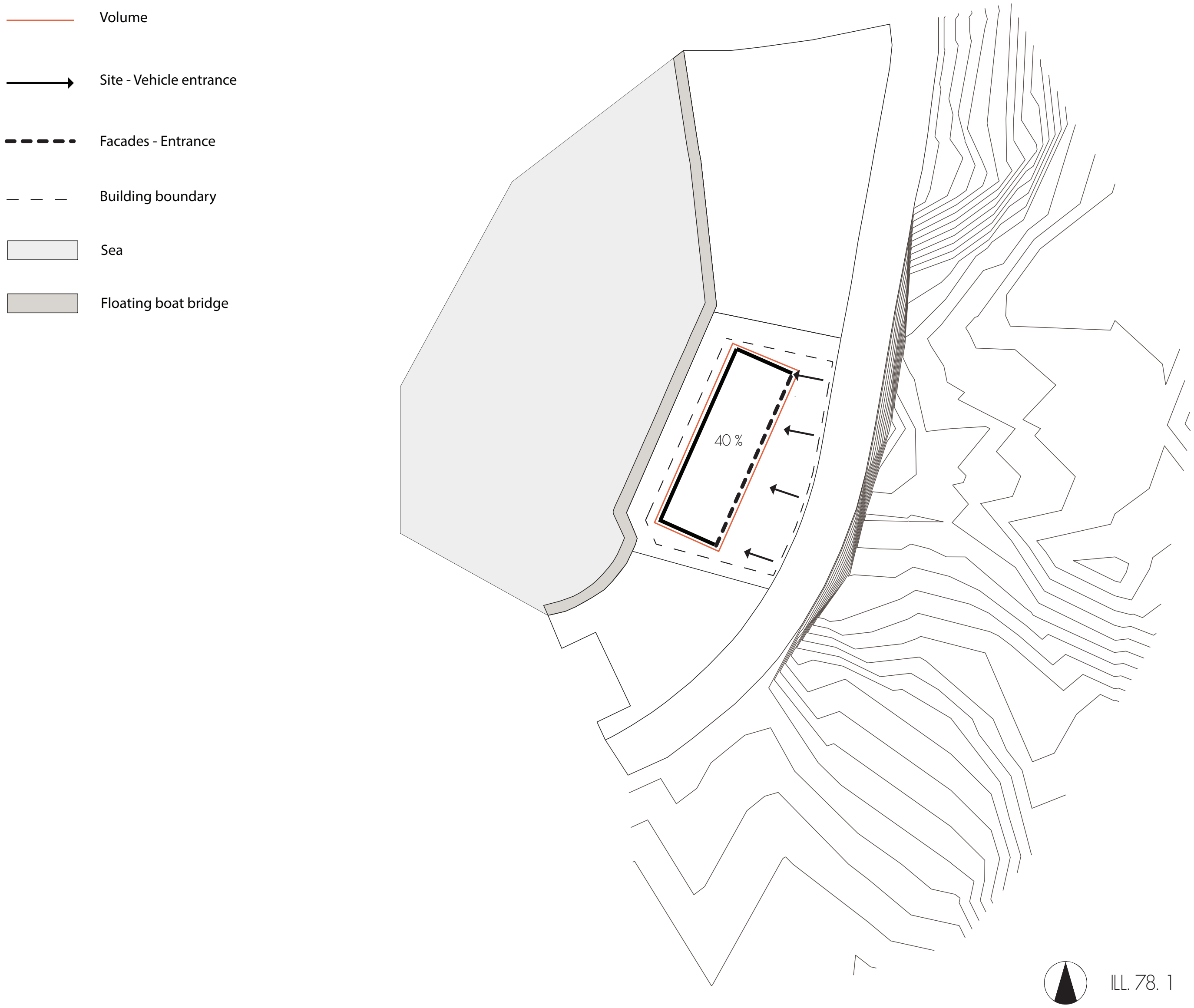
Marked with yellow, there is no desire to open up activity as the eastern part of the site is near a road. This space should mainly be used by the residents. The hearts on the master plan indicate the areas that are preferred to be used for social interaction, where the heart towards the south is already titled as a public area and can be used by everyone. The heart placed at the site should be a gathering spot for the residents and thereby support social sustainability and well-being.





ILL. 77. 1

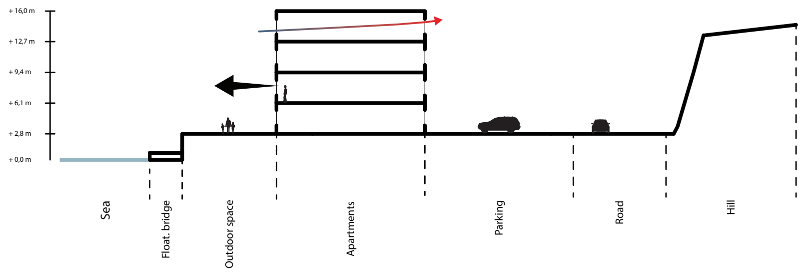
INITIAL BUILDING STRATEGIES



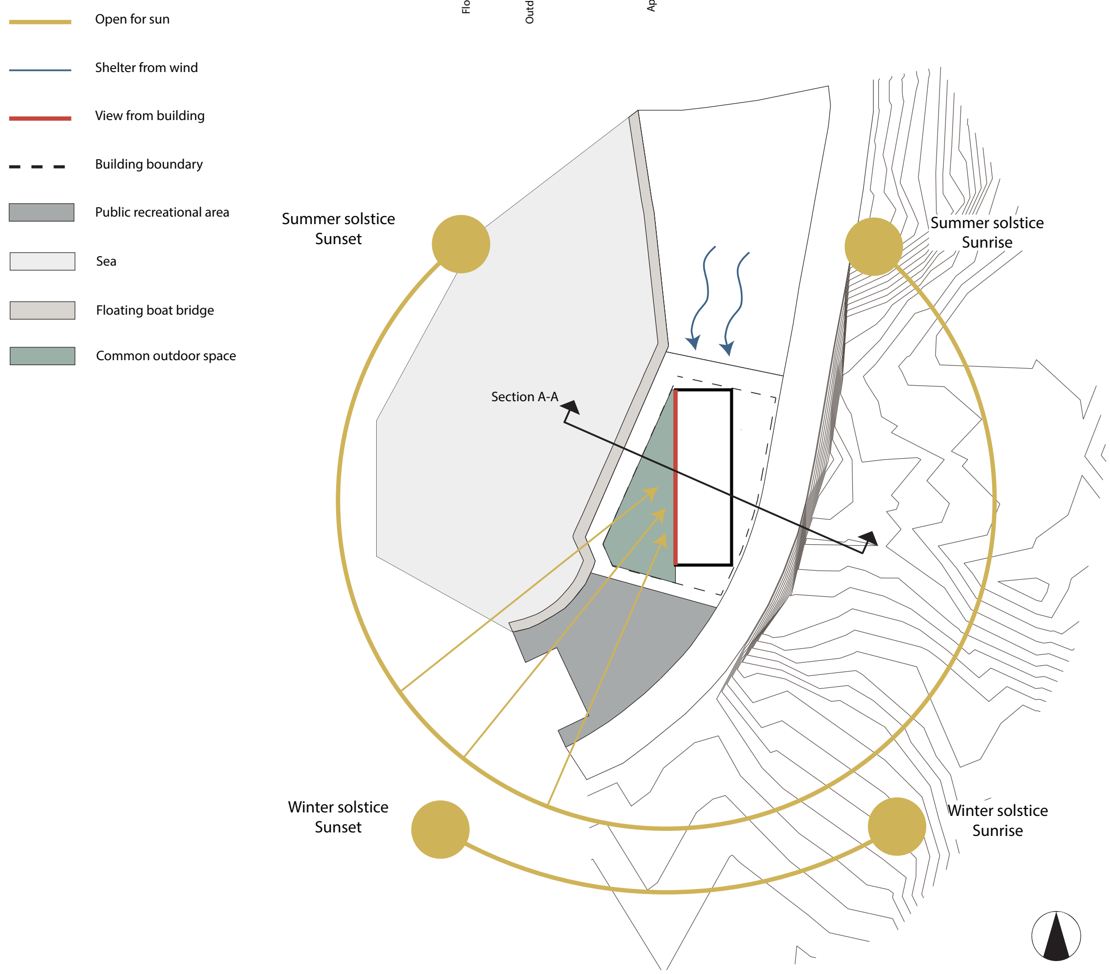
ILL. 78. 1

Initial building strategies are shaped to follow reasoning parameters to achieve a sufficient integrated process and to form approaches which will guide the design.

To economically make sense due to site costs, the maximum allowed footprint of 40 % and the building height should be utilized. Vehicle entrance must happen in the east part of the site. The entrances in the building design could very well be in correlation with the vehicle entrance and therefore placed at the eastern part of the site.



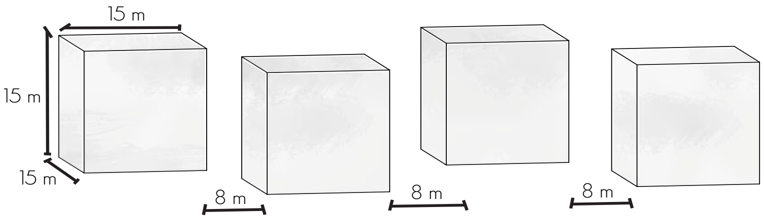
ILL. 79. 1



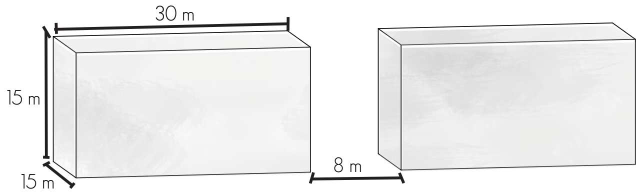
ILL. 79. 2

The width of the site should be utilized to enable view and proximity to the sea and harbor for all apartments. In correlation to daylight, the building should open up towards the south, to enhance the amount of direct sunlight reaching the apartments and throughout the day. Furthermore, each apartment should enable cross ventilation with inlet air from west to enhance natural ventilation during summer for thermal and atmospheric comfort. The common outdoor spaces should be placed in front of the building to provide a great view and daylight from south and west. The building must shelter from wind to offer useable spaces such as for the balconies.

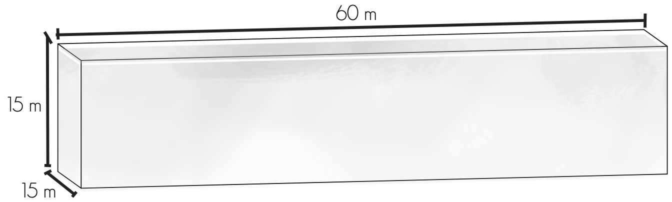
VOLUME STUDIES



A 5400m² Facade



B 4500m² Facade

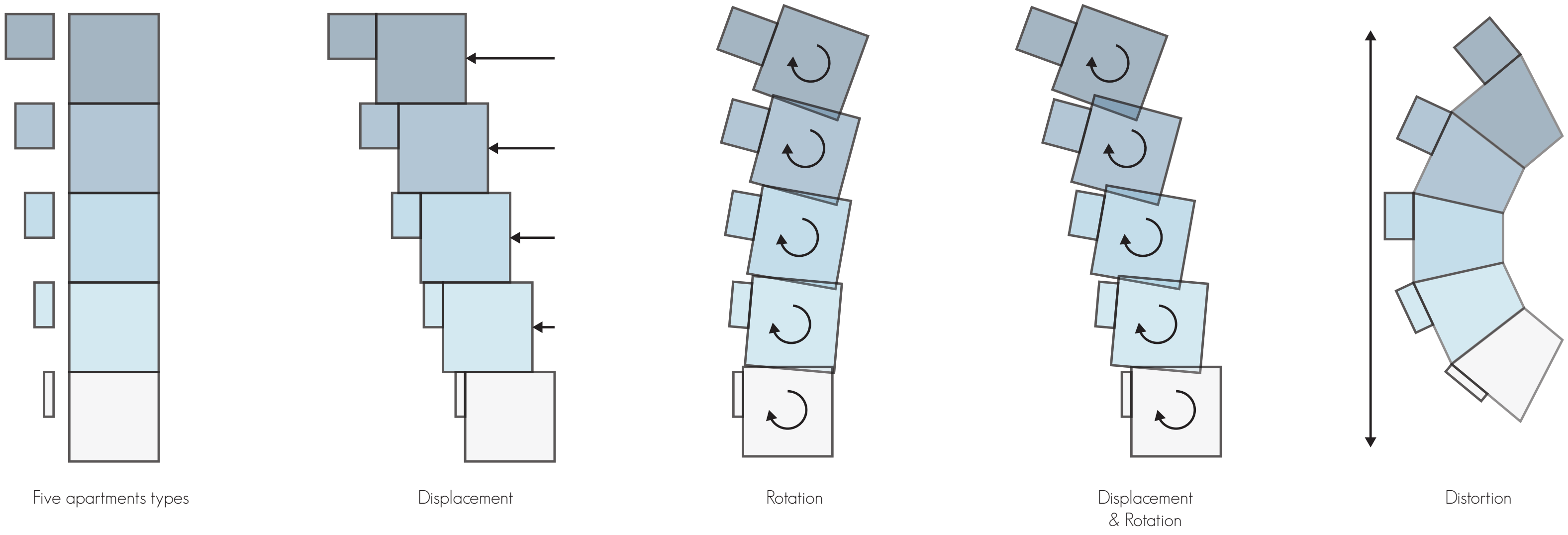


C 4050m² Facade

ILL. 80. 1

Volume studies are established to consider parameters such as energy demands, cost, daylight, natural ventilation, and views.

By providing each apartment stack per unit (see chart A), a minimum distance of 8m should be reached between all buildings due to fireproofing demands, which will cause much "lost" space on the site. However, the units will provide more daylight due to the "free" facades that the unit offers, and natural ventilation will be more accessible. If the facades with fireproof walls should contain windows, the cost of the project will increase due to fireproofing demands of the windows.
The more units, the more surface to floor ratio will occur, resulting in more substantial energy consumption and more heat loss, and more material will be utilized which do not fit a sustainable approach. Comparing the many units with a design only accomplished by using one unit (see chart C). The single unit is more efficient regarding energy consumption and heat loss, based on a smaller surface to floor ratio. The project will also be less expensive if no fireproof walls are needed. Penetration of daylight in the entire apartment may be more difficult to achieve (except apartments at each end of the volume) based on that each apartment will only be provided with two window facades. Natural ventilation may also be difficult to achieve in connection to cross ventilation. If the design is based on using two units (see chart B) the volumes would be beneficial concerning daylight, ventilation and provide good view toward the sea from all apartments, with larger facades for most of the apartments. However, it can be challenging to find enough length on the site for the desired number of apartments. The volume-based on one unit (see chart C) and of two units (see chart B) will be investigated further.



ILL. 81. 1

This chart illustrates five strategies which can be applied to both volumes (see previous page chart B & C)

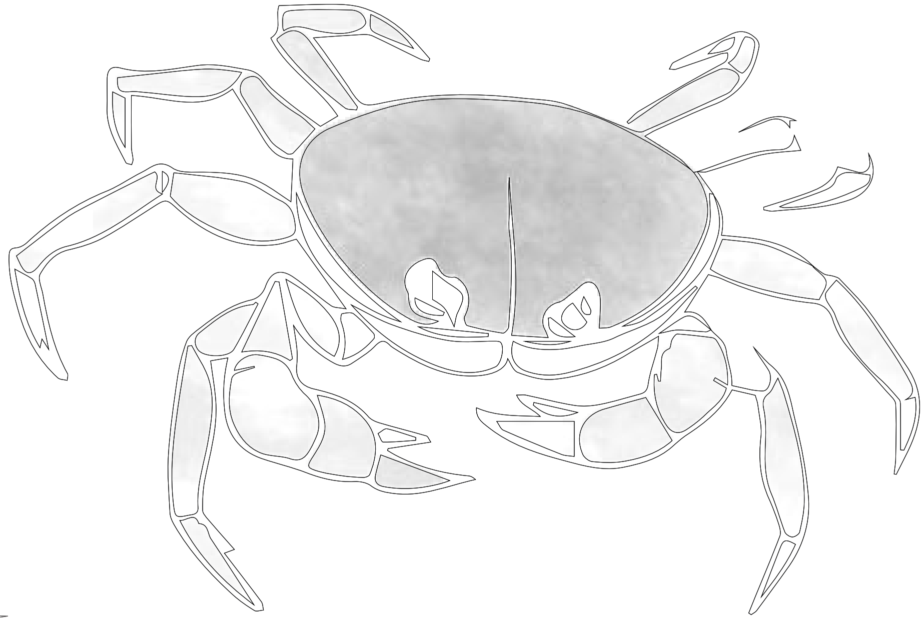
As seen on the chart the volume is cut into 5 "blocks" containing five different apartment stacks starting with the smallest and ending with the largest size. The five buildings can be up to 4 floors resulting in up to 20 apartments, to accommodate the economic requirements for the project.

The blocks are then displaced towards the west to open for direct daylight towards the south (as well as from west) while also sheltering from the north wind in the private as well as common outdoor space.

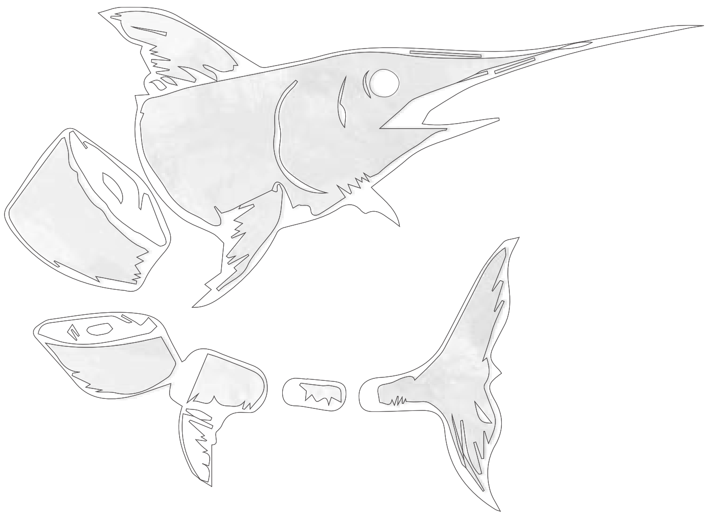
Rotation of the volumes forms a more dynamic appearance, more variations in daylight and view for the various building volumes, and perhaps a more natural shape (relating to nature). Furthermore, distortion of the volumes, allows the total surface area on the west of the building to become more substantial, and the east facade becomes smaller and wraps around the space, forming an intimate atmosphere on the back side (entrance to the apartments). On the front side, the direction of the view varies.

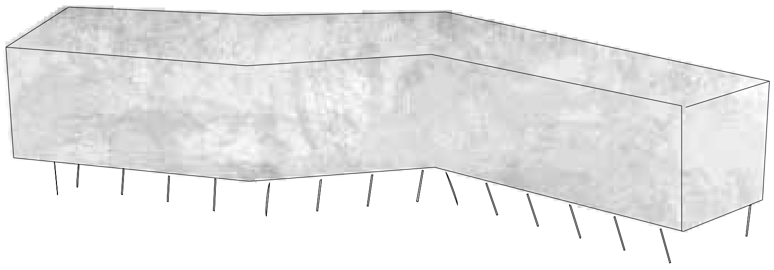
CONCEPTUAL IDEAS

The conceptual ideas based on a Nordic architecture approach where complimenting the landscape, and finding inspirational shapes in the surrounding context are presented.

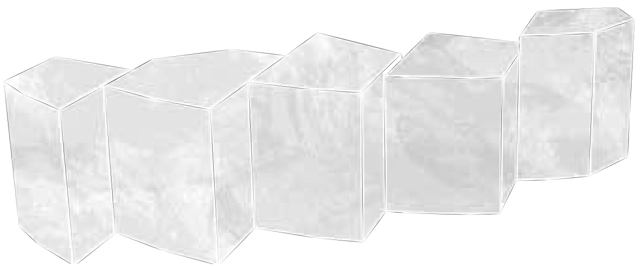


To contribute to the local fishing habits an inspiration coming from the fish is proposed.



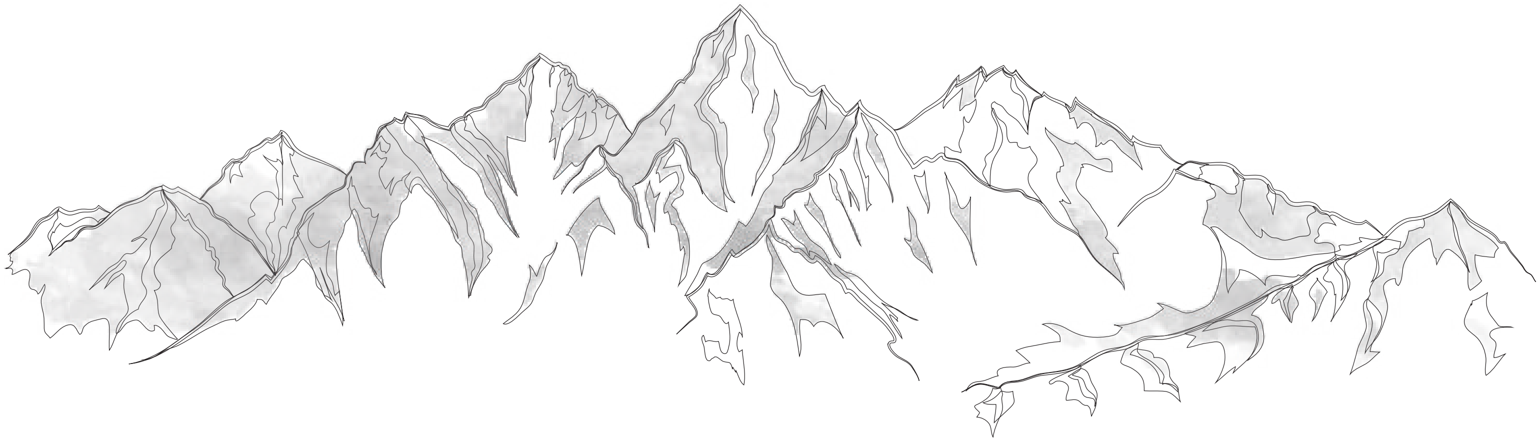


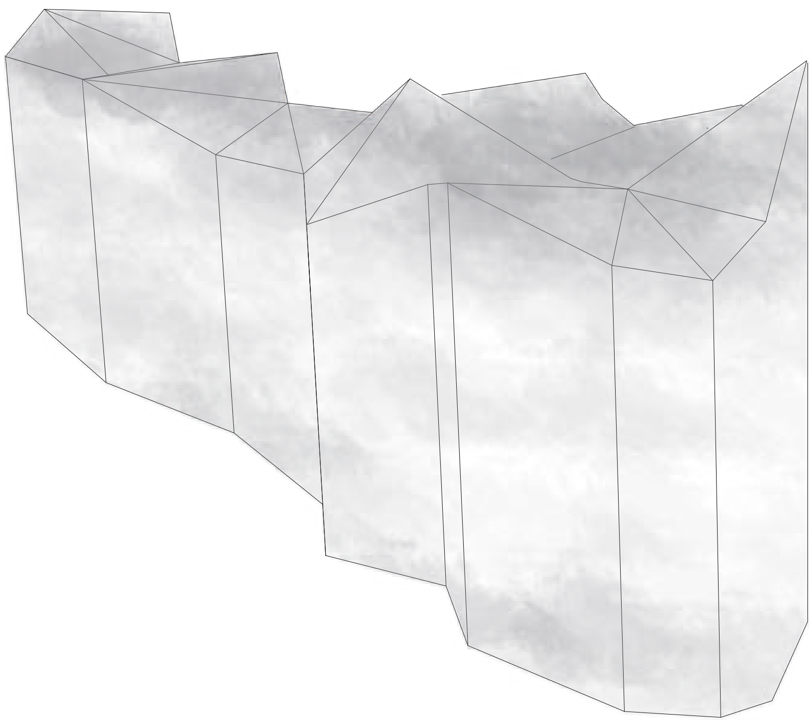
Another species that is often found in the fjord is the red king crab. The crab holds its heavy body weight with long red/brown legs.



ILL. 82. 1

ILL. 82. 2



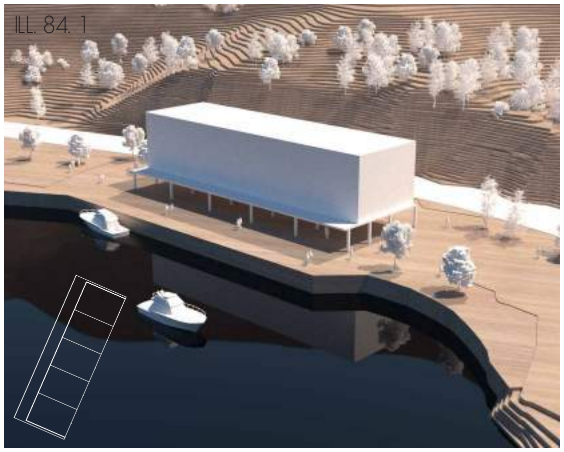


Many mountains are found in the Norwegian landscape that surrounds much of the land and forms peaks at the top.

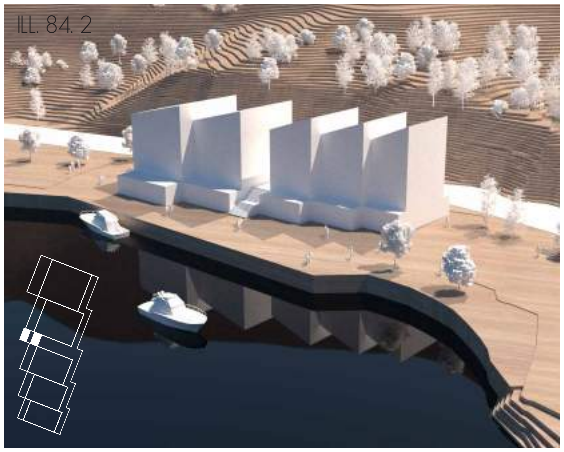
ILL. 83. 1

INITIAL MASSING IDEAS

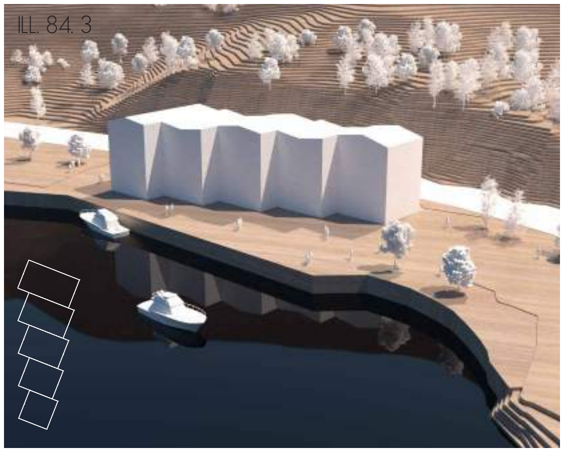
Based on the initial strategies several conceptual iterations are made, where considerations and inspirational elements lay the basis for numerous massing investigations. On this page, a selection of these massing proposals is presented and weighted on different parameters.



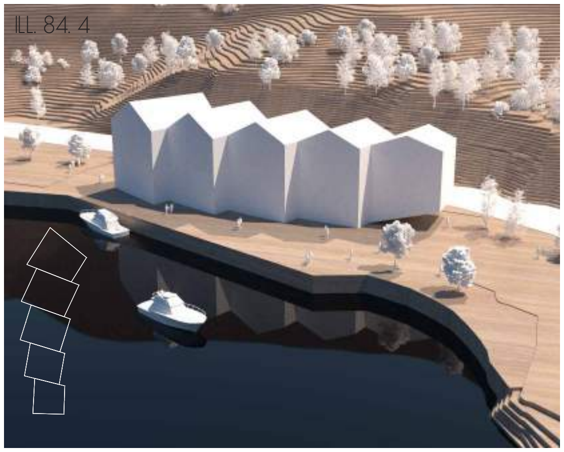
1. Provides covered outdoor space in connection with the harbor front as well as the possibility for covered parking.



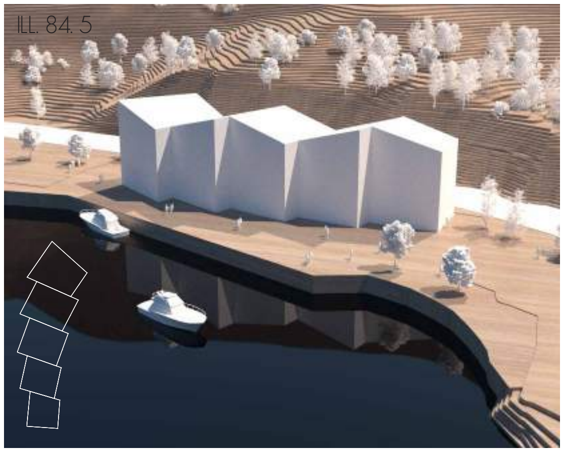
2. Elegant expression, with roofs that invites sunlight. The raised platform creates a semi-private space for inhabitants.



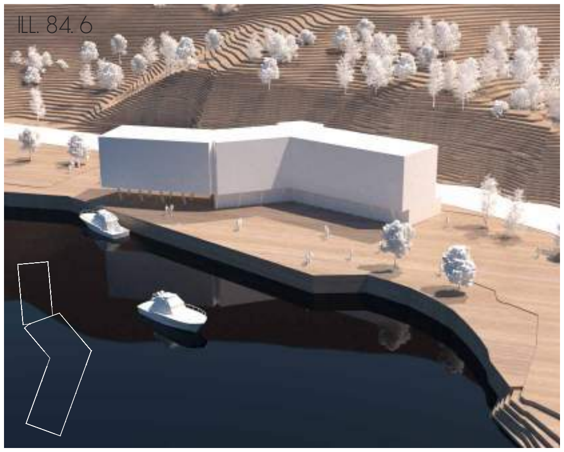
3. A more subtle expression inspired by traditional local architecture.



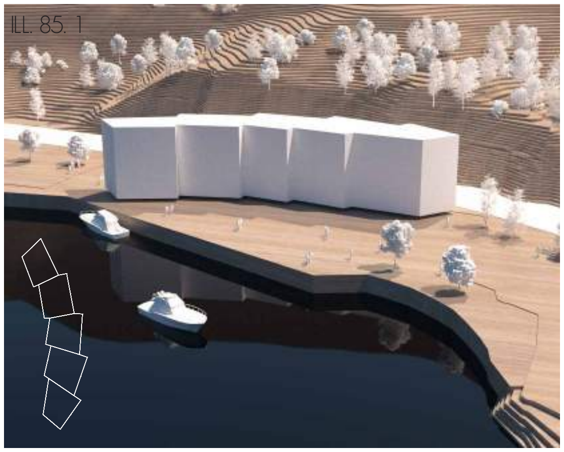
4. Takes inspiration in the traditional contextual shape with a modern twist.



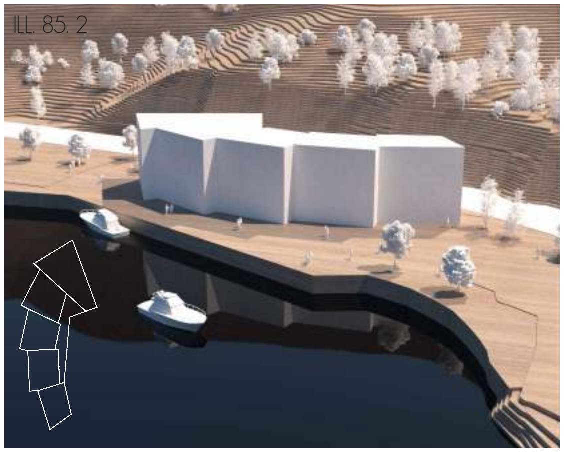
5. The design gives a dynamic interaction between landscape and building.



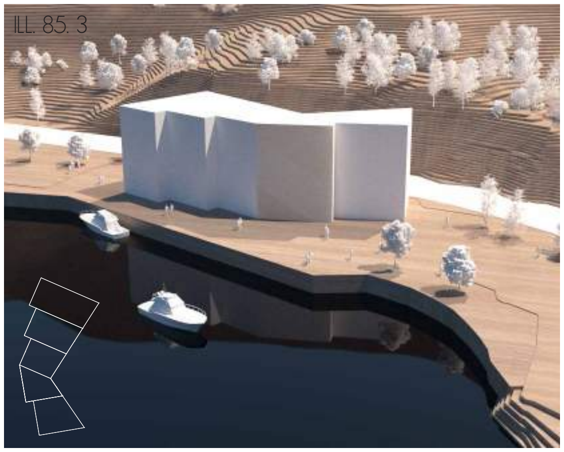
6. The shape is too strict in the landscape.



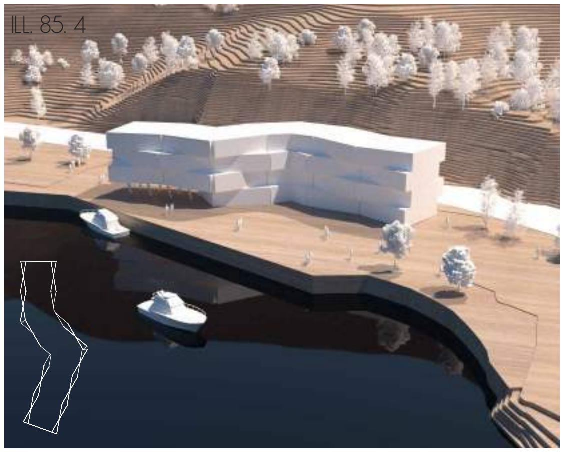
7. Embraces the outdoor space in front the building, forming a central gathering spot.



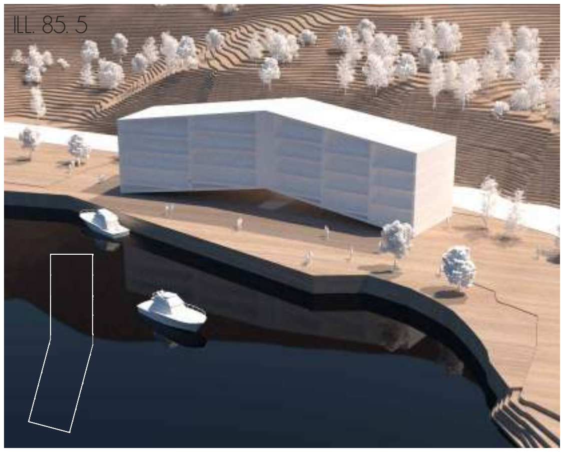
8. Embraces east side of the building and creates an intimate space.



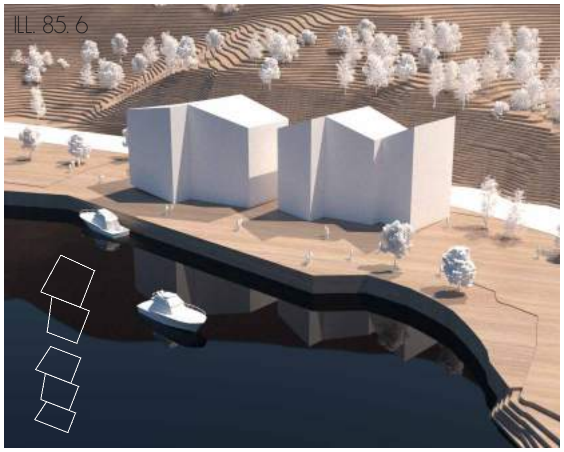
9. The building opens up and invites from north and south along the harbor.



10. The shape gives an organic ambiance. However, various spaces cannot be utilized.



11. Space beneath the building cannot be fully utilized.

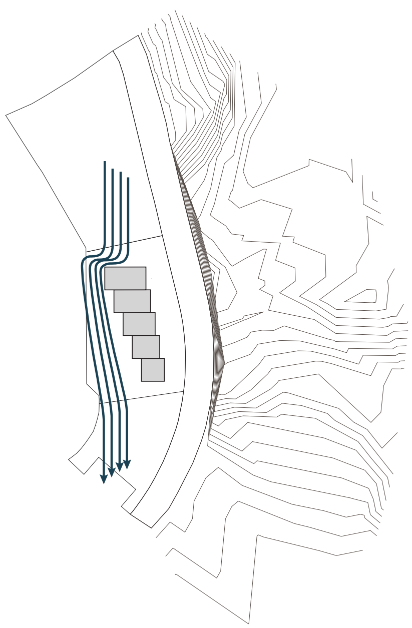


12. Makes a dynamism combining pitched roofs, shifting and rotating. Separating the center by offering a path in between west and east.

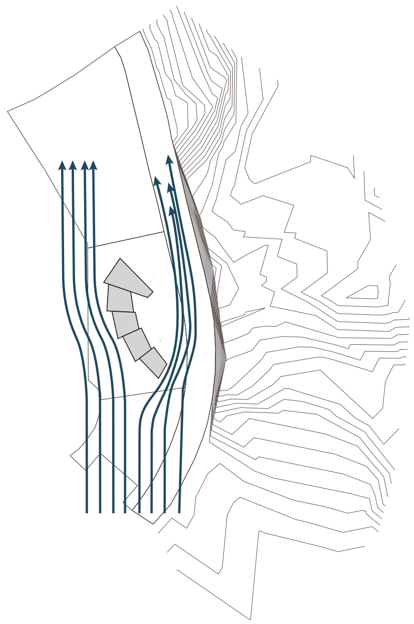
INITIAL MASSING - CLIMATICS

The various conceptual iteration is simulated and analyzed concerning their effect on daylight and wind. The iterations are all based on the same principle: dividing the apartments into five segments, and gradually shifting them towards west, starting from the south, the building opens up for direct sunlight from south on the shifted part of the western facades, and forms a sunny common outside space in front of the building. In terms of wind from the north, the shifted volumes form a partial shelter area for the common outdoor space, while the placement of balconies on the western facades are entirely sheltered, as illustrated on iteration A. The shape also protects from winds coming from south behind the building, forming shelter at the entrance side of the building, where the effect is further improved by distorting the building, by pulling the building together at the edges, as illustrated in iteration B. The common outdoor space is, however, exposed for winds coming from the south, and forms a dark area in between the building and the mountain towards east. The daylight conditions are adequately improved on the eastern part of the site by forming a gap in the center of the building, which opens up for daylight from west (see chart C). Furthermore, contrary to previous conjecture, a wind tunnel effect only occurs in heights above 10 meters in the formed passage, as a result of western winds, due to the 10-12 meter high rock formation behind the building. The rock wall obstructs the wind at heights below 10 meters, causing the wind to move around the building, where the terrain is lower. The knowledge gained from this chapter is kept in mind for the further development of the overall building shape and the balconies.

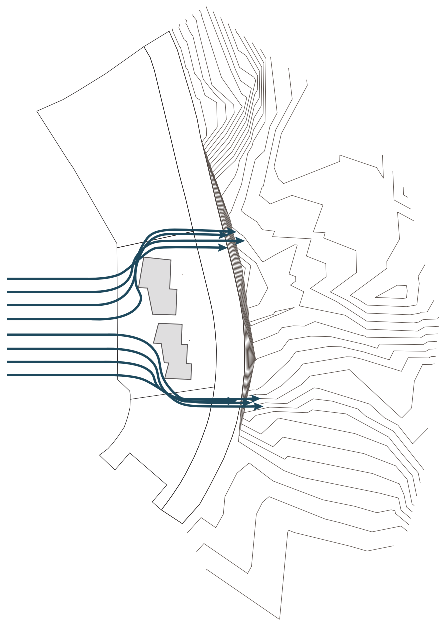
All results of these analyses can be seen in the appendix, in the chapter concerning initial sun and wind studies.



A

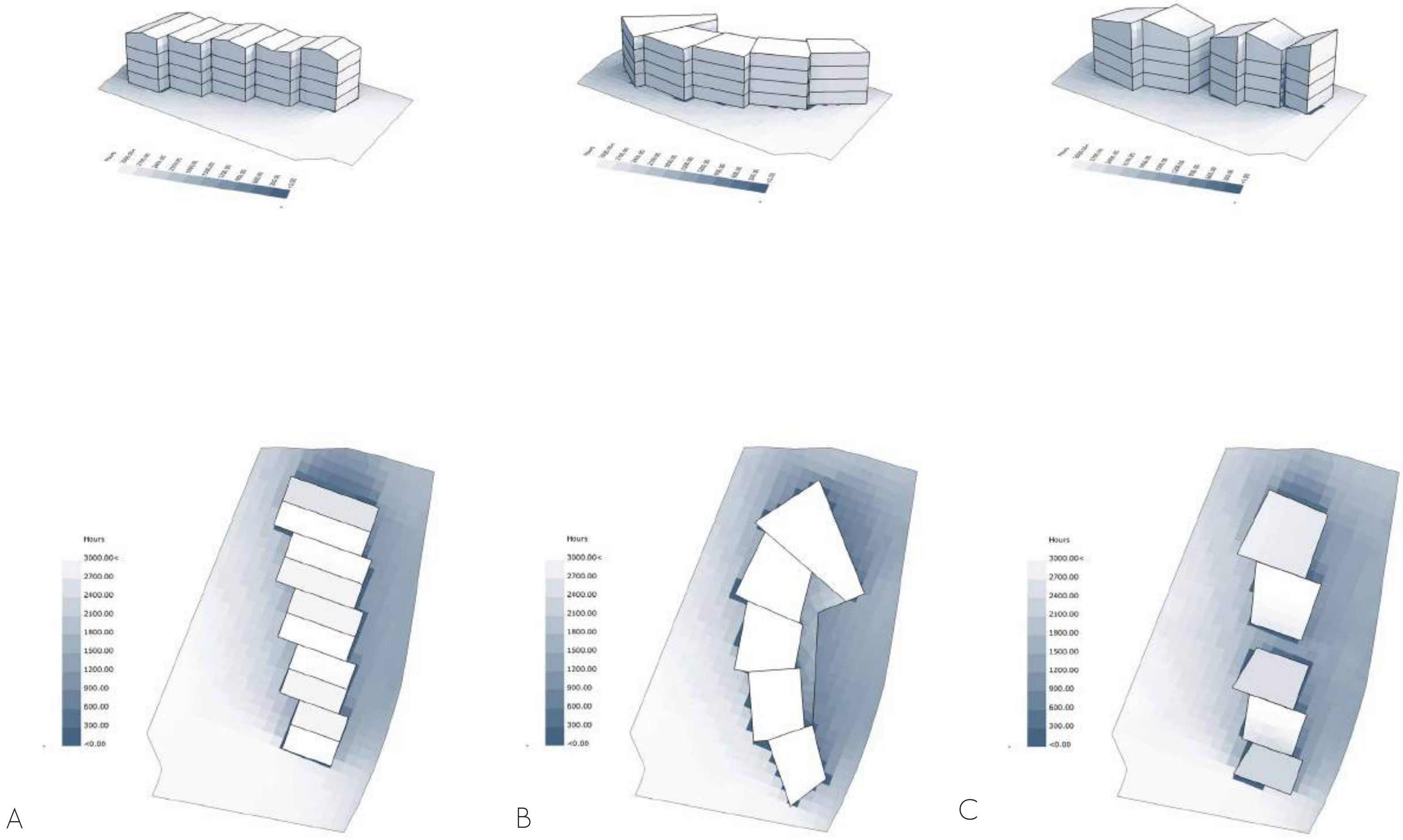


B



C

ILL. 86. 1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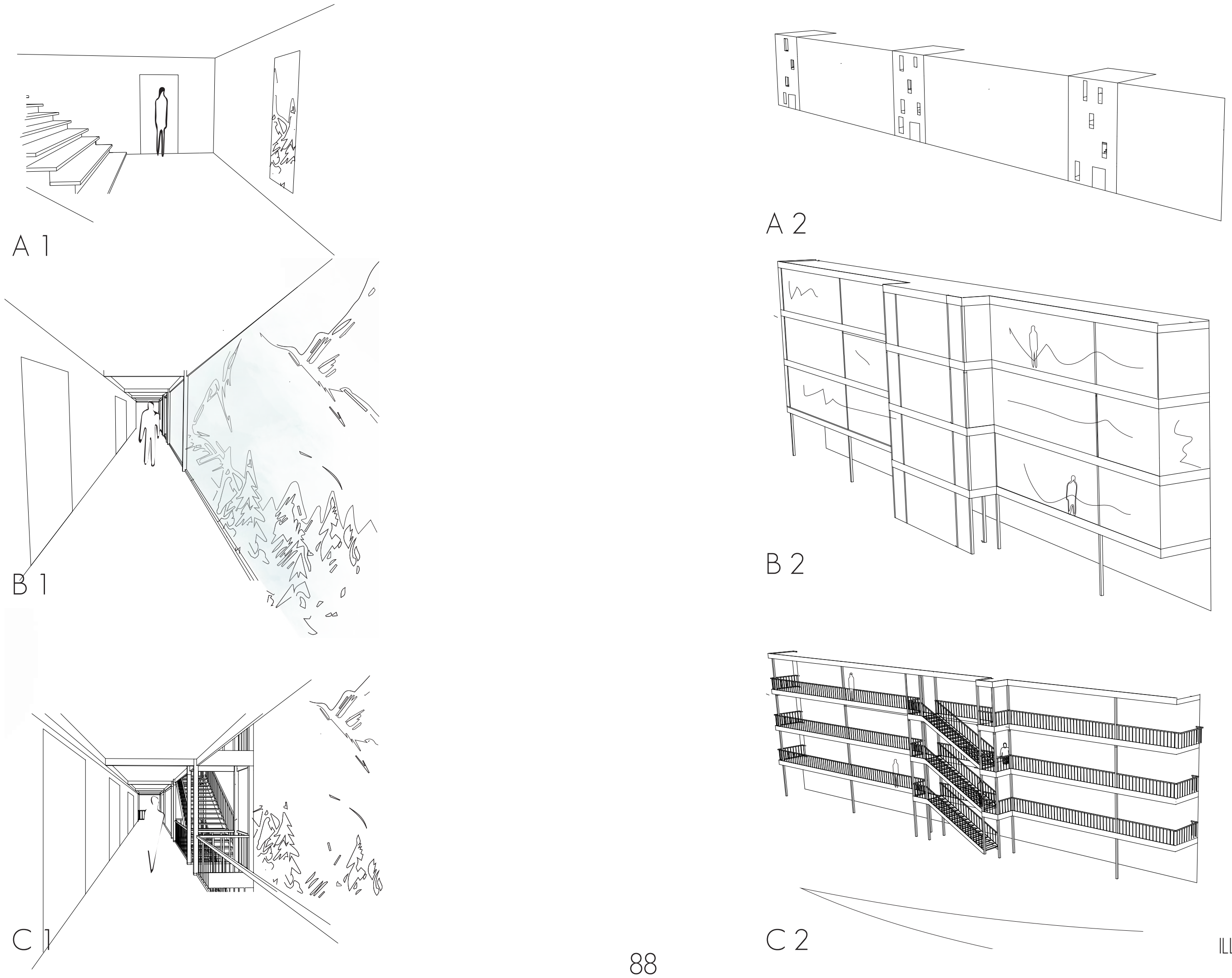
A
B
C

ILL. 87. 1

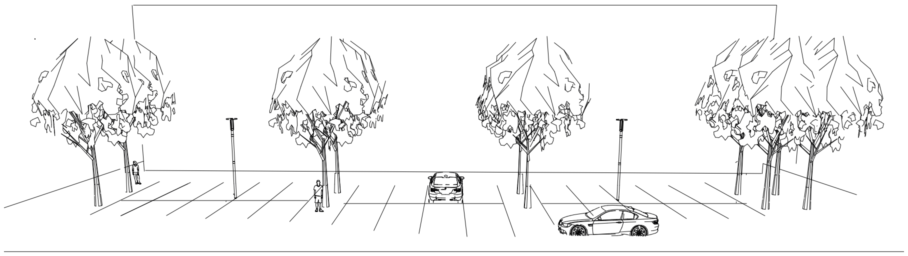
FUNCTIONAL IDEAS

Access conditions are examined through three classical staircase examples. The first example (see chart A 1 & A 2) consists of an integrated staircase with an elevator, which gives a holistic expression in the facade (see chart A 2). This method allows the staircase to be near each apartment, and users to be covered from bad weather. The disadvantage of using an integrated staircase is that the staircase, in general, is placed between two apartments per floor which will require three staircases and three elevators resulting in added material use and added cost. The integrated staircase can be applied for three apartments, meaning that the middle apartment only will be provided with one open façade. The second proposal (see chart B 1 & B 2) consists of a central staircase among a sealed gallery shared by an entire floor. Harsh weather will not be an issue; however, this method may reduce daylight, privacy, and natural ventilation. The third suggestion is a typical open corridor placed on the edge of the facade also is shared by an entire floor. The advantage is that only one elevator is required, however, is the user exposed to bad weather, noise and less privacy. To distribute users to the apartments, long slaps will be needed for strategy B and C resulting in increased material use and therefore do not sup-

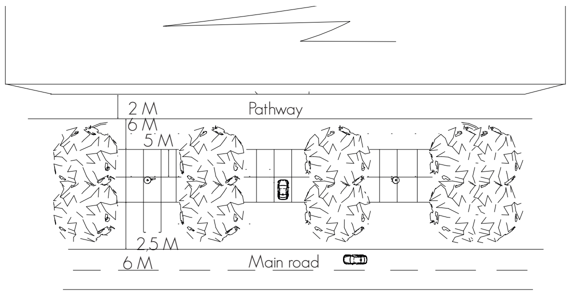


ILL. 88. 1

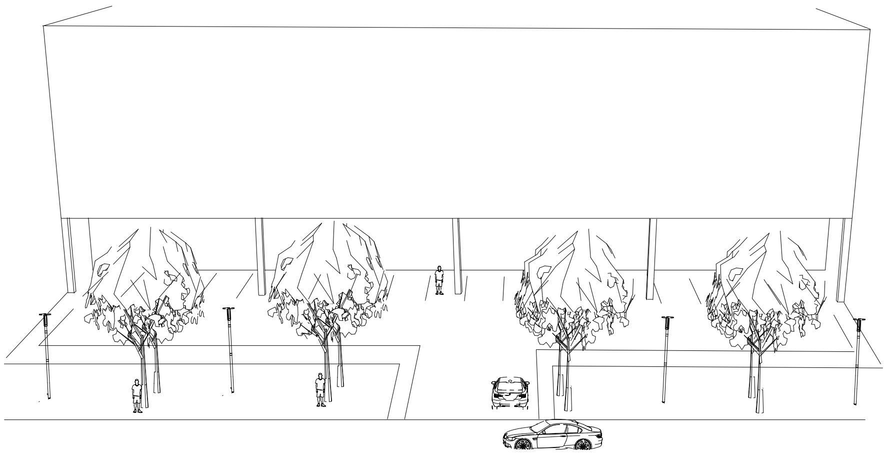
port a sustainable approach. The integrated staircase uses less material for slaps, and by placing one staircase between three apartments one staircase will be removed. To design towards sustainability, strategy A will be investigated further. It is required that each apartment has 1,5 parking space available, resulting in a requirement between 23-30 (15-20 apartments) parking spaces. As mentioned earlier in site considerations, the parking should be added towards the east, with the close connection to the main road. Two options have been established, where the first proposal (see chart A 1 & A 2) provides two lines of 14 parking spots with space for walking between the parking spaces, giving a total amount of 28 cars. This setup will cover the building with parking and provide less opportunity to create green areas, space for other functions and vehicles will not be sheltered. The next proposal (see chart B1 & B2) uses half of the bottom floor from the building to feature parking, and remaining more space for green areas, however, this solution will only provide 16 parking spots. The preferred proposal is to use strategy B, regarding space to create green gathering spaces for the users to support well-being and social sustainability. The parking solution will be developed further on page 98.



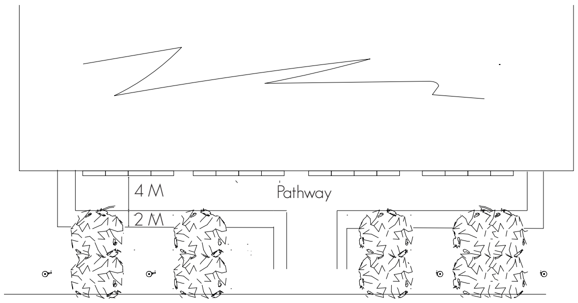
A 1



A 2



B 1

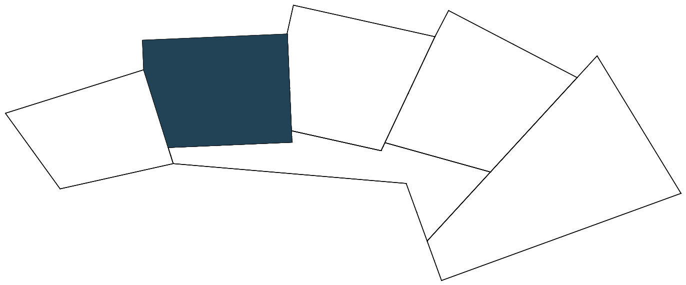


B 2

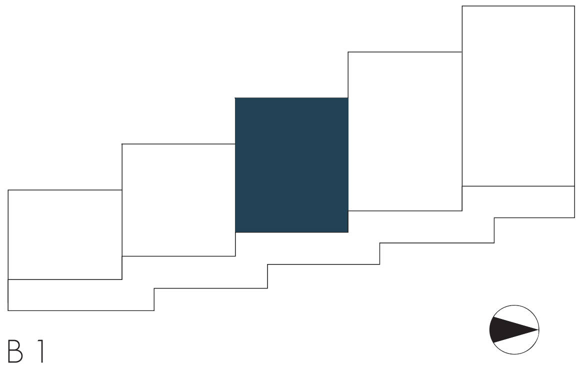
ILL. 89. 1

PLAN DEVELOPMENT

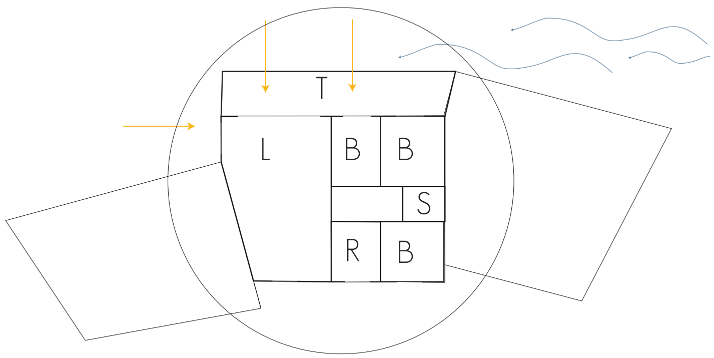
To create apartments with the desired qualities plans are investigated. In the appendix a table shows which significant parameters are emphasized, which among others includes good daylight conditions and natural ventilation. The first chart (see chart A 1) illustrates a broad floor plan which more likely will be able to let daylight penetrate into the apartment as the plan is wider than it is deep. The same plan solution also provides a good opportunity for placing bedrooms on the west facade as the plan makes room for it. Natural ventilation is easier to integrate as the depth is shorter which will provide a good air flow. On the next floor plan (see chart B 1), which is narrower and deeper, most of the function with the need of daylight are placed towards the east and west facade in the apartment. Natural ventilation may be difficult to achieve based on the long and narrow plan. The next step is to investigate whether there is enough space on the site to apply the broader apartments.



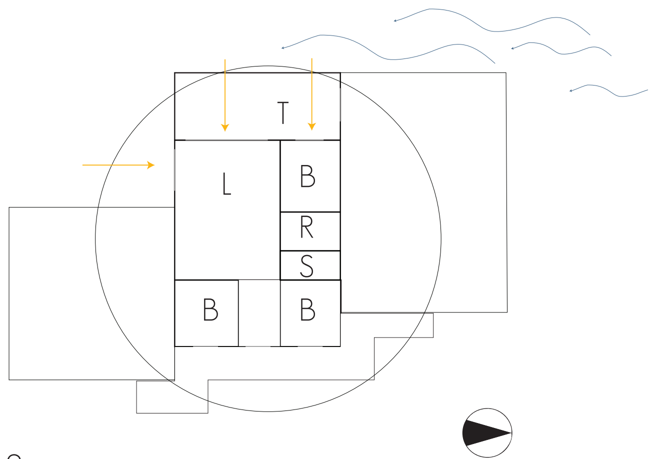
A 1



B 1



A 2



B 2

ILL. 90. 1

SUMMARY

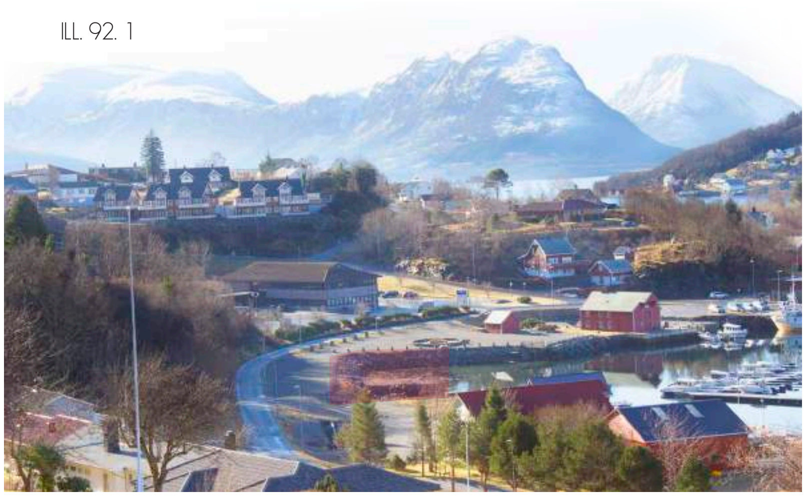
The initial investigation of the process leads the project towards following focal point for the coming site visit;

- Shelter from wind by shifting building
- Rotate and shift building to open up for south
- Centralize view towards the harbor
- Connect frequently used areas (shopping & marina)
- Create a gathering spot with daylight
- Consider a design volume with least amount of surface
- Find inspiration in nature - Nordic architecture
- Use integrated staircase (three apartments sharing)
- Place parking under the building to enhance common spaces
- Reach for a wider plan solution

SITE VISIT

During the initial phase, a visit to the site was organized. This text is a intermediation of the sensuous experience during the site visit. Norway, breath the ambiance and let the senses guide the walk. When approaching the site, titanic mountains reveal themselves. They are the figures of bigness, dynamism, and power of a majestic and scenic nature. The pebbles dried by the sun, squeak under the feet while a deserved 3600 look is taken. The portrait of this nature reflects on these inhabited crystal-clear waters, carrying the animated expression of the human presence. It is a precious spot for the locals, that gather to spend a sunny afternoon in the company of friends, close to their cherished boats. At the same time, a discrete breeze channeled by the narrow fjord blowing the hanging leaves of the trees that climb the rocks in the background. This peaceful hamlet and the landscape hugging it all around, are undoubtedly part of the realm of tranquillity and silence. Only the sound of nature can be heard, and it is so beautifully overwhelming that hearing your own breath can feel disturbing. The more the look directs up, the more the flora changes; from the evergreen trees longing the fjord, then to the coniferous and finally to the smaller shrubs timidly dressing the summits of the mounts. A shy but inflamed light awakes the entire area and touches the wooded skin of the nearby vernacular architecture, defined by colorful houses and the white boats. A wounded mountain behind the site: it is the home of the chirping birds, exploiting the small cracks and openings on the mineral element to conceive a nest.

ILL. 92. 1



ILL. 92. 2

ILL. 92. 3

ILL. 92. 4

THE ROCK

The concept is simply but efficiently drawn from the previous studies. Mass studies, local plan regulations, the importance of the artificial and natural context notably, the economic activity and environmental sustainability, the well-being, the functional demands as well as the climate; they are the bricks that one upon the other, build the concept. But the most important feature influencing the spawning of the concept here is laying on an approach that is typical of the Nordic Architecture: the one of admiring Nature. The surrounding rock formation behind the site is analyzed (see picture below), an idea comes to mind:

The wounded mountain. A piece of the rock formation has been removed at some point (exploded) to form the space to host the road. This force created by the man leads to the concept; give the missing part of the wounded mountain back in the form of architecture, shaping a natural element, where materiality and textures will be considered as a reminder of the significant rock taken away from this stunning landscape.

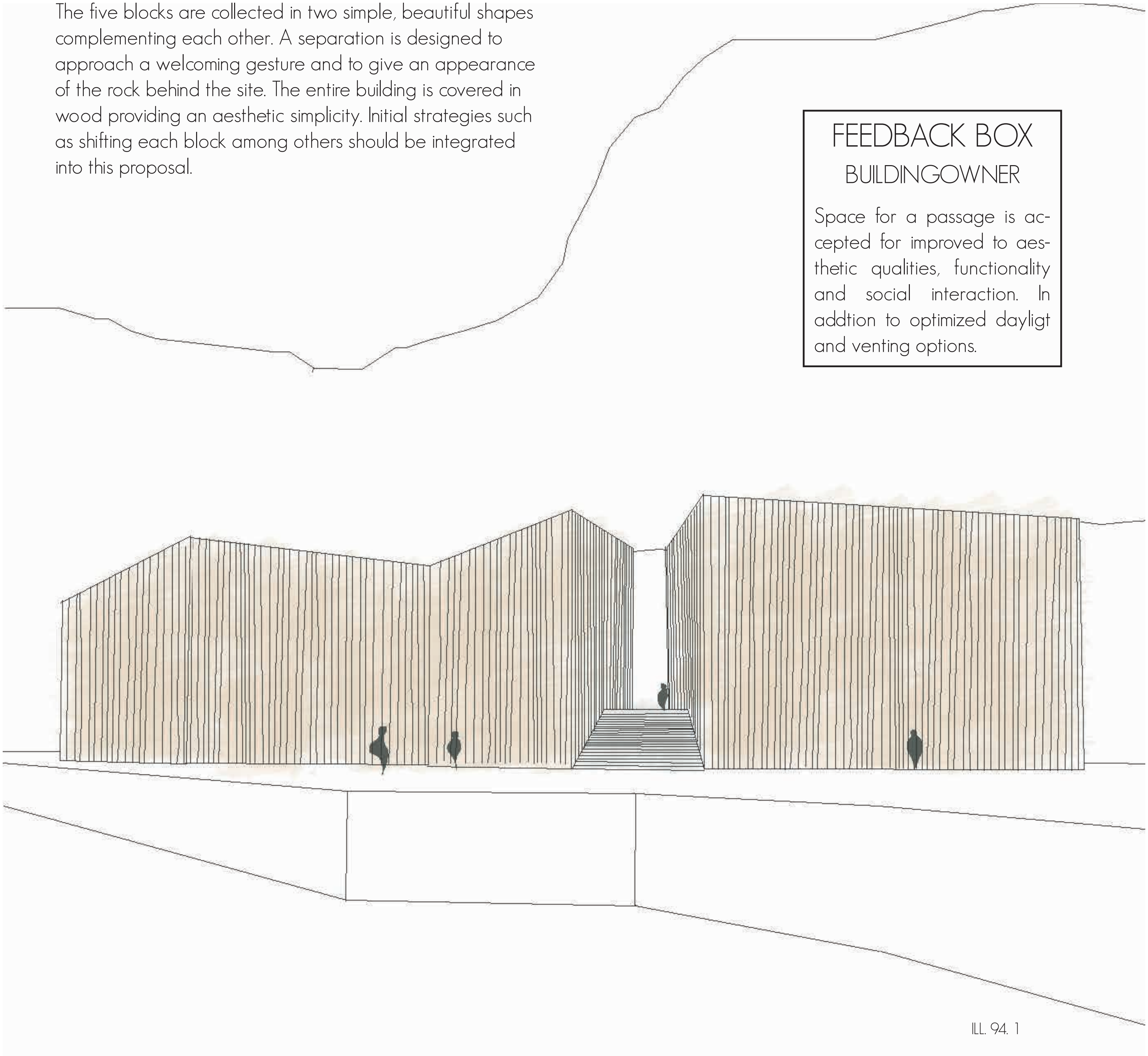
ILL. 93. 1

CONCEPT PROPOSAL

The five blocks are collected in two simple, beautiful shapes complementing each other. A separation is designed to approach a welcoming gesture and to give an appearance of the rock behind the site. The entire building is covered in wood providing an aesthetic simplicity. Initial strategies such as shifting each block among others should be integrated into this proposal.

FEEDBACK BOX
BUILDINGOWNER

Space for a passage is accepted for improved to aesthetic qualities, functionality and social interaction. In addtion to optimized dayligt and venting options.

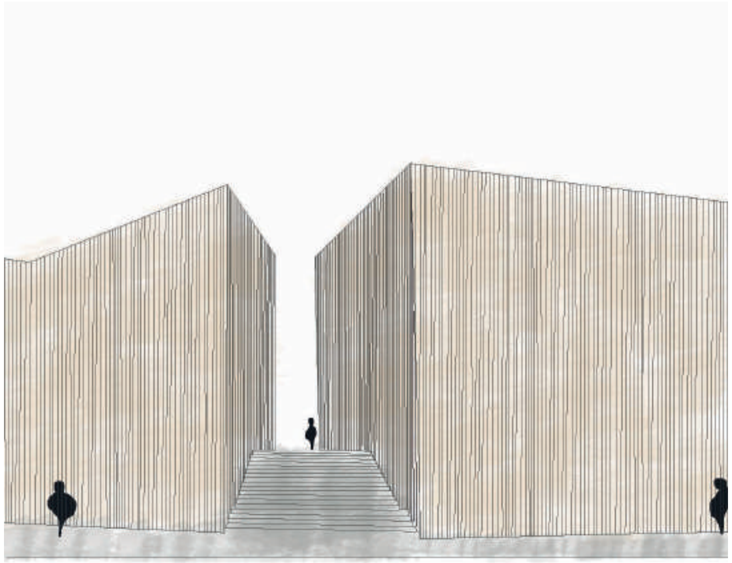


ILL. 94. 1

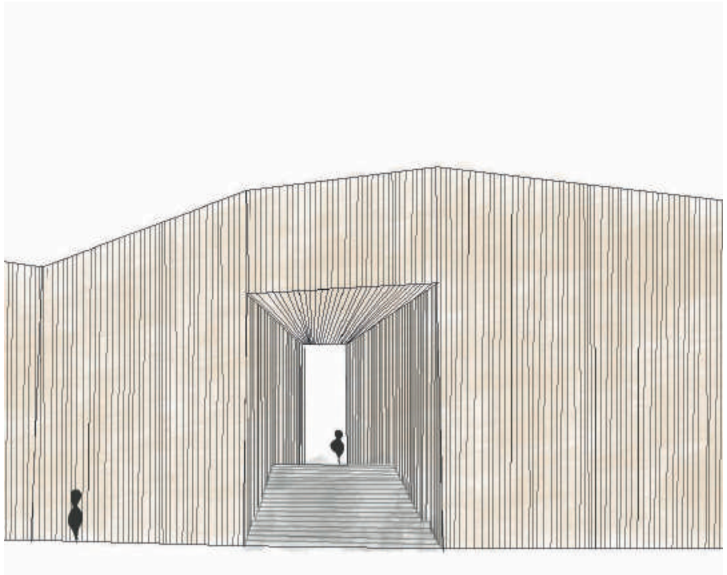
FURTHER DEVELOPMENT

The passage makes an opportunity to raise a level by adding a platform (see charts below). This elevated passage provides at common gathering space for residents, which is covered from wind arriving from the south and raised from noise. The platform offers an extension with the passage sunlight during midday and holds parking area beneath. By adding the platform, the lowest apartments (under the platform) will not be able to use the façade next to the parking, which provides most of the lower apartments with only one open façade.

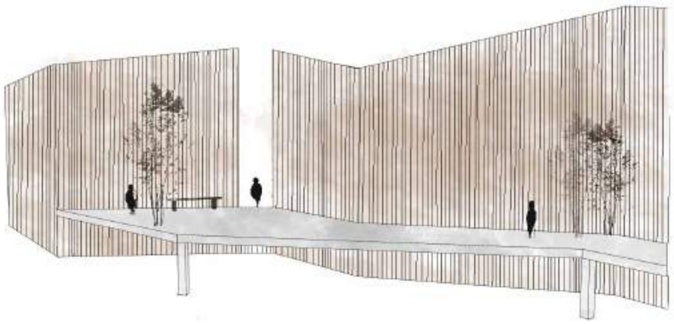
Two examples of the passage are presented (see chart A 1 & B 1). Option A 1 illustrates an entirely open space between the two buildings. This solution provides the common area with more daylight, and aesthetically visualizes a sharp cut. The second opportunity gives space for one additional apartment which is placed between the opening of the passage. This solution may result in poor daylight for the platform, reasoned by blockade of direct sunlight at the top. Solution A will be investigated further.



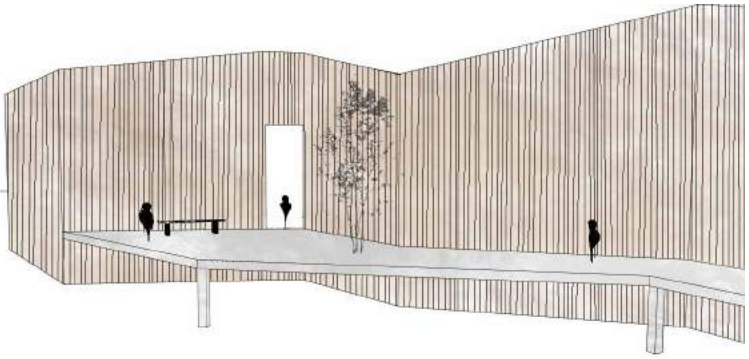
A 1



B 1



A 2

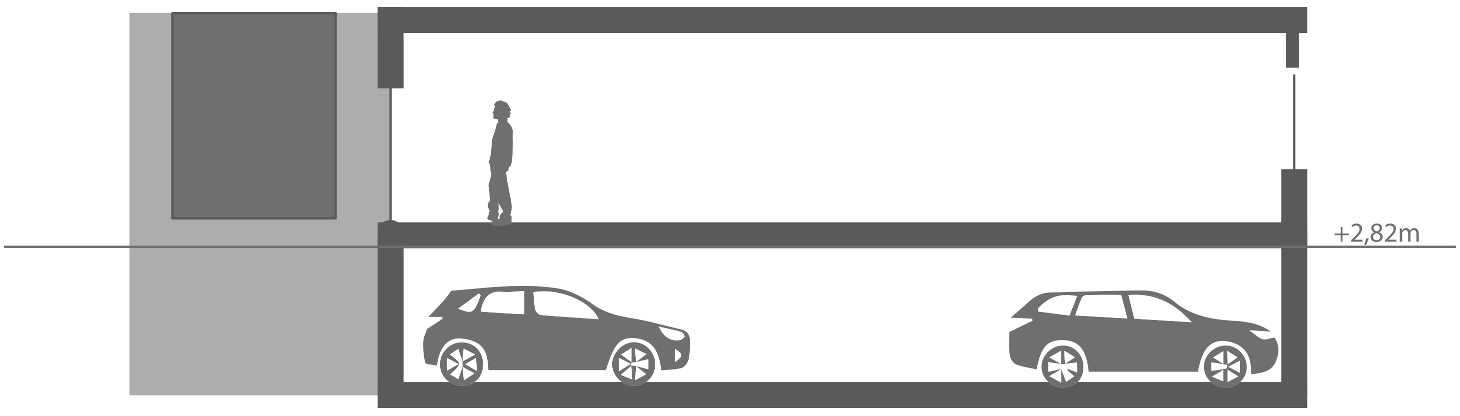


B 2

ILL. 95. 1

PARKING DEVELOPMENT

After careful research, new knowledge of the applicable rules about parking, reveals that parking is not included in BYA (build area) as long as the structure does not exceed 0,5 m above the average terrain level. This new knowledge means that the parking can now be placed beneath the building, creating new possibilities for the utilization of the previous occupied space.



ILL. 96. 1

PLAN DEVELOPMENT

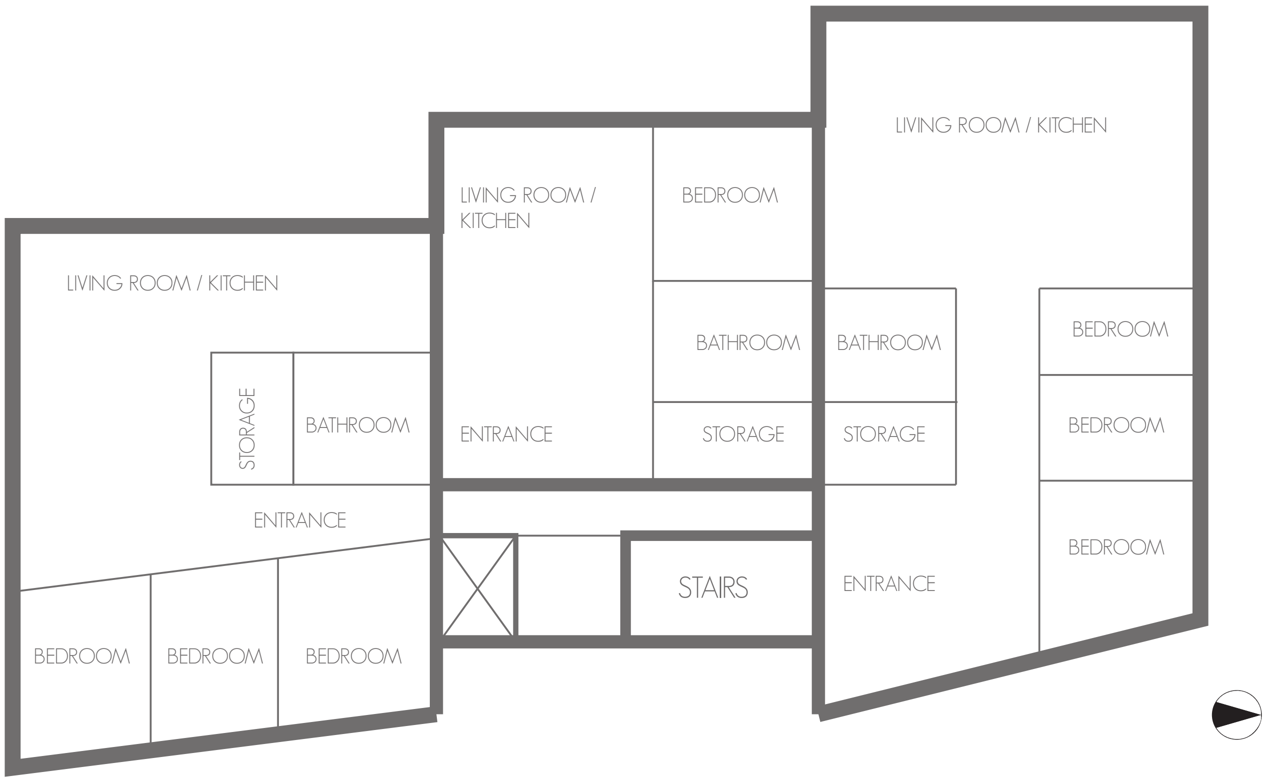
As mentioned in conceptual ideas by placing three apartments next to each other with one central staircase, the middle apartment will be affected. As illustrated in the plan below, it is seen that the staircase blocks the whole east facade of the middle apartment. The apartment in the middle must contain a bedroom which requires daylight, forcing it to be placed towards the west facade. Simultaneous there will be little opportunity for cross ventilation throughout the apartment in connection to atmospheric and thermal comfort.

FEEDBACK BOX
BUILDINGOWNER

Apartment sizes can be upgrated to accommodate potential buyers wishes.

FEEDBACK BOX
REAL ESTATE AGENT

Potential buyers prefere, apartments above 100m^{2}, with living room and kitchen in one open space towards sea view.

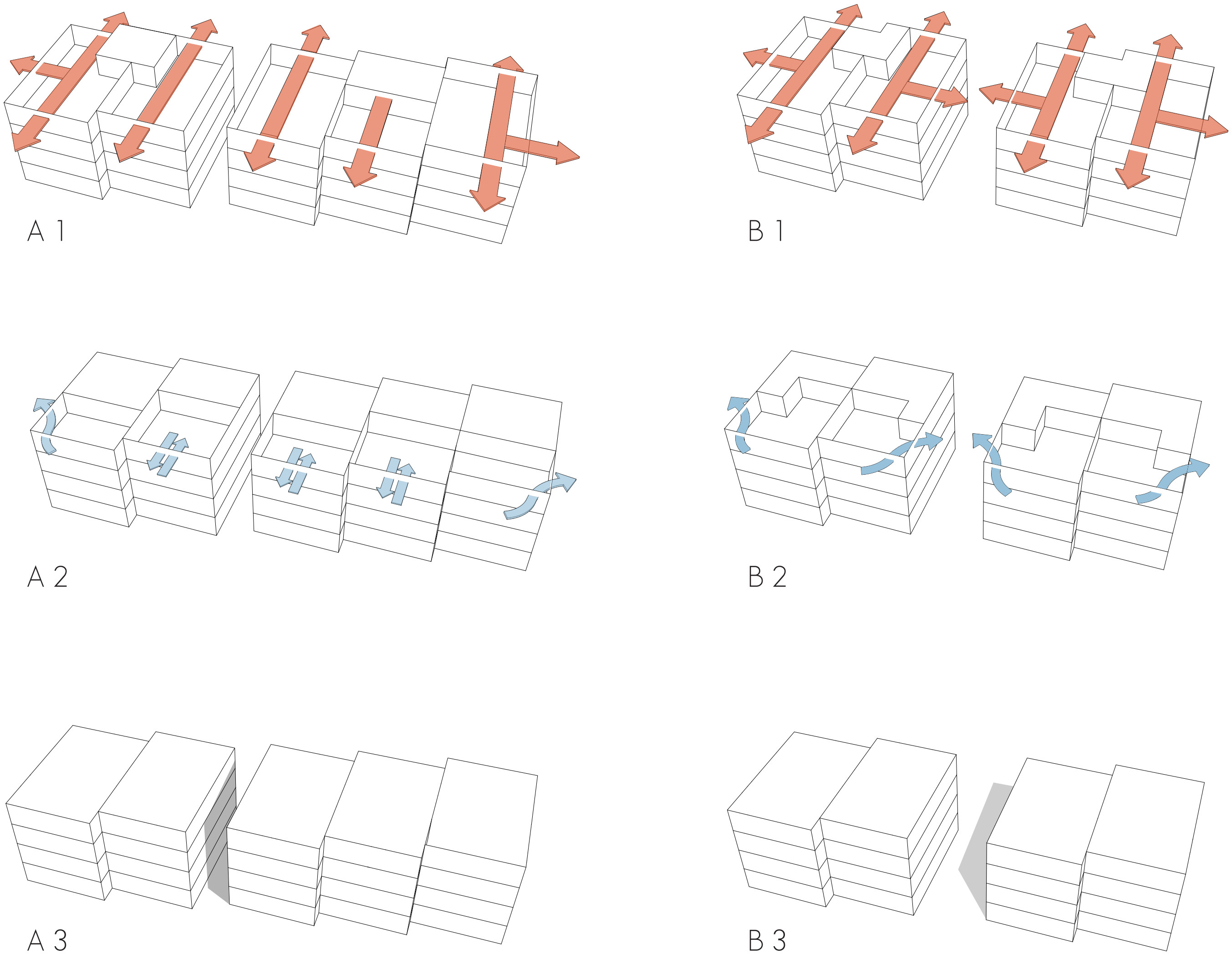


ILL. 97. 1

PLAN DEVELOPMENT

After careful consideration, it is concluded that the middle apartment performs too poor concerning daylight and ventilation. As seen on the charts A & B, two situations are illustrated. The diagrams A illustrates five stacks of apartments and the diagrams B four stack. As shown in diagram A 1, the two end apartments allow three open facades, whereas the two apartments meeting the passage only have two (too expensive to install fire windows) and where the middle apartment has one. Due to a vulnerable middle apartment, a situation without it is visualized. When removing the middle apartment, more space on the site is received, which allows the passage to have a distance of 8 m between the two buildings. This results in the walls to be established without fireproofing, and thereby windows can be added.

With the possibility of more openings, natural ventilation will also be optimized, as cross ventilation can be introduced instead of the single-sided ventilation. Diagram A 3 shows a narrow dark passage nonetheless, creating 8 meters distance between the buildings, the passage receives more daylight.



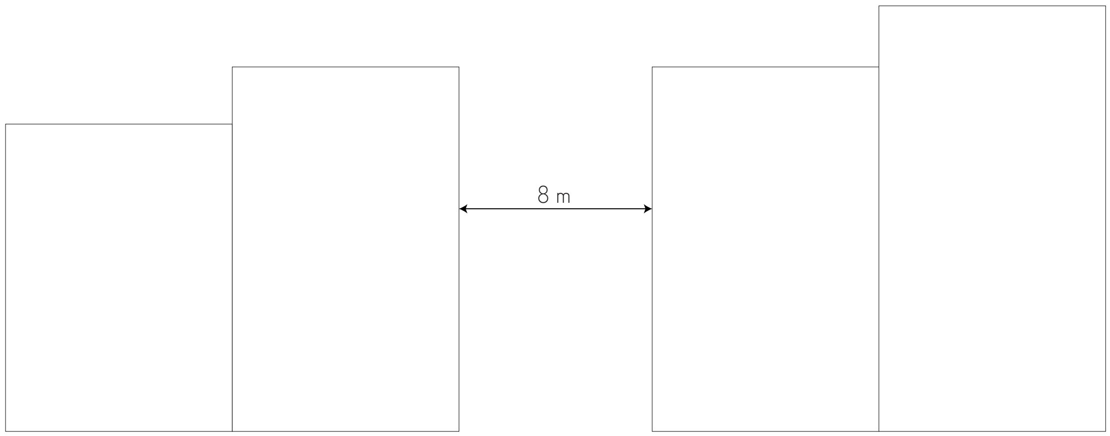
ILL. 98. 1

With a block removed, the design must be optimized in relation to floor plans to be worked in correlation with ventilation, view, staircase, distribution of rooms and daylight.

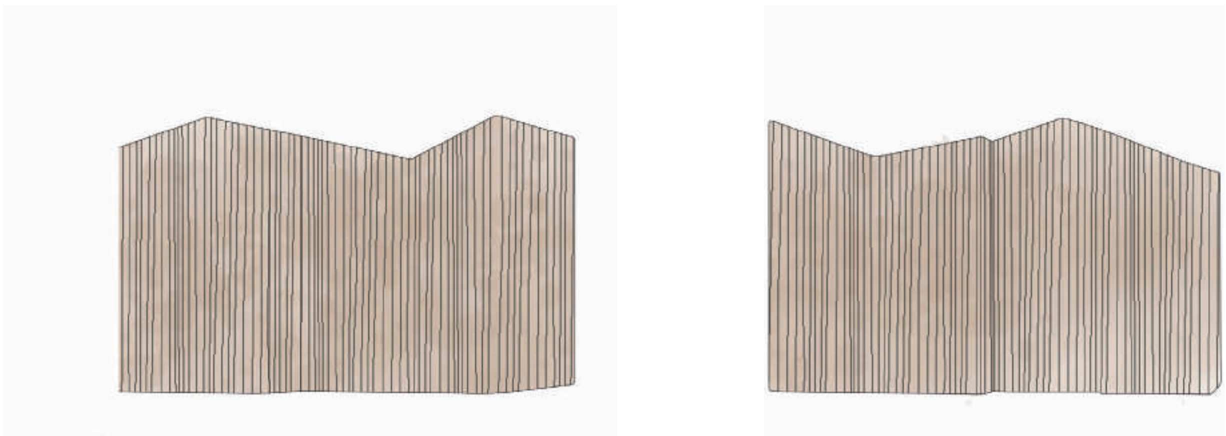
FEEDBACK BOX

BUILDINGOWNER

Removing middle block (four apartments) is acceptable due to low interrest in limited conditioned apartments from potential buyers.



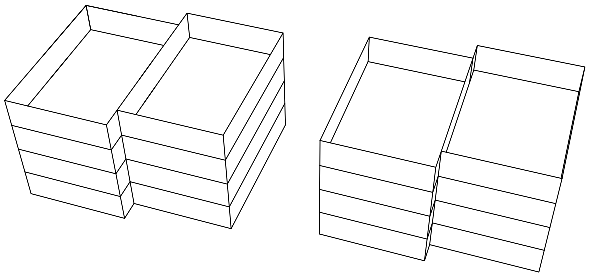
ILL. 99. 1



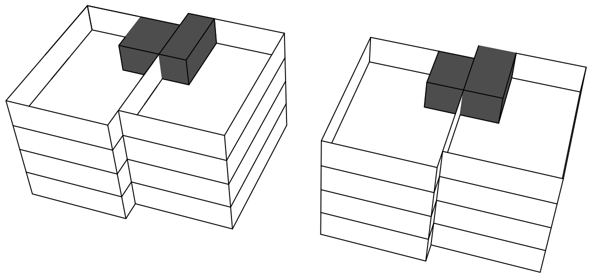
ILL. 99. 2

FURTHER PLAN DEVELOPMENT

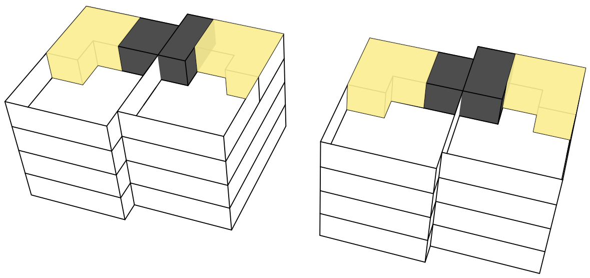
The four blocks are modified where following elements are added; A. The four blocks stand side by side with a displacement to open daylight. B. Two integrated staircases are added which is located between the apartments. C. Bedrooms are placed at the rear of the apartment with access to daylight. D. 4 m2 storage space is placed against the closed facade. E. Bathrooms are situated centrally in the apartment with the possibility of daylight. F. Living room and kitchen are located facing the sea view. G. Kitchen is moved to bathroom wall to reduce the number and length of pipes. H. Windows is added to form cross ventilation.



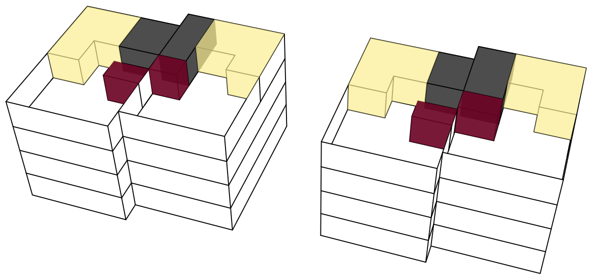
A. Four blocks



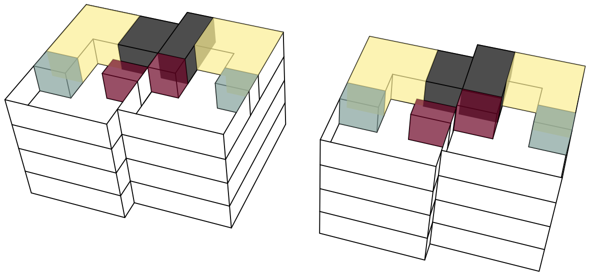
B. Staircase



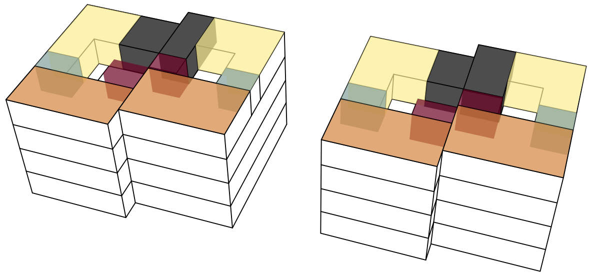
C. Bedrooms



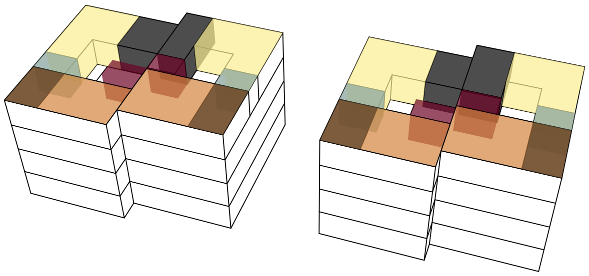
D. Storage



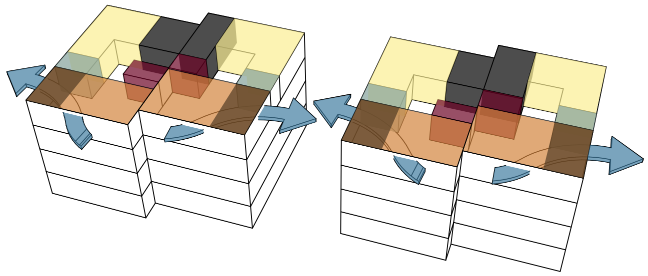
E. Restroom



F. Livingroom



G. Kitchen



H. Cross ventilation

ILL. 101. 1

ROOF DEVELOPMENT

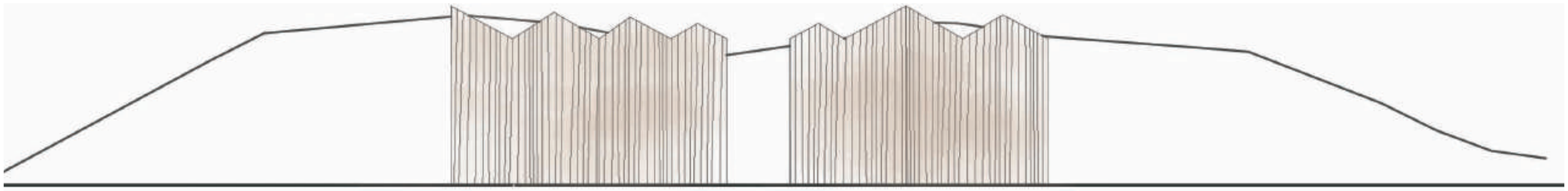
Processing the roof in correspondence with the local plan some difficulty may occur. As mentioned in the local plan, the maximum height of the roof is 17 m above sea level if designing a pitched roof with angles between 28-35 degrees, and 16 m above sea level if designing a flat roof. As shown in the drawings A 1 and A 2, by following this limitation, several small pointed roofs will take place which will give the design a chaotic aesthetic expression. It is chosen to deviate from the local plan's references of the angles as it is "discovered" that there is a high probability of seeking dispensation for changing the angles as long as the maximum height is not exceeded and thus does not bother other houses over 17 m above sea level. Iterations of the roof without regard to the suggested angles is processed (see next page diagrams A-H)

FACT BOX

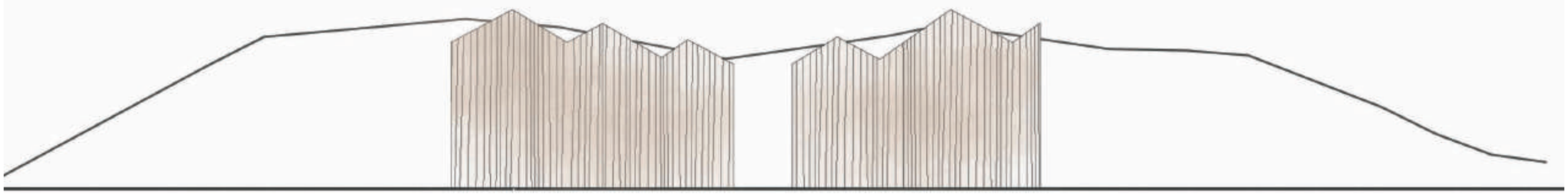
BUILDINGOWNER

Deviation of local plan, according to roof inclination, is approved. The buildingowner, expects to get approval from the municipality

With this knowledge, the proposal from chart E, is chosen for further development, as corresponds very well with the desired concept for the project, with a shape being derived directly from the cliff behind the site.

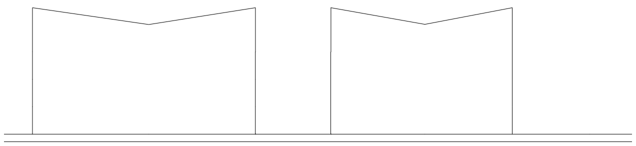


A 1

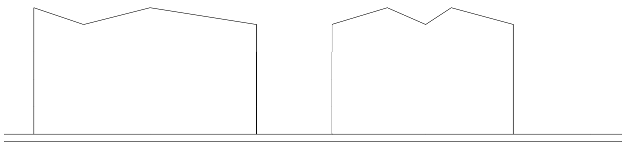


A 2

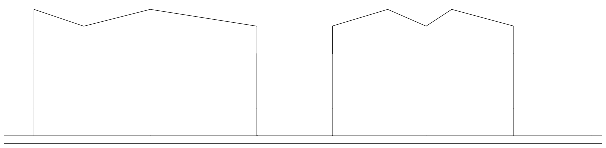
ILL. 102. 1



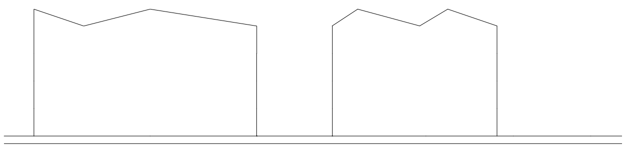
A



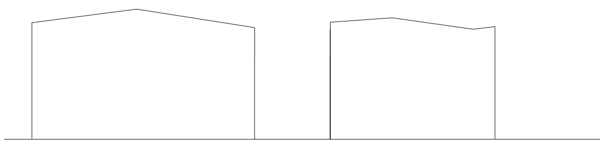
B



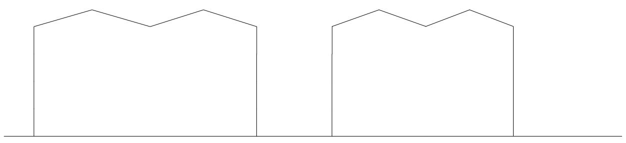
C



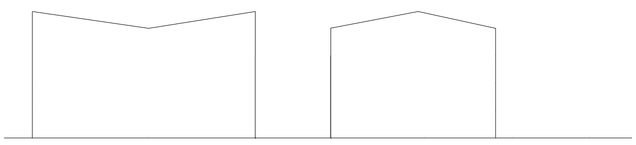
D



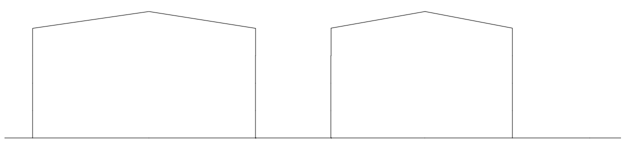
E



F



G

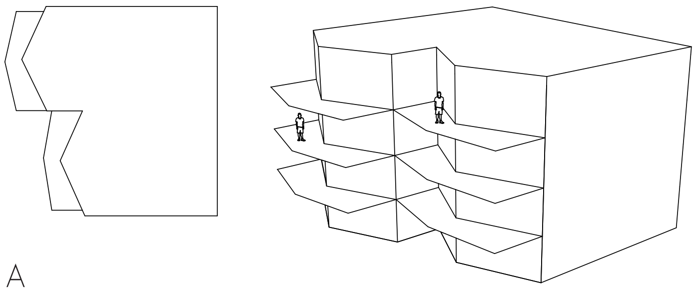


H

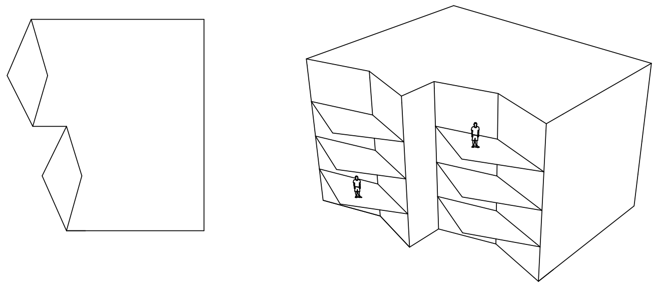
ILL. 103. 1

TERRACE SHAPE DEVELOPMENT

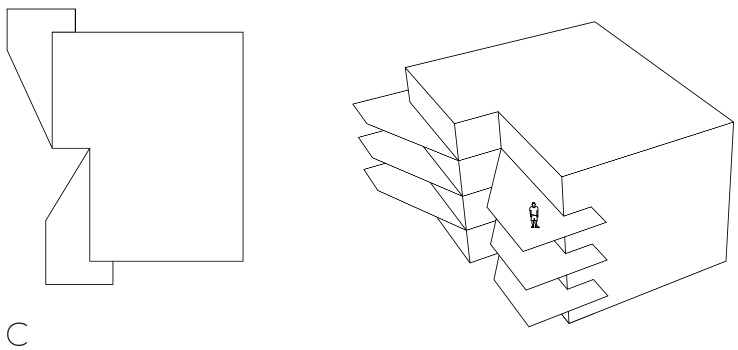
As it is a goal to shape the teracces to reflect the rockformation initial shaping concepts has been developed. A few of them are selected for further integration in the design process of the teracces. The selected conceptual ideas are; B, C and E.



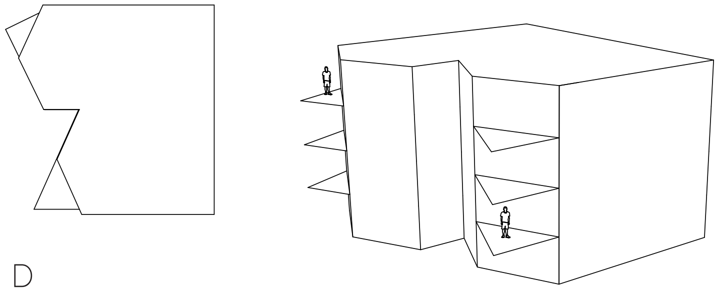
A



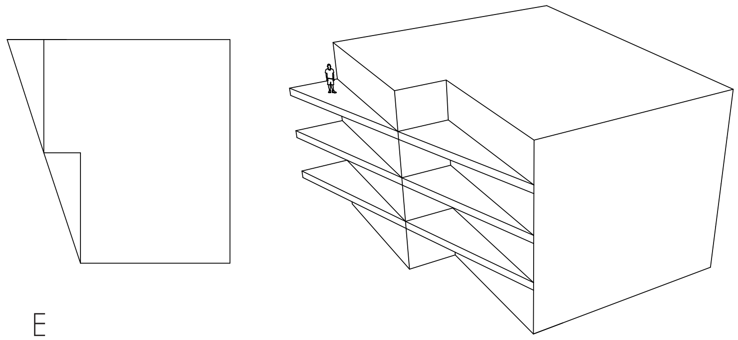
B



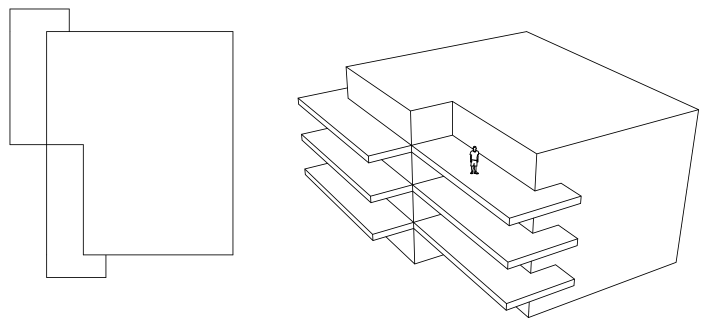
C



D



E

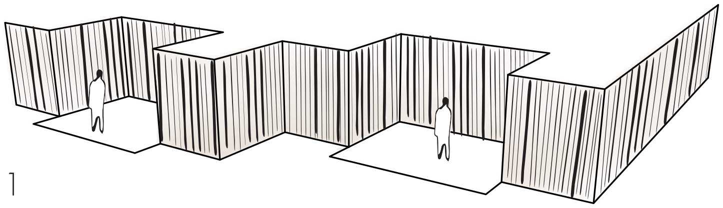


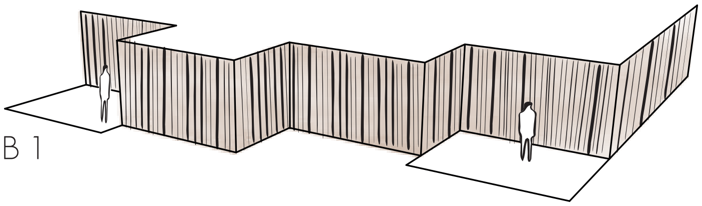
F

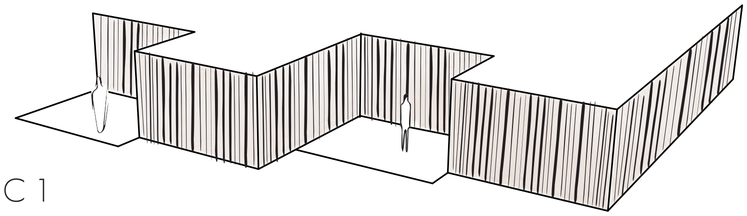
ILL. 104. 1

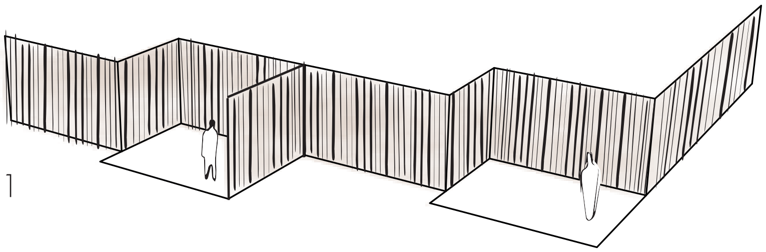
TERRACE PLACEMENT DEVELOPMENT

The terraces are placed on the western facade of each apartment in order to optimize the daylight conditions, and to offer a view towards the harbor. To avoid disturbs from nearby apartments, several iterations are made regarding the placement of the terraces. Chart A distributes the terraces in the middle of the apartments, which forms two small spaces for the livingroom and kitchen, (see chart A 2) with limited functionality. Design B1 (see also B 2) offers a suitable space for the kitchen/dinning area. However, the living/dining area shades for the direct sunlight from the south, where Chart C provides the same issue for both terraces. The optimal solution for the placement of the terrace is solution D, both in terms of sheltering from wind, and maximizing the daylight conditions. Wind from south may also occur during winther which should be adressed.

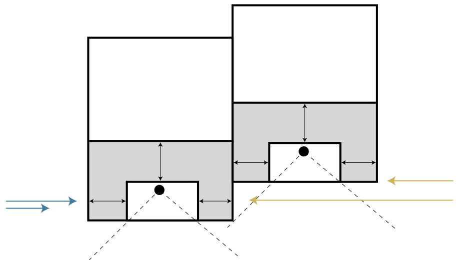

A 1

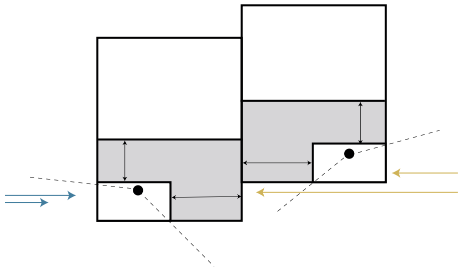

B 1

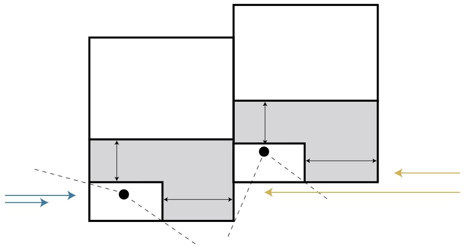

C 1

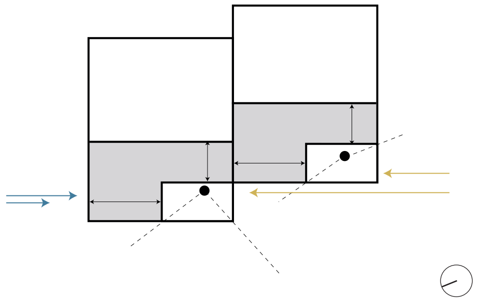

D 1

ILL. 105. 1


A 2


B 2

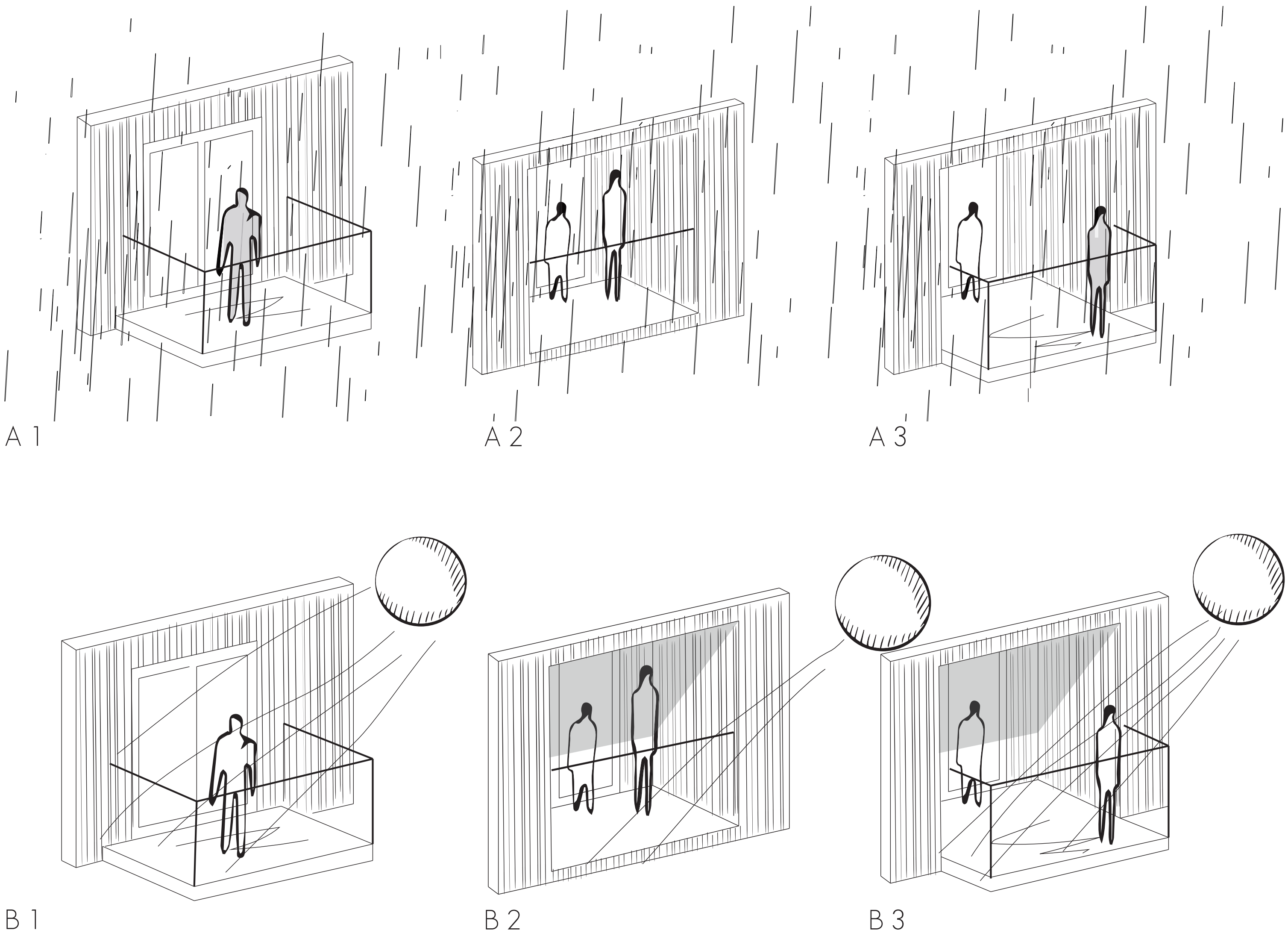

C 2


D 2

ILL. 105. 2

TERRACE DEVELOPMENT

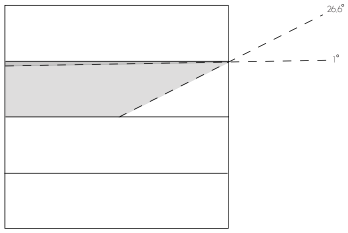
Sheltering from bad weather is of great importance to allow usage of the terraces all year around. To avoid getting wet during rainy days, the terraces should be covered from above. To provide all apartments a cover, the terraces are pushed back in the apartment (see B 2). However, this may provide less sunny hours. By adding an extension (see B 3) the terrace will be flexible in terms of offering sun and cover from wind and rain.



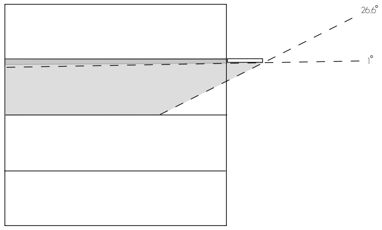
ILL. 106. 1

During summer (21. June 2018) when the azimuth is direct towards the west, the altitude of the sun will reach 26,7 o (see A 1) meaning that nearly half of the apartment will be filled with light. [Suncalc.org, 2018] When adding a shading as in chart A 2 or A 3 less direct sunlight will enter the apartment. The lowest amount of direct sunlight will penetrate the apartment when combining solution, A 2 + A 3 which will result in A 4. During winter, when the sun altitude is near lowest, the apartment will still benefit from solar radiation as in solution B 4. This solution will both support less overheating hours during summer and provide passive solar heat gain during winter.

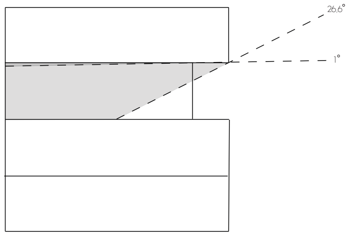
WEST Azimuth: 270 ° Altitude 26,6 °



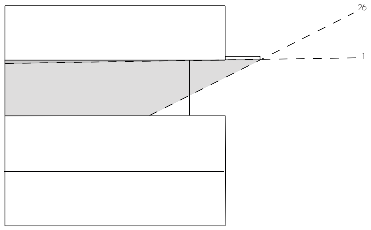
A 1



A 2



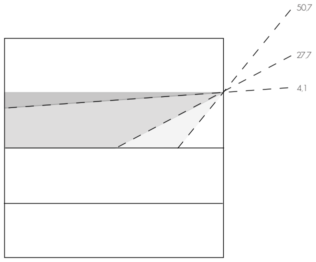
A 3



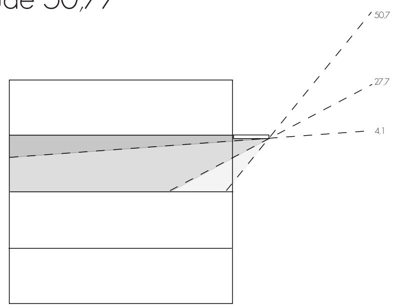
A 4

21 march 18:40 1°
21 june 18:40 26,6°
[Suncalc.org, 2018]

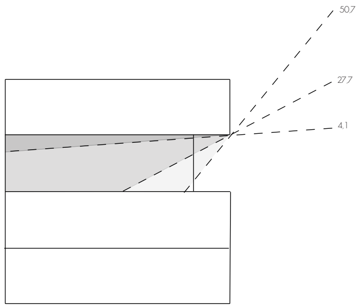
SOUTH Azimuth: 179,5 ° Altitude 50,77 °



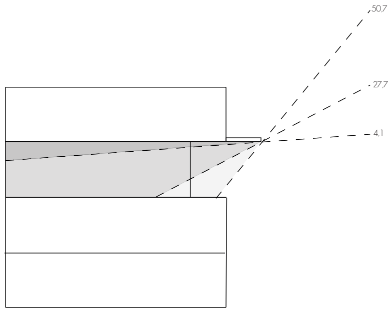
B 1



B 2



B 3



B 4

21 march 12:40 27,7°

21 june 12:40 50,7°

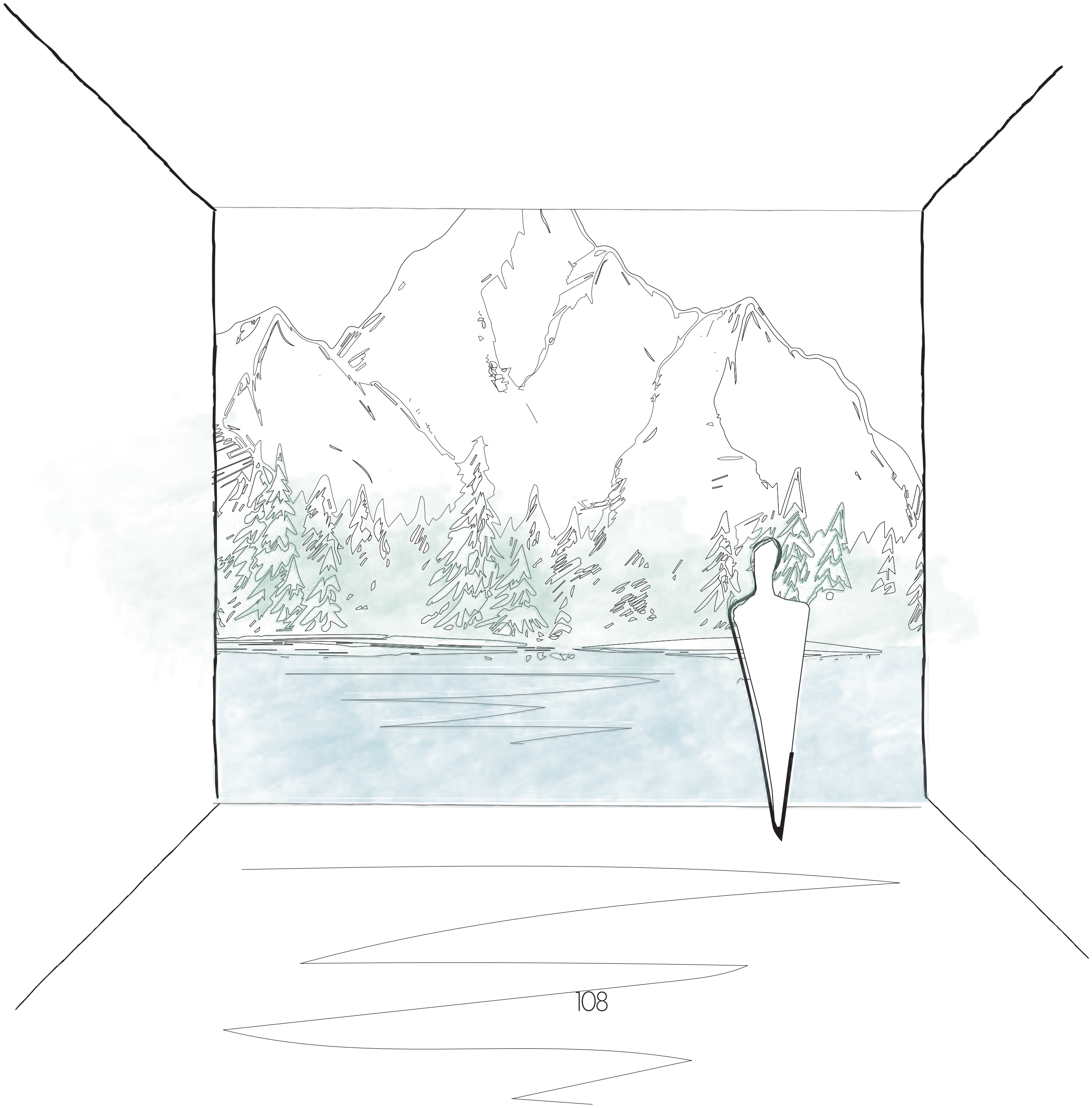
21 december 12:40 4,1°

[Suncalc.org, 2018]

ILL. 107. 1

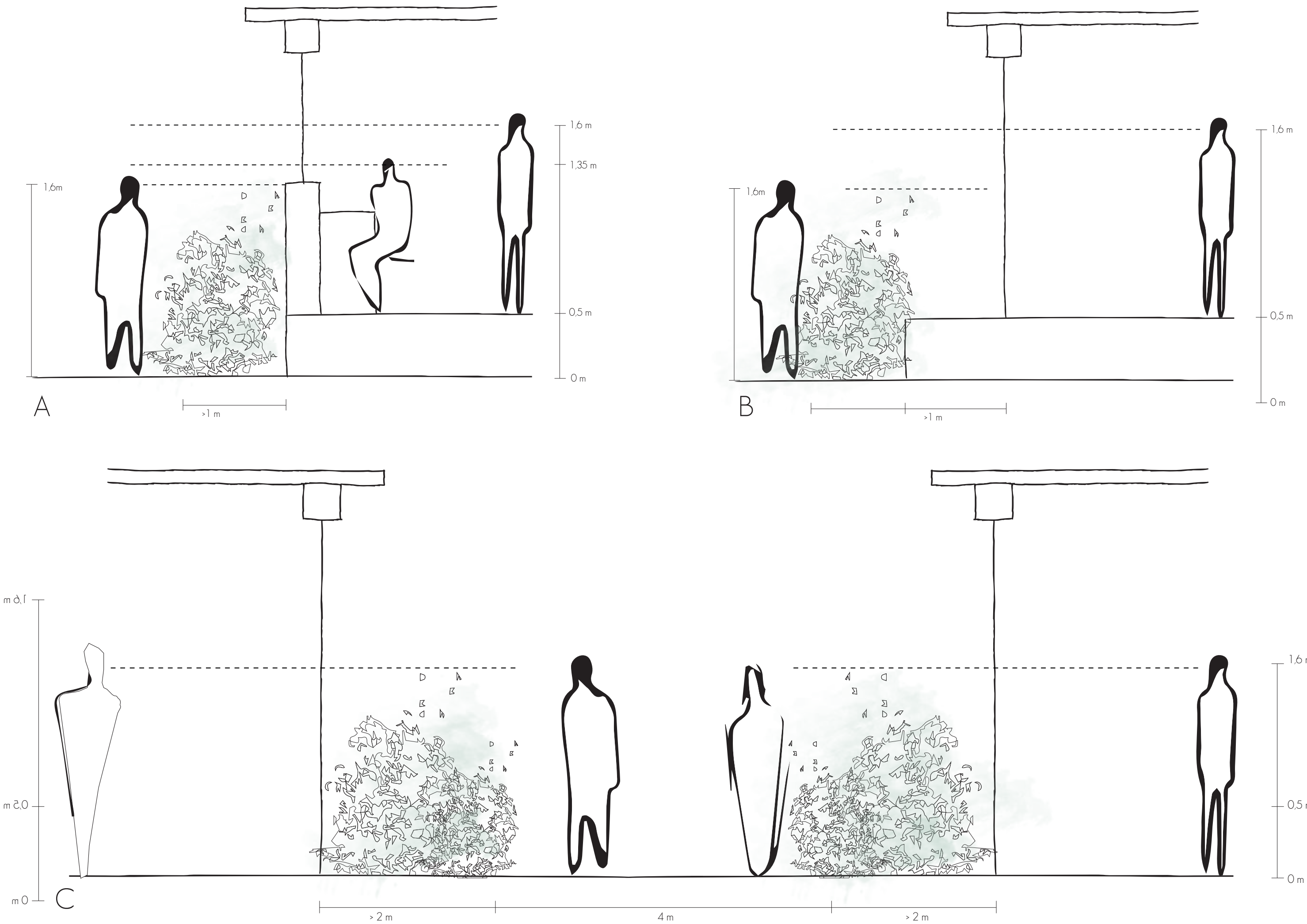
WINDOW DEVELOPMENT

As mentioned in the well-being chapter, views towards nature is a crucial step towards mental health, where the aspiration is to grant the common spaces with large windows oriented toward the west.



ILL. 108. 1

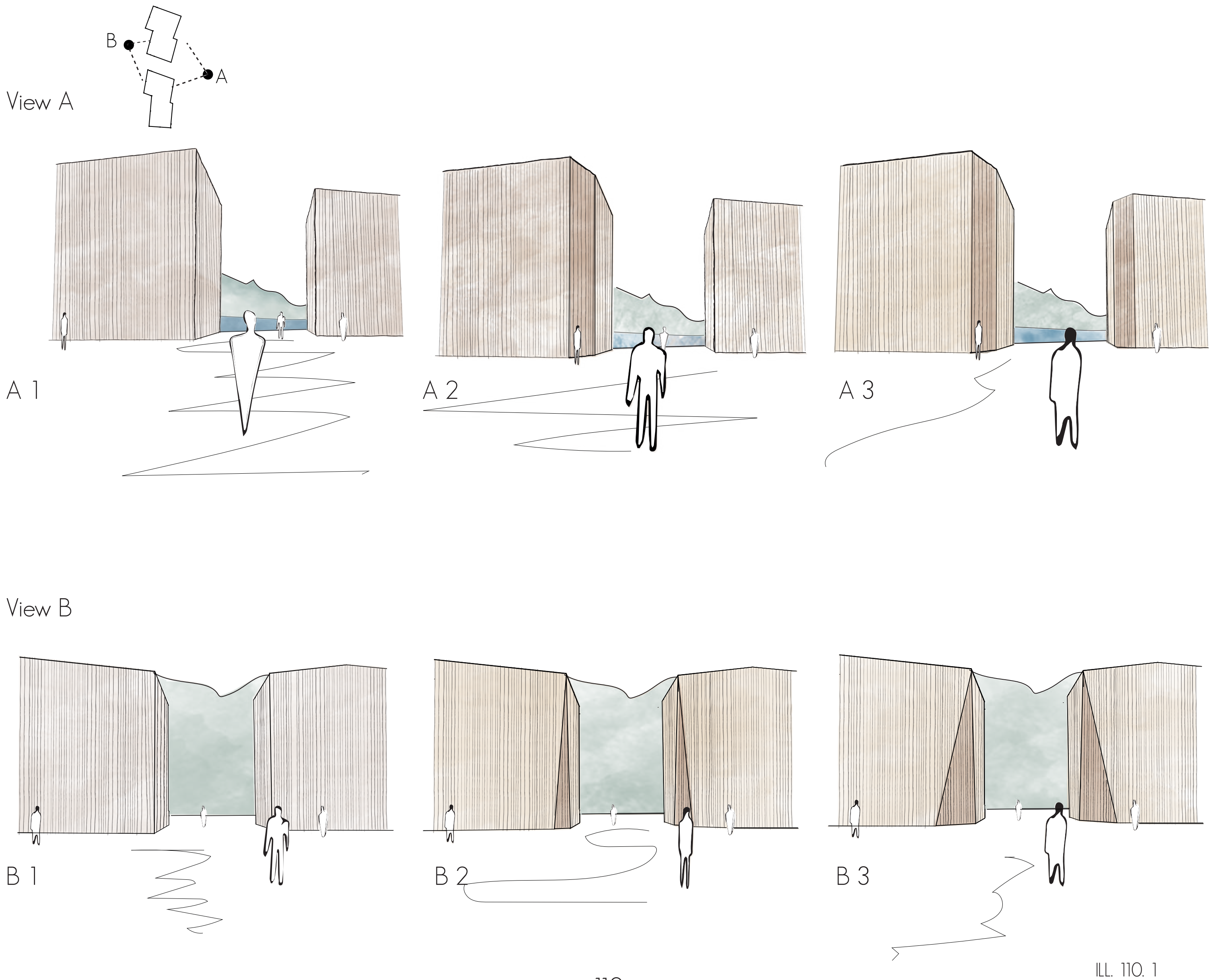
As the building is designed with a ground floor, solutions to avoid disturbance from bypassers should be investigated. The apartments are raised 0,5 m above ground level to offer privacy, with windows raised with a minimum height of 1 m (see chart A). The ground level apartments facing east (see chart B), contains floor to ceiling windows, where the idea for privacy is to place a barrier with flora, only interrupted where the narrow vertical windows are placed. Some apartments may have windows going from floor to ceiling in between the passage (see chart C), where 4 m path in the central axis should be available for bypassers, where the last 4 m should be distributed evenly and function as a flora barrier, again only interrupted by the narrow vertical windows.



ILL. 109. 1

CUT DEVELOPMENT

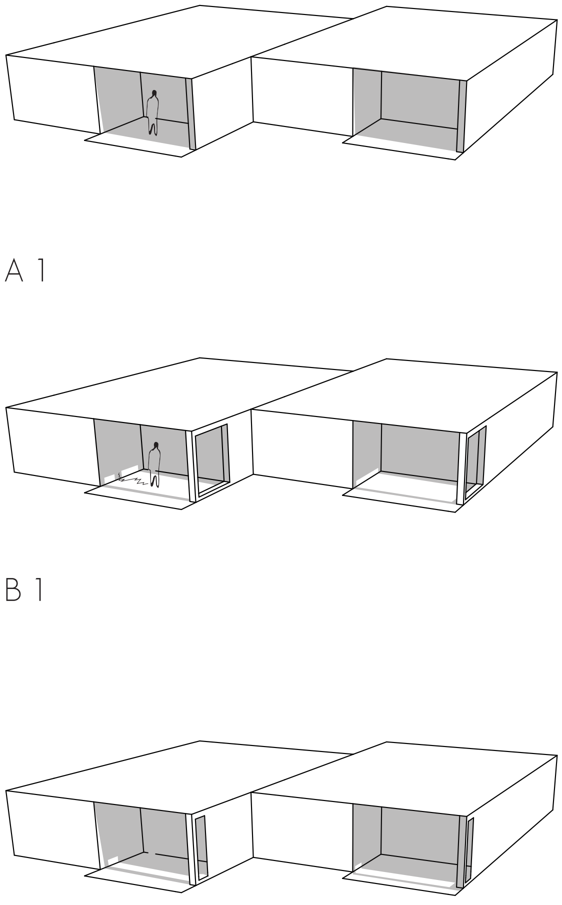
Designing with movement is a crucial part of this project. The desire is to lead people the right direction and to meet the building with a more sensitive approach and with an inviting expression. The first chart (see diagram A 1) illustrates the building without any further change. The next diagram (see A 2) shows a vertical line cut from the top of the building all the way down to the bottom of the building. A more significant cut has been made in chart A 3. Comparing the straight vertical cut with chart B 2, a more triangular cut has been created which is considered more leading.



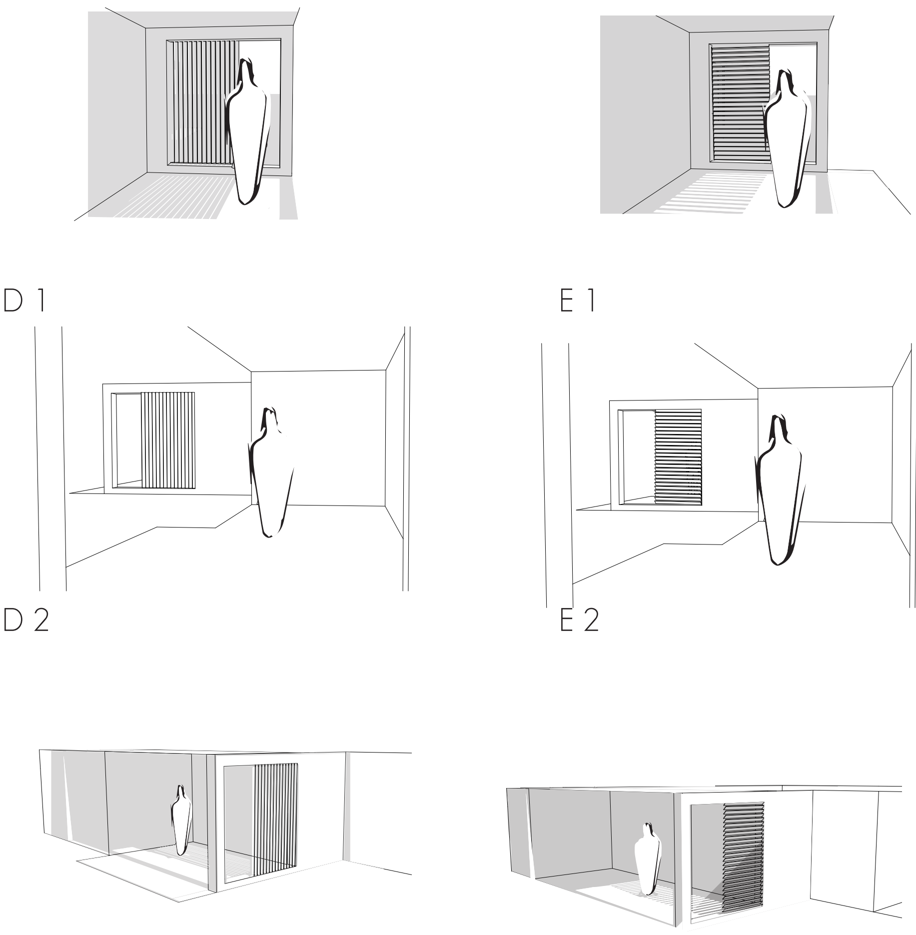
ILL. 110. 1

LAMELLA DEVELOPMENT

The chosen location of the terraces (see terrace placement development D 1 - D 2) entails that too large openings may seem unpleasant between neighbors and disturb privacy. Openings are examined (see diagrams A 1, B 1 & C 1), where B 1 with the most significant opening is the most suitable for supporting a good view, however, to avoid unwanted clashes with the neighbors a shielding is added in the openings. It is desirable to use lamellas (see diagrams D-E) to continue the use of the tree, thus creating a sliding transition in the design. The vertical solution (D) is optimal to use as it gives the freedom to have a certain degree of visibility oriented away from the neighbor and towards the view. The horizontal solution limits the possibility of having a view as it should either be rotated upwards or downwards to avoid looking into the neighboring balcony or apartment. Solution D (D1, D2, D3) is chosen.



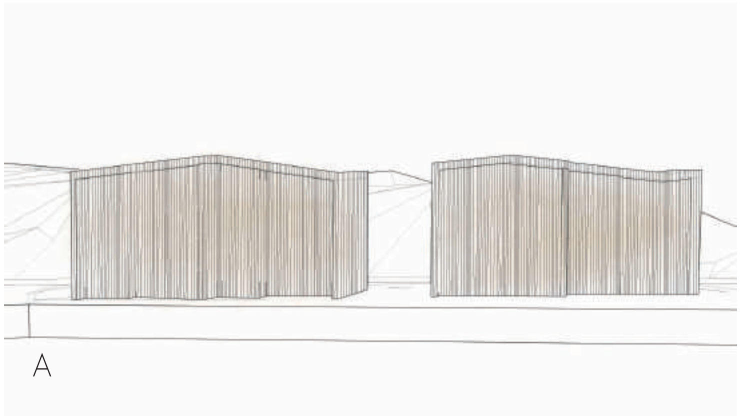
ILL. 111. 1

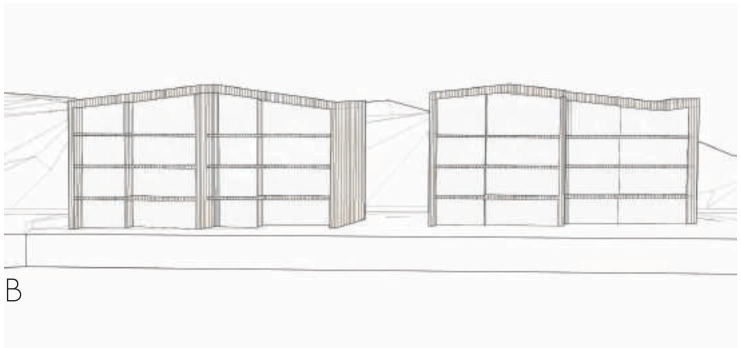


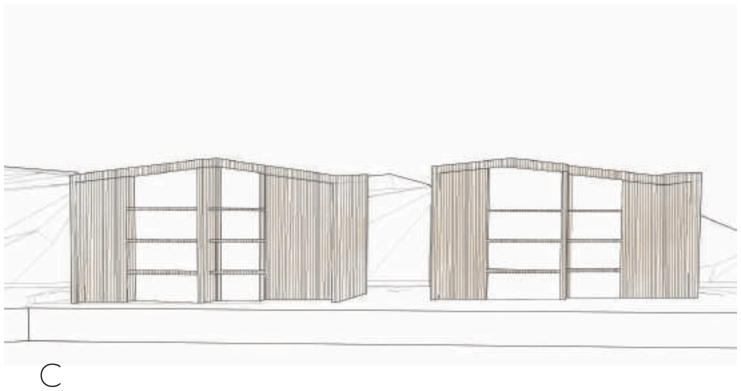
ILL. 111. 2

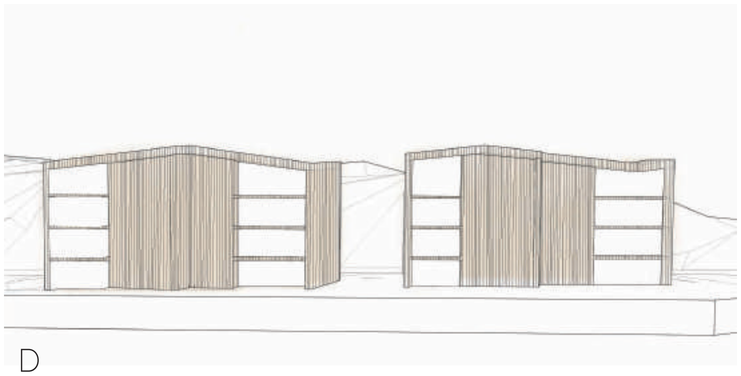
FACADE DEVELOPMENT

The skin of the building that should be proudly placed among the mountains will be the face towards the city's inhabitants. The wooden facade that naturally slides into the surroundings must be broken up with windows and will, therefore, be examined in relation to the closed tree facade. The first drawing (see chart A) shows a beautiful harmony between the simple facade and roof. Breaking the facade up with windows located on a vertical line centrally placed in between the two buildings (see chart C) creates a transparent and less massive facade. If the building is completely broken up with windows (see drawing D), the tree loses its dominance, where lightening apartments instead are allowed to reflect in the water during night. The great need to support well-being, light rooms with good prospects to nature, will require several windows towards west, (see A 1 & A 2 on the next page) which will dominate the wood. The window sizes are designed in accordance with results gained from multiple iterations made in Bsim calculations which provides a maximum amount of glazing to avoid many overheating hours. The remaining facades are influenced much more by the brown wood, as the functions placed near the facades require smaller window areas. The facade diagrams A 1, B 1, C 1 and D 1 show a rigid system of windows that strictly follows a vertical pattern. The remaining diagrams A 2, B 2, C 2 and D 2 symbolize the dynamic cliff that is not dependent on a strict expression. As this project emphasizes nature, it is decided to work on the dynamic facades.

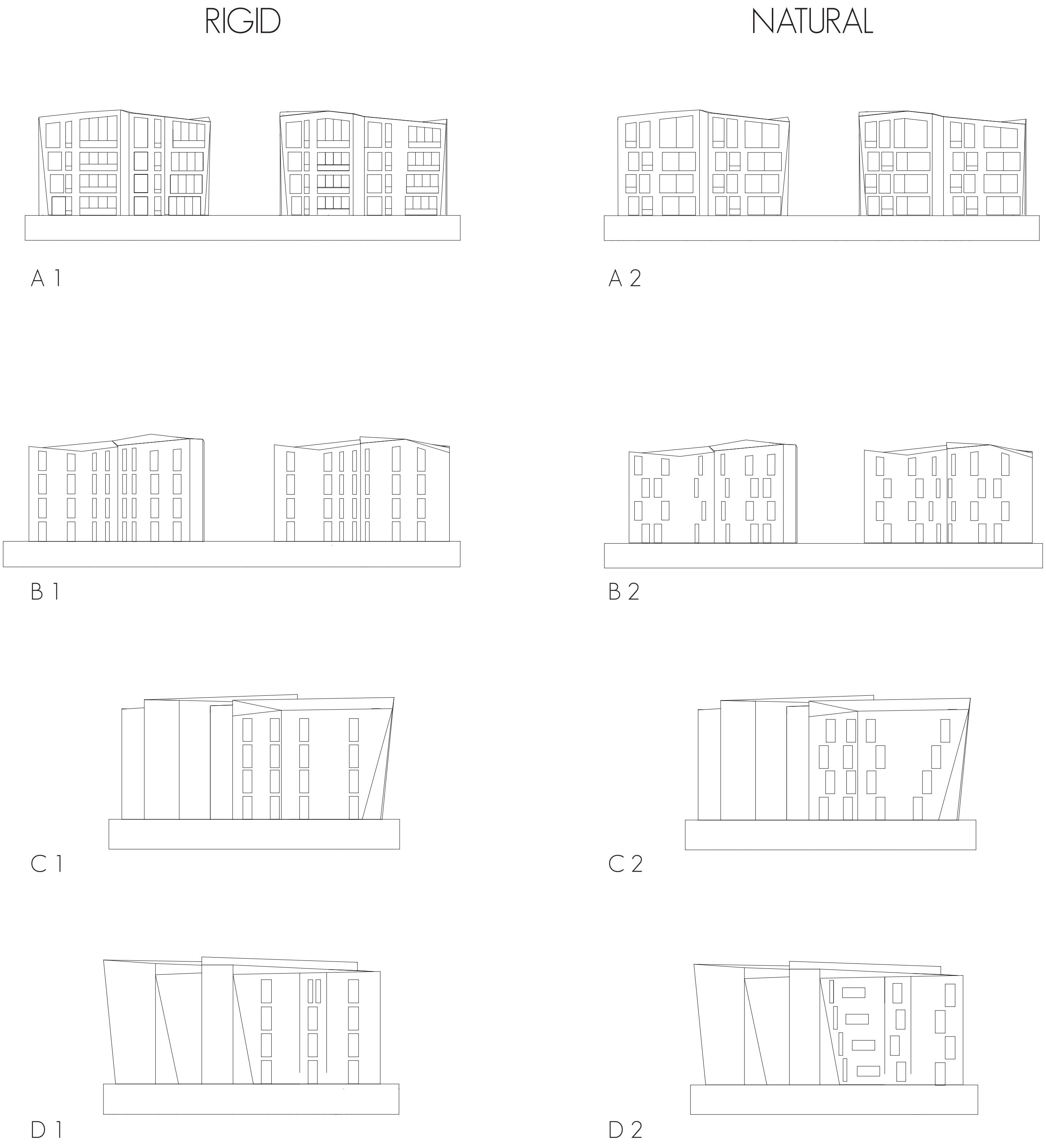








ILL. 112. 1



ILL. 113. 1

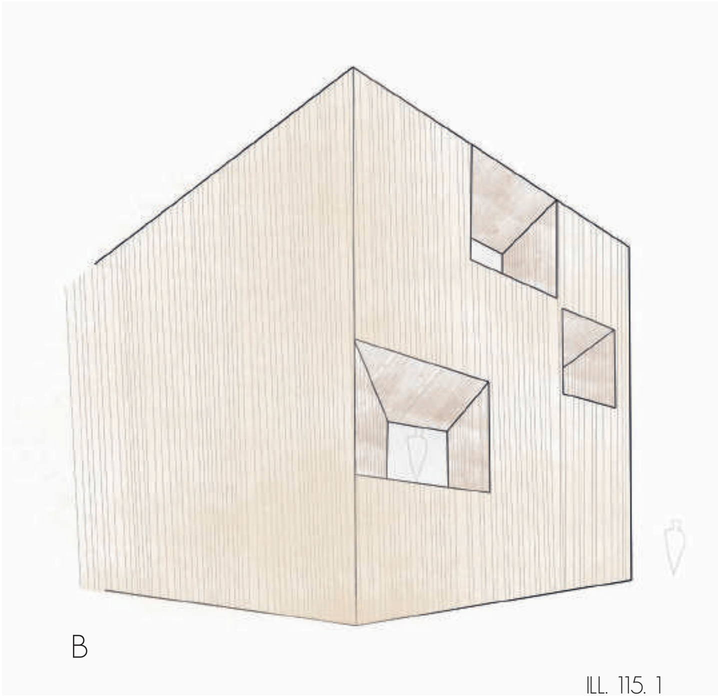
THE BIRD NEST

Natural rock formation, found near the site, creating shelf like gestures, as inspiration for the facade design.

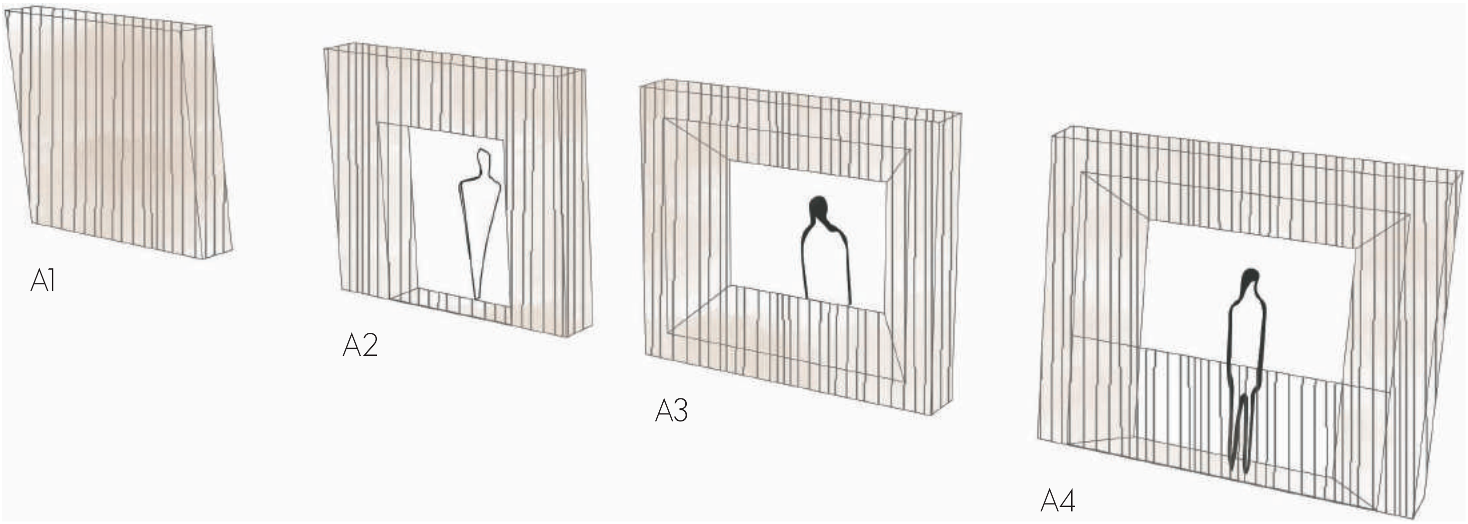
ILL. 114. 1

THE BIRD NEST

The plenty birds living on the island exploit the many possibilities of the rock. Each year preparation for a nest is formed and placed in the many caves which independent of each other is located irregularly in the rock formation.
The symbolism of the intimate, warm and embracing cave is the final step in the design development to imitate the cliff in the best way. The facade symbolizing the clip (see A 1) is added with appropriate window size (see A 2) as a result from Bsim calculations. The window is defined with four displaced surrounding walls that gives a broader perspective from the apartment (see A 3), and the final move extends the window (see A 4) for use in conjunction with a small terrace. The bird nest windows will be placed in connection to bedrooms (see drawing B).



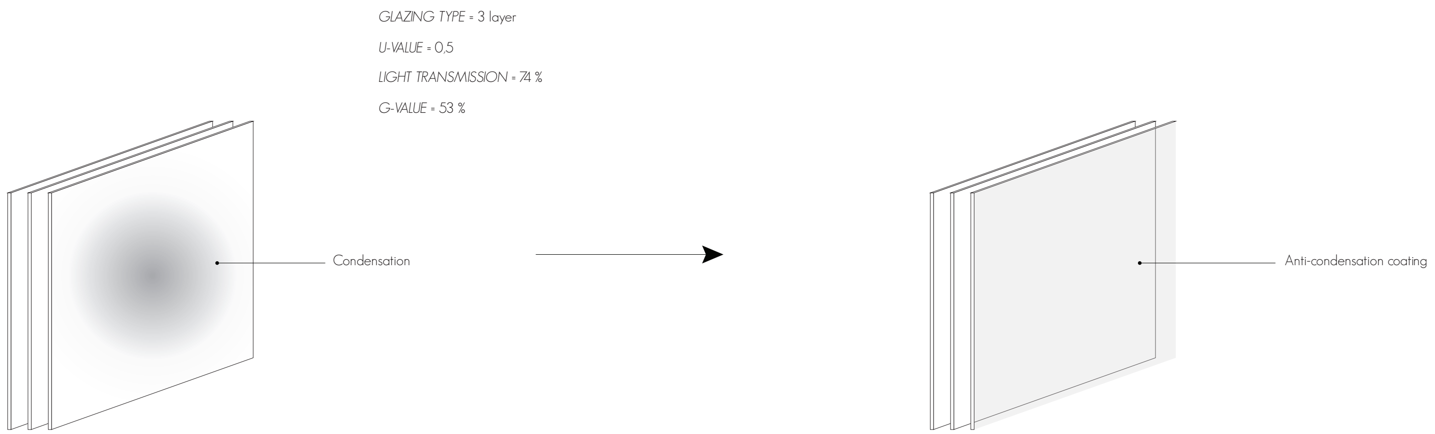
ILL. 115. 1



ILL. 115. 2

WINDOW - CONDENSE

Under certain conditions, condensation can occur on the exterior surface of highly insulated windows or glazing elements, which are required to meet the 2020 energy frame. The phenomenon occurs when the outside air makes contact with the exterior surface of the glazing, where the surface temperature is lower than the dew point temperature in the air surrounding it (Byggforsk.no, 2018). The condensation on the exterior surface can also freeze when the moisty surface is cooled down to below the freezing point, both resulting in obstructed view as well as reduced light transmission of the glazing. A reduction of light inside the dwellings, before the sun heats the air and warms up the glazing, may cause interference with the experience of the apartment and the aspects of well-being during morning hours. The risk of condensation can be reduced by applying a thin and hard coating on the exterior. The coating causes the exterior glazing layer becomes slightly hotter, ultimately reducing the risk of condensation (Glassfakta, 2018).



ILL. 116. 1

ILL. 117. 1

BSIM

For the simulations in Bsim, the most critical apartment in the complex have been chosen. This apartment has been selected because it has; smallest volume, large glass ratio, large windows towards west and south.
The simulations have been made for the whole apartment.

The general purpose of the Bsim simulations is to achieve an understanding of how the design choices affect the atmospheric comfort of the apartments. Therefore, we have chosen to look at temperature, CO2 concentration, air change and relative humidity, to evaluate on. After a few initial simulations, different design iterations have been made to optimize the results by improving possibilities for natural ventilation and implementing balconies as shading. While these iterations have been analyzed in Bsim, daylight analysis has simultaneously been conducted in Revit.

Environment:
In the simulation model, it has been estimated how the mountain on the east side of the building will affect the simulations and to compensate for this, a mass has been placed in the simulation model to create shading. This estimation of the mountain might cause slightly inaccurate results. Furthermore, the available weather file from Norway does not contain any wind information; this means that Bsim cannot simulate venting – and this causes very poor possibilities to get rid of overheating. For this reason, the standard Denmark _ 2013, from Sbi has been used for the simulations.

Equipment:
As the heat load from appliances is used default values found in Bsim, with 168 hours of usage time pr. Week.

Heating:
In reality, the apartment has floor heating in the upper part of the slab. But due to some trouble with the floor heating simulations in Bsim, the simulations are made with "regular heating." Because of the buildup and the placement of the floor heating, both of the systems are fast responding systems, and it should have a considerable impact – though there can be differences regarding energy consumption.
The MaxPower for the water-to-water heat pump system has been set to 10W/ m2; this is whats needed to meet the heating demand.
During summer the set point for heating has been set to 21 degrees while the rest of the year it is set to 24 degrees.

PeopleLoad:
As a standard value for a nuclear family, it is estimated to 3,5 persons using the apartment. For housing, it is usually estimated that the usage is 168 hours a week. Therefore, the people load is set to 100%, when someone is home.

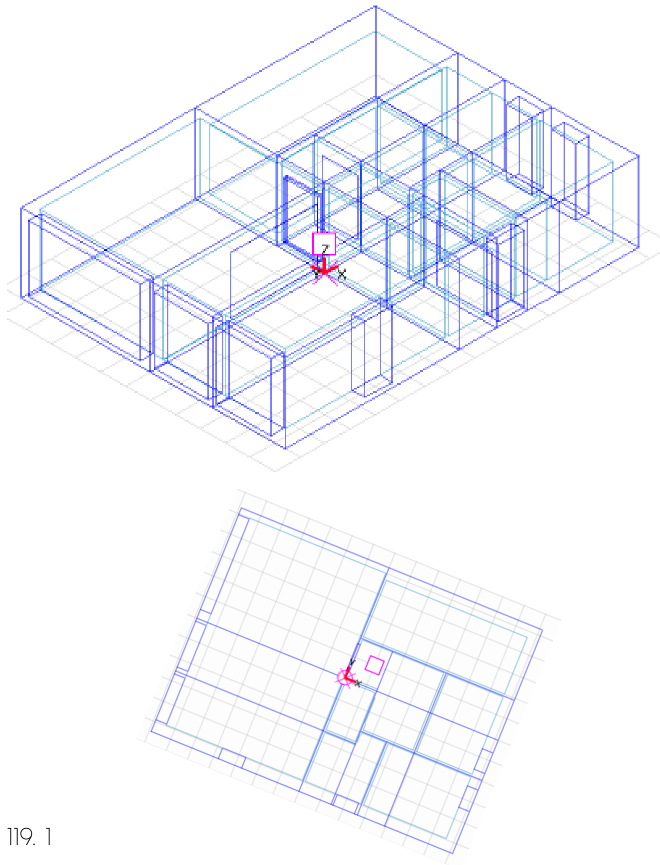
Ventilation:
DS-EN15251:2007 writes: Recommended design ventilation rates in residential buildings:
The exhaust of pollutions in wet rooms (Bathroom, Kitchen, toilet)
General ventilation of all rooms in the dwelling.
General ventilation of all rooms in the dwelling with fresh air criteria in the main room (bed and living rooms)

Venting:
Venting is made with different schedules for the different seasons. During summer when there is a lot of solar heat gain, the venting set point is set to 20 degrees, to start venting before the apartment is getting overheated. During spring and autumn, the venting set point is at 22 degrees, and during winter it is 24 degrees.

Infiltration:
In relation to Building 2020 the infiltration is 0,07 l/s per m2 gross floor area. 112,18m2 * 0,07 l/s = 7,8526 l/s -> 25,2m3/h

Divide with Apartment Gross Volume to find basic airchange:
25,2m3/h / 359m3 = 0,0702/h

ITERATION 1



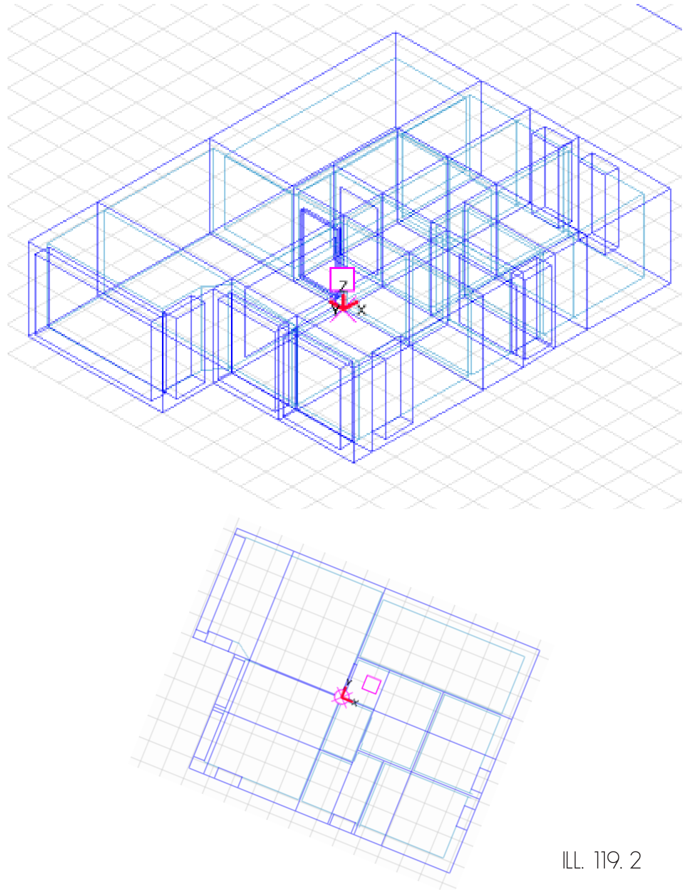
ILL. 119. 1

For this first iteration, the west facade is planar and has large windows to capture the view over the fjord and the mountains. This iteration is mostly based on single-sided natural ventilation and limited possibilities for cross ventilation.
This results in a significant amount of overheating in the apartment and poor condition regarding CO_2 concentration.

Above 27 degrees - 264 Hours
Above 28 degrees - 145 Hours

CO_2 concentration: 380-2625ppm (mean 928ppm)

ITERATION 2



ILL. 119. 2

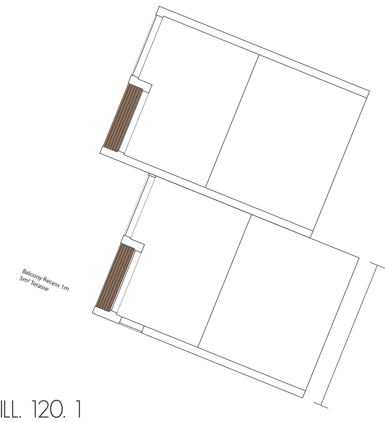
For this second iteration, half of the west facade has been recessed two meters, and a new window has been added to the wall piece between the two western facades. This is done to improve natural venting possibilities. Furthermore, the mechanical ventilation was turned up a bit during spring and autumn, to improve the CO_2 concentration in that period.
The decreased volume and the extra window had a negative impact on the amount of overheating hours.

Above 27 degrees - 343 Hours
Above 28 degrees - 210 Hours

CO_2 concentration: 383-816ppm (mean 523ppm)

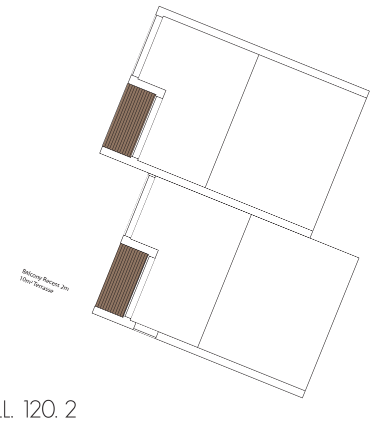
BALCONY DIAGRAMS 1:500

To get the largest possible balcony area, with as little cantilevering as possible, multiple facade/ balcony iterations, were conducted with the knowledge gained from Iteration 1 and 2, but with the balcony added to provide shading towards south/west, on the west facade. Additionally, the impact on daylight conditions is accounted for in this part.



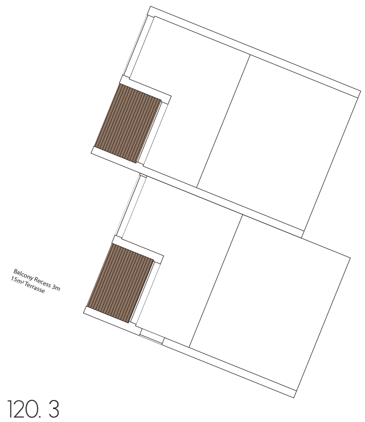
ILL. 120. 1

Balcony 1m recess ~ 5m^2 Terrasses
Above 27 degrees - 98 Hours
Above 28 degrees - 38 Hours
CO_2: 382-768 ppm (mean 534 ppm)



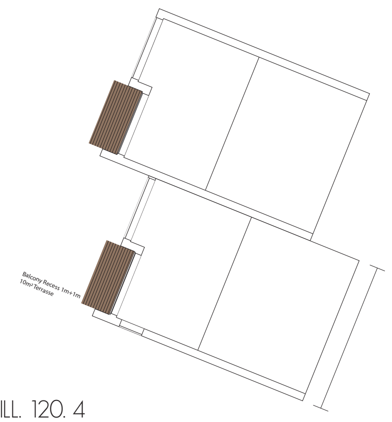
ILL. 120. 2

Balcony 2m recess ~ 10m^2 Terrasses
Above 27 degrees - 105 Hours
Above 28 degrees - 44 Hours
CO_2: 383-814 ppm (mean 536 ppm)



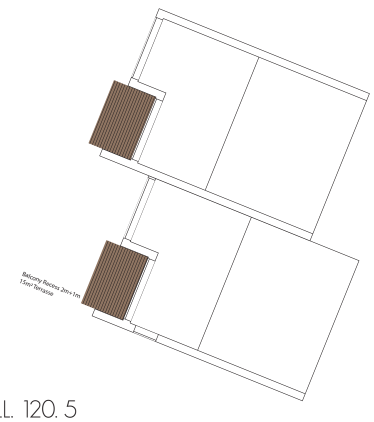
ILL. 120. 3

Balcony 3m recess ~ 15m^2 Terrasses
Above 27 degrees - 112 Hours
Above 28 degrees - 46 Hours
CO_2: 384-817 ppm (mean 536 ppm)



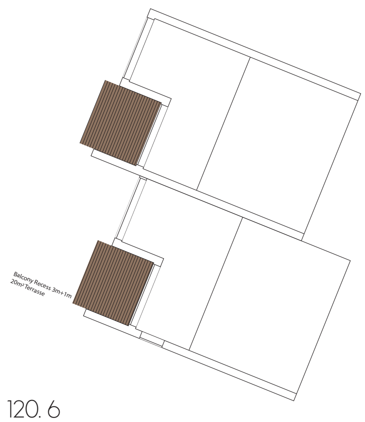
ILL. 120. 4

Balcony 1m recess + 1m canteliever
~ 10m^2 Terrasses
Above 27 degrees - 97 Hours
Above 28 degrees - 37 Hours
CO_2: 382-768 ppm (mean 534 ppm)



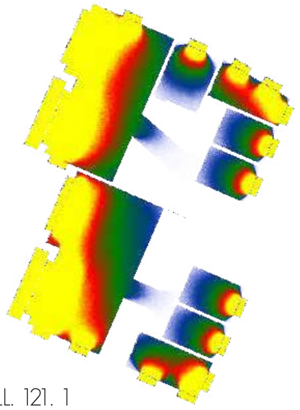
ILL. 120. 5

Balcony 2m recess + 1m canteliever
~ 15m^2 Terrasses
Above 27 degrees - 104 Hours
Above 28 degrees - 42 Hours
CO_2: 383-814 ppm (mean 536 ppm)

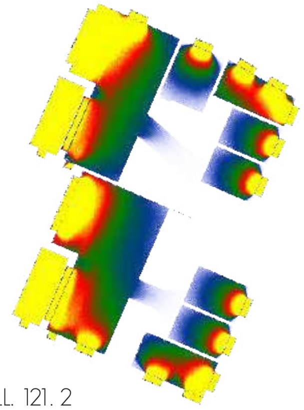


ILL. 120. 6

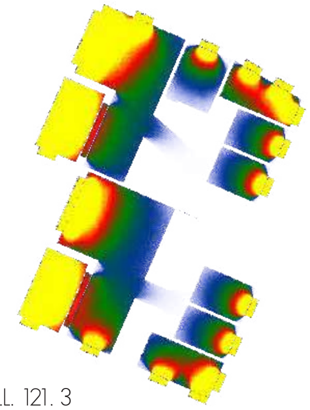
Balcony 3m recess + 1m canteliever
~ 20m^2 Terrasses
Above 27 degrees - 112 Hours
Above 28 degrees - 46 Hours
CO_2: 384-817 ppm (mean 536 ppm)



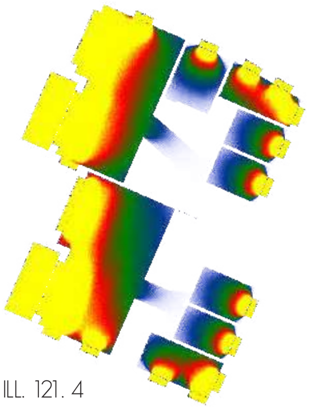
ILL. 121. 1



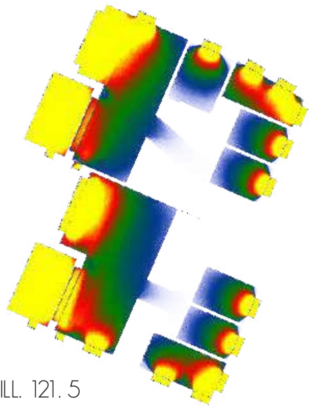
ILL. 121. 2



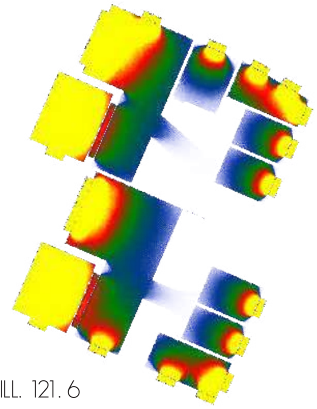
ILL. 121. 3



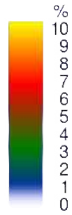
ILL. 121. 4



ILL. 121. 5



ILL. 121. 6



From the Facade/ Balcony iterations made earlier, the iteration with 2m recess and 1m cantilevering balcony, it the one fitting best to our wishes for balcony area while being close to meeting the requirements for the indoor environment.
To cope with the prevailing overheating, the large living room window on the west facade was reduced from 10 to 8m2.

ENERGY

During the early design phase, general considerations were made in terms of shaping a housing complex with low energy consumption. More detailed calculations were carried out during the further development of the design- and synthesis phase by utilizing the calculation tool Be18. This tool can help monitor how the various changes affected the total energy demand of the dwellings. This phase included an investigation into energy-efficient, locally available building elements and technical installations, from which the numerical data was utilized for the energy calculations.

The housing complex has an energy consumption of 18 kWh/ m^2year and is thereby within the limit of the requirements of the Building Regulation 2020 energy frame. The final design proposal utilizes a combination of passive and active strategies to reduce the energy needed to run the building within a comfortable indoor environment, following the Danish Indoor Environment class 2.

PASSIVE STRATEGIES

The passive strategies include a reasonable floor-to-surface ratio, as well as ensuring a well insulated and airtight envelope in order minimize heat loss. Furthermore, the retracted balconies have been placed directly above each other to exclude additional heat loss and line losses from horizontal surfaces. To allow for large glazing partitions to be implemented along the west-facing facades, several passive strategies have been utilized to prevent overheating, and thereby exclude any additional energy needed for mechanical cooling to ensure thermal comfort. The strategies included a combination of passive cooling and permanent shading. A cross ventilation strategy was planning early on in the design process, and further developed throughout the design process in order to remove excessive heat gains from solar radiation by using wind pressure and thermal buoyancy as driving forces. Furthermore, the balconies are retracted, and partially extruded from the envelope to reduce the total heat gain from solar radiation, providing permanent shading for a considerable part of the glazing inside the spaces, ultimately providing the user with a satisfactory thermal and atmospheric comfort without the use increasing the energy demand of the building.

ACTIVE STRATEGIES

Active strategies have been implemented to reduce the energy required for heating and venting the spaces. Decentralized, demand-controlled mechanical ventilation systems have been installed in all the apartments in order to minimize heat loss during winter while achieving a satisfactory atmospheric comfort. The system has a high heat recovery and low electrical consumption. The system is provided with CO2 sensors, and fully adjustable in terms of controlling the airflow, giving the users the option lowering the airflow while away from their home, as well as shutting the system off completely to save energy (Exhausto.no, 2018). In terms of the heating system for room heating and domestic hot water, the building draws advantage of the available seawater on the site by implementing a seawater source heat pump system. The heat pump uses electricity to transfer the thermal energy of the sea into the building (Byggforsk.no, 2018), consuming only one-fourth of the energy it produces (Thermia.no, 2018).

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
110,9	0,0	110,9
Total energy requirement		25,0

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
53,0	0,0	53,0
Total energy requirement		25,0

Energy frame BR 2015 / 2018

Without supplement	Supplement for special conditions	Total energy frame
30,3	0,0	30,3
Total energy requirement		25,0

Energy frame Buildings 2020

Without supplement	Supplement for special conditions	Total energy frame
20,0	0,0	20,0
Total energy requirement		18,0

Contribution to energy requirement

Heat	0,0
El. for operation of bulding	10,0
Excessive in rooms	0,0

Net requirement

Room heating	15,9
Domestic hot water	16,3
Cooling	0,0

Selected electricity requirements

Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,5
Heat pump	7,9
Ventilators	1,6
Pumps	0,5
Cooling	0,0
Total el. consumption	27,7

Heat loss from installations

Room heating	0,0
Domestic hot water	3,2

Output from special sources

Solar heat	0,0
Heat pump	32,2
Solar cells	0,0
Wind mills	0,0

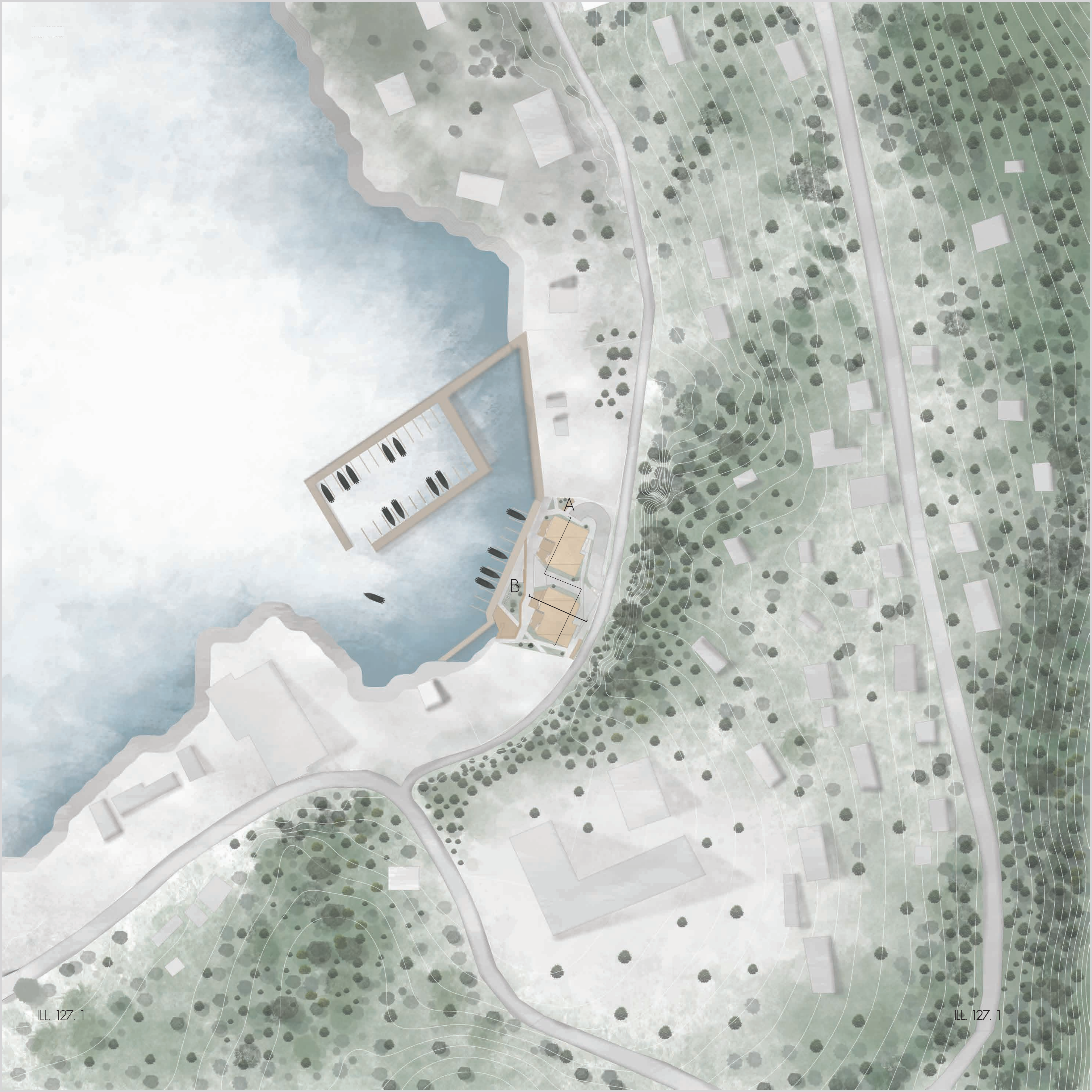
ILL. 123. 1

08 PRESENTATION

ILL. 125. 1

CONCEPT DIAGRAM

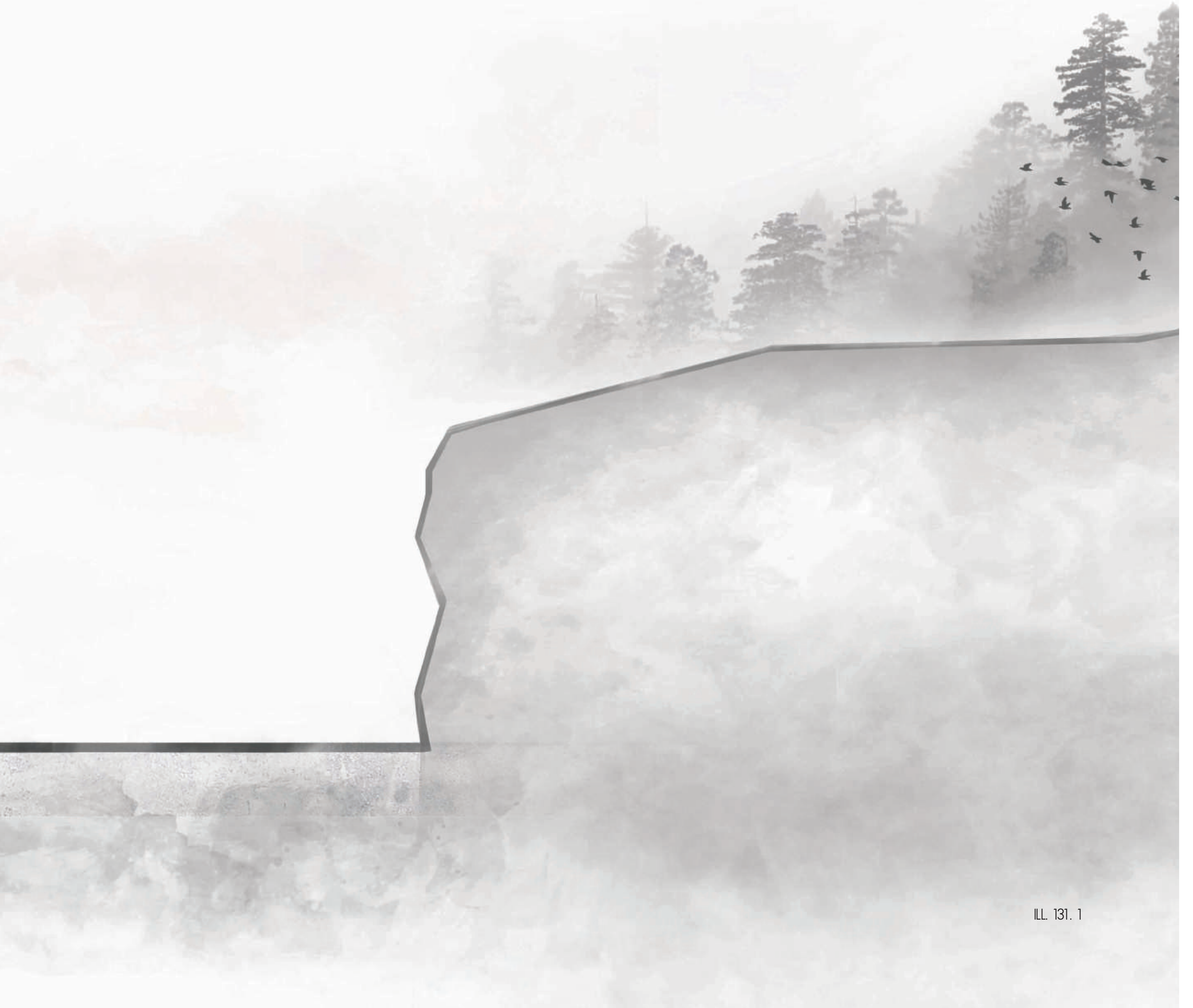
ILL. 126. 1


A
B
ILL. 127. 1
ILL. 127. 1

SECTION A 1:200

ILL. 129. 1

SECTION B 1:200



ILL. 131. 1

EXTERIOR VIEW
Experiencing the complex from a boat on a nice quiet evening.

ILL. 133. 1

MASTERPLAN - APARTMENTS 1:200

ILL. 134. 1

DESIGN OF THE EXTERIOR SPACE

The design of the outdoor space is based on strategies regarding the five ways of well-being to enhance well-being. Instead of looking at single parameters, this design has strived to generate a holistic take on well-being, by; creating a connection among neighbors by offering accessibility and proximity to outdoor spaces, a place to sit, to observe the beautiful landscape while talking to neighbors.
Walkable flows in and around the building, direct access towards the city center and marina with a pedestrian-friendly environment, with a view to greenery, water, and landscape to keep active. The passage opens a view and generates a visual axis to remind inhabitants of taking notice of the surroundings. The water near common space encourages people to interact and face each other while conversing, and in the green areas, social gardens are introduced to motivate users to move away from a self-centered mindset and thereby to contribute community of neighbors.

EXTERIOR VIEW II

The façade reveals its appealing weathered timber cladding in a silver greyish color and stands in contrast with the warm wood inside the apartments.

ILL. 137. 1

ELEVATION WEST 1:200

ILL. 139. 1

ELEVATION NORTH 1:200

ILL. 140. 1

ELEVATION SOUTH 1:200

ILL. 141. 1

ELEVATION EAST 1:200

ILL. 143. 1

PENTHOUSE APARTMENT VIEW I

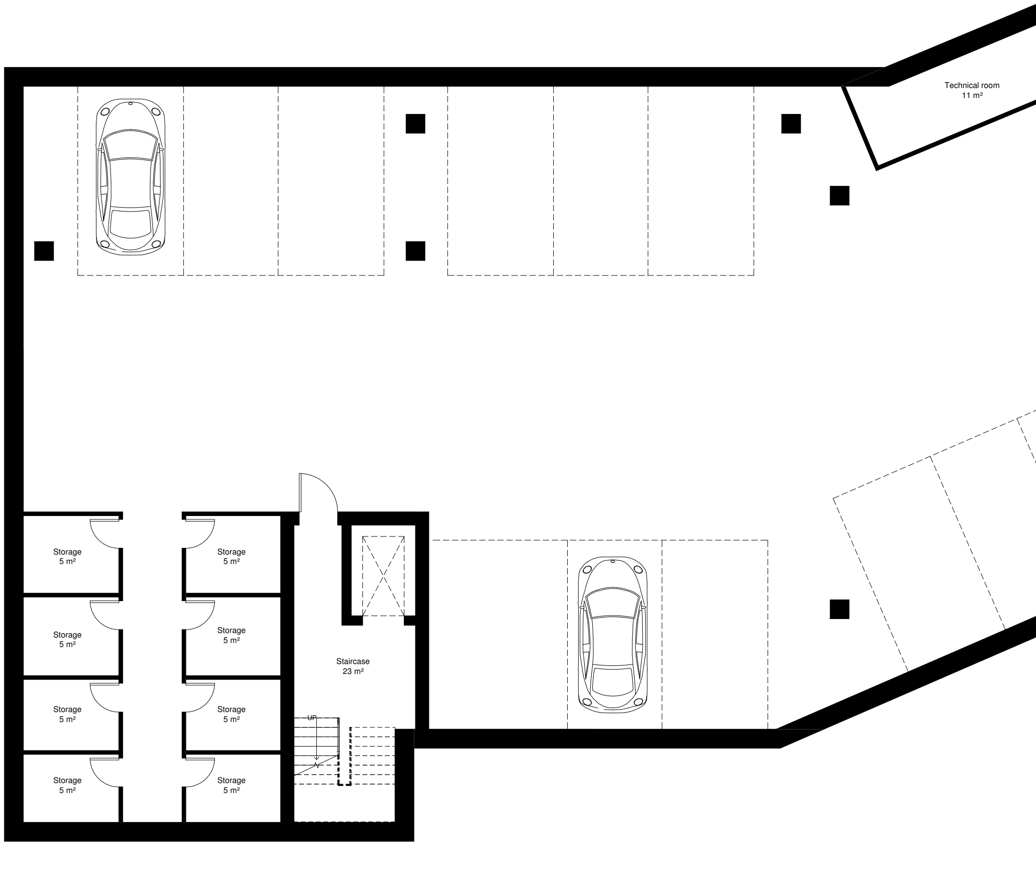
A spatial apartment covered in boiled Cross-laminated timber from top to bottom lightens the large space with its stained surface and provides a beautiful clear illumination.

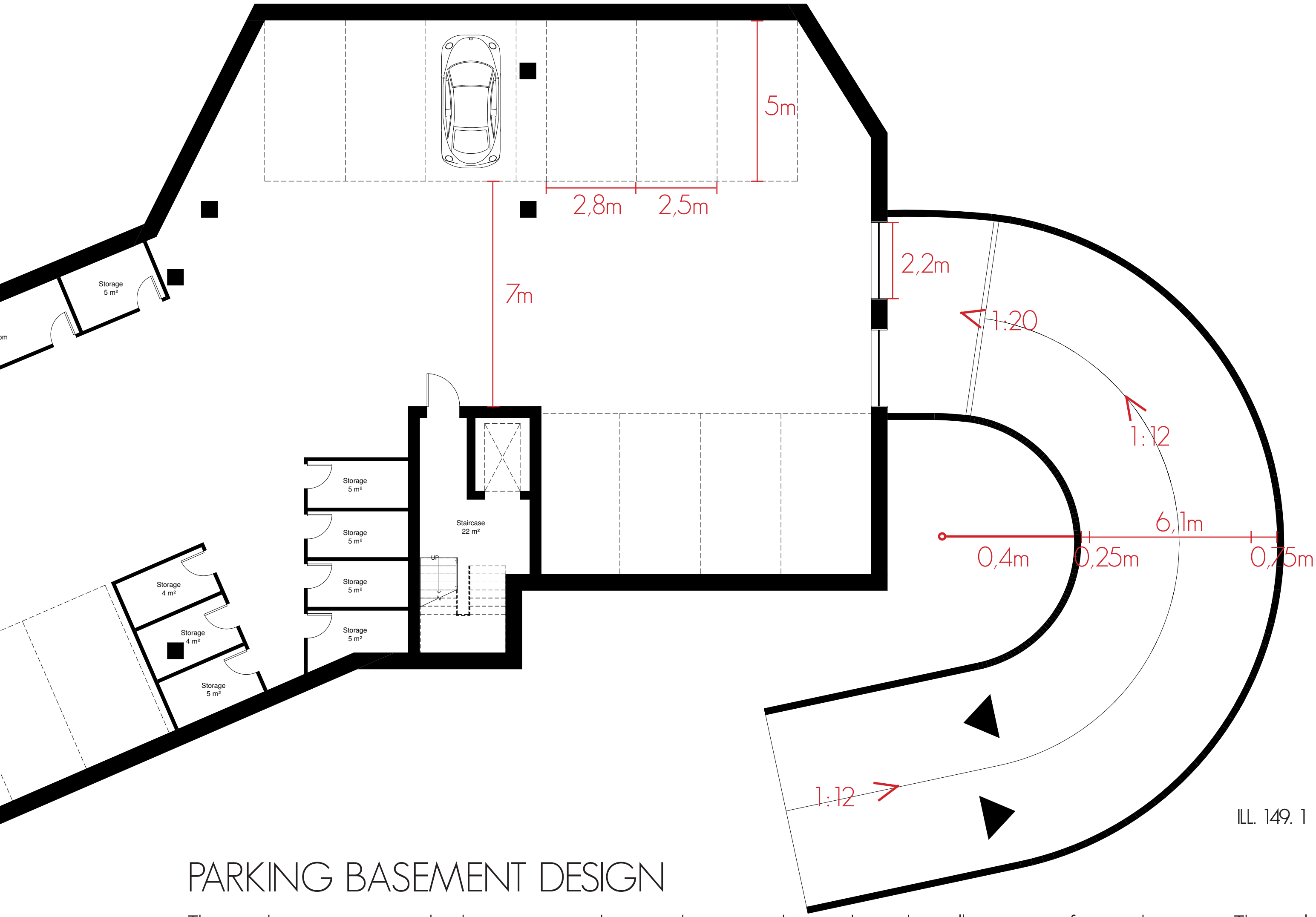
ILL. 145. 1

GROUNDFLOOR VIEW
View from a private terrace on the ground floor apartment, with a view over the common area, towards the sea.

ILL. 147. 1

PLAN - PARKING 1:200



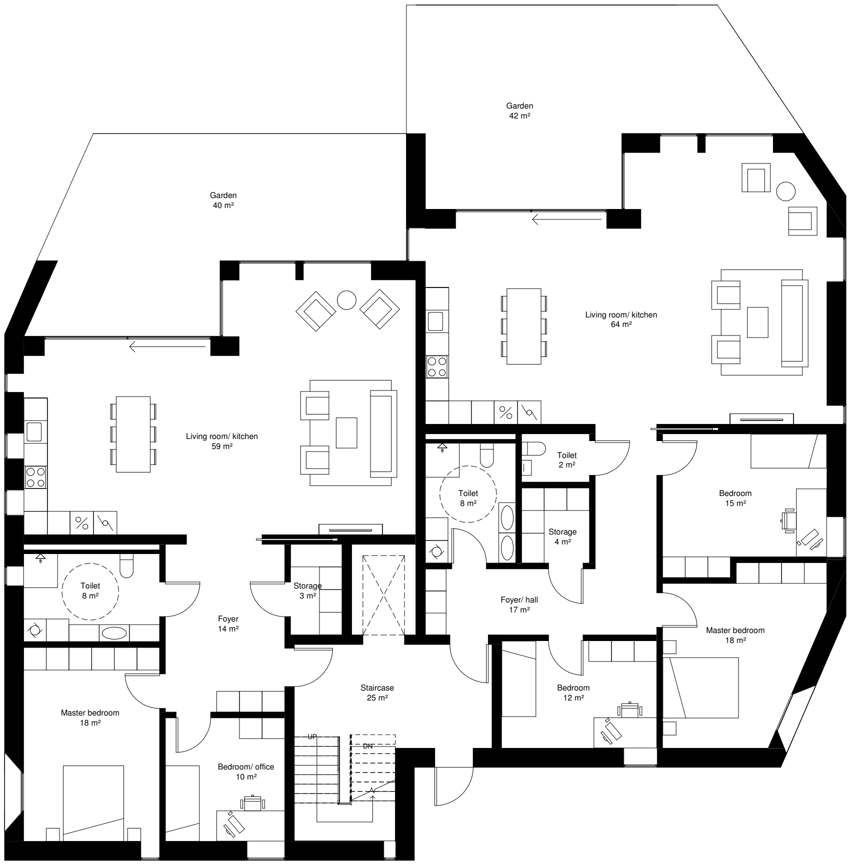


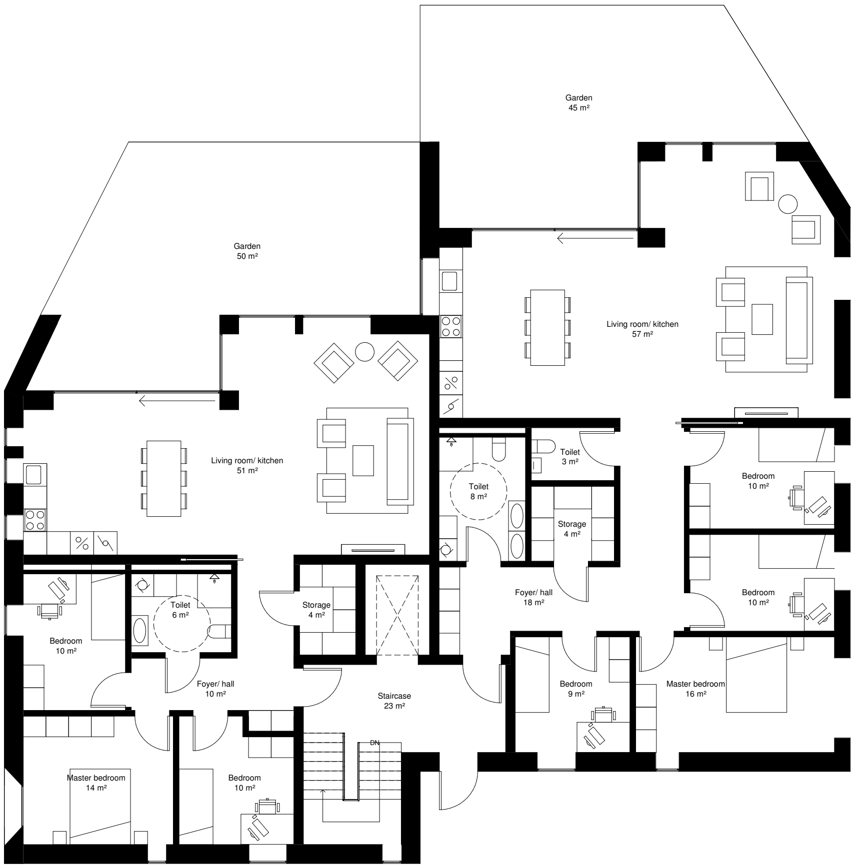
ILL. 149. 1

PARKING BASEMENT DESIGN

The parking garage in the basement is designed in accordance to Norwegian standards. In garages with less than 40 spots, the most space efficient solution is with a 90° angle to the drive way. Regular spots are dimentioned 5x2,5m and spots next to walls or colums are 5x2,8m, with 7m maneuver distance between them. The access way is a two-way ramp, bend with a 4m radius. This causes an encrease of width, from 5,1 to 6,1m. The added meter is unevenly distrubuted to allow acces for pedestrians. The inclination of the ramp varies from 1:20 at the top, and the controle point at entry gate, to 1:12 inbetween. [Byggforsk.no, 2018] Finally the whole garage is designed, only to exceed the building boundary, towards west. This is to accomodate the necessary parking and storage, and to form elevated terrasses for the groundfloor apartments - and thereby benefit from the large parking demand, to encrease privacy on level 0.

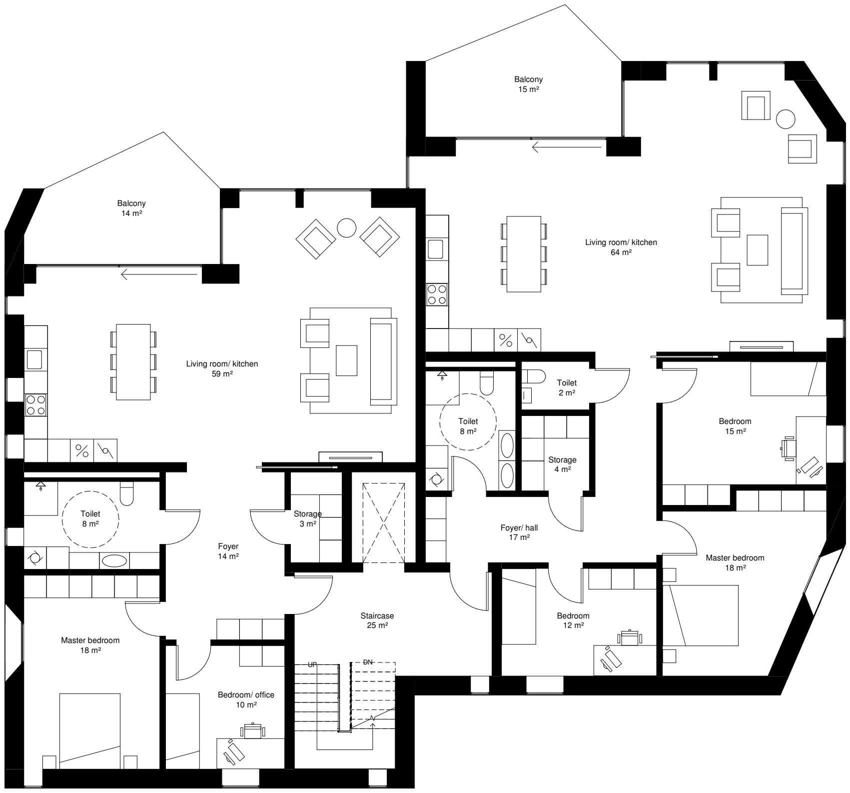
PLAN - GROUND FLOOR 1:200

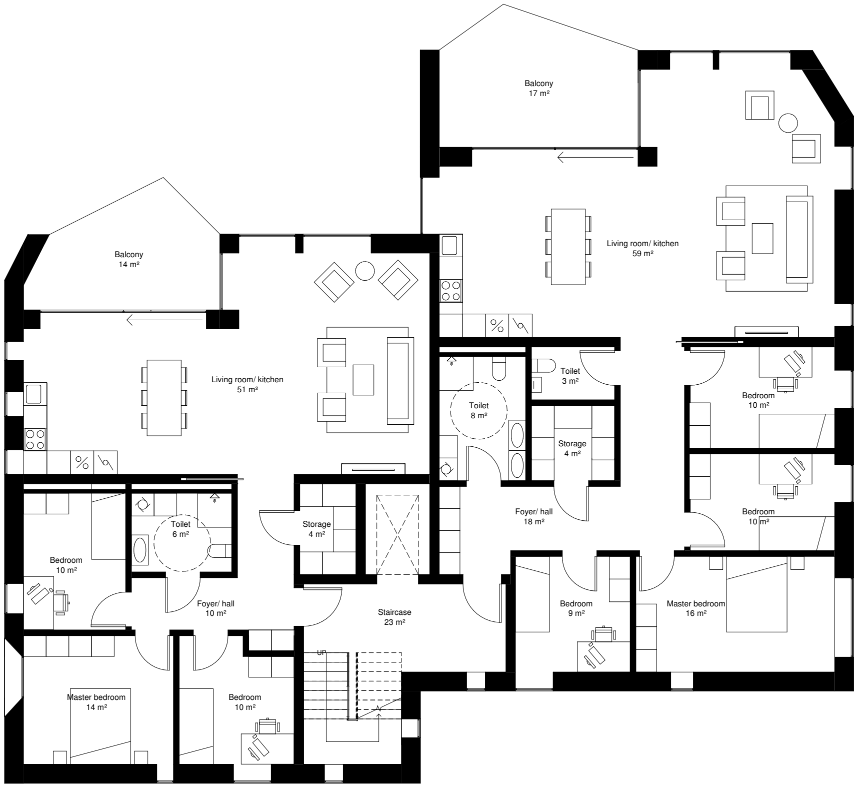



Garden
45 m²
Garden
50 m²
Living room/ kitchen
57 m²
Living room/ kitchen
51 m²
Toilet
3 m²
Toilet
8 m²
Storage
4 m²
Bedroom
10 m²
Bedroom
10 m²
Foyer/ hall
18 m²
Bedroom
10 m²
Toilet
6 m²
Storage
4 m²
Foyer/ hall
10 m²
Staircase
23 m²
Bedroom
9 m²
Master bedroom
16 m²
DN
Master bedroom
14 m²
Bedroom
10 m²

ILL. 151. 1

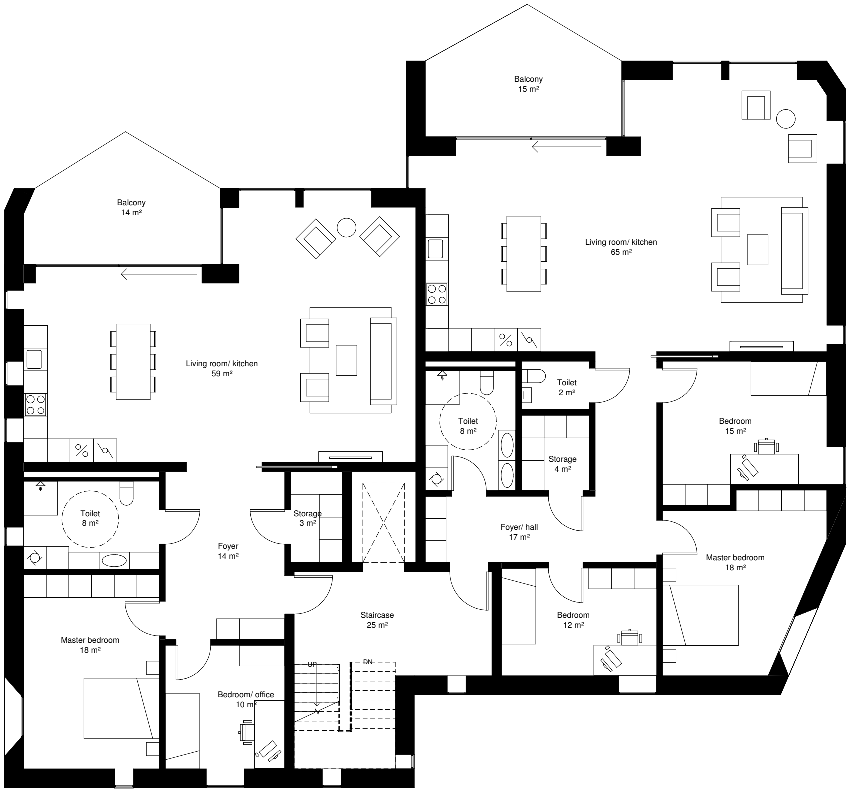
PLAN - 1ST FLOOR 1:200

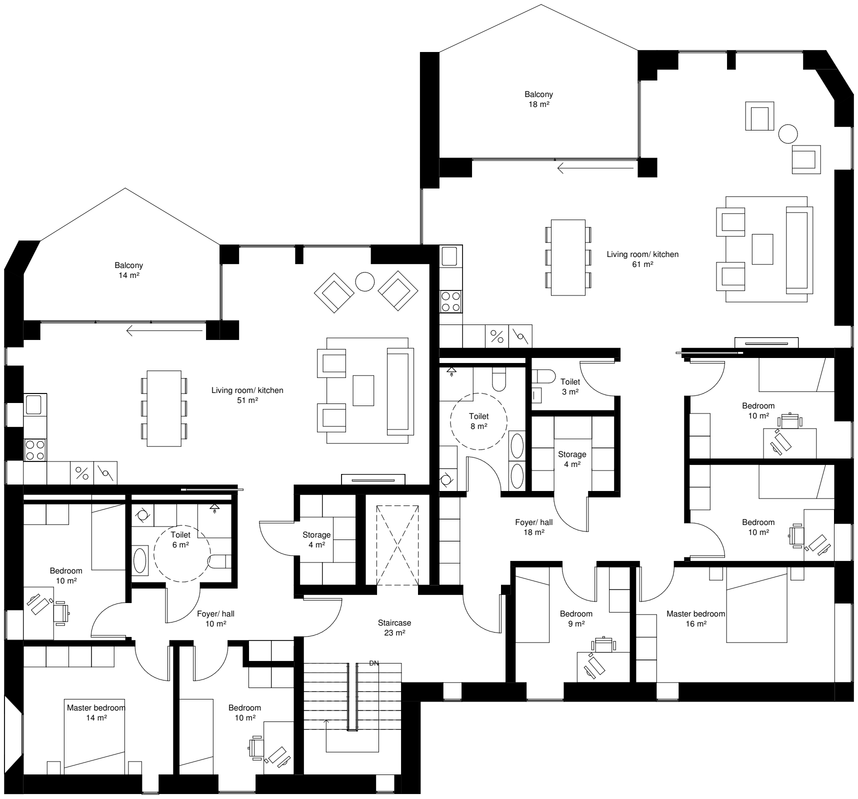



Balcony
17 m²
Living room/ kitchen
59 m²
Balcony
14 m²
Living room/ kitchen
51 m²
Toilet
3 m²
Toilet
8 m²
Storage
4 m²
Bedroom
10 m²
Bedroom
10 m²
Foyer/ hall
18 m²
Bedroom
10 m²
Toilet
6 m²
Storage
4 m²
Foyer/ hall
10 m²
Staircase
23 m²
Bedroom
9 m²
Master bedroom
16 m²
Master bedroom
14 m²
Bedroom
10 m²
UP

ILL. 153. 1

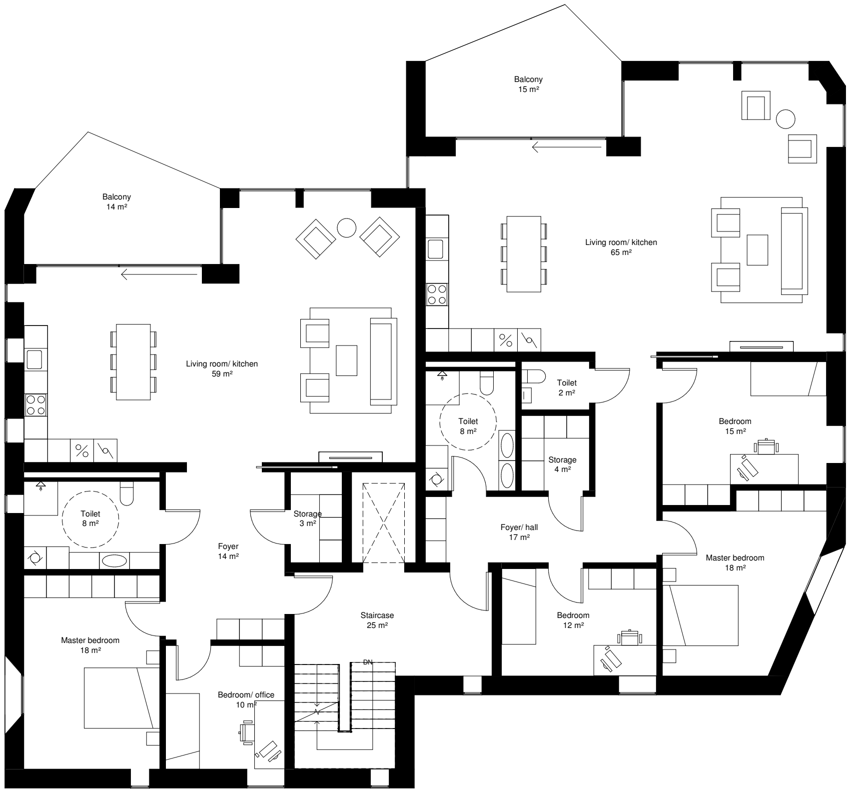
PLAN - 2ND FLOOR 1:200

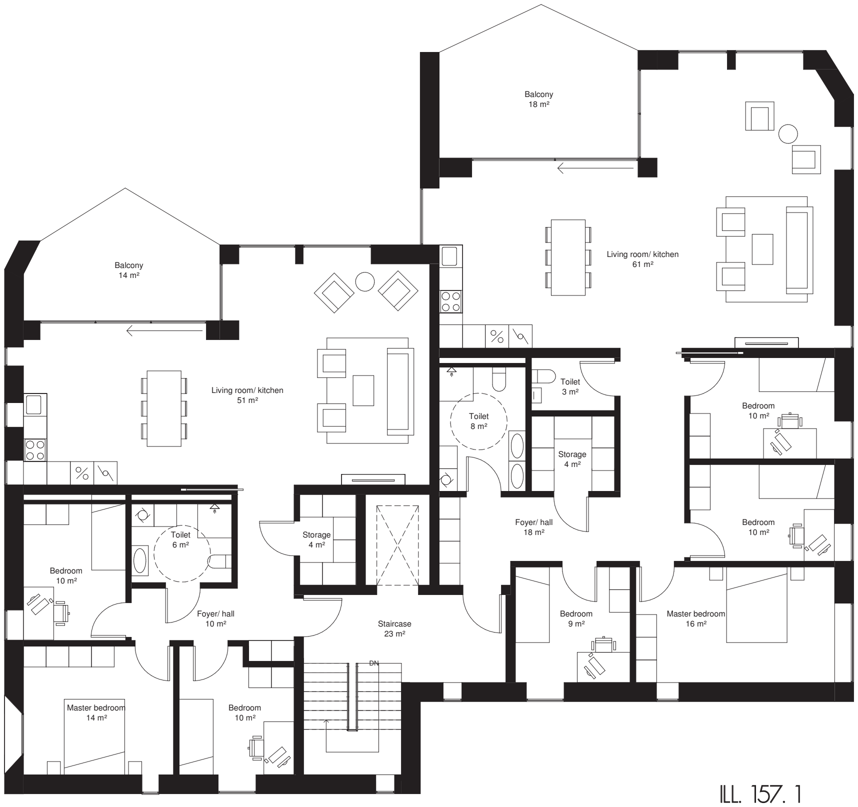



Balcony
18 m²
Living room/ kitchen
61 m²
Balcony
14 m²
Living room/ kitchen
51 m²
Toilet
3 m²
Toilet
8 m²
Storage
4 m²
Bedroom
10 m²
Bedroom
10 m²
Foyer/ hall
18 m²
Bedroom
10 m²
Toilet
6 m²
Storage
4 m²
Foyer/ hall
10 m²
Staircase
23 m²
Bedroom
9 m²
Master bedroom
16 m²
Master bedroom
14 m²
Bedroom
10 m²
DN

ILL. 155. 1

PLAN - 3RD FLOOR 1:200





ILL. 157. 1

	Apartment 1					Apartment 2					Apartment 3					Apartment 3				
	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY	NO.	EST. AREA	TOTAL AREA	HEIGHT	PERSON CAPACITY
	[pc.]	[m2]	[m2]	[m]	[pc.]	[pc.]	[m2]	[m2]	[m]	[pc.]	[pc.]	[m2]	[m2]	[m]	[pc.]	[pc.]	[m2]	[m2]	[m]	[pc.]
Bedrooms	2	14	28	2,5-3,5	1,25	3	15	45	2,5-3,5	1,3	3	11	33	2,5-3,5	1,3	4	11,25	45	2,5-3,5	1,25
Kitchen	1	25	25	2,5-3,5	3	1	25	25	2,5-3,5	4	1	21	21	2,5-3,5	4	1	25	25	2,5-3,5	5
Living area	1	34	34	2,5-3,5	3	1	39	39	2,5-3,5	4	1	30	30	2,5-3,5	4	1	34	34	2,5-3,5	5
Bathroom	1	8	8	2,5-3,5	1	2	5	10	2,5-3,5	1	1	6	6	2,5-3,5	1	2	5,5	11	2,5-3,5	1
Entrance	1	14	14	2,5-3,5	3	1	17	17	2,5-3,5	3	1	10	10	2,5-3,5	3	1	18	18	2,5-3,5	4
Storage	1	3	3	2,5-3,5	-	1	4	4	2,5-3,5	-	1	4	4	2,5-3,5	-	1	4	4	2,5-3,5	-
Technical Space	1	1	1	-	-	1	1	1	-	-	1	1	1	-	-	1	1	1	-	-
Subtotal:			113		-			141					105					138		
Balcony	1	14	14	2,5-3,5	5	1	15	15	2,5-3,5	4	1	14	14	2,5-3,5	4	1	17	17	2,5-3,5	5
Parking	1,5	11	16,5	-	-	1,5	11	16,5	-	-	1,5	11	16,5	-	-	1,5	11	16,5	-	-
Bike parking	3,5	3,2	3,2	-	-	3,5	3,2	3,2	-	-	3,5	3,2	3,2	-	-	3,5	3,2	3,2	-	-
Exterior common area	1	25	25	-	5	1	25	25	-	4	1	25	25	-	4	1	25	25	-	5
Total unit area:			171,7					200,7					163,7					199,7		

ILL. 157. 2

PENTHOUSE APARTMENT VIEW II

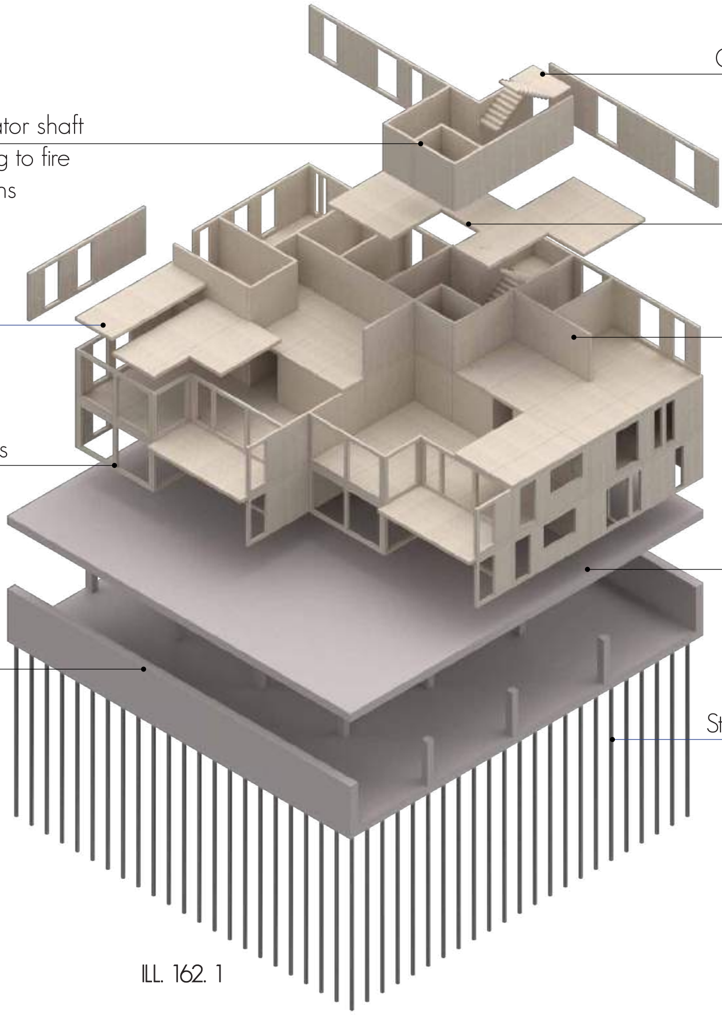
View from penthouse apartment towards the magnificent scenery of the mountains on the West.

ILL. 159. 1


EXTERIOR VIEW III
EXPERIENCING THE COMPLEX WHEN WALKING ALONG THE PONTOON BRIDGE.

ILL. 161. 1

CONSTRUCTING IN CROSS LAMINATED TIMBER



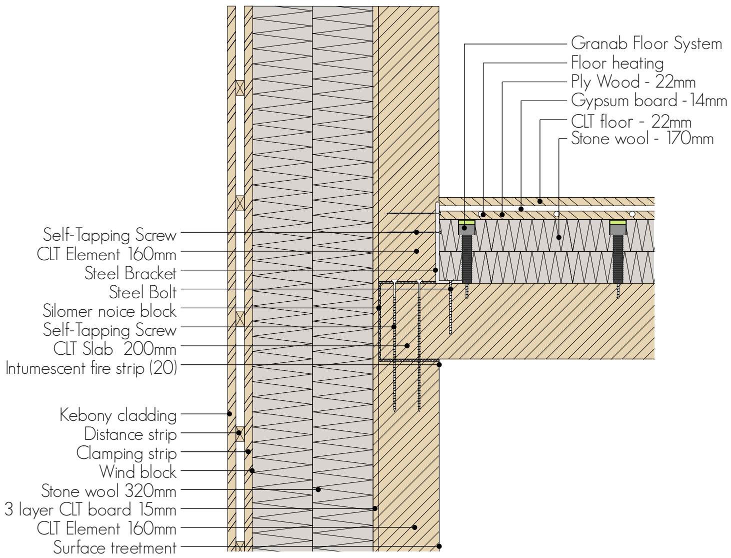
ILL. 162. 1

This chapter will elaborate on the building construction, concerning the principle loadbearing elements, assembly details, sound insulation and fire protection. The general idea of the construction for this project is to keep as many parts as possible in Cross Laminated Timber (CLT), particularly to reach sustainable solution, and to reduce the own-load of the construction. The most common CLT construction types is a slab/wall construction and a slab/stick construction. For this project it has been chosen to design a slab/wall system, where all elements, inner- as well as outer walls, are load-bearing, as seen on construction principle illustration. All elements in the construction is designed to meet the Norwegian requirements for fire safety and soundproofing. Fire regulations: In Norway dwellings, is categorized as risk class 4, based on the evaluation model from the Norwegian Directorate for Building Quality. [Byggforsk, 2009] When the building is a risk class 4 building in four storeys, the building has to fulfil fire resistance class 2 requirements.

Load-bearing elements must meet REI60 fire resistance.

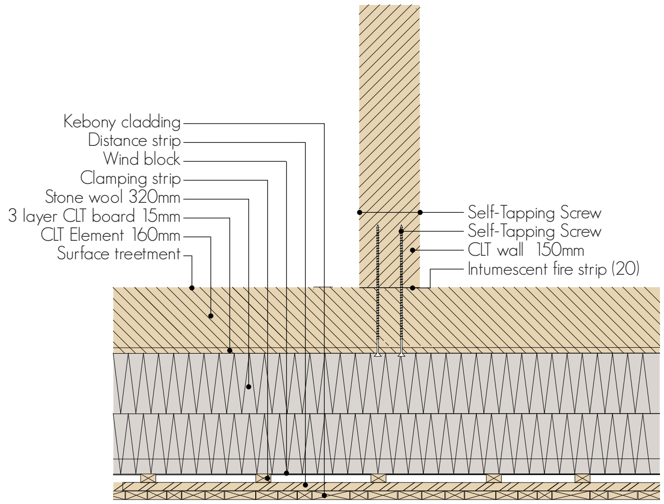
- R (Resistance) Must keep its ability to carry the load.

Wall to slab detail 1:20



ILL. 163. 1

Wall to inner wall plan detail 1:20



ILL. 163. 2

- E (Integrity) Must keep out flames and gasses.
- I (Insulation) Must keep out high temperatures.

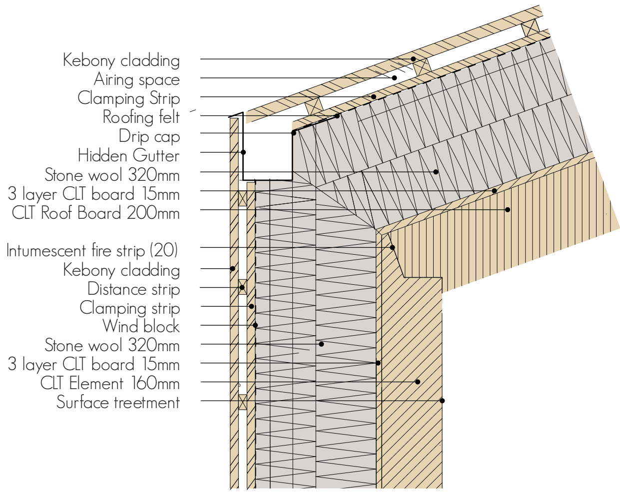
All the above-mentioned abilities need to documented by SINTEF, for each building element. This documentation is usually a result of a 1:1 fire test. As that is not possible for this project, solutions from already build project has been collected and modified slightly to fit the Midsund Apartment project. Generally, CLT constructions is dimensioned to achieve the necessary fire resistance and load-bearing ability by taking the predicted carbonization in to account. According to NS 3470-2, the nominal carbonization speed is 0,7mm/min. [Byggforsk, 2009]

Sound insulation: According to article 522.891, concerning story buildings in CLT, from ByggForsk, the threshold for impact sound between housing units are 48-53dB. [Byggforsk, 2009] To accommodate this a standard floor package from Byggforsks recommendation has been chosen and modified to using a floating floor, for even better performance.

Selected elements and hidden assembly detail are illustrated on this page, while all of them are displayed in appendix.

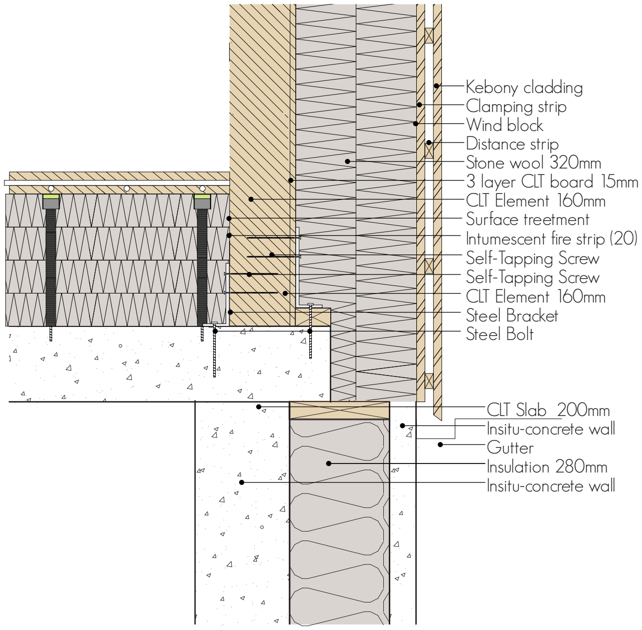
DRAWINGS ETC.

Wall to roof detail 1:20



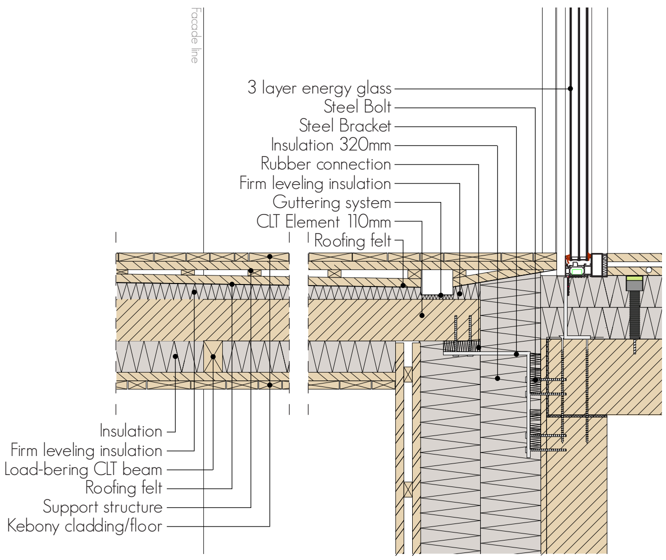
ILL. 164. 1

Foundation to wall detail 1:20



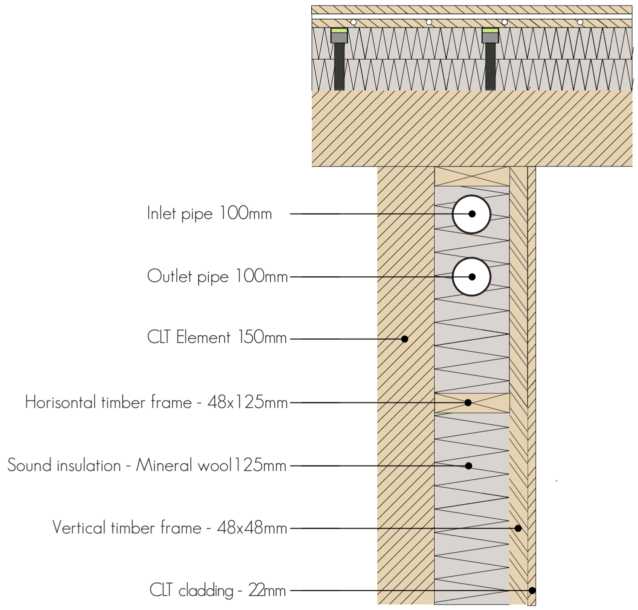
ILL. 164. 2

Balcony detail 1:20



ILL. 164. 3

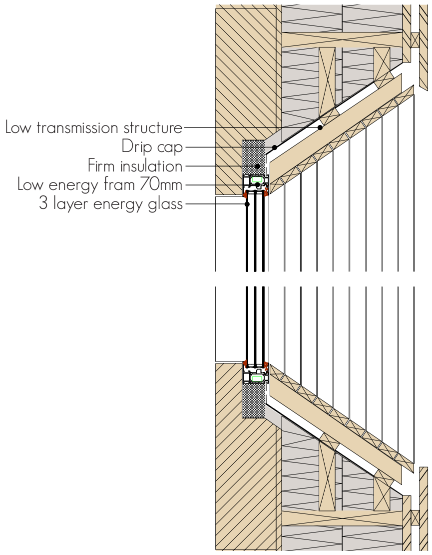
Integrated ventilation(Interior wall)1:20



ILL. 164. 4

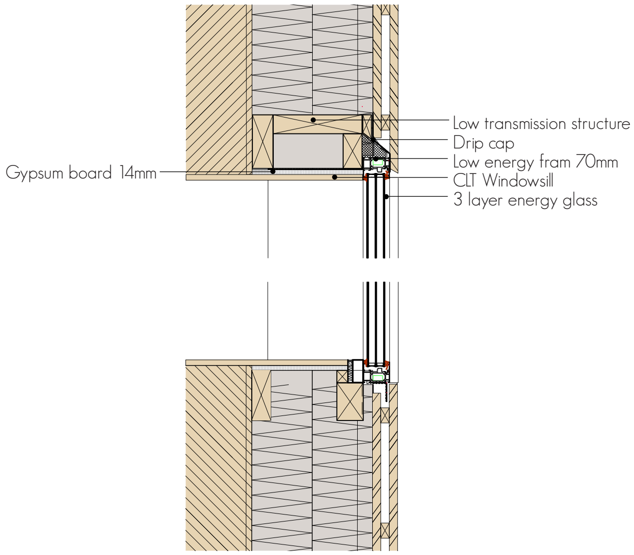
DRAWINGS ETC.

Recessed window detail 1:20



ILL. 165. 1

Facade line window 1:20



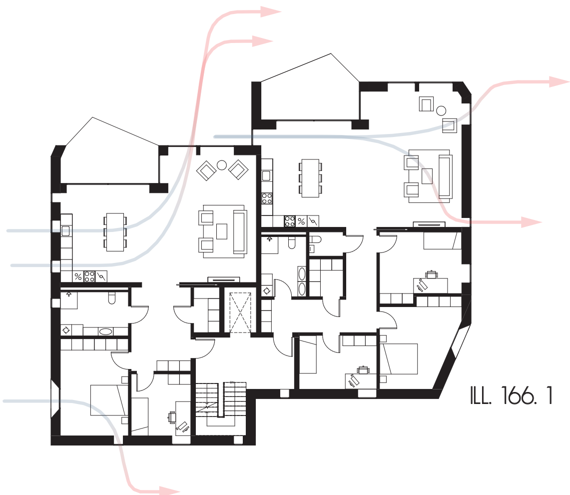
ILL. 165. 2

PASSIVE & ACTIVE STRATEGIES

The objective of the ventilation strategy for the dwellings is to ensure a balance between a high degree of indoor air quality, thermal comfort, adaptibility and energy efficiency. The strategies have been utilized in order to achieve the requirments for the 2020 energy frame by utilizing passive and active strategies for atmospheric and thermal comfort within the dwellings.. During winter, natural ventilation contributes to heat loss, whereas a mechanical ventilation systems with heat recovery consume electricity. By merging these two strategies in a hybrid solution it possible to achieve a satisfactory indoor environment with a low energy consumption.

NATURAL VENTILATION

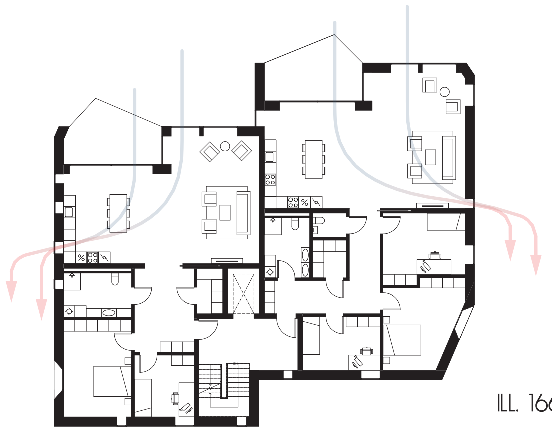
During summer, when the heating demand is low, natural ventilation strategies have been applied, utilizing two driving forces, wind pressure and thermal boyancy, to ensure thermal and atmospheric comfort within the dwellings. Calculations and verifications of the natural ventilation have been carried out and developed throughout the design process to ensure a comfortable environment. The final calculations are based on the most critical apartment during the synthesis phase, situated on the second floor in the southernmost apartment. The necessary airflows needed to maintain



ILL. 166. 1

ILL. 166. 2

ILL. 166. 3



ILL. 166. 4

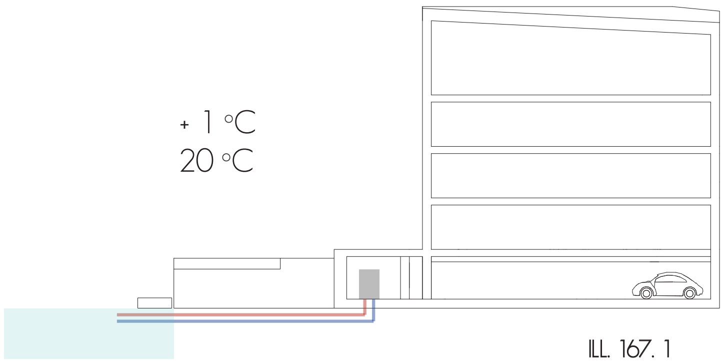
a good atmospheric comfort have been calculated in the in terms of CO_2 levels as well as the experienced air quality (Annnex x), while the effectiveness of the ventilation rate, and location of the neutral plane was calculated and verified in terms of the sizes, orientation and placement of openings (Annnex x), and further verified in the simulation software Bsim. In terms of the thermal comfort, Bsim was used to simulate the potential overheating for the most critical spaces.

The most critical aspect of the design and planning of the natural ventilation of the dwellings was to enable an effective and flexible, passive cooling strategy for the living/dining spaces to ensure thermal comfort. The spaces are critical due to the solar heat gain associated with the implementation of large, exposed glazing partitions towards the extraordinary view from the western facades. The final design proposal draws advantage of the predominant wind directions during summer from south and west, by utilizing a cross ventilation principle that enables an efficient and reliable passive cooling design, whether the wind is direction from south, west or southwest. By placing the openings on the windward facades close to the floor, and the openings close to the ceiling on the leeward facades, the efficiency of the natural ventilation is further enhanced, when the outside temperature is lower than the air inside due to thermal buoyancy. This allows the denser, cold air to lift the warmer air up and out of the building at a higher efficiency, while simultaniously providing an optimal, vertical position of the neutral plane, ultimately improving the comfort of the occupants. Aside from the living/dining spaces, the cross ventilation has also been applied to south-oriented master bedrooms due to a combination of relatively large glazing partitions towards south, and an internal heat gain from two persons. The remaining bedrooms are single sided.

MECHANICAL VENTILATION

To improve the atmospheric comfort inside the dwellings, mechanical ventilation systems are implemented in all the apartments. The systems are decentralized, demand controlled ventilation systems, where each apartment has its own unit, offering the users full control of the air flow for each room, where the airflow can be regulated according to CO_2 load and temperature mesasurements. The systems have a low electrical consumption, as well as a heat recovery of up to 92 %, providing the users with an energy efficient solution for a satisfactory atmospheric comfort during winter. [Exhausto.no, 2018] The ventilation systems are placed in a central location inside the dwellings, in the main bathroom, to reduce the total pipe length and pressure loss for the distribution of inlet and outlet air flows. The main bathroom is placed adjacent to the secondary bathroom and kitchen to shorten the pipe length for outlet air, where the units are installed in between the floor slabs and a false ceiling. The ventilation pipes are integrated in the interior walls to increase the floor-to-ceiling height, as well as to avoid the use of false ceilings, which would conceal the load bearing, cross laminated timber of the floor slabs. The pipes are placed close to the ceiling inside the interior walls, above door openings, from where the airflow is distributed to, or extracted from the various spaces. On the exterior, the inlet and outlet openings are integrated in the facade with the same wooden cladding, forming a harmonious, holistic appearance.

SECTION OF HEATPUMP SYSTEM

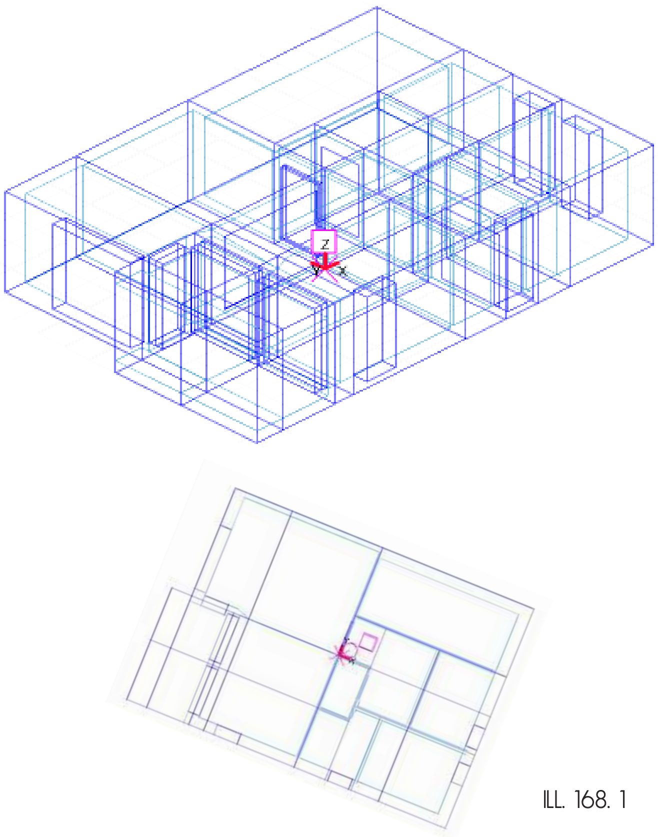


ILL. 167. 1

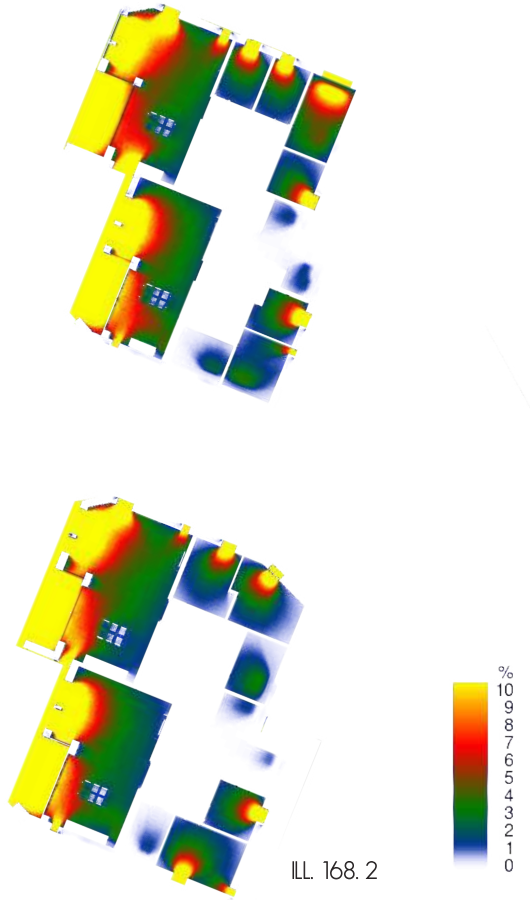
BSIM & DAYLIGHT RESULTS

All the the facade/ balcony iterations made in the design process were made with Inlet-control, as the initial idea was to have a central aggregate, but to avoid too much pipeing though the massive CLT elements, each apartment will have its own aggregate, why the ventilation control is changed to VAV-Ctrl. The final results are illustrated in the following. All Bsim Results can be see in appendix.

Resultas
Hours above 27 degrees - 48 Hours
Hours above 28 degrees - 10 Hours
CO_2: 380-687 ppm (mean 556 ppm)
AirChange: 0,7-3,3% (mean 1,5/h)
RelHumidity: 23,6-53,5% (mean 37,6%)
Daylight: 5% in min. 50% of the space.



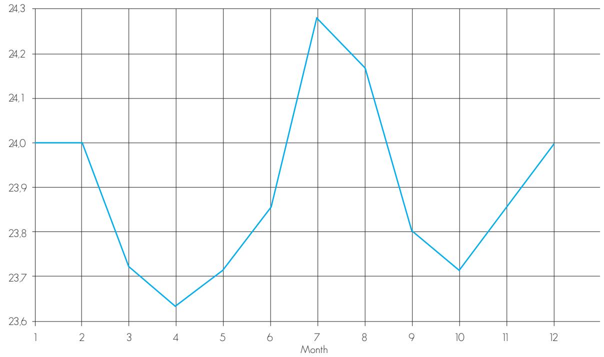
ILL. 168. 1



ILL. 168. 2

These results are reached with initiatives that correspond with the ideas of the desired overall aesthetical design expression of the building. This means that there is still few overheating hours (within the limits). To deal with this, external, movable shading devices on the livingroom window towards west, could have added, but as the simulation results are meeting the requirements, this option is discarted, to avoid interpher-ence with clear-cut design of the open west facade.

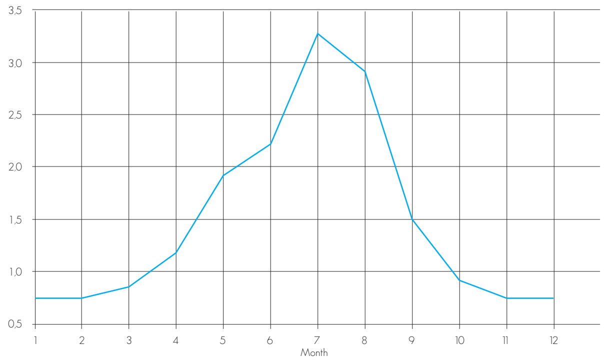
Temperature:
The maximum allowed overheating is:
100 hours above 27 degrees - 48 hours for this project
25 hours above 28 degrees - 10 hours for this project
The graph on the right shows the mean temperatures in the most critical apartment throuhout the year.



TopMean (Apartment)°C

ILL. 169. 1

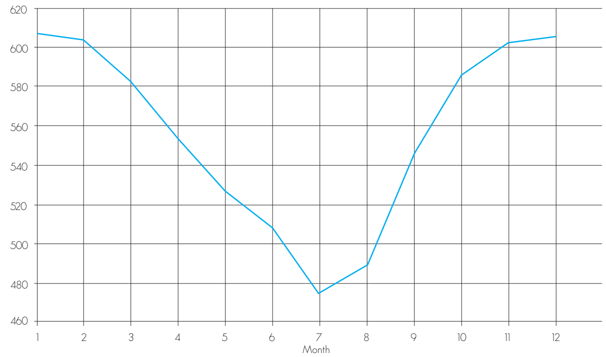
AirChange:
It is recommended to have an avarage airchange of 1-2 for residential buildings, the results of our Bsim analysis shows that our avarage airchance in 1,5/h, with the largest airchange in summer, due to an encreased amout of natural ventilation, to cope with overheating. [Engineeringtoolbox.com, 2005]



AirChange (Apartment)/h

ILL. 169. 2

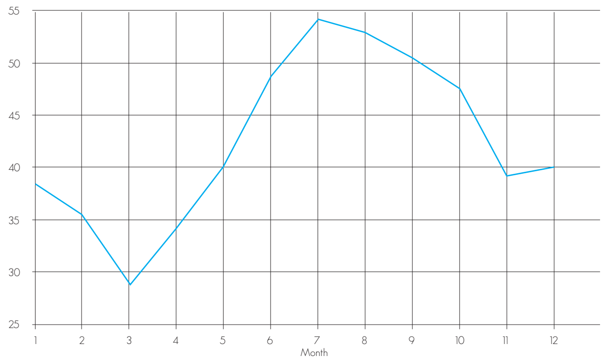
CO_2 Level:
Initially our goal was to achieve building class 2 - Below 850ppm, but as the reuslts for CO_2 shows, we are meeting the requirements for building class A, below 700ppm.



Co2(Apartment)ppm

ILL. 169. 3

Relative humidity:
To ensure the best possible conditions for the wood construction, the relative humidity should be 30-65% [Schmeichel, 2018]. This is achieved, accept for a slightly lower humidity in March, which should not have any critical impact.



RelHumid(Apartment)%

ILL. 169. 4

EXTERIOR VIEW IIII
The building reveals itself in a crystal-clear reflection during night.

ILL. 171. 1

09 EPILOUGE

ILL. 173. 1

CONCLUSION

The fundamental motivation for this project has been to design attractive and sustainable apartments, which aim to create an architectural and sustainable framework for life quality, derived from the five ways of well-being. This motivation has led to an investigation of how to create well-being through, different aspects of sustainability; social-, environmental- and economic sustainability, and how these can be applied and expressed architecturally.

Throughout the development of the project, iterations have been conducted, to integrate various parameters concerning technical, functional and aesthetical challenges, while simultaneously considering and incorporating the changing interest of the stakeholders, as well as an economic aspect.
This interest-changes became noticeable, as a result of attempting to bridge practice and academic aims, both in the process of designing environmental and socially sustainable solutions.

Based on new knowledge acquired from the project, research and dialogue with stakeholders, the predefined goals for energy consumption were adjusted during the design phase, and as the results of the BE18 shows, the design fully comply with both Danish and Norwegian low energy standards, as well as the wishes from the stakeholders, with an overall energy consumption of 18kWh/m2/y.
Furthermore, results from the indoor environment simulations from Bsim shows that the predefined technical aims for thermal and atmospheric comfort, and daylight factors are achieved satisfactorily.

When working with the aspects of social sustainability, another focus derived from the future plans of Midsund has been to accommodate the five ways of well-being, through intentional and unintentional meetings, combined with a balance between privacy and interaction with the neighboring inhabitants and guests visiting. In a physical manner, this is treated by differentiating distances between private user functions, a larger semi-public outdoor space, and the physical, visual and auditive connections on the site.

The architectural qualities, integrated within the project is to a large extent awakened by the natural resources at the site, with inspiration from a Nordic architecture approach and Genius Loci. During the study trip to the site, it became clear that the project by default would stand out as a landmark, due to a different scale, introduction of a new typology and a very central location in Midsund. Therefore, the architectural development of the concept became a balancing act of blending in, while contributing to a modernization of the vibrant waterfront and enhancing the resources on the site, to create added value for the users, without exponentially increasing the economic cost.

This enhancement of the site is achieved, with a design concept and the choice of material, both emerging from the very near context; the rock behind the site, the forests on the mountainside, crystal clear reflections of the fjords and the traditional building techniques of surrounding buildings. All translated into a delicate, contemporary unification of elements relating to, and expressing the very place specific qualities into a holistic building merging with the site.

REFLECTION

As this project is both an academic- and an actual project, it has been discussed multiple times, throughout the process, how to deal with this topic and how to find a balance between complying with the wishes of the stakeholders and with the academic guidelines.

The implementation of an economic aspect added, an additional layer to the already complex methodology of the Integrated Design Process. As we have been trying to create added value, with little economic cost, we have been reflecting upon, the balance between architectural quality and potential profit for the stakeholders, and how this have influenced potential buyers' willingness to invest.

An example of this balancing could be the aspect of Zero Energy Building. As earlier mentioned, this goal was adjusted in accordance to the wishes of the stakeholders, justified with the renewable energy available in Norway. Was it the correct approach, to give in to the adjusted wishes of the stakeholders or should we have pushed more for a ZEB solution, maybe even have proposed to make a ZEB plus? Would this be possible while still complying with the wished and the financial interest of the stakeholders? Or could the solutions potentially have been implemented for the academic purpose, and been discarded during the realization of the project, without compromising any qualities of the project?

Due to this aspect of realism, a lot of energy were put into research on regulations, details, and legislation, this added complexity in the project sometimes slowed down the process, and often too many iterations were tested before decisions were made. Could the decision making have been more efficient, while still achieving satisfactory results?

The decision to use inaccurate weather data was justified with a primary focus of solving the academic task and illustrating the understanding for the tools used in this process. As we know these inaccurate weather data have influenced the results, it is an interesting reflection how more accurate results could have had an impact on the process and potentially the final design?

For further development of the project, consideration has been made on how the entrance of the building on the east side could have been softened, to appear more inviting, and possibly more functional, with a covered space in front of the door.

Additionally, it has been discussed whether or not to create a common indoor workshop space. However, this idea was finally not investigated, due to a concern whether potential buyers would pay extra for these facilities or not. Would it have solved the issue, if these facilities would have been built as a unit separated from the main complex? – or as a part that could be added after the completion of the project?

Last but not least, more investigations on external movable shading could have been made. With the current design, the critical apartment will experience approximately ten overheating hours above 28 and 48 hours above 27 degrees a year. We chose to allow this in order not to compromise the overall design of the project, but with more time, solutions to cope with this problem could have been integrated to a satisfactory level.

The navigation between the academic environment and practice can be difficult when the values conflict, but because of the many challenges, the project has been a great learning experience, with a unique opportunity of getting an insight to the professional environment.

As well as achieving knowledge on how these different inputs, can lay the basis for an apartment project of satisfactory architectonic and sustainable quality.

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