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DUNESIDE CLIMATE CENTRE

MsC04 - ARCH14 - May 2021

DUNESIDE CLIMATE CENTRE

Master Thesis 2021

FIG 01 ATLAS OF PLACES

title page.

department of architecture, design & media technology

DUNESIDE CLIMATE CENTRE	**TITLE**
SUSTAINABILITY	**THEME**
1ST FEBRUARY 2021 - 27TH MAY 2021	**PROJECT PERIOD**
ARCH - 14	**GROUP**
4TH SEMESTER OF SCIENCE IN ENGINEERING	**SEMESTER**
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161	**PAGES**
14	**APPENDIX**

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abstract.

This thesis presents the making of 'Duneside', a centre for climate change, located at the Danish west coast city, Blokhus. The thesis is written in relation to the master's programme in Sustainable Architecture at Aalborg University, and is based upon interdisciplinarity between the fields of architecture and engineering that both support and challenge one another. In accordance with the Integrated Design Process (IDP), interdisciplinary investigations are conducted iteratively with preliminary and continuous research and analyses throughout the design process. As the centre mediate climate change, attention is brought to the impact of the centre, and actions minimizing both environmental and physical impact on the surroundings are implemented. A large part of the analyses is therefore related to life cycle assessments of materials and design for disassembly principles. The project challenges present time building strategies, as it rethinks constructions through implementation of traditional building principles and aspires to be constructed of solely ecological materials. The aim of this thesis is to design a building that takes a social stance, by becoming an epitome for sustainable constructions, and motivating towards climate friendly living and increased appreciation of nature.

00.1 table of contents.

00.2 reading guide.

structure of the thesis

This report consists of three sections: Program, Presentation and Process. The sections are based upon The Integrated Design Process, being the chosen methodical approach of this thesis. The program consists of all preliminary research and analyses that set the framework for the design process, which in IDP would be the first two to three phases. The presentation follows the program, and communicates the final design through plans, sections and facades, as well as visualisations and diagrams. Lastly, the design process will present the process of the making of the design proposal. Throughout all three sections there will be references to an annex, in which supporting content to the report can be found.

The Integrated Design Process is an iterative approach, continuously building upon knowledge, using various theories and methods throughout all phases. However, the process is presented chronologically, despite being highly iterative, in order to communicate the project best possible.

Due to the Covid-19 pandemic, a large part of the project has been conducted digitally, however, the report is designed for a physical presentation, where the pages will be seen as spreads rather than individual pages on screen. Therefore, the report shouldn't be read throughout from left to right, top to bottom, as the layout is highly designed as spreads with adjoining text and illustrations to present the various investigations. Furthermore, the report will have multiple sub-conclusions throughout but will finish with a general conclusion and reflection.

00.3 foreword.

purpose of the thesis

The 'Our Common Future' report from 1987 placed sustainability on the political agenda, which has continued to be a relevant topic for discussion ever since.

"Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"
(WCED, 1987, p. 15)

The report highlights that sustainability is not only an environmental matter but relates very much to a social and economic aspect as well. It also implies that sustainability begins with humans, and that action towards increased sustainability is needed. As of 2018, the building sector was responsible for 39 percent of energy and process-related CO2 emissions, of which manufacturing of the commonly used materials such as steel, cement and glass, uptakes 11 percent (United Nations Environment Programme, 2019).

This thesis aims to exemplify sustainable constructions through a building made of exclusively ecological materials, that seeks to inform of climate change and inspire towards sustainable living. With a location in the distinctive nature at the Danish west coast, the project is placed in a setting where such a building not only would improve sustainability, but also responds to the general atmosphere and characteristics.

00.4 motivation.

thoughts and expectations

THOUGHTS:

'the act of thinking about or considering something, an idea or opinion, or a set of ideas about a particular subject' (Cambridge dictionary, n.d. b)

EXPECTATIONS:

'the feeling or belief that something will or should happen' (Cambridge dictionary, n.d. a) The following presents our expectations of this thesis.

The following presents our thoughts on architecture in relation to some of the several other aspects related to constructions. This is only our thoughts and not based on facts.

Originating in an interdisciplinary approach towards architecture, which has been the predominant subject in the education of Architecture and Design at Aalborg University, the contradictions between the field of architecture and engineering has become very clear, as the various technical factors have occasionally become limitations rather than opportunities, when the two fields are perceived as opposites. The rather large number of different technical aspects from which the design process can be approached tend to overrule the architectural, and equivalence between the two can seem unobtainable. The opportunities of integrated design lies in finding architectural qualities based on technical aspects and vice versa, increasing the quality of the final design. Given the nature of the project site for this thesis, attention to its atmosphere seems relevant. Looking back at building traditions, the danish functional tradition had created a connection with nature, that in recent times has been lost due to energy consumption regulations and standardized buildings, copied from site to site with limited concern of the microclimate (Poulsen and Lauring, 2019). For this thesis, this has led to a focus upon choice of materials that responds well to the environment both architecturally and technically, and thus increases the general appreciation of nature through architecture that utilizes the properties of the available material. The climate adaptation and mitigation (cf. Sustainability pp. 39-40), that lies within this materialistic focus, are repercussions of choices made in the past, that in some ways have restrained the architectural choices we can make today, just as the choices made today will have an influence on the choices of tomorrow.

As this thesis unfolds, we see an opportunity to exemplify sustainable constructions through consensus between the architectural and engineering fields. Thus, the two will have equal influence on the final building design, as architectural theories and atmospheres corroborate with the choice of materials.

01.0 PRELIMINARY

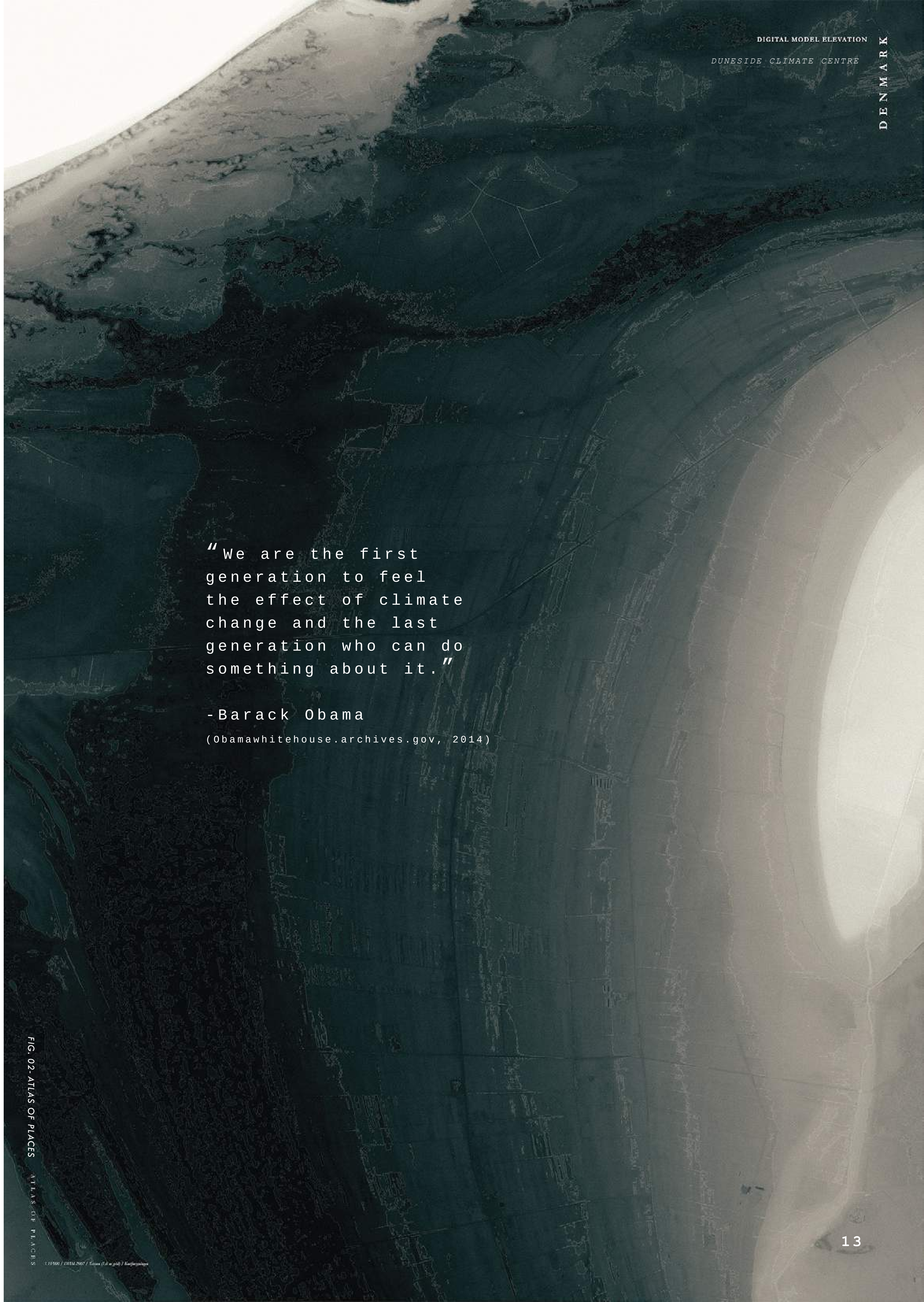


FIG. 02- ATLAS OF PLACES

"We are the first generation to feel the effect of climate change and the last generation who can do something about it."

-Barack Obama

(Obamawhitehouse.archives.gov, 2014)

CLIMATE CHANGES AT A GLOBAL SCALE

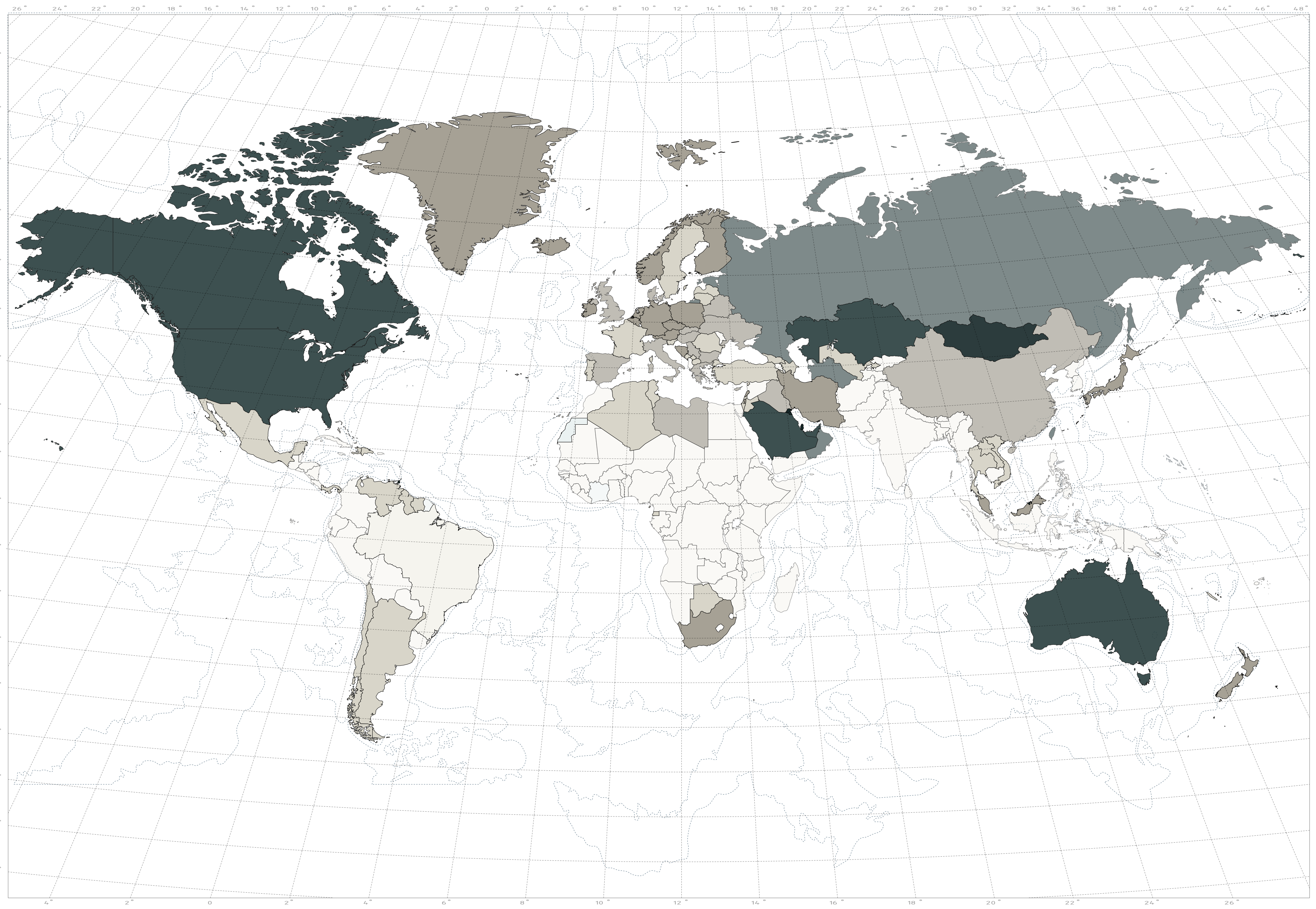


FIG. 03- (ICOS, 2021)

carbon dioxide t/year

0-1 | 1-2.5 | 2.5 - 5 | 5-7.5 | 7.5 - 10 | 10-15 | 15-20 | 20 - 50

GLOBAL
SINCE 1880
1.09 °C ↑
CURRENT LEVEL
1.02 °C

SEA LEVEL
RATE OF CHANGE
3.3mm ↑
CURRENT LEVEL
~95 mm

ICE SHEETS
RATE OF CHANGE
149 GT ↓
CURRENT LEVEL
~-2586.7 GT

CARBON DIOXIDE
SINCE 2010
27 ppm ↑
CURRENT LEVEL
415 ppm

(NASA, 2021)

01.1 confrontation.

creating awareness

HUMAN - CAUSED CLIMATE CHANGE

"Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems." (IPCC, 2014, p.2).

Our actions throughout history are resulting in colossal repercussions on our natural environment (Stern, 1993), and has led to overall temperature rise, melting snow and ice sheets, rising sea levels, concerning $C0_2$ levels and more, as illustrated in fig. 02 (NASA, 2021). Nonetheless, we continue our everyday in the direction of consumerism, without properly acknowledging our part in the problem confronting society with factors such as pollution, environmental degeneration, and global warming, leading to larger polarization, social injustice and poverty (White, Habib and Hardisty, 2019). Failing to limit population growth, reduce greenhouse gases, implement renewable energy, preserve the environment, use renewable materials, halt deforestation, minimize pollution and restore ecosystems, is leading to a jeopardization of our future (Ripple et al. 2017). It is therefore time to take responsibility to reflect upon our habits as consumers and contemplate how we as individuals can contribute towards a brighter, greener and healthier future.

DENMARK'S POSITION ON CLIMATE CHANGEE

As accentuated in the statistics on the following pages, (fig 04) it is apparent that even though the majority (63%) of the Danish population is worried about climate change, then the extent to which they feel well-informed about the subject is considerably smaller (39%) (Mejeriforeningen, 2020). This forces us to ask ourselves if it is due to the complexity of sustainability and its distance from our everyday concerns, or if it boils down to the present forms of communication which occur mostly digitally with possible nodes of confirmation bias? The media provides evidence of climate change in a visual magnitude, but seemingly not to such a convincing degree that it compels us to change our behavior, or gives us the feeling of full understanding of the subject. Is it therefore possible to consider other methods of creating awareness and providing relevant information on the subject? Chansomnak and Vale mention *"People interact with architecture not only by living, working or learning in it, but also through indirect messages that architecture represents via its design process, built form, functions, and patterns of use and maintenance. To educate people for sustainability, architecture should be recognized as a tool or medium that encourages people to live more sustainably."* (Chansomsak and Vale, 2008, p. 1). Is it therefore possible to use architecture as a medium for educating and raising awareness upon climate change?

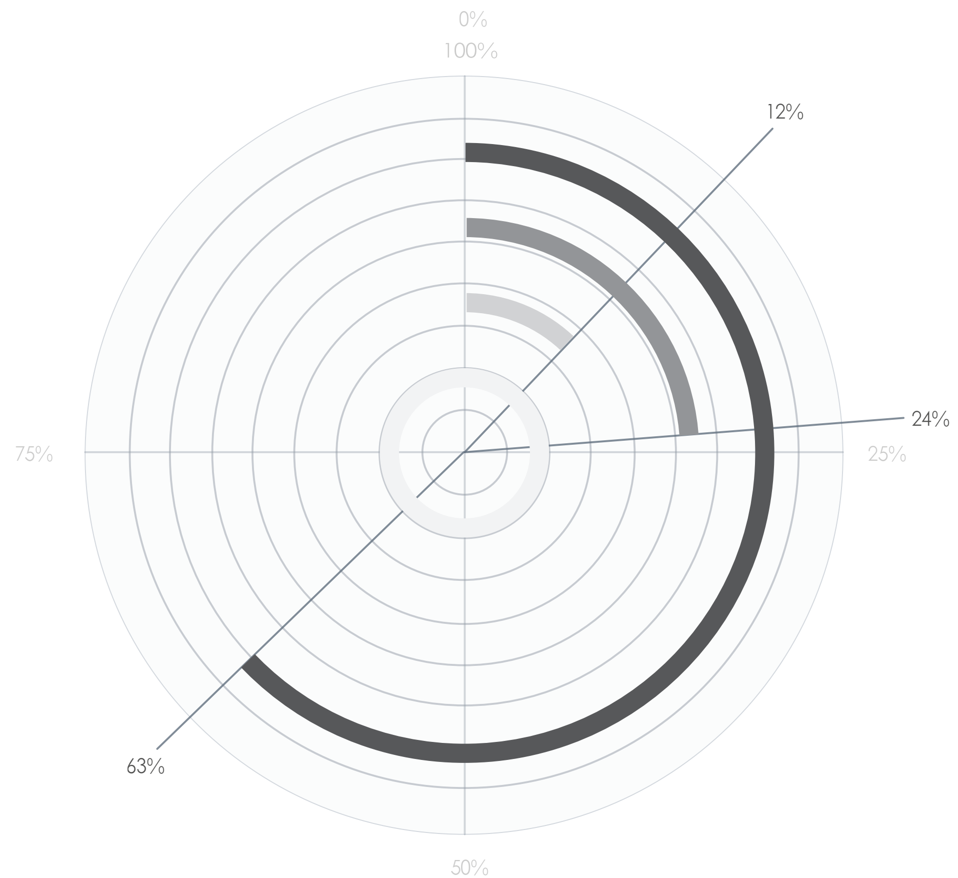
How and to what extent can architecture mediate, inform, and inspire users to shift their attitude and behavioral intentions?

STANCE ON SUSTAINABILITY OF THE DANISH POPULATION

"I AM WORRIED ABOUT CLIMATE CHANGE" →

% OF CITIZENS WHO AGREE:

63 %

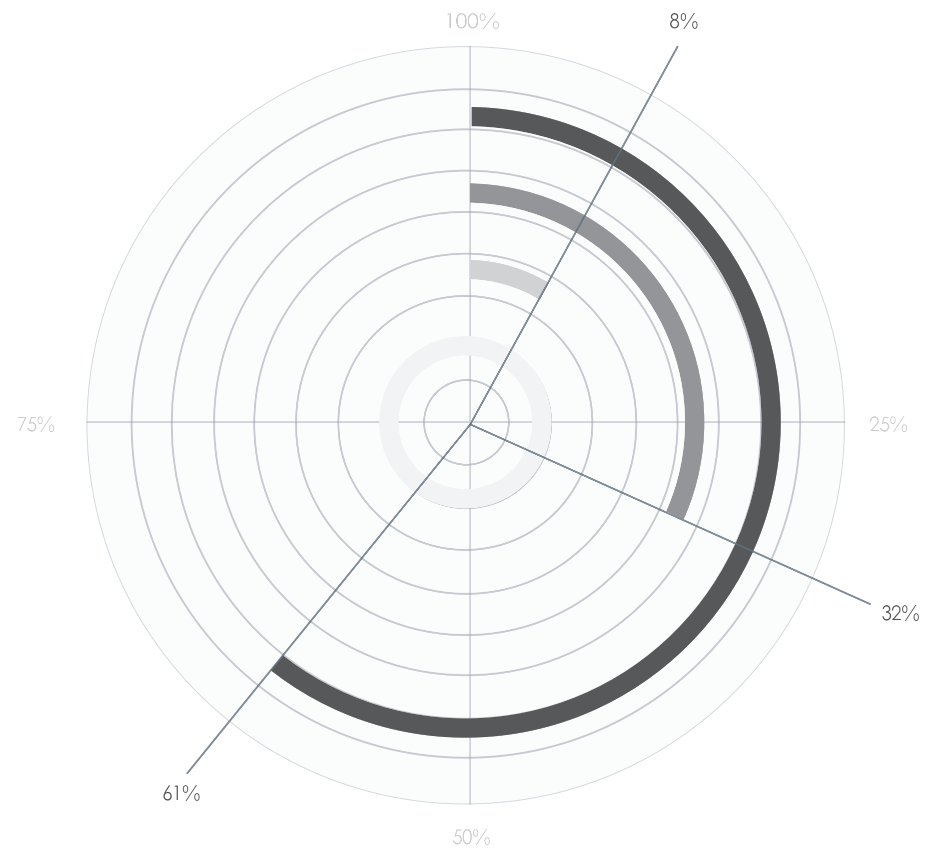


agree
disagree
don't know

"I HAVE CHANGED MY BEHAVIOR OVER THE PAST YEAR DUE TO CLIMATE CONSIDERATIONS" ←

% OF CITIZENS WHO AGREE:

61 %

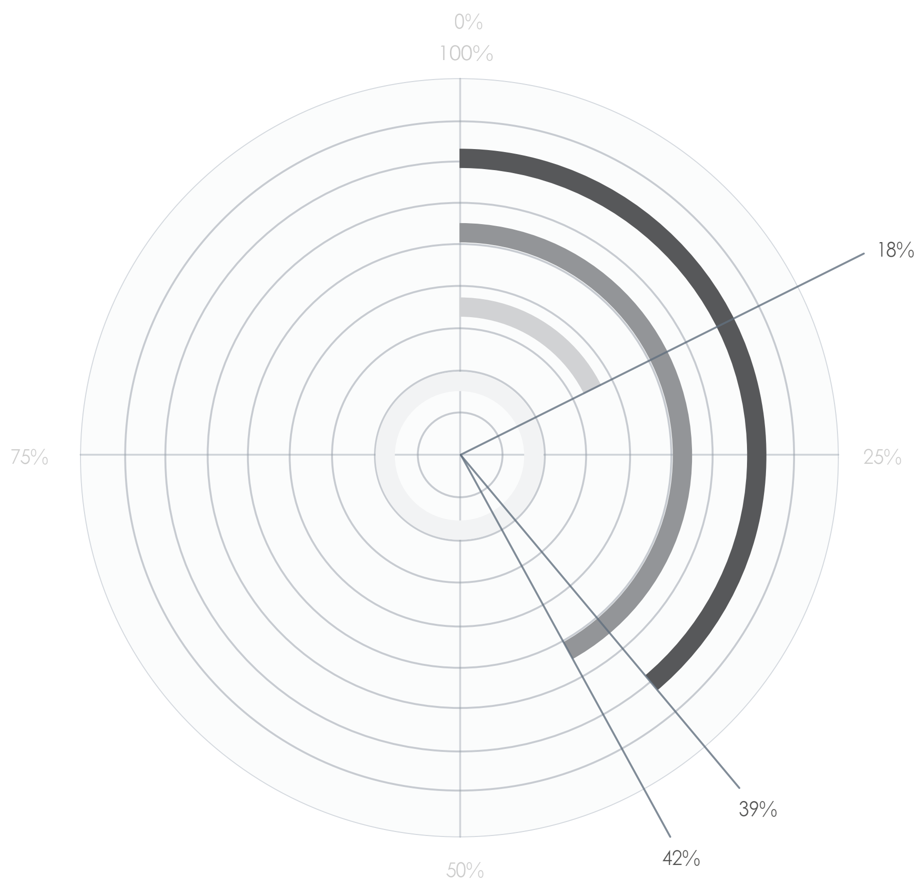


agree
disagree
don't know

"I FEEL WELL INFORMED ABOUT SUSTAINABILITY" →

% OF CITIZENS WHO AGREE:

39 %

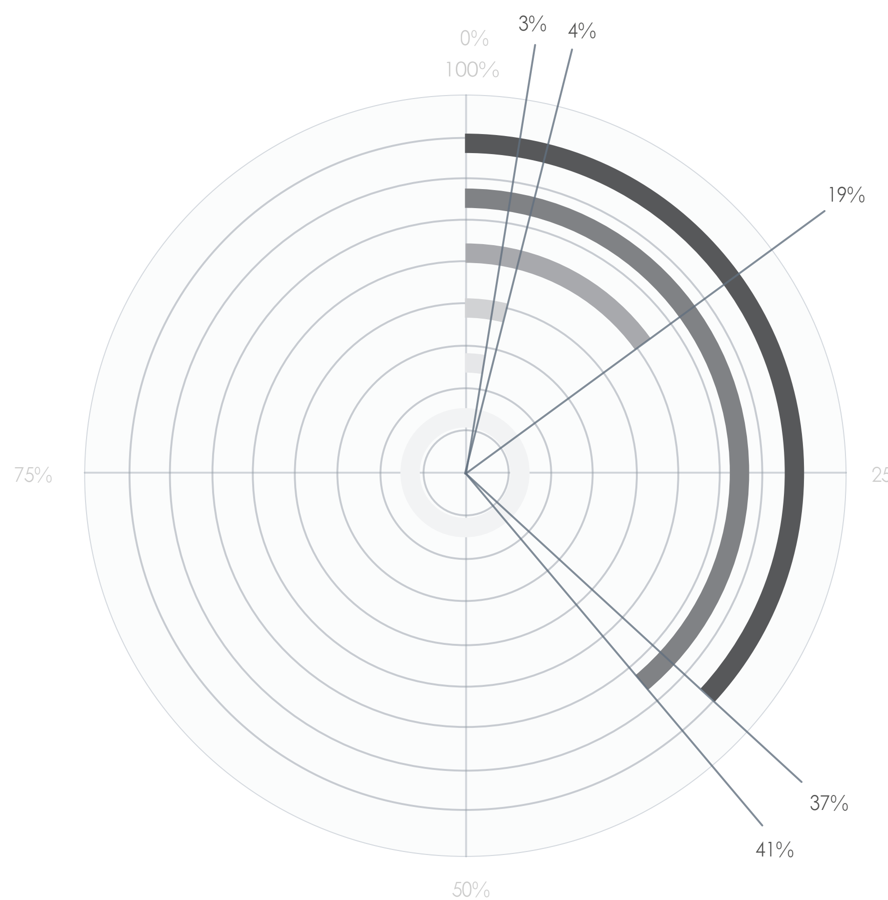


agree
neutral
disagree

"WE MUST CHANGE OUR HABITS TO PRESERVE OUR PLANET" ←

% OF CITIZENS WHO AGREE:

78 %



strongly agree
agree
neutral
disagree
strongly disagree

FIG. 04- Statistics on Danes' knowledge on climate change

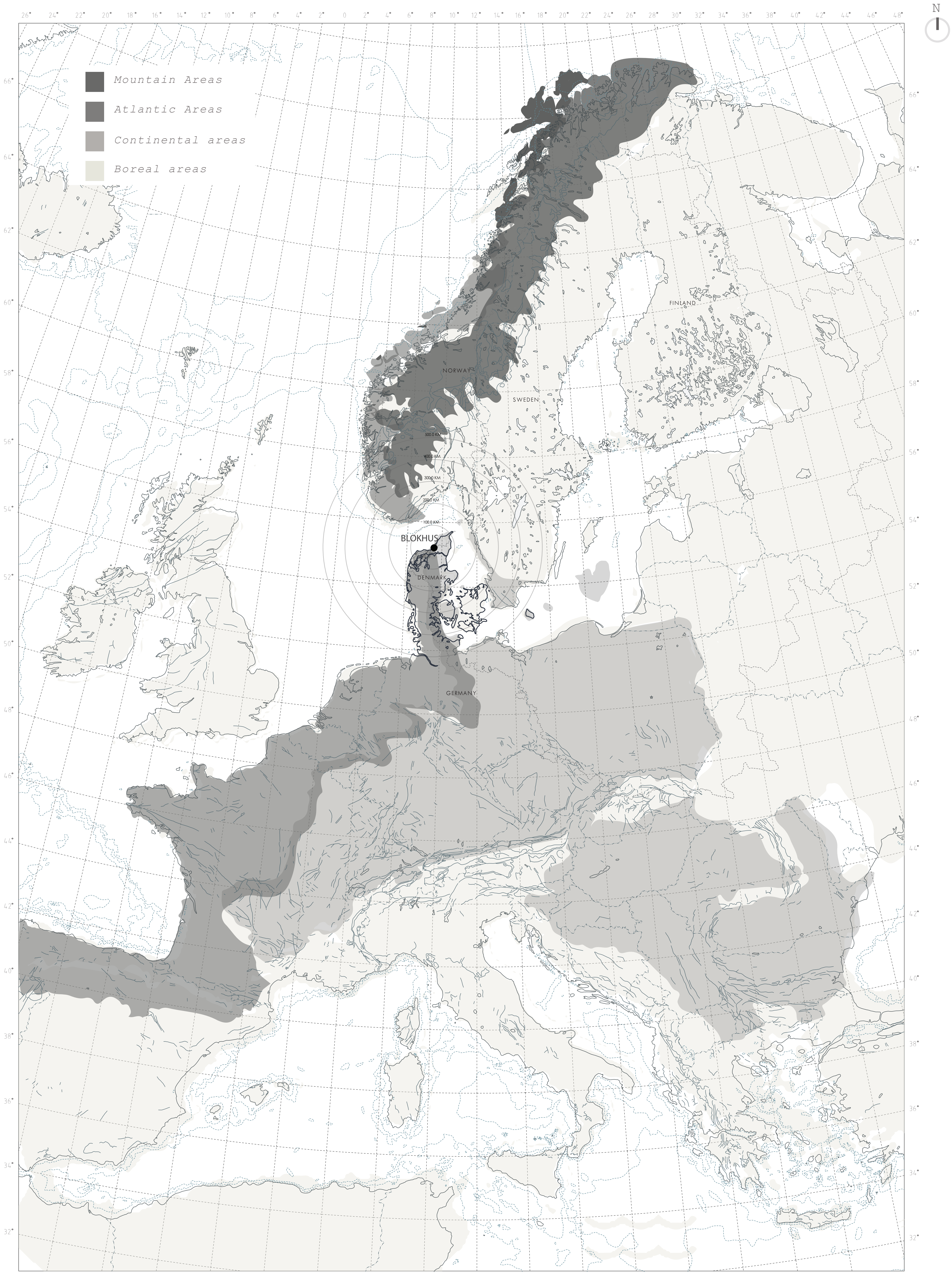


FIG. 05- 1:10,000,000 Climate Map of Scandinavia

01.2 introduction.

scope of the project

MOUNTAIN AREAS

Higher temperature rise than the European average
Less extent and volume of glaciers
Increase in plant and animal species
High risk of extinction of species
Increasing risk of forest pests
Increasing risk of landslides

ATLANTIC AREAS

Increased number of incidents with heavy rainfall
Increased river flow
Increased risk of flooding at streams and coasts
Increased risk of damage from winter storms
Lower energy consumption for heating
Increasing a number of climate-related hazards
Changes in the potential for hydropower
Less ski tourism

CONTINENTAL AREAS

Rise in heat extremes
Less summer precipitation
Increased risk of streams crossing their banks
Increasing risk of forest fires
Decrease in the economic value of forests
Increased demand for energy for cooling

BOREAL AREAS

Increased number of incidents with heavy rainfall
Less snowfall and less ice cover on lakes and streams
Increased precipitation and increased water flow in watercourses
Increased potential for forest growth and increased risk of forest pests
Increasing risk of damage from winter storms
Higher harvest yield
Lower energy consumption for heating
More energy from hydropower
Increased summer tourism
Changes in the potential for hydropower
Less ski tourism

(Det Europæiske Miljøargentur, 2020)

PRELIMINARY

The following section introduces the scope of this thesis. It considers the initial problem as a foundation for the theoretical and analytical phases, as well as the potentials and platform for building an Education Centre for Climate Change in Blokhus. It aims to provide the reader with a basic understanding of the direction of the thesis.

PLATFORM
architeture as a catalyst

ecological definition: locally grown, non-chemical natural materials

natural materials definition: a material extracted directly from the environment without going through a chemical process allowing them to return to the ecosystem.

We are facing a global environmental crisis as climate change is rapidly advancing, impacting nature, human beings, and the ecosystem (NASA, 2021). Different areas in the world are facing distinct challenges in terms of climate change, and it is vital to understand the specific challenges facing the context of where a building is to be designed. The map of Northern Europe in fig. 04 illustrates the various types of areas and their environmental challenges. Denmark is a part of the Atlantic / continental areas, indicating the following main issues; Summers will mostly become warmer and drier, with heightened periods of drought and occasional heavy rainfalls, whilst winters will become milder and wetter, concluding an overall rise in temperature throughout the years. These shifts in temperature will additionally increase the risk of extreme weather, resulting in recurrent violent storms, heat waves and increased maximum water levels (Grauert et al., 2013). Considering these various challenges which Denmark is already facing, or inevitably will be facing in the future, this thesis aims to present a solution to how the building sector can advance with a larger attention to our planet. Therefore, the following initiating problems arise:

'What are the major climate issues facing Denmark and to what extent can architects take responsibility and design towards a sustainable future?'

And

'What are the opportunities and repercussions of different materials, aesthetically, structurally, and ecologically in the building sector?'

POTENTIALS
of an educational centre for climate change in Blokhus

Sant Chansomsak argues that when presented with a design solution which provides health and comfort whilst still considering different approaches towards improving the natural environment, it initiates a positive outlook on the architecture, and may therefore be amenable to altering their habits and attitude (Chansomsak and Vale, 2008). The centre therefore presents an opportunity to mediate and enhance awareness and knowledge about climate change and the possible prospects of our future if we as human beings do not alter our habits. It is a place which encourages learning and sharing with the concept of a 'learning landscape' through interaction and movement. Due to the lush natural surroundings of the site and Blokhus, the centre can incorporate the dynamic environment to inspire and spark environmental consciousness, with the building itself functioning as an epitome for how to build ecologically and sustainably whilst still ensuring well-being of the users.

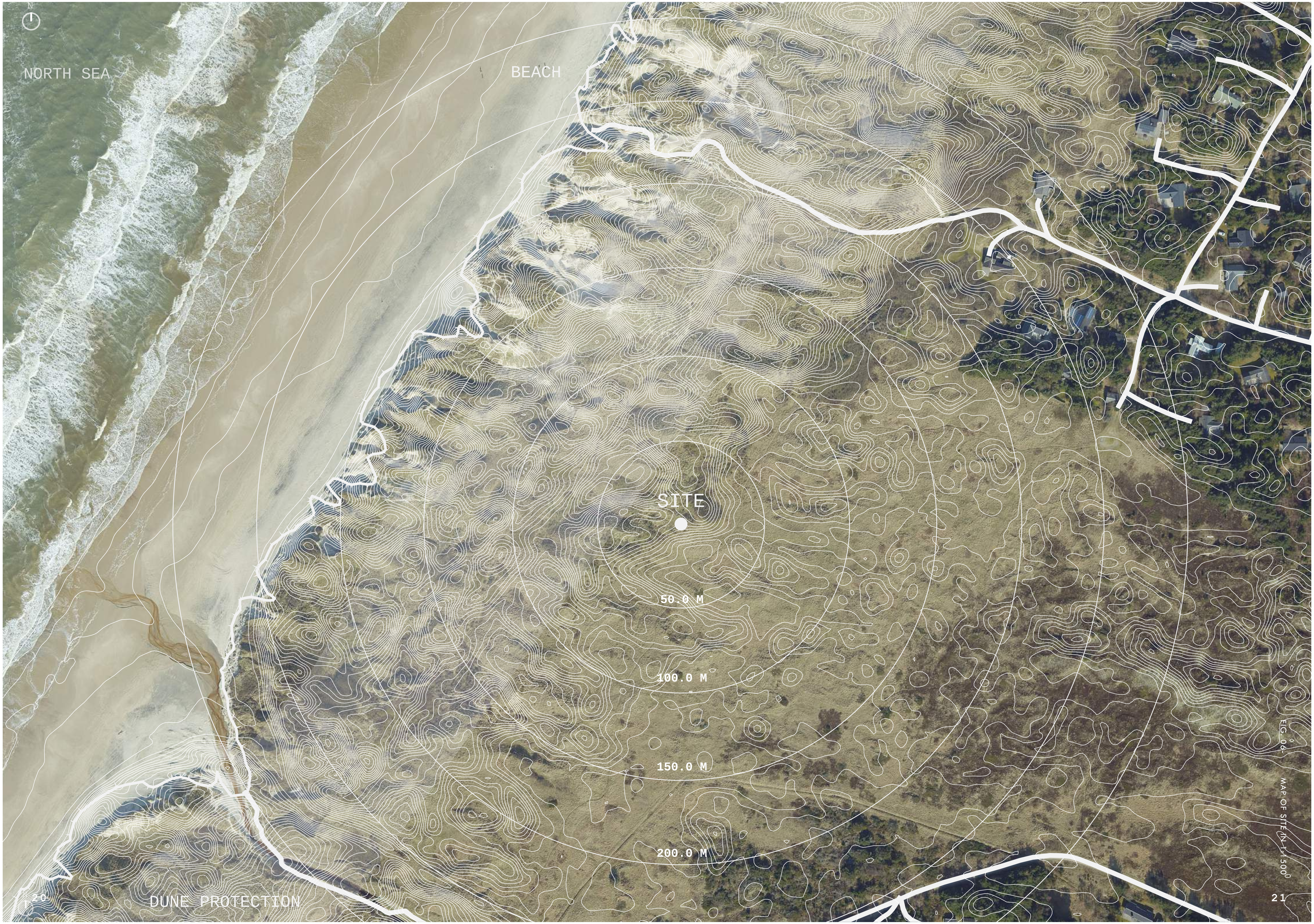


FIG. 06- MAP OF SITE IN 1:1500

01.3 blokhus.

a city of tourism

↑ FIG. 07- *Landmark in Blokhus*

TRADE TO TOURISM

region: north jutland

municipality: jammerbugt

climate : atlantic / continental

origin: 1600's

population: 511

(Statistikbanken, 2021)

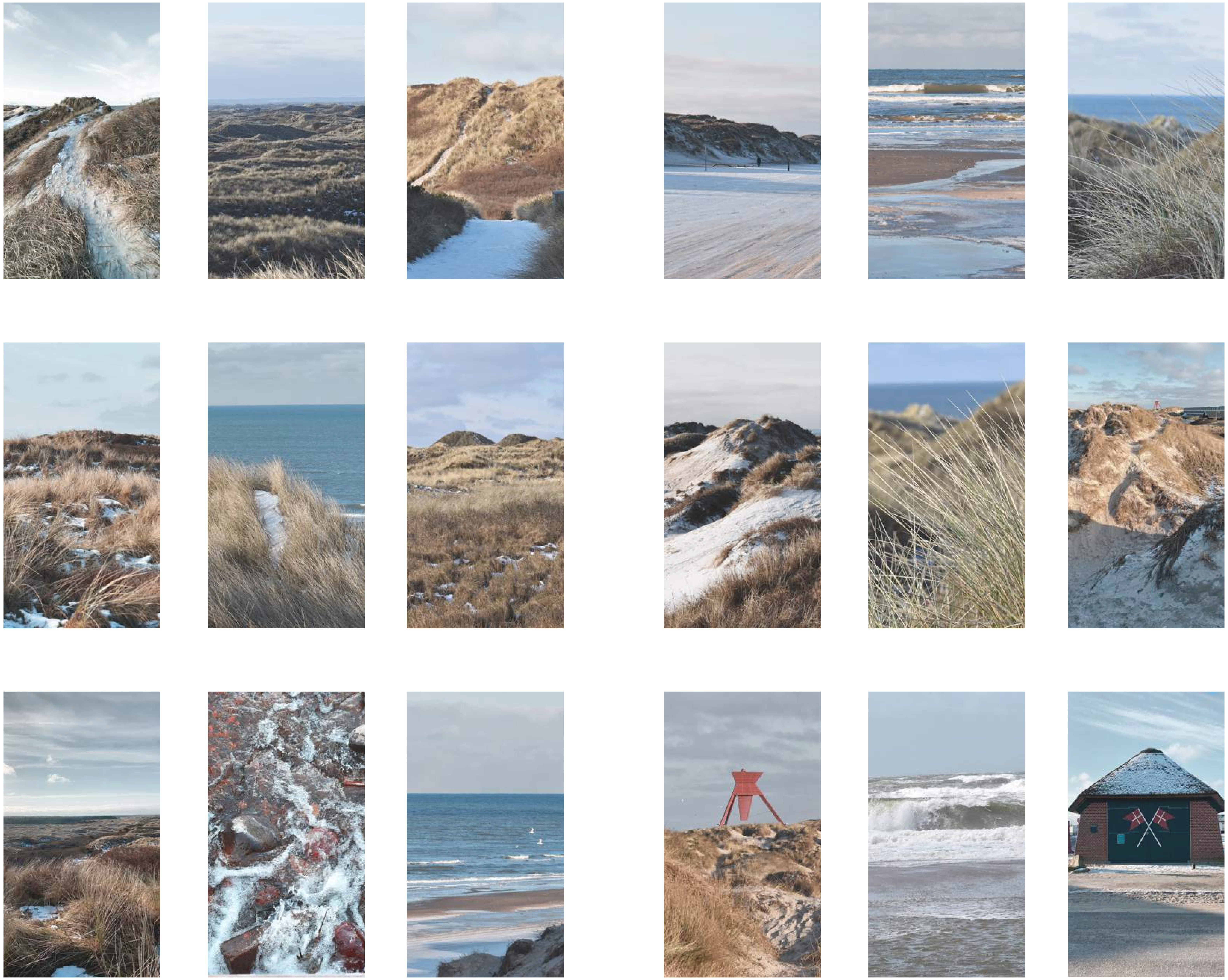
Situated on the northwestern coast is a part of Denmark that does not look like anything else with a raw and rich nature and endless horizon. The small city of Blokhus has through its time functioned as a trading post, where the connection to the sea has generated trade with Norway. Timber and iron were sent from Norway – and agricultural goods were sent back. The long and relatively flat beach has served the visitors and sparked a tourism attraction, where the identity of the city has shifted from a trading post to a haven for the summer holiday houses. The town is formed around a town-square and small-scale building tradition, with its white facades and red roof tiles. The maritime character stems from the years when it served the naval traffic along the west coast of Denmark through its distinct red and white colour (VisitNordjylland, n.d.).

BLOKHUS CHALLENGES

Denmark's annual CO_2 emissions:

32.08 million t

Due to its geographical placement, the sea and the landscape surrounding the town face a great vulnerability and exposure to the effects of climate change. Incidences in recent years regarding climate changes has increased and brought consequences such as temperature rises, extreme weather conditions and rise in sea levels. Hence challenging the identity of the maritime town, where the long beach, the cultural heritage and danish landscape might disappear. The implications climate change brings are multilayered, encompassing numerous fields of life as we know it, where the loss of tourism will undoubtably change Blokhus economically, geologically, and demographically (Margheritini, 2020).



← FIG. 08- Images from Blokhus & site

02.0 METHODOLOGY

"A profound design process eventually makes the patron, the architect, and every occasional visitor in the building a slightly better human being."
– Juhani Pallasmaa
(Archtalks.com,2010, para.5)

FIG. 09- ATLAS OF PLACES

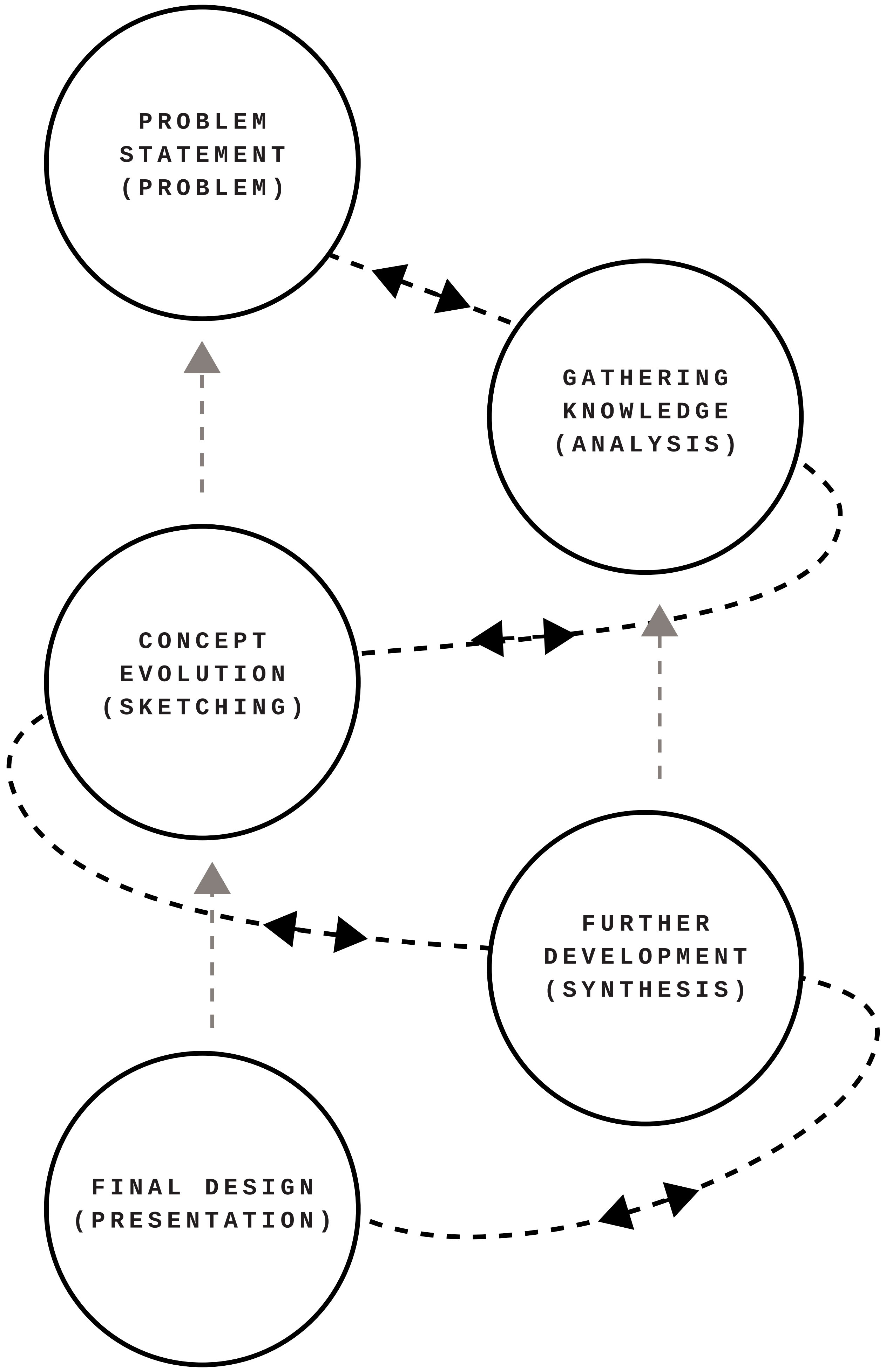


FIG. 10- *Integrated design process diagram*

02.1 approach.

process & methodologies

PRELIMINARY

"A methodology is a defined, structured set of processes, procedures and techniques on "how" to get the work accomplished within the frame of the decline or domain. Methodologies most often include a set of specific practices for diagramming notation and documenting the results of the procedure for communicating the work; systematic approach for carrying out the procedure for doing the work; and an objective quantified set of criteria for validating the work." (IasaGlobal, n.d., para 2.)

Designing in architecture is a complex process, and therefore having a structured set of processes, procedures and techniques is beneficial in allowing one to make justified judgements and reflect and discuss upon constructed design decisions, addressing sustainable, social or contextual circumstances.

THE INTEGRATED DESIGN PROCESS

Throughout the studies at Aalborg University, the Integrated Design Process (IDP) has been favored over other methods due to its adaptability to incorporate different fields of architecture such as engineering and sustainability from the beginning of the design process, enabling a more holistic end design. It facilitates a focus on design, construction, building operations and occupancy through five phases: problem, analysis, sketching, synthesis and presentation. The IDP is presented as an iterative approach, where various tools in different phases provide a greater insight into the project (Hansen and Knudstup, 2004). For this thesis, the IDP will serve as an instrumental map for the design process, which can be seen on pages 32-33.

TOOLS & METHODS

A systematic understanding of the importance of all the aspects; social, cultural, functional and technical, are vital in attaining a balanced depth in the design. Therefore, a fundamental understanding of the importance and role of each tool, and their relation to one another is useful and is presented on the following pages. Tools, such as research articles, photography and mapping, are used to gather relevant knowledge, especially in, but not limited to, the early phases of the project. They provide information from both architectural and technical fields and can set a base for the project. In order to validate choices throughout the design process, simulation tools can be used for in-depth analyses. The selection of tools for such studies is widely distributed and all aspects of the project can be analysed. The limitations of the tools lie in their ability to keep up with newest research and trends, and the fact that there is one tool for each analysis. In extension, several tools for sketching and presentation can communicate the project but adds another layer of tools used. Much time is spent on adding the same model data to numerous programs, and the design process could benefit from being able to make all analyses based on just one model.

ACCUMULATING KNOWLEDGE

Aims to develop theory from methodical application of research

LITERATURE STUDIES
Critical studies of various design theories such as those of Juhanii Pallasmaaaa, Peter Zumthor, Christian Nordberg Schulz and Anne Beim have been executed as a foundational framework for the project. This method is abundantly used throughout the early phases of the Integrated design process, enabling an architectural platform for idea generation, and decision-making. It is however also used throughout the remaining phases of the IDP apart from the presentation, in order to constantly gather new information relating to the area of research and provide inspiration and a critical perspective.

Tools: Research articles, databases, books, general knowledge, rules of thumb

CASE STUDY
Studies of actual cases in the analysis phase of the IDP initiate incentive and aim to gather knowledge of effective and ineffective practice, providing a foundation for the sketching and synthesis phases. In the case of this thesis, case studies covering the areas of materiality, sensory architecture, sustainable architecture, and functions have been considered. Crucial to this method is establishing the purpose of the study with a critical eye, framing the analysis and omitting irrelevant information. This method often functions parallel to literature studies.

Tools: Literature, general knowledge, contacts, field trips, architectural magazines, databases

ON AND OFF-SITE STUDIES

Intends to gather vital information of the current context

MAPPING
Mapping provides significant information about the site and surroundings in distinct scales of the plan, addressing qualities and obstacles, thereby defining strategies of possible blockage or usage. Data such as infrastructure, vegetation, functions, etc., have been presented through mapping in the analysis phase providing an insight into the setting of the context. Locations of local building materials, flooding and wind have also been investigated to trigger a sustainable approach.

Tools: digital programs (QGis, klimatilpasning.dk), on- and off-site observations

GENIUS LOCI
Predominantly performed in the analysis phase, 'Genius Loci' is a study of the sensorial aspects and atmospheres of a site by addressing it as a space instead of a place. The approach is performed through observations, noting down the experiences by means of words, illustrations or photographs in pursuit of communicating a subjective experience. The graphical interpretation and presentation of abstract, personal experiences is a challenging aspect of this method, however, lays a foundation for implementing them in the design-initiating phases.

Tools: photographs, sketching, note taking, site visits

TECHNICAL METHODOLOGY

Generates results by means of technical data

PARAMETRIC DESIGN
Parametric design presents the potential to combine technical aspects and design solutions from the very beginning, saving time and supporting the notion of integrated design, enhancing the quality of the final design. This approach is valuable in simulating various sustainable notions from the beginning of defining the problem, analyzing it, sketching and fabricating the synthesis.

Tools: Rhino and it's plug-ins (grasshopper, ladybug, honeybee)

CALCULATIONS
Essential to reinforcing the IDP is implementing computations from the beginning of the design process. In the initiating design phases, it is largely beneficial to include fast calculations to test if the design has potential to fulfill various vital requirements in terms of energy use, indoor comfort, structure, etc. The distinct calculation tools at hand can vary between quick hand calculations to complicated validating calculations.

Tools: BE18, Microsoft excel, calculations by hand

SIMULATIONS
Simulations are generally implemented in the analysis, sketching and synthesis phases. This provides extensive knowledge of both microclimate and building, granting awareness of the total performance. The simulation method has distinct approaches such as single-parameter and staircase simulations and Monte Carlo method.

Tools: BSim, Monte Carlo, Velux Visualizer, Rhino plug-ins (grasshopper, ladybug, honeybee), CFD

IDEA GENERATING METHODOLOGIES

Creates a structured approach towards a mostly intuitive process

MOOD BOARD/COLLAGES
Design generating feature used in all phases, however predominantly the analysis and sketching phases, which initiates design flow, inspiration and architectural position, defining direction of the design. The approach of the method is collecting ideas from moods, senses, feelings, expectations, cases and materials. The aim of the method is being able to disclose an idea to a neutral party.

Tools: sketching, photographs, InDesign, Photoshop, Illustrator

SKETCHING
Sketching consists of generating ideas based on the prior analyses conducted in cooperation with other methods such as brainstorming, mood boards and mind mapping. The sketching is based around a vision and considers different boundaries and criteria. The method is an iterative process and an essential part of the Integrated Design.

Tools: analogue sketching, digital sketching in Rhino, Revit, Sketch-up

VOLUMETRIC STUDIES
Converting a 2D drawing into a 3D model unveils potentials and challenges with a proposed design. Creating this constant shift between 2D and 3D is valuable as it presents the possibility of grasping various unresolved issues. A digital model is a useful tool throughout the entire process, as it allows for considering details separately and in connection to one another, granting a larger perception of the proposed spaces.

Tools: analogue model making, Rhino, Revit, Sketch-up

PRESENTATION METHODOLOGY

Summarizes and advertises the final design to a third party

INFOGRAPHICS
Infographics can graphically communicate a supply of data aiming to present information swiftly yet coherently. They can enhance insight through means of graphics which magnify the ability to see patterns and trends.

Tools: Illustrator, Excel, Photoshop, analogue hand drawings

ILLUSTRATIONS
Illustrations aim to visualize a concept, process or an explanation, often being communicated in a specific style in combination with composition. It aims to communicate what can't be written in words and can be executed through all phases of the process.

Tools: Illustrator, Revit, Photoshop, CAD tools, Rhino

RENDERS
Renders focus on generating photorealistic illustrations from 2D or 3D models by digital means. Renders allow the project to be visualized presenting both interior and exterior spaces, communicating intended atmospheres and functions, and relations to other spaces.

Tools: 3dsMax, Lumion, Enscape, Vray

REPORT
Creating a systematic report covering all the aspects of the IDP, presents a good synthesis of the design process, from the initiating problem to the analysis, sketching and synthesis phase, to the final presentation of the project. The report provides an insight into the different thoughts and challenges faced along the way and provides a deeper empathy for the final design.

Tools: InDesign, Word

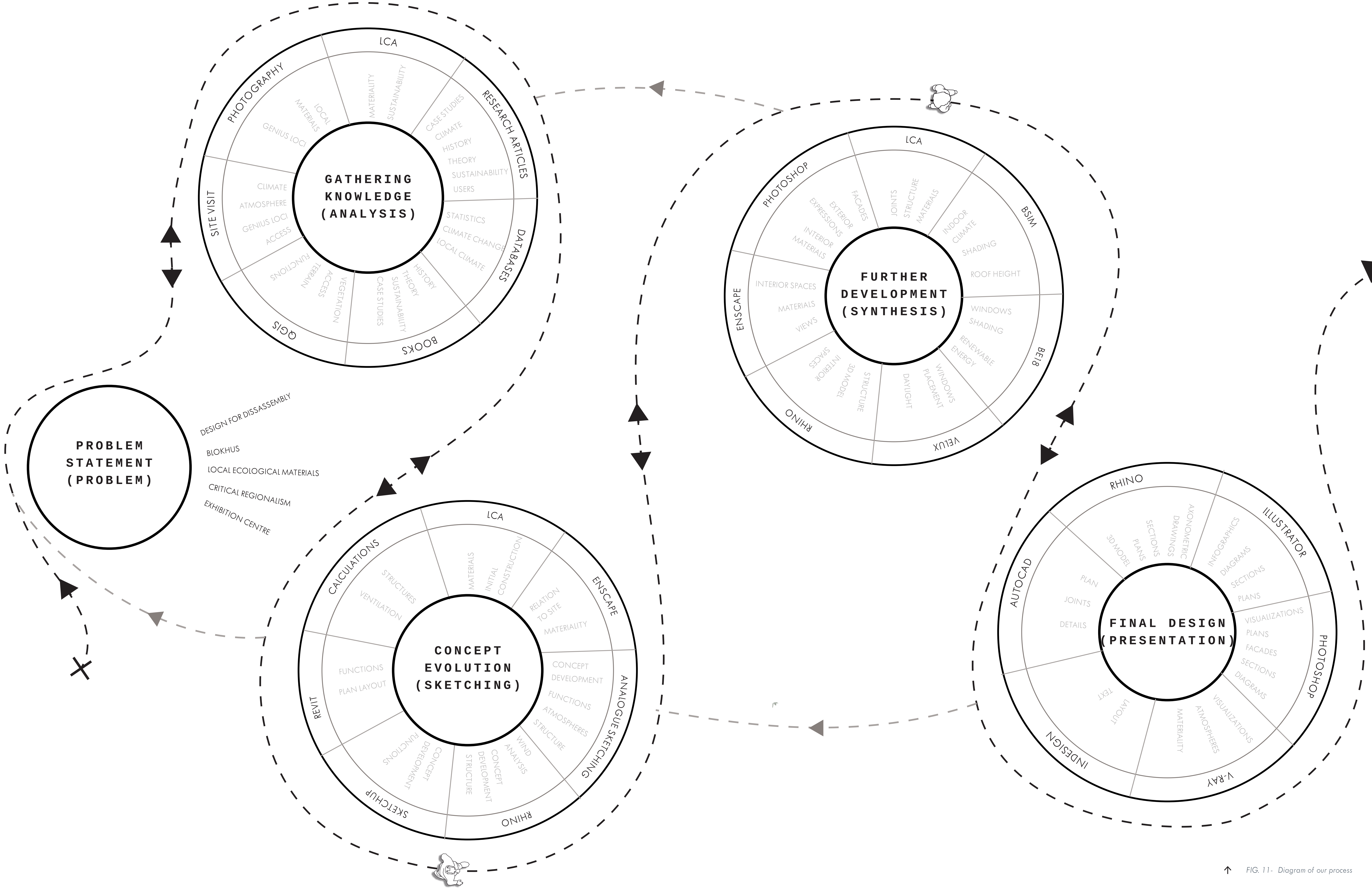


FIG. 11- Diagram of our process

03.0 THEORY

FIG. 12- ATLAS OF PLACES

'We place everything in relation to ourselves. Our surroundings influence us through their scale, light, shade, colour etc. Our condition depends entirely on whether we are in the city or in the country, whether we are in big spaces or small spaces. By training our ability to perceive these differences and their effects on us, by being in touch with our surroundings, we get to the nature of architecture.'

-Jørn Utzon

(Andersen, 2011, p.20)

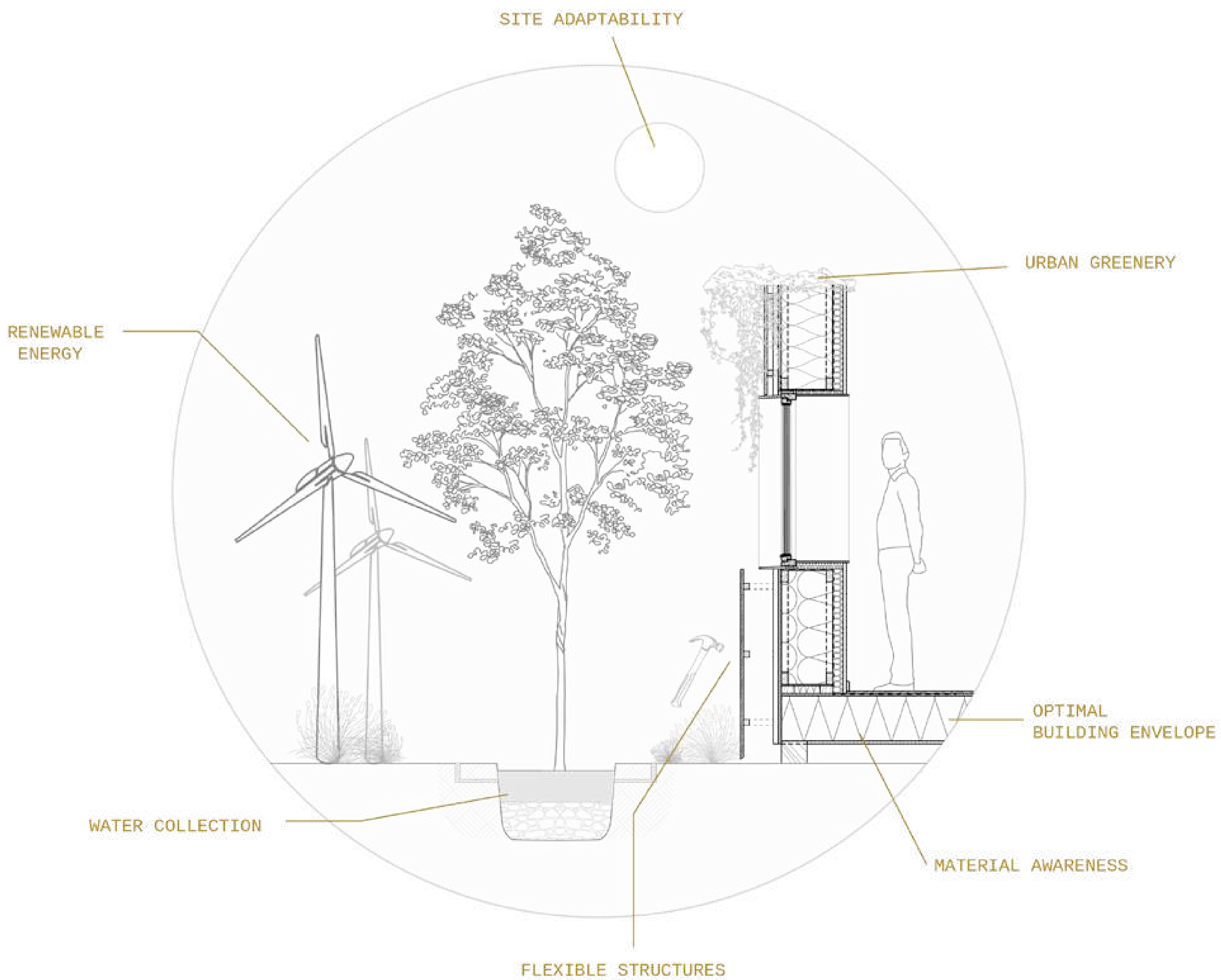


FIG. 13- Climate mitigation and adaptation strategies

03.1 sustainability.

a theoretical study

PRELIMINARY

This study examines the fundamental ramifications of the definition of sustainability, and the objective is to provide a digestible understanding of it and the present strategies in relation to architecture. The study will focus on climate mitigation and adaptation in the building sector, including a case study of The Marika-Alderton house by Glen Murcutt, and will touch lightly upon critical regionalism in relation to a case study based on Jørn Utzon's Can Lis in Mallorca.

CLIMATE CHANGE AND THE BUILDING SECTOR

Buildings deplete a colossal supply of energy during their entire life cycle (from construction, through operation, to dismantling) consuming non-renewable resources and dispensing greenhouse gases into the atmosphere. We tend to spend most of our time in buildings (often more than 90% of our day), triggering the energy budget to account for more than half of worldwide consumptions. (Altomonte, 2008). Effectively there are two possible strategies to consider when designing for climate change in the building sector; intervening to diminish the sources or increase the sinks of greenhouse gases in the atmosphere (mitigation) and/or adjusting in natural or human systems in response to present probable future climatic stimuli or their effects (adaptation) (IPCC, 2001).

CLIMATE MITIGATION

'the process or result of making something less severe, dangerous, painful, harsh, or damaging' (Merriam-Webster)

Mitigation strategies for climate change in buildings mainly revolve around initiating solutions such as reducing $C0_2$ levels, promoting energy savings, integrating vegetation and boosting biodiversity, considering management of waste, and using renewable energies. Altomonte argues that using advanced technologies in an integrated context could be effective in reducing consumption and emissions in the building sector. However, he goes on to argue that *"considering the momentum of climate change already built up, long-term mitigation actions will necessarily need to be coupled with short-term adaptive strategies that could warranty the continuous sustainable development of human civilisations"* (Altomonte, 2008, p.106).

The vast research and different methods and technologies in the mitigation area is constantly being developed, however some of the most common strategies are the following:

-Performing analysis such as LCA for materials – provides an overview of the affects on climate change in terms of, for example, $C0_2$ emissions, and gives an insight into the advantages and disadvantages of variously assembled building envelopes. This also ties in with circular building, in terms of considering the lifetime of the different materials, and their effect on the climate throughout (Altomonte, 2008).

-Urban greenery, allowing for direct sun shading, considering the mitigation of air movement when/where necessary, and the adjustment of the heat transfer by means of green envelope components, including green roofs and facades (Pisello et al., 2018).

-Exploiting environmental factors to generate renewable energy. This could for example be wind energy, geothermal energy, hydropower, solar energy, etc.

-Designing building envelopes which shield internal spaces from changes in solar radiation and minimize thermal losses, to minimize the amount of energy necessary for an optimal indoor thermal comfort.

-Using technology such as simulation programs in order to optimize buildings to use less energy, and to for example be orientated optimally for solar cells

-Maximizing daylight transmission and distribution. Can be done through means of prismatic screens, manually or automatically controlled blind systems, etc.

(Altomonte, 2008).

CLIMATE ADAPTATION

'adjustment to environmental conditions: such as modification of an organism or its parts that makes it more fit for existence under the conditions of its environment or a heritable physical or behavioural trait that serves a specific function and improves an organism's fitness or survival' (Merriam-Webster)

The strategies of adaptation to climate change provide a framework for considering awareness about the correct degree of flexibility and durability in buildings, and are strictly related to the specific context in which the buildings are located (Dave, Varshney and Graham, 2012). Loonen defines adaptive buildings as 'climate adaptive building shells (CABS) defining them as following *"A climate adaptive building shell has the ability to repeatedly and reversibly change some of its functions, features or behaviour over time in response to changing performance requirements and variable boundary conditions. By doing this, the building shell improves overall building performance in terms of primary energy consumption while maintaining acceptable indoor environmental quality."* (Loonen, D. Costola and Hansen, 2013, p. 485). For example, in the context of Blokhus, where one of the main issues is the prospect of flooding, (see pages 58-59) flexible and adaptive structural systems, and water reduction/ treatment strategies would be beneficial.

Marlay Dave focuses more on the flexibility of materials, prefabrication of building parts, and the overall structure of the design and argues that a building which is designed for adaptability would cover the following :

-end of the building life

-the design as a system of temporal layers and designed for adjusting to the changes the building and its components would endure during the entire lifecycle.

-designing for a long life; or for long term durability and sustainability of the building and lasting comfort for its occupants

-spatial flexibility, structural flexibility, flexibility to assist materials and transformations of components.

-designing for disassembly — for independence between separate layers or components with various functions (Dave, Varshney and Graham, 2012)

Koen Steemers leans towards a favorability towards adaptation rather than mitigation, arguing that climate change is expected to continue relentlessly for the next 40 years, even with the most sufficient mitigation technologies implemented, and therefore buildings will need to respond to an imminent measure of climate change, nevertheless. Additionally, he mentions that climate mitigation has a long track record in research making it a well-established research field and emphasizes the lack of research in knowledge of adaptation to climate change (Nikolopoulou & Steemers, 2003). He focuses on the behavioral adaptations of the inhabitants in terms of adjusting their requirements to environmental conditions and how they can directly influence the design and operation of buildings, suggesting the following three predominant categories:

Spatial: The ability to design, rearrange and adjust internal spaces in relation to the environmental conditions, improving occupant comfort. Additionally, the ability to move location, for example creating flexibility to work from home along with a variety of transitional spaces such as sunspaces, open plan areas, quiet courtyards, etc.

Personal: The ability to adapt clothing, modify activity levels, take drinks, change posture, etc. in relation to external weather conditions.

Control: The possibility of providing a level of direct control and interaction with building fabric and systems, and creating a relation with the external climate using, for example shutters, views, natural ventilation through openings, etc.

(Nikolopoulou & Steemers, 2003).

← *FIG. 14- (MURCUTT, 2008)*

CASE STUDY OF MARIKA-ALDERTON HOUSE

Architect: Glenn Murcutt
Year: 1994
Location:Yirrkala community, Northern Territory, Australia

One of the prominent architects who focuses on sustainability, and more specifically adaptability is Glenn Mercutt who states, *"I'm very interested in buildings that adapt to changes in climatic conditions according to the seasons, buildings capable of responding to our physical and psychological needs in the way that clothing does. We don't turn on the air-conditioning as we walk through the streets in high summer. Instead, we change the character of the clothing by which we are protected."* —Glenn Murcutt, 1996 (RTF, n.d. para. 2.) Changeability is something that Murcutt work into most of his buildings. He argues that architects must be able to take advantage of the natural environment, light, heat and humidity, to benefit the internal climate. Also, the materials of which the building is made, should be chosen responsibly with considerations of context and landscape. (RTF, n.d.)

His design, the Marika-Alderton House in Yirrkala, Northern Territory, follows native traditions while providing shelter and adapting to its surroundings, instead of forcing the landscape to adjust. The northern territory is conditioned with a tropical climate, including heavy winds, harsh sunlight, high temperatures, humidity levels, rainfalls and a cyclone season (Ibid). The building is orientated in relation to the wind and sea, positioned to receive fresh sea breeze from the north. It is equipped with a raised floor and perforated screens, letting air flow under and through the building, through pivoting venturi tubes, enabling a cooler interior whilst equalizing the air pressure, proving beneficial in a major cyclone (Carter, 2011). The building can be opened entirely on the east and west, initiating proximity with nature. An operable and permeable envelope consisting of deep overhangs projected from the building protecting it against the sun with tilting plywood panels substituting conventional windows and are equipped with louvered shutters, providing the user with control of the desired indoor environment throughout the day (Ibid). It is different solutions like this which are the driving forces towards a more ecological and sustainable future in the building sector.

CRITICAL REGIONALISM

All architecture is affected by climate, partly because a building needs to protect its interior against exterior climatic influences, partly because the building needs to be protected against erosion caused by climate. The interaction between place and climate is of critical importance in architecture, and of equal importance to the sense of place. Architecture is a connecting link between place, climate and human life (Dahl, 2010). This is also what the movement of critical regionalism was centered around, in which Curtis argues that regionalism was a time in which the architects really started to focus on the local environment, considering climate, topography, light, culture, landscape and natural material, however keeping in mind the new technologies and importance of participation in the global culture (Curtis, 2013). There is this constant discussion between tradition and globalization which really characterizes that period. Supporting this argument, Kenneth Frampton, who contributed immensely to the definition of critical regionalism, states, 'It should adopt modern architecture critically for its universal progressive qualities, but at the same time should value responses that are particular to the context. Emphasis should be placed on topography, climate, light and tectonic form' (Frampton, 2019) Hence, it can be discussed that regionalism led to a phenomenological approach dealing with human and the multi-sensual, with societal focus on sustainability and resource consumption, technological development, and relation to place and light. Frampton also advertises 7 claims in which he argues that the relationship to the local environment, along with the acknowledgement of international expressions is elementary to critical regionalism. Emphasis is also placed on tectonics, understanding of materials, as well as sustainability and resource consumption (Ibid).

CASE STUDY OF CAN LIS

Architect: Jørn Utzon
Year: 1972
Location: Mallorca, Spain

A relevant embodiment of critical regionalism is Jørn Utzon's Can Lis in Mallorca from 1972, which focuses on the relation between man and the surroundings, incorporating local building techniques and materials to create a shelter from the dynamic climate, whilst still including the aspects and techniques of the globalized modern architecture. Utzon is perceived as one of the architects who was largely aware of the 'nature of architecture', stating '*We place everything in relation to ourselves. Our surroundings influence us through their scale, light, shade, colour etc. Our condition depends entirely on whether we are in the city or in the country, whether we are in big spaces or small spaces. By training our ability to perceive these differences and their effects on us, by being in touch with our surroundings, we get to the nature of architecture.' (Andersen, 2011, p.20)*

Upon entering the living room, everything is orientated towards the 5 window openings facing the surrounding nature and sea. The contrast between the dark raw cave-like space and the large amount of light penetrating through the large openings, suggests nature and context as the dominant feature. Utzon uses the local sunlight as a variable in relation to the materials to constantly create new atmospheres and spaces in the room. The early ray of sunlight enters from the east and follows the course of the day through the 5 windowpanes, until it reaches the last two openings where a long ray of sunlight extends through the space, acting as a form of time keeping. At the same time, once seems to lose any sense of orientation and time stands still due to the interplay between the acoustics and the smell of sea and stone (Roberts, 2013).

Central in Can Lis is the double height living room in which the sections of the individual horizon act as an invitation to sit down on the semicircular seat and watch the drama that nature plays out. Consisting of a series of spatial framings, in which nature is the central motif, there is a constant contrast between the artificial and the natural. By building the glass into the room and sloping, as well as the frames outside the windows, it becomes like a thin membrane to nature where you get a sense of being one with nature. However, at the same time, it provides the feeling of sitting in a natural cave and looking at a painting, something that must not be touched or experienced directly.

Therefore, it can be argued that Utzon's focus on the surroundings is different to for example that of Glenn Mercutt's, and to the general notions of adaptation and mitigation, as there is more of a focus of the poetics of nature, and to be one with the nature, rather than focusing on minimizing CO_2 or strategies such as designing for disassembly. However, this aspect of designing with the surroundings in a more phenomenological perspective is also critical in enhancing the appreciation for our surroundings through interacting and experiencing, providing larger architectural quality and significance.

FIG. 15- (UTZON FOUNDATION, 2019)

It follows from these definitions that mitigation decreases all impacts (positive and negative) of climate change and thus scales down the adaptation challenge, whereas adaptation is selective; it can take advantage of positive impacts and reduce negative ones (Goklany, 2005). To effectively mitigate long-term impacts and adapt in the short-term to inevitable climate alterations, the challenge is thus to identify and effectively put in place the design methodologies by which sustainable technologies can be integrated with current building models in order to guarantee the continuous social and economic growth of human developments, whilst limiting emissions and effectively responding to the consequences of climate alterations which are expected in the next few decades (Altomonte, 2008).

Altomote and Luther have suggested an elementary and unambiguous sustainable design framework defining some guidelines for the integrated and sustainable design of buildings, keeping in mind the distinctions in every contextual situation. The guidelines aim to set up a holistic and iterative methodology considering both methods of adaptation and mitigation (Luther & Altomonte, 207) (see 'Altomonte and Luther's guidelines').

Critical regionalism is represented by an architecture in which sensuality transcends the immediate geometric order, an architecture in which the essentials are the actions that put man in relation to the surrounding environment. When you compare it to the basic strategies of climate mitigation and adaptation, the notion of critical regionalism includes a touch of phenomenology and can be perceived as a synthesis of sensory theory (see page 49) and the above-mentioned sustainable theory.

In conclusion, one of the predominant challenges facing the world today is implementing mitigation strategies mandatory to prohibit the irreversible global warming that could have catastrophic impacts to the plant and its ecosystem, and to promote integrated methods in adaptation of settlements and activities to anticipated future climate conditions. Considering the guidelines by Altomote and Luther, this project aspires to integrate these different notions of sustainable methods in relation to the context of the site, regarding the potentials and difficulties of incorporating them in the architectural field towards a more ecological and holistic design.

This raises the practical question of how to design a building which can adapt to its surroundings and reduce energy consumptions and consequent environmental impacts while simultaneously granting a longevity of the building that is worth keeping through architectural significance and quality.

SYNTHESIS ON SUSTAINABILITY

Altomote and Luther's guidelines:

1) Site & Climate Analysis (Olgyay, 1963)
2) Flexible & Adaptive Structural Systems
3) Renewable & Environmental Building Materials
4) Modular Building Systems
5) Building Envelope Systems
6) Renewable & Non-conventional Energy Systems
7) Innovative Heating, Ventilation & Air Conditioning Systems
8) Water Collection & Storage Systems

(Luther & Altomonte, 2007)

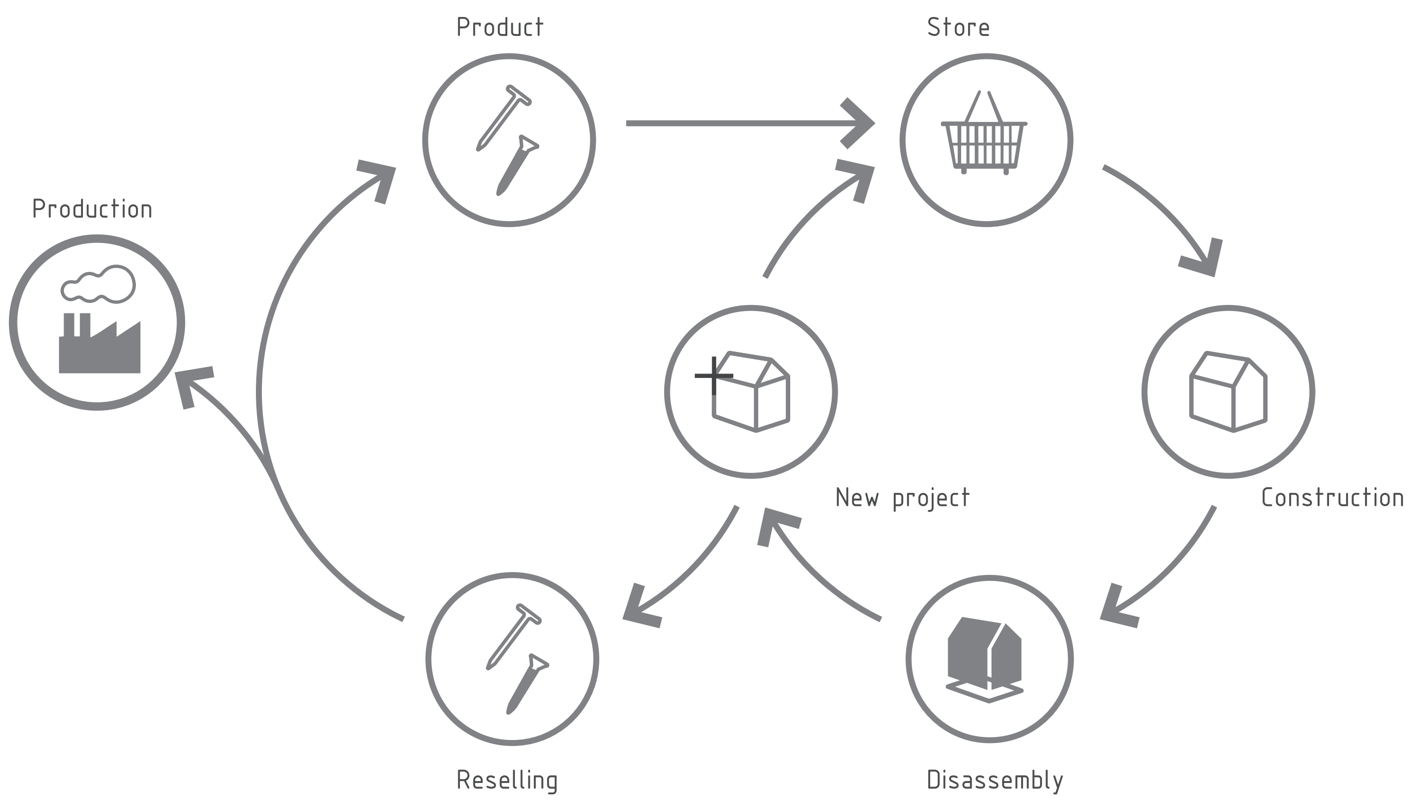


FIG. 16- Circular architecture

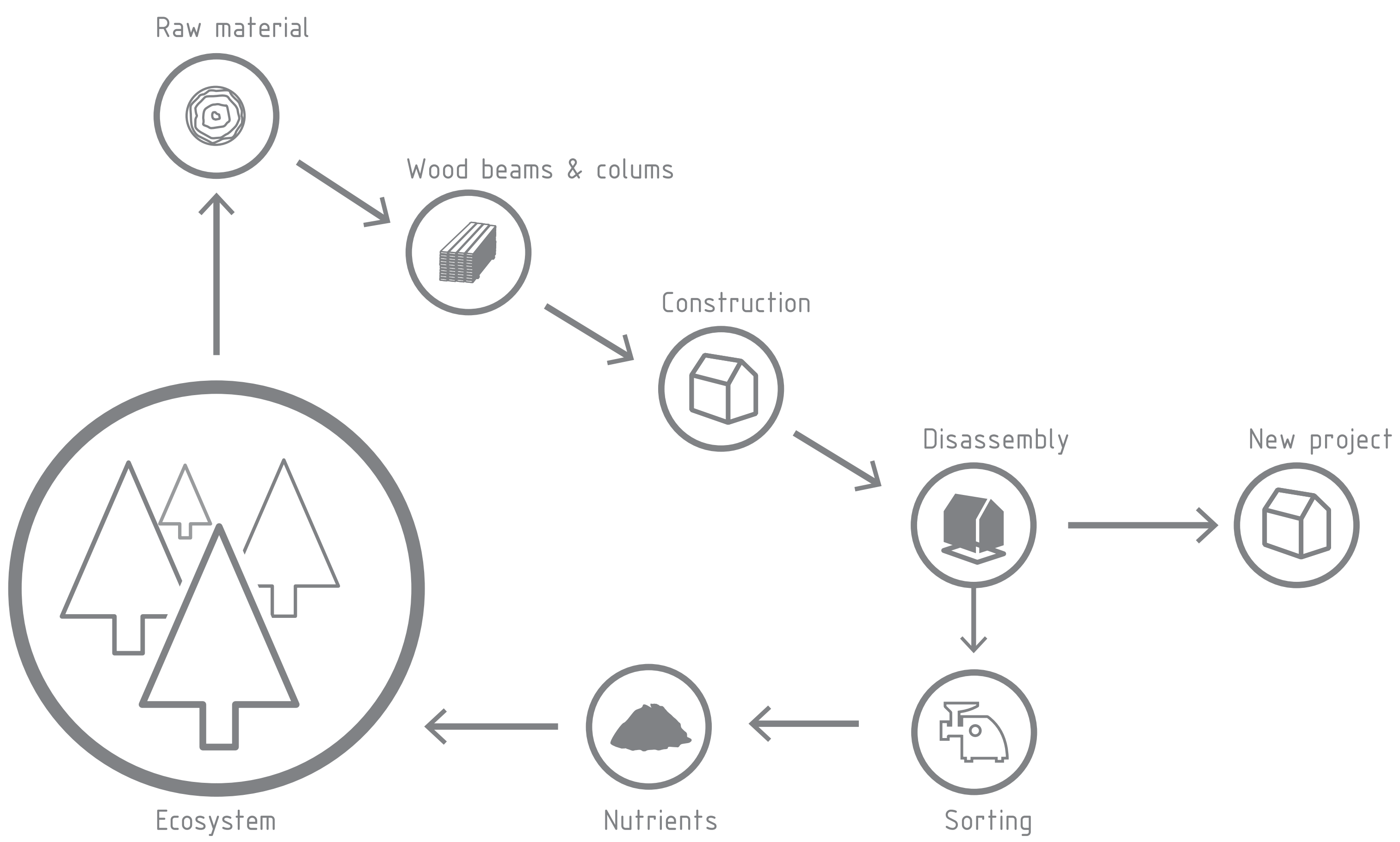


FIG. 17- Design for disassembly

03.2 materialistic potential.

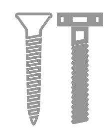
a theoretical study

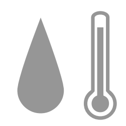
PRELIMINARY

Sustainability is one of the largest challenges for the building industry. Introducing sustainability in the building sector has led practitioners to investigate and implement principles of reducing the environmental impact. Among are lowering energy and material consumptions, relying more and more upon natural and renewable sources. The up to now considerable environmental impact and use of resources has put the building industry in a position to contribute significantly to sustainable development. This highlights the importance of considering strategies that are less harmful to the environment and also to increase the use of reuse, in order to lower the impact from early planning throughout the building's lifetime (Akadiri, Chinyio and Olomolaiye, 2012).

"A sustainable project is designed, built, renovated, operated or reused in an ecological and resource efficient manner. (...) An ideal project should be inexpensive to build, last forever with modest maintenance, but return completely to the earth when abandoned." (Akadiri, Chinyio and Olomolaiye, 2012, p. 127).

CIRCULAR ECONOMY





The construction industry is responsible for up to 40% of the materials being used and about 35 percent of the world's waste. Switching from a linear economy to a circular economy is one potential solution to this enormous challenge. Today the building industry follows a model based on cradle to grave, which means that the value generated during extraction and production is lost at the end of a buildings lifecycle. An alternative model based on cradle to cradle, challenges the linear approach, where products must be produced so that their basic materials can be separated and repurposed. This approach can be divided into a technical and biological model (Guldager Jensen and Sommer, 2019).

The biological consists of material that can be considered a part of the ecosystem and thereby function as potential nutrients for natures production of natural resources. Timber is an example of a material that is biodegradable, where the material can be returned into nature and thereby serve as potential nutrients for the ecosystem. Wood is often treated or mixed with non-biodegradable materials that results in the material being exposed to toxicity and chemicals that prevents it from getting back into its natural loop (Ibid).

The technical aspect consists of materials that after end-use can be isolated and reused in new buildings and structures without losing value. Steel, concrete, and brick are often in this category. One example of this is Gamle Mursten, which reuses and sells bricks from demolished buildings. This concept has gotten a lot of tractions because of the material's quality and patina (Gamle mursten, n.d.).

DESIGN FOR DISASSEMBLY

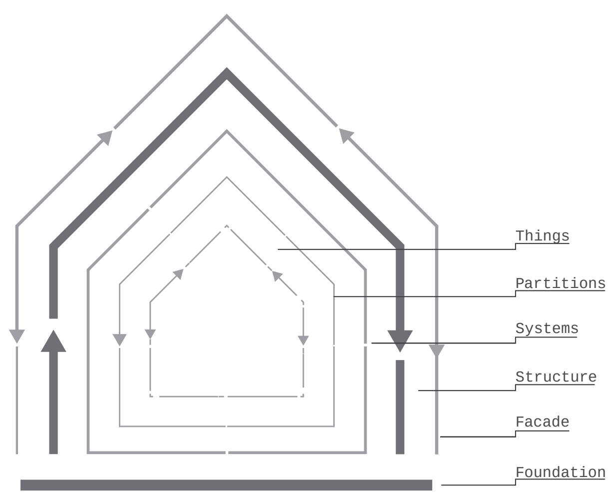


FIG. 18- Circular economy

The most significant challenge the building industry faces today, is the lack of thought and planning for the lifecycle of the materials that is being used. Within the realm of sustainability, DFD emerges as a strategi that can benefit the materials in repurposing and upcycling. Design for disassembly is a holistic approach to design, where the goal is to make it easy to disassemble any given construction into its individual base components. The strategy is a cornerstone in sustainability, since it establishes a way for the various components in which they can be reused, reassembled, and recycled. DFD can also be an architectural design strategy that enables buildings to transform and better adapt to changing circumstances (Guldager Jensen and Sommer, 2019).

The individual components should be assembled according to lifetime of the different layers, where the longest lasting element in the building should be behind the layers with the shorter lifetime. Combined with the use of parallel layering and tools such as bolts, screws and springs the connections enable the disassembly process (Guy and Ciarimbol, 2008).

Strategies and tools:

-Using screws and bolts to attach the materials together. Today it is very common in the building industry to use nails to attach elements. Unfortunately, this result in damage of the materials surface and structure.

-Using standard and uniform fasteners is an important part of design for disassembly as this helps minimize and improves the process of disassembly.

-Glue and other chemically produced binders damage the materials. By using clay and lime mortar, the materials can be easily disassembled again.

CASE STUDY OF BRAUNSTEIN TAPHOUSE

Architects: ADEPT
Year: 2018-2020
Location: Køge, Denmark
Area: 1000 m^2

The Braunstein Taphouse, by the Copenhagen-based ADEPT architects, is a project that encompasses form, materiality and design for disassembly. The project is located on a harbour dockside in a climate change sensitive area, and due to its architectural qualities in forming an environmentally sustainable building on temporary placement in its contexts, the project becomes a noticeable example hereof (Divisare, 2020). Strategies such as design for disassembly has been integrated in the architecture to meet the challenge of this temporary placement of the building (ADEPT, n.d.).

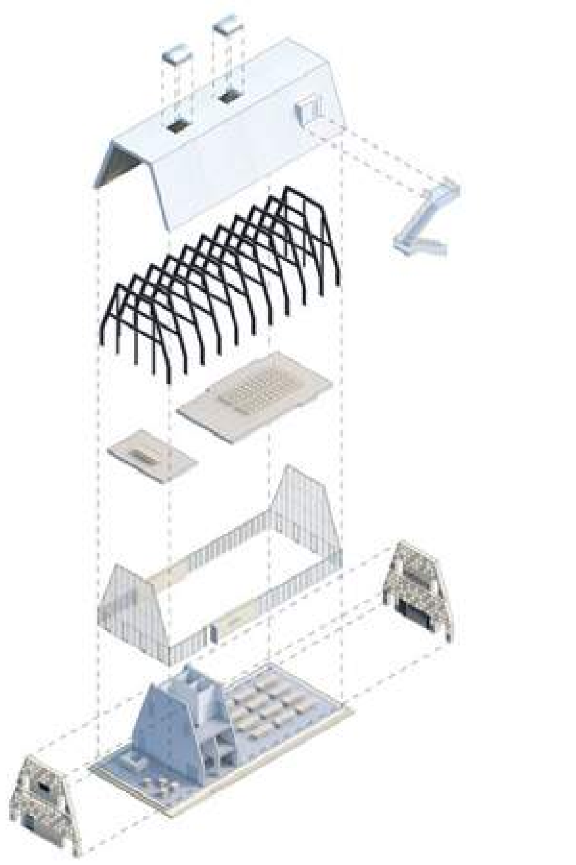
The vision for the project was also to address the lifetime of the building and the individual components and thus enabling recycling of building components by either moving the entire building to a different site or by using the materials in an entirely different project. The Taphouse functions as a visitor center, where the nearby people can come and on one end enjoy a café and on the other a restaurant. With its simple construction the taphouse is composed of few materials and connected with mechanical joints, where each layer has been carefully placed and ordered to realize a minimal volume of waste. The materials are furthermore without paint or any chemical binders, this is evident in the treatment of wood cladding on façade and the wooden floor. The use of toxic treatment and paint has been known to destroy natural materials ability to decompose and thus serving as nutrients for the ecosystem. The building also seems to speak with its surrounding based and the overall expression and form language, but also through its choice of materials on the exterior where the harsh harbor environment dictates a clear need for durable and flexible abilities in the materials. Hence, the polycarbonate that is designed with a click-joint system which enables design for disassembly and easy maintenance (Ibid).

RETHINKING CONSTRUCTION

A key question within sustainability is how resources are used in today's construction, and how to ensure that the materials we are building with can be used in new and innovative ways. Stewart Brands book "how buildings learn" from 1994, argues that a building should have simple constructions consisting of few materials, as it helps the process of dismantling, sorting and recycle the individual material. In addition, he emphasizes the need for simple assembly principles that make it possible to dismantle the building structures without the use of special skills and tools. Hence the necessity of the legibility of the construction as being of great importance to reuse the existing resources, and thus enabling disassemble (Brand, 1994).

As previously stated, there are two types of categories, where materials can be recycled either through natural ecosystems, where natural material is biodegraded and converted into nutrients or through technological recycling systems, where industrial materials like metals are recycled. In the book "Cradle to Cradle - Remaking the Way We Make Things". The authors suggest that detailing joints and material combinations is key in sustainability and that designing buildings based on modular systems combines the different strength and qualities of the resources that are available. Modular based architecture has long been a strategi in optimization of sustainable materials (McDonough and Braungart, 2002). EcoCocon, a company in Europe has developed a module system based on using natural materials. The modules are made of natural materials, whereas 10% is made from timber and 89% from straw. The wood comes from sustainable forestry and the straw it is harvested from local farms. The system performs well and has received Passive-house and Cradle to Cradle certification. The materials used are pure and without any treatment and constructed so that thermal and acoustic comfort is archived. The system draws upon the qualities of natural materials, such as the clay plaster's ability to regulate humidity, and the airtight, yet vapour permeable construction (EcoCocon, n.d.).

↑ *FIG. 19- BRAUNSTEIN (HJORTSHOJ, N.D.)*



↑ *FIG. 20- BRAUNSTEIN AXO (HJORTSHOJ, N.D.)*

Another aspect to sustainable thinking is the use of traditional building technique, where the craftsmanship knowledge and the treatment of the materials is key to understanding sustainability. Traditional building techniques are also rooted in materials that are locally produced and harvested. A great example of this is the traditional half-timbered houses, where the use of timber and stone from the local area form the buildings. The craftsmanship and the detailing of the joints gave these buildings a functional and aesthetical quality that we today admire (Bak-Andersen, 2020).

Rethinking construction also entails repairing and maintaining the building materials properly. For example, choosing the right wood for external use and using natural materials like lime mortar mixed with hair from animals to seal around the wooden window, and additionally, using natural surface treatment for maintaining the wood. The use of wood and the natural materials that are available can also be linked to ecological tectonics, where the physical properties of building materials, their qualities and service life are to a large extent dependent on the way in which they are regarded and built into constructions and are subsequently maintained. In ecological tectonics, there is thus an understanding embedded that buildings consist of parts that are linked to a wider context of nature and cultural systems. This understanding contributes to a new dimension within tectonics and sustainable architecture, which recognizes the connection between the materials used, the ecosystems of which they are a part, and the resources that are available (Beim et al., 2014).

ECOLOGY OF TECTONICS

The concept of tectonics is a multilayered field, encompassing numerous theories and ideas on the subject, and has broadly been debated throughout history. Architecture centered around tectonic notions refers to the general contextual setting and the ingrained connotation – from the choices of materials, over certain construction details, to the weathering of the buildings in the course of time (Beim et al., 2014). A variety of the theories and thoughts on tectonics focus largely on the surroundings, such as Kenneth Frampton who emphasizes the importance of structural integration in detailing, in which his point of view is influenced by technique, execution and conditions of context (Frampton and Cava, 1995). At the frontline of combining notions of tectonics, ecology and surroundings is Anne Beim, with her thoughts on the Ecology of Tectonics (Beim et al., 2014). She defines ecology as not only ecological systems in nature, but also recognizes 'environmental dimension, life cycle of resources social organization, and the longevity of the contextual qualities of design'. She states: *"It embeds the concept of buildings as parts tied together as a whole in a broader context of natural and cultural systems. This understanding feeds a new ethical dimension into tectonic practice that recognizes the correlation between the materials used, the ecosystems they form a part of and the resources we share as common members of the global community. Using this sort of knowledge as a guiding principle in the design and construction of architecture seems crucial in view of the environment crisis we are facing today."* (Beim et al., 2014, p.20). This attention towards tectonics is intended to not only regard its potential to inflict an architectural value of space, but also to reconsider its relation to environmental conditions.

CASE STUDY OF WADDEN SEA CENTRE

Architects: Dorte Mandrup
Year: 2017
Location: Ribe, Denmark

An example of a modern project that embraces Danish building traditions and the use of natural materials is the Wadden Sea Centre by Dorte Mandrup. The building appears to be one with the surrounding landscape, as the shift between the flora and the rise of the building meet each other. The roof of the building dominates the architectural expression mainly through its materiality and the shape of it. The roof is cladded with thatch, where the harsh and salty environment in which the building is situated provides the needed material, as it grows in the nearby contexts. The salty atmosphere provides natural protection for the straw, which also keeps it untreated and natural throughout its lifespan. The process of using old danish building traditions referees back to the roots that are deeply imbedded in the use of nature and handcraft. The straws are dried and harvested in the same place, where they afterwards are tied together forming a beautiful material that defines the building in the surrounding landscape (Dorte Mandrup, n.d.).

The visitors are able to experience the very fabric of the Wadden Sea Centre as it is sculptured through materiality. The leading architect Dorte Mandrup says: *"The main concept of the architecture is a new sculptural interpretation of the existing building culture of the region. It has been our ambition to build a project that points towards the future and has its roots in the local building tradition and history. Thus, we aim to bring the architecture of the Wadden Sea into the 21st Century"* (Aasarchitecture, 2017, para 4). The Wadden Sea Centre is first defined by the placement on open land with nature surrounding on all sides, and secondly the use of natural materials in a modern form language that brings new life to the traditional building culture (Dansk Arkitektur Center, n.d.).

← *FIG. 21 - (MØRCK, N.D.)*

03.3 sensory architecture.

a theoretical study

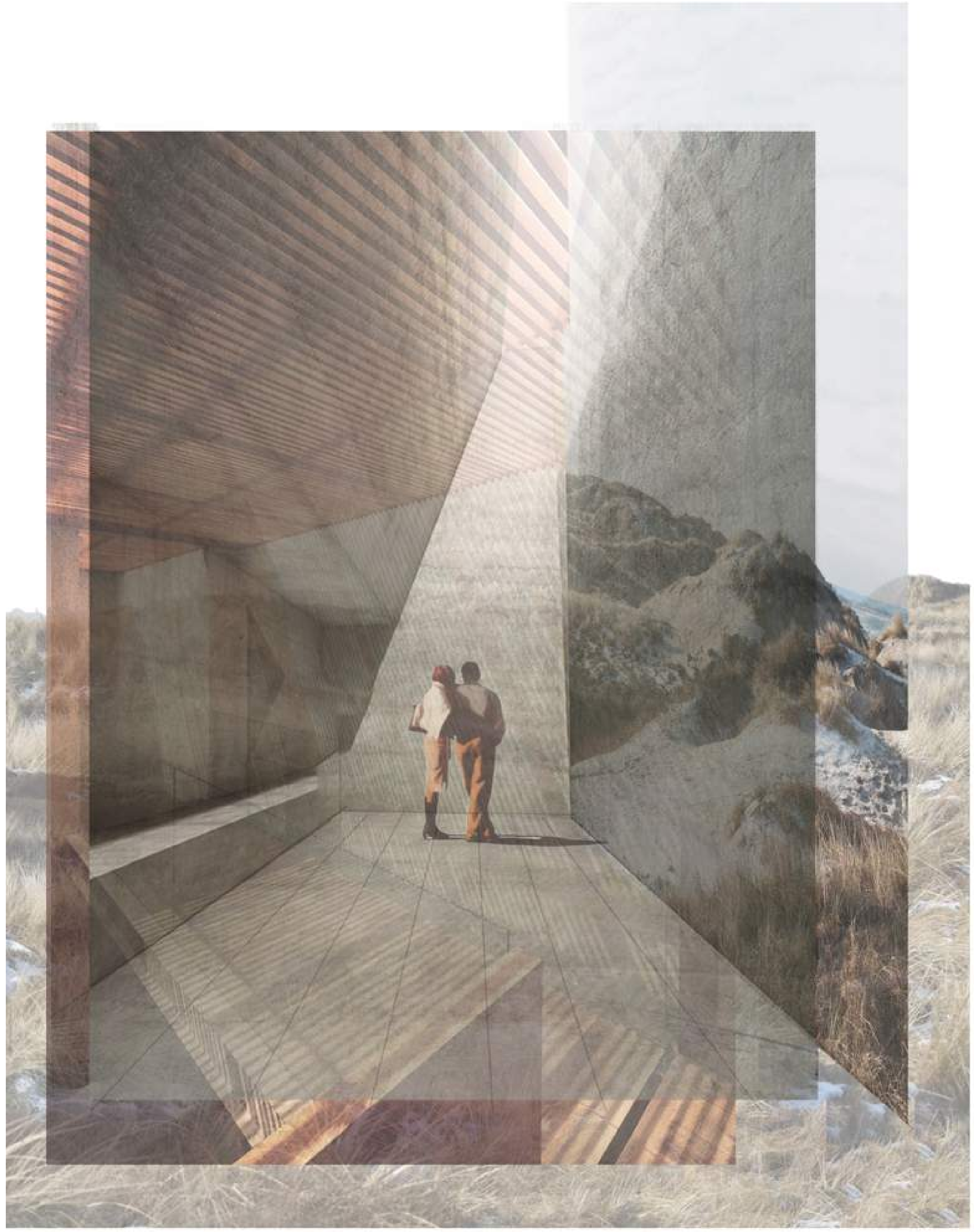


FIG. 22- Sensory architecture collage

PRELIMINARY

Phenomenology is not a uniform theory, but a way of understanding human relation to the outside world and is perceived as a prerequisite for the project. It abolishes the divide between subject and object and emphasizes the importance of individual critical understanding and awareness for the architect in order to grasp the delicate notion of architectural quality (Foged and Hvejsel, 2018). In order to grasp the notion of phenomenology in architecture, the study acknowledges the theories of Genius Loci by Christian Norberg-Schulz, Atmospheric Architecture by Peter Zumthor, and Architecture and the Senses by Juhani Pallasmaa, and includes a case considering the phenomenological approach of Daniel Libeskind's Jewish Museum in Berlin. The study and its synthesis will not delve into the various theories, but rather highlight different aspects which deem relevant to the desired focus of this project.

CHRISTIAN NORBERG SCHULZ
& genius loci

The Norwegian architect Christian Norberg-Schulz' concept of 'Genius Loci' translates into 'Spirit of the Place' and accentuates the awareness of the atmosphere of a given place (Norberg-Schulz and Seyler, 1979). As an epitome of Schulz' stance on the meaning of a place the following quote emerges " *Place is evidently an integral part of existence. What, then do we mean with the word 'place'? Obviously, we mean something more than abstract location. We mean a totality made up of concrete things having material substance, shape, texture and color. Together these things determine an 'environmental character', which is the essence of place. In general, a place is given as such a character or 'atmosphere'.*" (Norberg-Schulz and Seyler, 1979, p.414). He stresses the importance of a symbiotic relationship between architecture and the surroundings. Schulz indicates a layer of intangible phenomena resides in our understanding and sub-conscience of a place provoked by the tangible (sun, clouds, seasons, forests, lakes, stone, interactions, etc.) phenomena. We identify ourselves with a certain place, suggesting the notions of accommodation, arrival, gathering, interaction and meeting (Norberg-Schulz and Seyler, 1979).

PETER ZUMTHOR
& atmospheres

Swiss architect Peter Zumthor accentuates the sensory aspect as vital for the aesthetics of architecture. In practice he uses his theory by designing architecture which centralizes materiality, atmospheres, the coalition between building and landscape, and human perception. The building should emerge from the landscape and become a part of the surroundings, creating a gesture (Zumthor, 2018). He continually advertises the conception of atmosphere, narrating the fundamental components in order to create it in his writings. For instance, he touches upon the idea of atmosphere emerging between architecture and the surroundings, and its climatic and topographic conditions (Ibid), and the ability of acoustic properties of a material in space being able to articulate the characteristics of the interiority and allude us to respond in a pertinent manner (Ibid). He also acknowledges the compatibility of materials, indicating their range of possibilities in terms of properties, processing and combinations can articulate a space in various ways depending on its interplay with, for example, light. His approach to architecture is in close relations to the gestures of the Nordic, which is working sitespecific with focus on light, shadows and materiality, while at the same time integrating the principles of tectonics and sustainability into the architecture by working with the details of the construction, the meeting between building and landscape and the integration of passive strategies, dependent on the local context. By combining the gestures and principles, he penetrates another dimension of architecture and reinforces the focus of this project.

JUHANI PALLASMAA

& his critical view on occularcentrism and focus on tactility

The Finnish architect Juhani Pallasmaa suggests the sentiment of a new vision and sensory balance in the quest for architectural quality. He states, *"I had become increasingly concerned about the bias towards vision, and the suppression of other senses, in the way architecture was conceived, taught and critiqued, and about the consequent disappearance of sensory and sensual qualities from the arts and architecture."* (Pallasmaa, 2012, p. 10). He indicates the narcissistic and nihilistic role of the eye and encourages attention on the interplay between the multi-sensory experience and architecture instead.

In relation to this and to Zumthor, Juhani Pallasmaa advocates atmosphere as a tactile encounter of one's existence and self-perception (Havik and Tielens, 2013). He recognizes the tactile experience as the most important of our five Aristotelian senses as it is an integration of them all; *"The skin reads the texture, weight, density and temperature of matter. (...) The tactile sense connects us with time and tradition"* (Pallasmaa, 2012, p.62). Additionally, he considers that the architectural qualities of atmospheres emerge from the architect's empathy, sensitivity and skills (Havik and Tielens, 2013). This understanding of how to experience the nature of our surroundings is, according to Pallasmaa, the most essential competence of the architect.

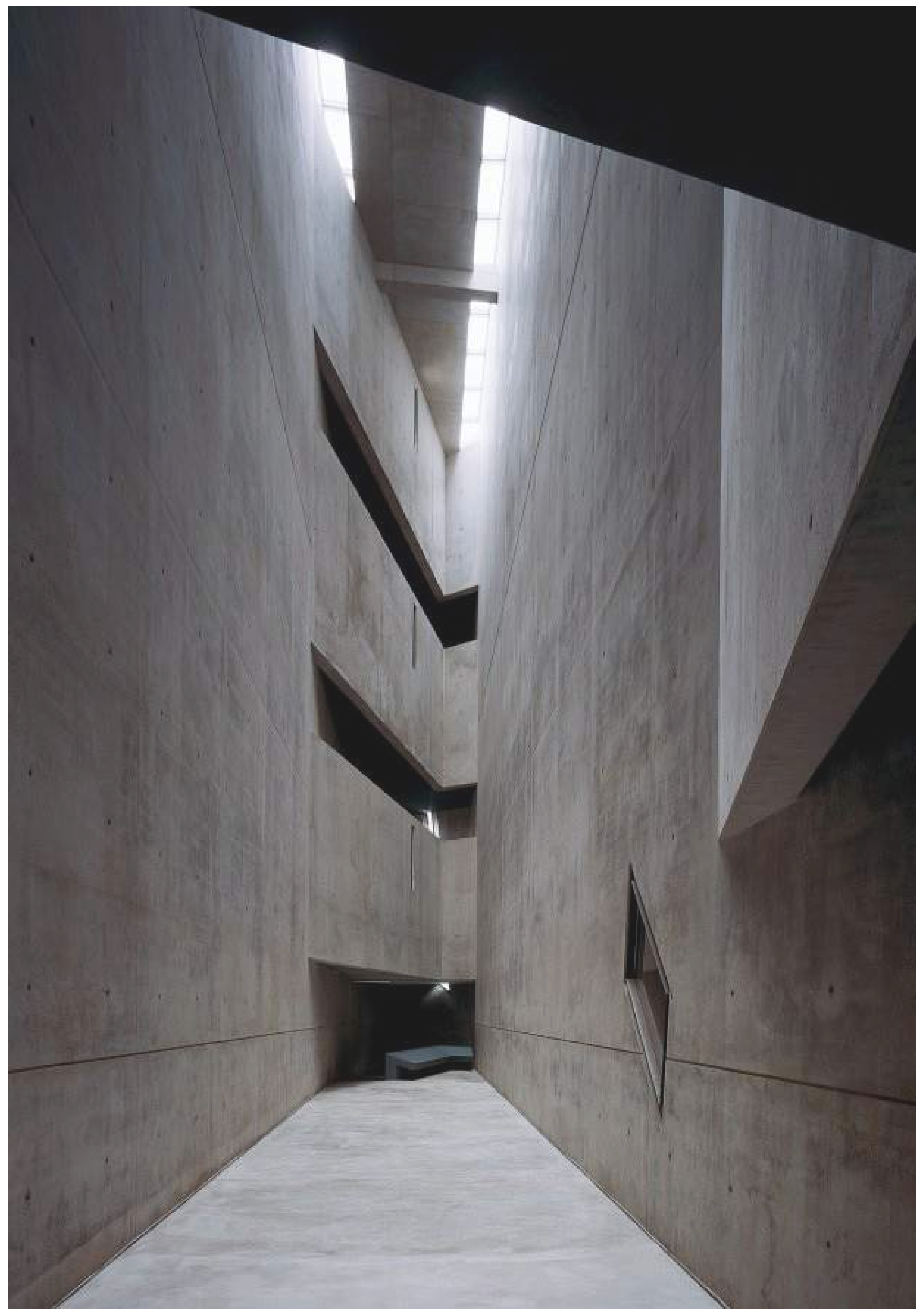
CASE STUDY OF THE JEWISH MUSEUM

Architect: David Libeskind
Year: 1999
Location: Berlin
Area: 15500 m^2

The Jewish museum in Berlin by Polish American Daniel Libeskind is both a tribute celebrating the accomplishment of the Jews in Berlin, as well as a memorial relating to the tragic Jewish past with a future-oriented aesthetic asserting the vitality of Jewish life (Libeskind and Binet, 1999). Creating an environment to be interpreted and experienced, the building zigzags with its titanium-zinc façade and features undergrounds axes, diagonal windows slashed into the façade, angled walls, and bare concrete 'voids' without heat or air-conditioning (Judisches Museum Berlin, n.d.).

Considering the relationship between building and person, the phenomenological structure comprises a series of composed sequences that play with contrasts such as spatial compression and expansion, working with spaces to create different atmospheres. The space is cool in temperature, the lights are bright, and the walls are a sterile white, all providing an uncomfortable consciousness and unwelcome feeling. Phenomenologically, the museum provokes reactions of absence, desolation, and invisibility – interpretations of disappearance of the Jewish culture. Through the practice of architecture as a means of narrative and sentiment catering visitors with a deeper understanding of the effects of the aftermath of the Holocaust on the Jewish culture and the city of Berlin. Eventually a person enters a void, in which the space is sectionally extensive with bleak concrete walls ascending 60 feet above eye level. In sacred moments, at the peak a narrow-slit washes the void with soft light administering an expression of hope. *"The emptiness that I witnessed at the cemetery actually confirmed my idea of the 'void' as an architectural device. The 'voids' of the museum provide a setting for nothing really to be displayed, because there is nothing really to be seen. It is just an emptiness which will never be eliminated from this city"* (Libeskind and Binet, 1999, p.37).

Like Pallasmaa, Libeskind considers the tactile aspect of architecture, however in a more kinaesthetic manner, stating, *"I think architecture begins simultaneously with the head and with the feet. One must experience it seeing it from afar and by walking through it. Later, one might think about it, but I think one experiences it first with one's ankles and shoes. In my opinion, that is where it begins: it begins at the ground."* (Libeskind and Binet, 1999, p.41). Libeskind provides a series of different spaces prompting an emotional journey of the individual by different means such as tilting floors and walls, descending into the ground, confined narrow spaces, etc., all different means of tactile involvement of the user in hopes of eliciting a deeper emotional awareness and connection, prompting an emotional recollection of the history (Libeskind and Binet, 1999).



← *FIG. 23- (BREDT, 1999)*

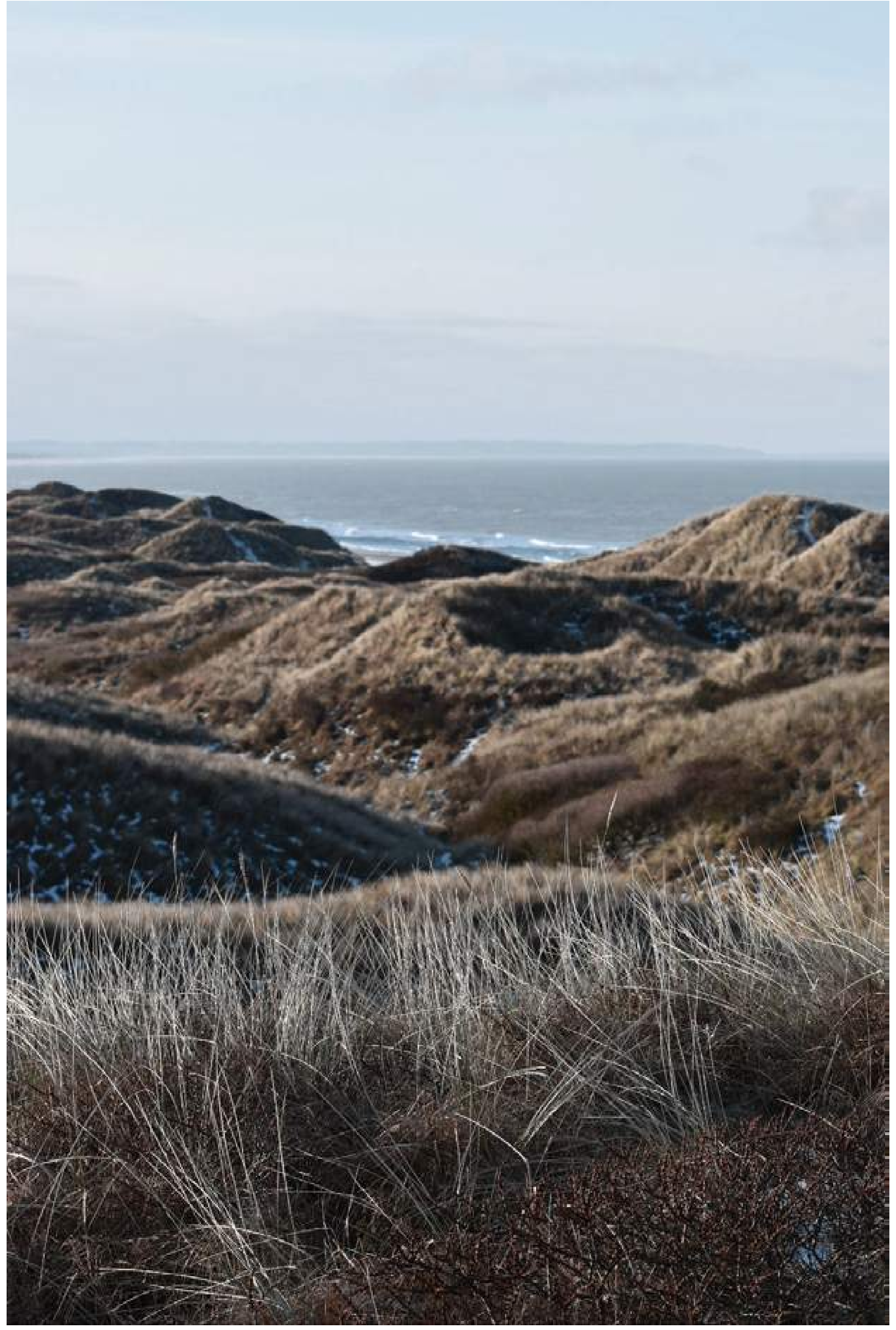


FIG. 24- Picture from site

03.4 architectural position.

a manifesto

WHAT IS OUR POSITION IN THE FIELD OF ARCHITECTURE?

This architectural thesis originates in an interdisciplinary approach to architecture, aspiring towards consensus between architecture and engineering. Our perception of successful architecture, roots in the corelation between building and context through awareness of atmospheres and environmental characters of the given place. Thus, the building should be an integral part of what already exists, and to be so, we believe that simplicity is key. Simplicity, found through harmony between the nature of the surroundings and the body of the architecture, defined and detailed according to the principles of the materials chosen to be compatible with the environmental context.

In extension, we believe in being able to remove all traces of the building. Working in the field of sustainable constructions, we find importance in limiting the impact of the building throughout its lifetime and not just pre- and post-building. The uncertainties related to the extent of climate change calls for rethinking constructions, considering disassembly as a possibility. We believe that each material layer should be able to be disassembled from the next, disposed or reused best possible. Thus, building with natural materials, that once disposed can return to become a part of natural and ecological resources, seems relevant. Building in balance.

The attention to sustainability is not limited to an environmental focus. In fact, the circular approach equally enhances social sustainability as it not only benefits the present, but also the future. Taking action now, aids future generations in promoting a sustainable way of living. In our opinion, it seems relevant to utilize the abilities of the environment in which the building is positioned. Through, adaptative, passive and mitigation strategies, the experienced quality of the indoor environment can be improved, without compromising with the quality of the future.

Architecture has a societal role. It has the ability to change the way we live which roots into the very presence of this thesis: **How can architecture motivate in a sustainable direction?**

04.0 ANALYSIS

"What if a building were more like a nest? If it were, it would be specific to its site and climate. It would use minimal energy but maintain comfort. It would last just long enough and then would leave no trace. It would be just what it needed to be."

-Jeanne Gang

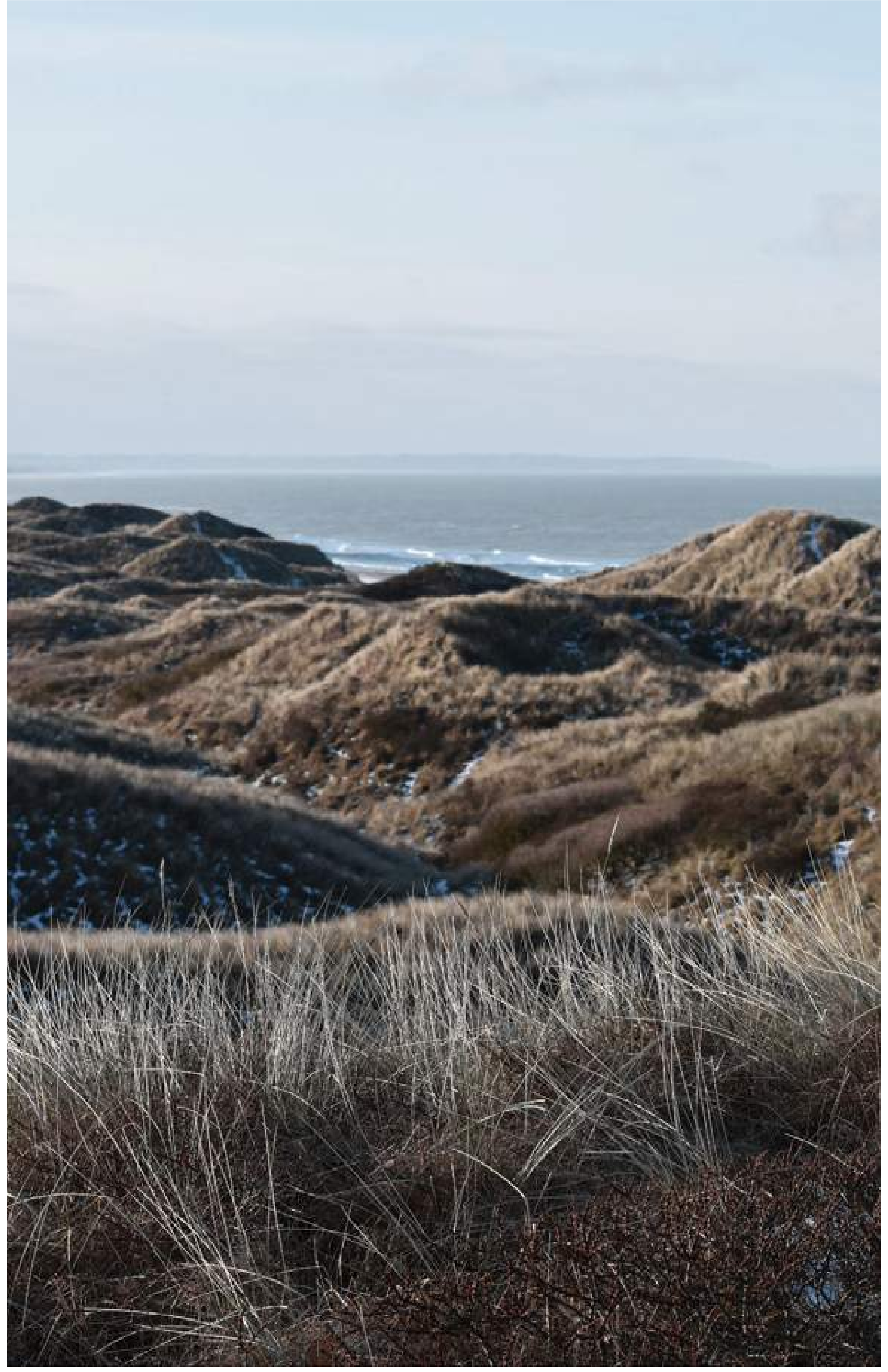
(Ruskin, 2016, p.81)

FIG. 25-ATLAS OF PLACES

04.1.1 genius loci.

grasping the phenomena of the place

"As we walk along the coloured facades and the straw roofs nearly touching our head, we feel the soft smooth sand beneath our feet. The gentle atmosphere takes us into a different world and the sandy road curves a bit and leads us into Blokhus beach. The first step we take feels heavy and the small protection we had from the nearby sand dunes and holiday houses disappears. In the mercy of the relentless cold winter wind we huddle together under the blue sky that paints the sea and the landscape. With the wind on our backs we follow the beach and head towards the site. Debris left from the waves that smoothly move back and forth seem almost mesmerizing all while the sun peaks through behind the sand dunes. A gentle sound that comes from the sea creeping lures us closer, all while the wind seems to get stronger as time nearly stands still and we feel like the beach stretches endlessly and disappears into the horizon."



"The sand dunes rise and fall creating a wall mirroring the waves as we look upon them. Standing before the sand dunes we see the movement of the sand and the tall grass that covers it like fur. A small and steep path created by the relentless wind leads us on top of the dunes where the breath-taking view stuns us and leaves everyone speechless. Standing between land and sea, we take in the scenery and realize that this might all change in the blink of an eye. In between this border lies our site surrounded by sand dunes and tall grass that vary in nuance from green to light yellow. Looking further ahead we see the tree line that forms a natural barrier. Moving down from the dune, we believed to be the tallest sand dune, we see another one reach above it and the whole landscape is formed like waves that crash into each other and everything seems to be moving."

WIND

Denmark's geographically location in the westerlies, causes winds from west to be predominant. In addition, coastal areas are further exposed to winds, due to the differences of temperature between land and sea. The character of the ground surface is also a contributing factor to how the wind will affect a certain site (Bjerg, 2012). The Danish Eurocodes places the site of this thesis in terrain category 2; a rather open space but with some obstacles being buildings and vegetation (Danish Standard Foundations, 1991). This analysis clarifies the conditions in the beforementioned environment, as it seems relevant to be considered and potentially incorporated as an active strategy, although no weather data is available for Blokhus. Weather archives from the Danish Meteorological Institute (DMI), show the weather conditions at Klitmøller, a comparable coastal city with available data (DMI, 2021).

0.2 - 5.0 m/s

5.0 - 11.0 m/s

> 11.0 m/s

site

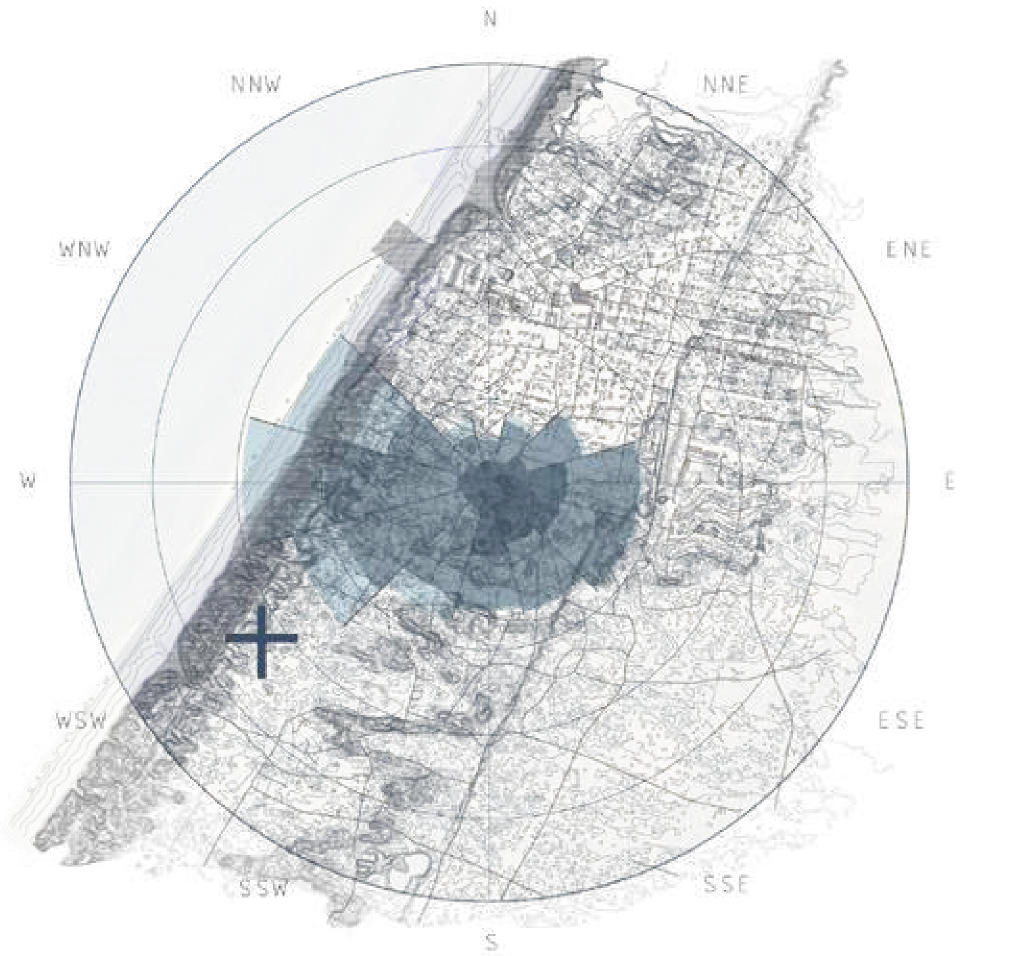


FIG. 26- *Wind on site*

FLOODING

The analysis of the flooding shows how the site will be affected in case of sea level rise. The Site is exposed to water and therefore also vulnerable to flooding. The analysis of flooding generates an understanding regarding waters significant role for the site and contexts. the analysis also enables us to think about the materials and strategies for tackling this problem. (Klimatilpasning, 2021)

worst case scenario(3m)

site

FIG. 27- *Flooding on site*

04.1.2 cartosynthesis.

microclimate & mapping

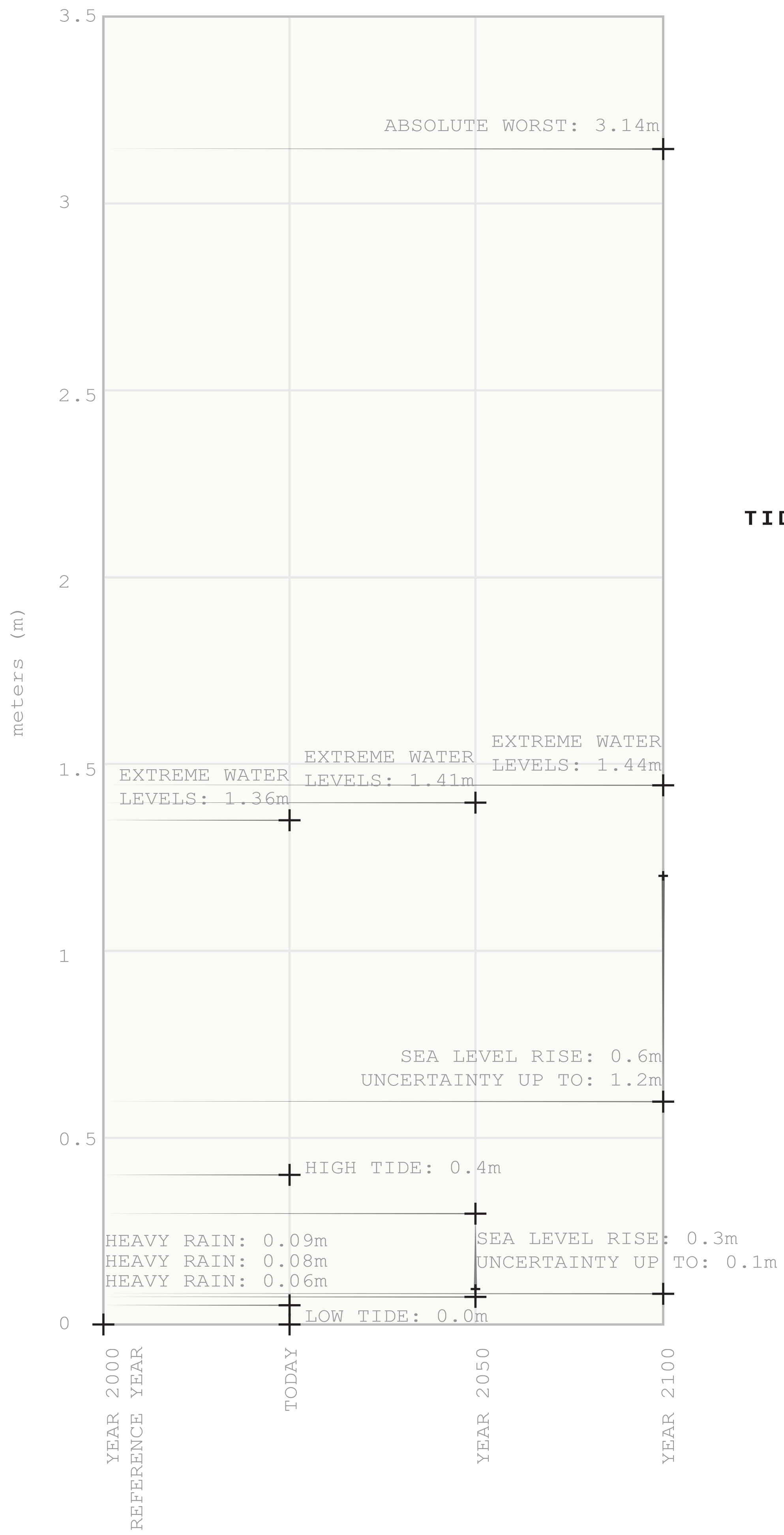


FIG. 28- *Various sea level changes*

PRELIMINARY The following analyses profile Blokhus, through means of mapping, facilitating an elemental understanding of the site and its surroundings. Due to the emphasis on the environment and surroundings, microclimate, infrastructure, vegetation, geology and functions have been examined as they are deemed as significant in providing a framework for the design phase.

TIDE & SEA LEVEL CHANGE Striving towards educating in climate change and sustainable action in generations to come, the educational centre should find itself protected from climate change related impacts. Coastal areas are especially exposed to impacts caused by sea level changes, including erosion. Sea level changes is a consequence of global warming, increasing temperatures in both land and ocean, causing ice to melt and the ocean itself to expand. Associated with short term variations such as extreme weather conditions, the sea level can rise even further (Nicholls and Lowe, 2004). Short-term variations are defined as 20-, 50- or 100-year incidences, being such rare events that only occur every 20, 50 or 100 year (Nielsen and Fonseca, 2019).

The illustrated data combines various sea level changes related factors, including the absolute worst-case scenario, combining high tide, the highest predicted sea level rise, the 100-year incidence of extreme water caused by storms and also the 100-year incidence of heavy rain.

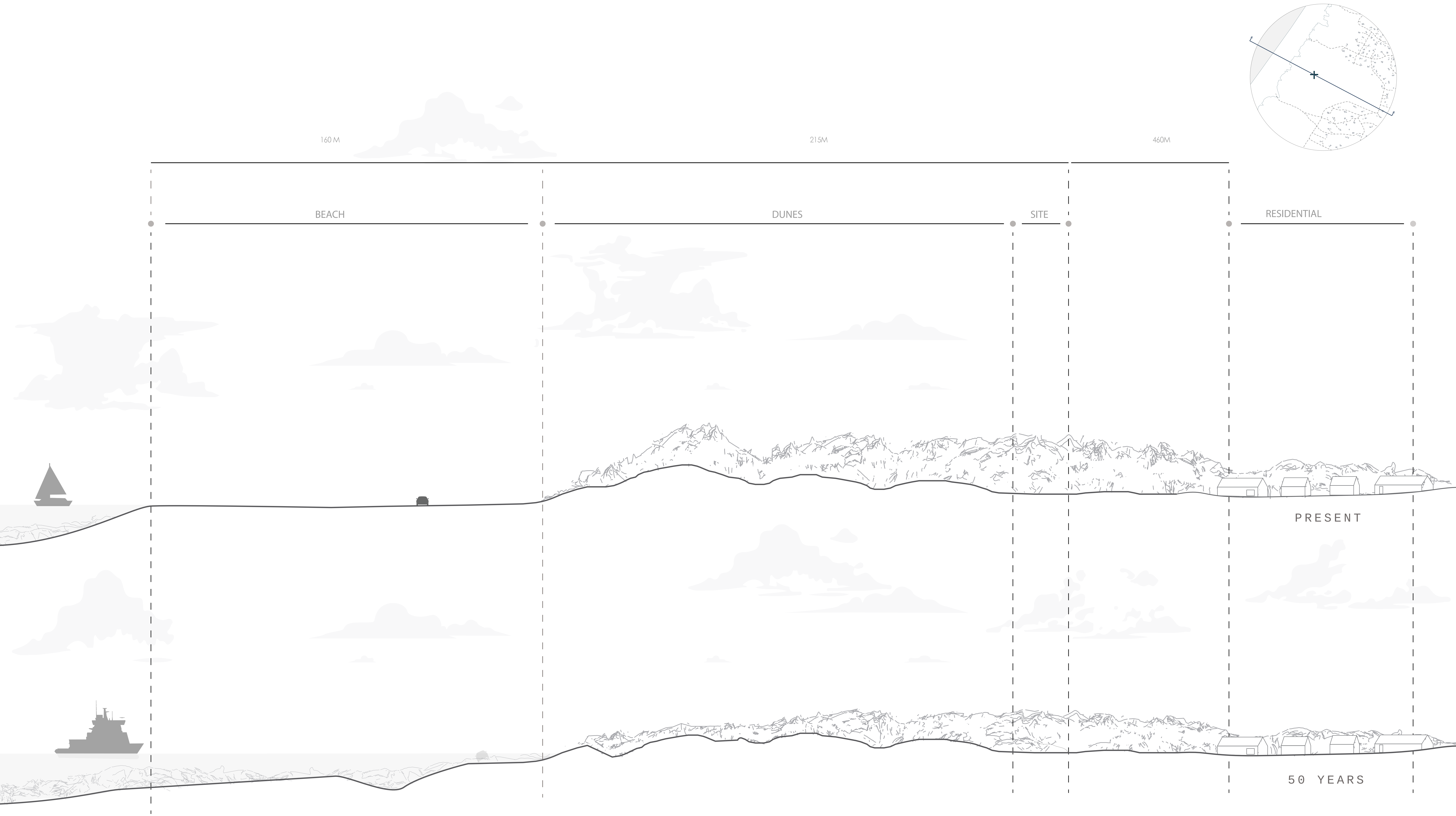


FIG. 29- Section in 1:1000 of site in the present, and predicted site in 50 years

MAPPING

INFRASTRUCTURE

Most of the infrastructure that is linked to the site are undefined and consist of a mixture between gravel and sand. Blokhus has a few roads made of asphalt, which leads to the stores and a few residential areas. The mapping of the infrastructure gives an understanding of the pathways and connection between the different functions around the context. It also generates ideas and strategies on how the visitor could arrive to the site and building.

smaller dirt roads

larger roads

coastal protection

site

FIG. 30- Infrastructure surrounding the site

VEGETATION

The site is surrounded by a diverse and rich nature. The dunes and most of the context is inhabited by Ammophila arenaria (Naturbasen, 2015). A particular type of grass that flourishes in harsh conditions. It is traditionally planted in newly formed dunes and old dunes to reduce the amount of sand carried by the wind. Surrounding the holiday-homes, different types of tress are planted to shade for the strong wind and towards the mainland, large areas of forest landscape dominate.

vegetation

coastal protection

site

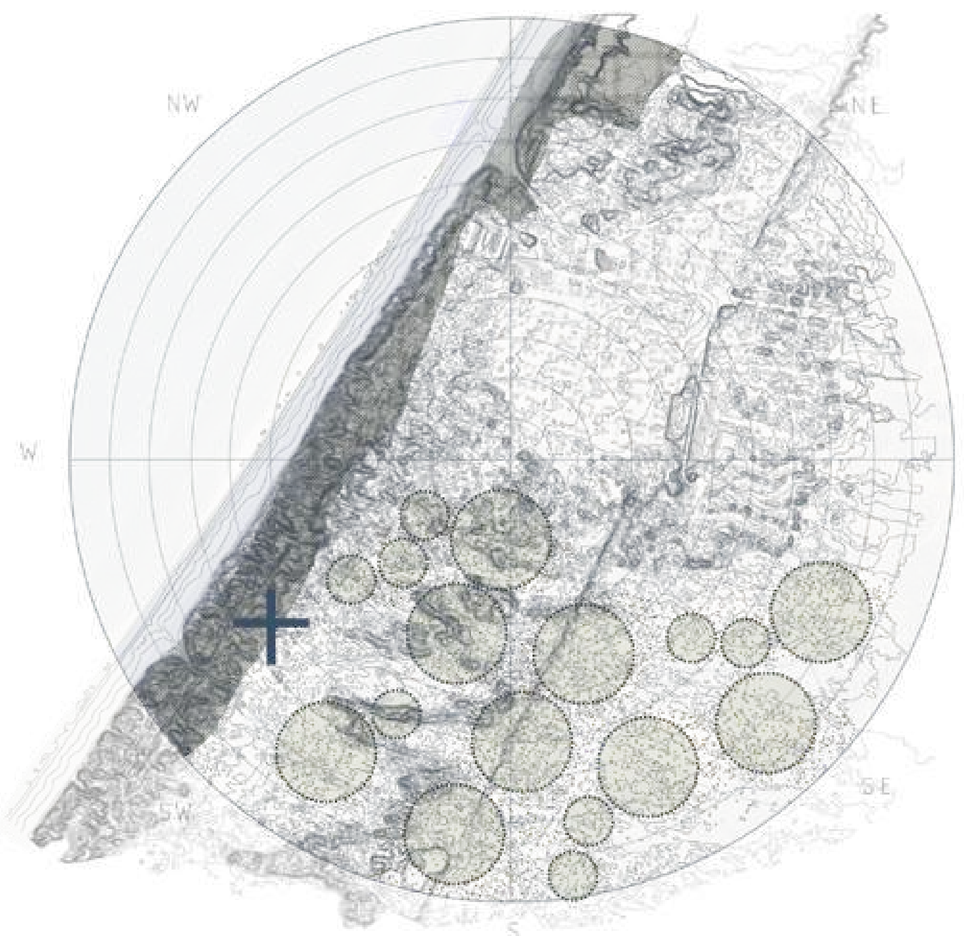


FIG. 31- Vegetation surrounding the site

FUNCTIONS

The context is predominantly defined by holiday homes that are spread out in the landscape. Blokhus has some boutiques and hotels mixed with a few residential houses in-between. The functions in the context are highly dependent on the attraction that is linked to the landscape and the long beach. This also gives a clear view on the different functions and their relationship towards the landscape and the surrounding nature.

retail & restaurant

summer houses

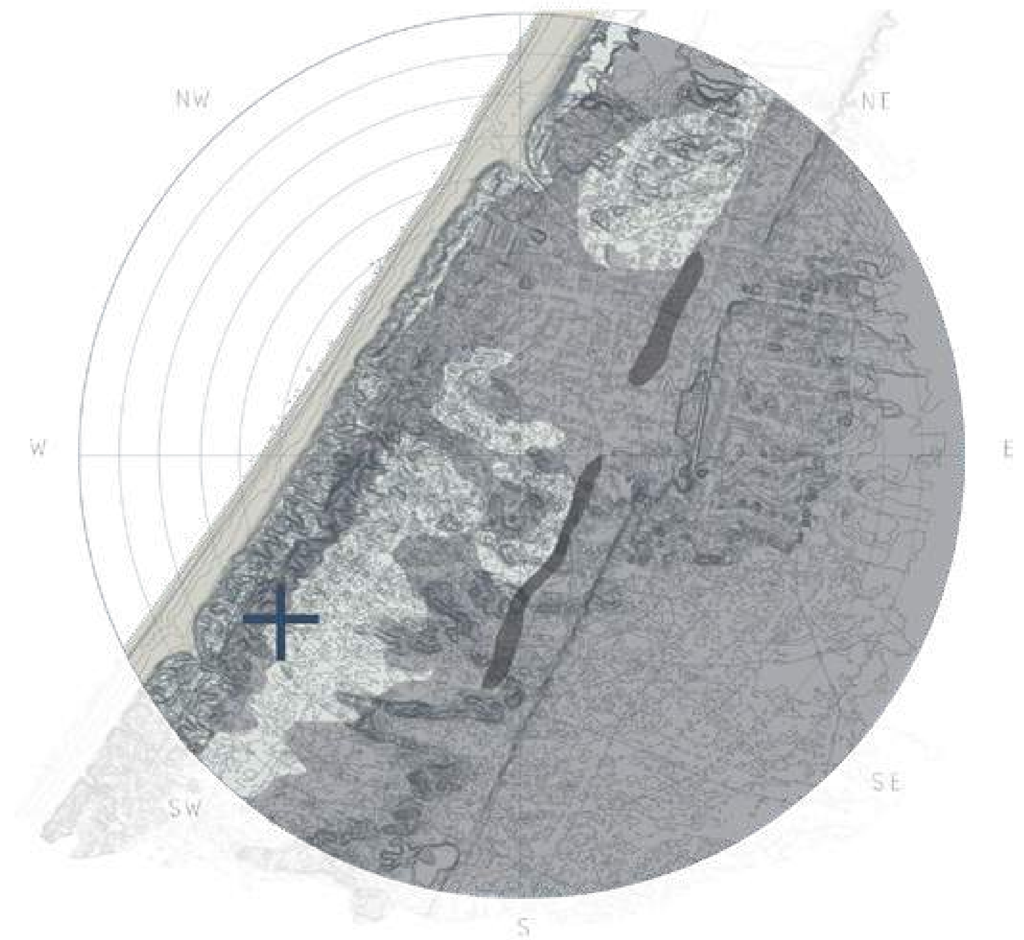
residential

site

FIG. 32- Functions surrounding the site

GEOLOGY

Blokhus is located in a sand landscape typical for the coast along Jammerbugt municipality. Characterized by the wide beach, the landscape is consistently changing, especially when looking at the sand dunes. These are followed by relatively flat landscape that contains a mixture of gravel, sand and other leftovers from the last glacial period. Looking into the bedrock the area can be divided into 4 geological soil types. Mapping the soil shows that a majority of the context is filled with sand and glacial sand where a small piece of the landscape contains moraine clay (Naturstyrelsen, 2021).



shifting sands

sea-deposited sand

beach sand

moraine clays

site

FIG. 33- Geology of the site and the surroundings

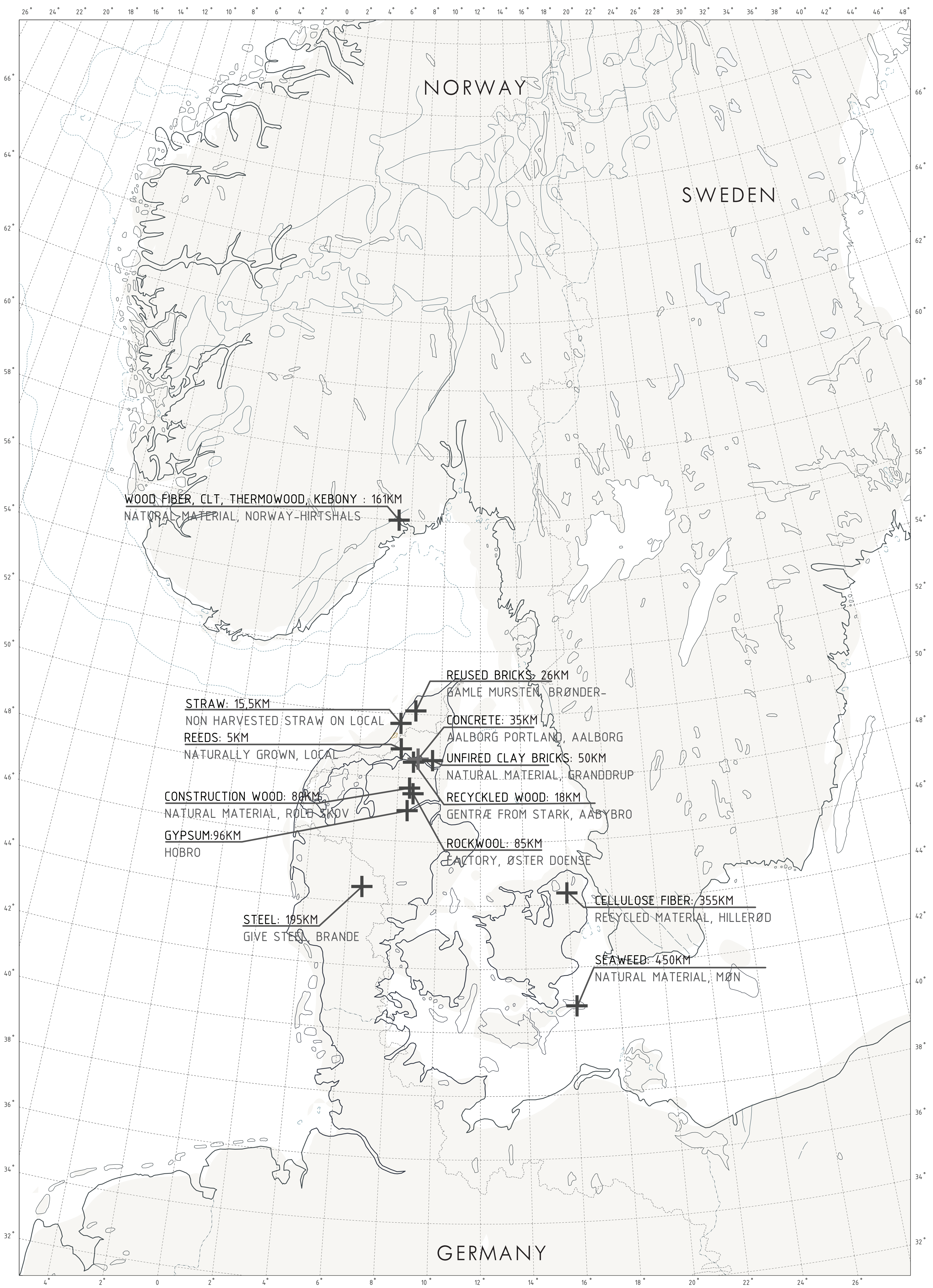


FIG. 34- Mapping of availability of materials in relation to site

04.2.1 materials.

a life cycle analysis

PRELIMINARY

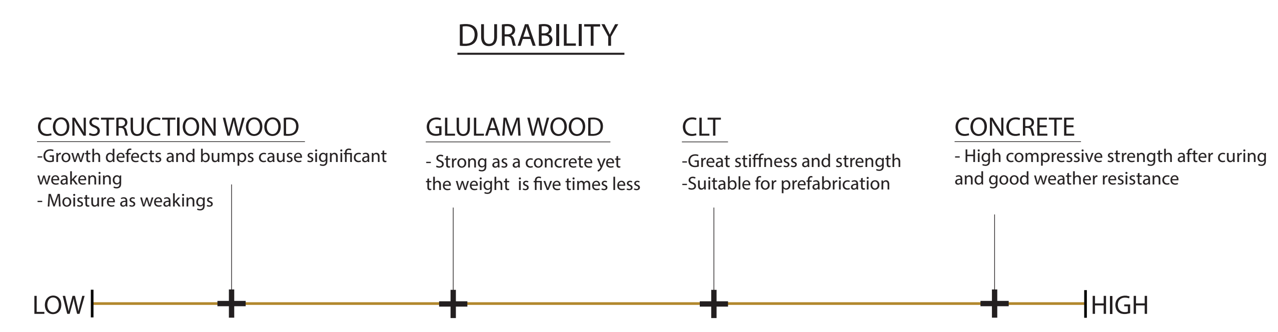
This chapter investigates building materials with the purpose of establishing an understanding of their materiality, abilities and sensorial perception. With the implementation of state-of-the-art building materials, it is important to study aspects related to their impact on indoor environment and the environmental advantages and disadvantages, validated through a life cycle assessment (LCA). Building materials can cause a range of environmental impacts in air, soil and water, resulting in climate change, ozone layer depletion and acidification of water to mention a few. The impacts can be calculated through different indicators that are addressed in a Life Cycle Assessment (Green Building Council Denmark 2017).

MATERIAL MAPPING

A key aspect of sustainability in materials, is their availability close to site. The materials should be harvested, produced and/or manufactured locally to the extent possible. As previously stated, the materials in sustainable projects, preferably natural, renewable and reuse, supports sustainability considerably (Asdrubali, D'Alessandro and Schiavoni, 2015). A series of natural and reused construction, insulation and façade materials have been selected to be analysed along with other closely available materials, some of which being traditional building materials for reference.

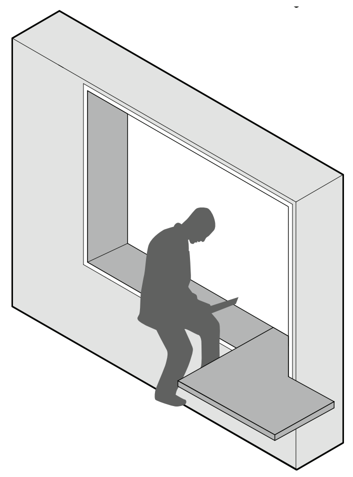
ABILITIES OF CONSTRUCTION MATERIALS

Choosing the right construction materials does not only allow the building to represent sustainability into its core; their abilities also have the potential of influencing the architectural expression. To choose between materials, a clarification of materiality as well as pre-investigations of environmental impacts is necessary. Three different wood-based construction elements are analysed, and compared with concrete, being a traditional and relatively local building material.

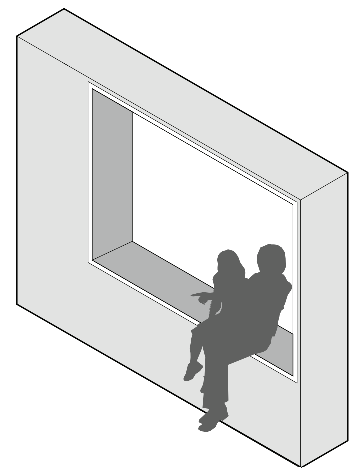


ZONES OR WALLS?

The Danish building regulations lists specific demands for energy consumption and thus proper insulation (Trafik-, Bygge- og Boligstyrelsen 2018). The introduction of non-traditional insulation materials is no exception. As the materials perform differently according to thermal conductivity, the thickness of the insulation layer differs, opening for various design possibilities.



↑ *FIG. 35- Extended window sill as furniture*

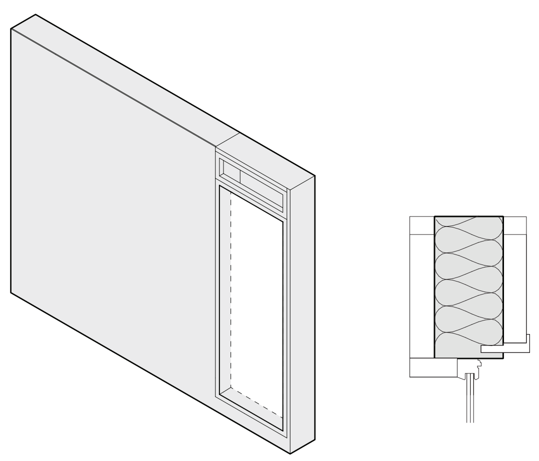


↑ *FIG. 36- Window sill as furniture*

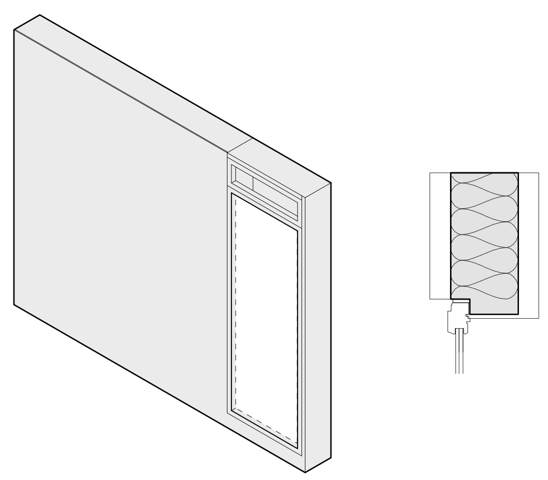
WINDOW PLACEMENT AND EXPRESSION

One of the possibilities and challenges a thicker wall provides is determining the placement of the window. According to the danish building tradition the window frame is placed close to the façade. The recessed window is normally found in the warmer climates, where it acts as solar shading strategy. The façade expression here is mostly depth from the shadows that are cast from the window cut (fig 37).

When the window is aligned with the façade more daylight enters the building, and the façade expression is more subtle. The alignment of the window with the façade provides opportunity to utilize the depth created inside, and thereby can serve as furniture and act as an extension of the interior space (fig. 38). (Brunsgaard, Heiselberg & Jensen, 2008).



↑ *FIG. 37- Recessed window*

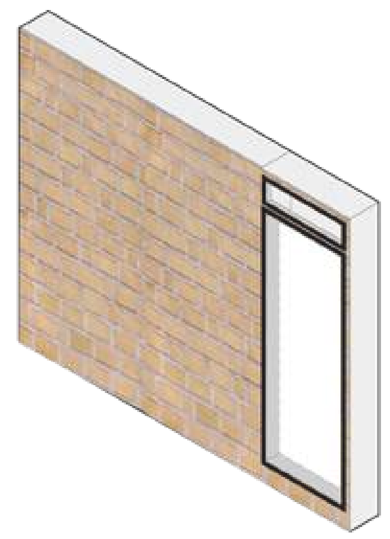


↑ *FIG. 38- Aligned window*

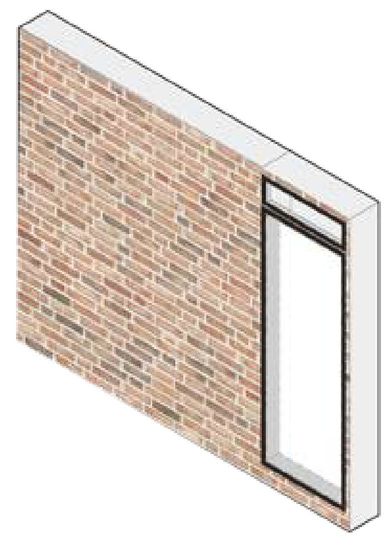
FACADE CLADDING

Over the last decade, building regulations have pushed towards sustainable constructions through energy usage standards. To accommodate these standards, building have become more and more insulated. The tendencies in modern architecture dictate simple geometries and details caused by the heavily insulated building envelopes, and connection with nature through large window facades (Poulsen and Lauring, 2019). With increasing average temperatures caused by climate change, overheating has become a common problem in Danish buildings. Cooling measures such as air conditioning will only increase the energy usage. However, the thick insulated walls can be incorporated in a passive shading strategy, lowering the solar contribution to internal heating (Poulsen, Lauring and Brunsgaard, 2019). Passive shading utilized as a mean to avoid overheating along with an optimal indoor environment is highly corelated with external and internal façade claddings. According to the district plan, external facades must present itself in black, white or earth tones and their mixtures with the greyscales (Jammerbugt Kommune, n.d.) leading to an investigation of architectural expression as well as properties of the following materials.

↑ *FIG. 39- Reeds*



↑ *FIG. 40- Unfired clay brick*



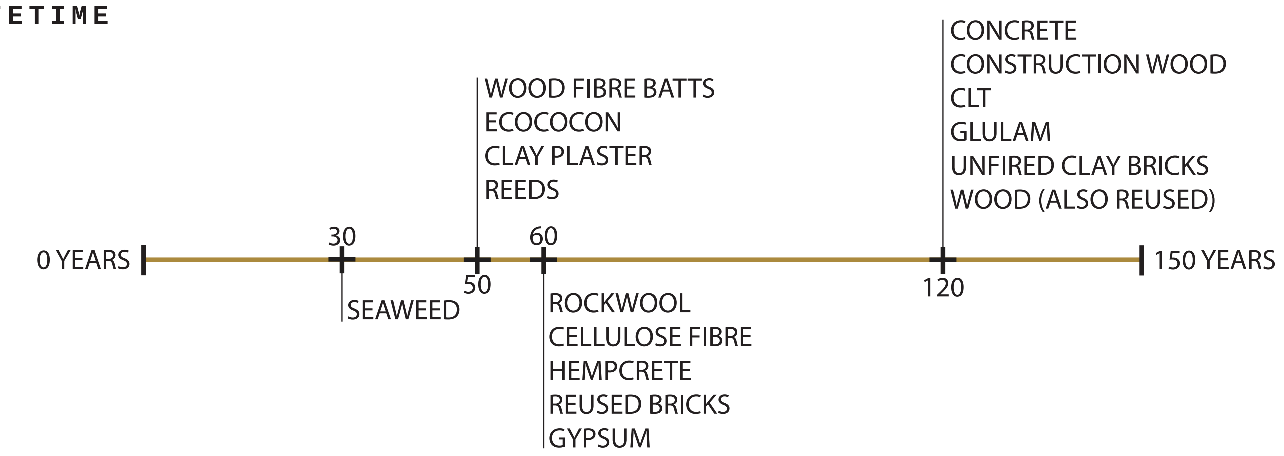
↑ *FIG. 41- Recycled bricks*

↑ *FIG. 42- Recycled wood*

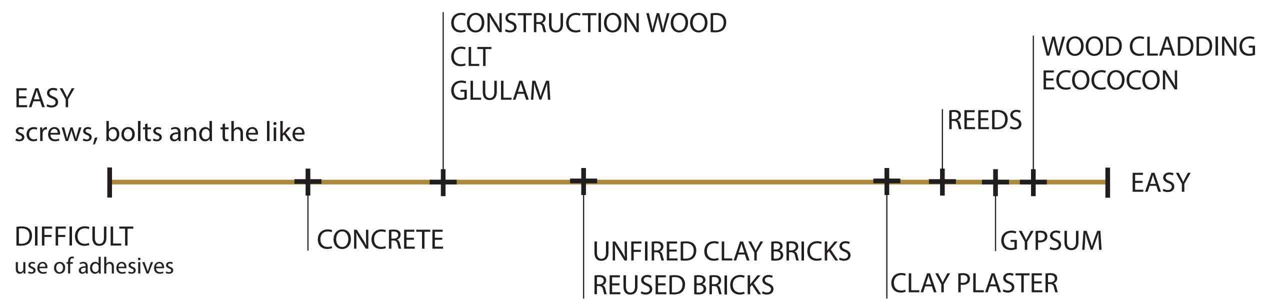
↑ *FIG. 43- Kebony wood*

↑ *FIG. 44- Thermowood*

LIFETIME



EASE OF DISASSEMBLY FOR CONSTRUCTION AND FACADE MATERIALS



MATERIAL PROPERTIES

Reeds
Reeds is a natural material that grows without use of any pesticides. In fact, the material contributes to a healthy indoor environment, as it promotes a diffusion permeable building envelope. Reeds also insulates due to the stationary air that lies in-between the reeds (Straatagetskontor, 2018).

Clay plaster
Clay is a natural material that does not go through processing prior to its use. Clay plaster contributes to a healthy indoor atmosphere through its moisture buffering abilities, that regulates the humidity in the room. The material is porous and open-textured which benefits the acoustics (Bygsundt, n.d.; Byggeladen, n.d.).

Bricks (Unfired and reused)
Just as clay plaster, bricks have moisture buffering abilities. The weight of the bricks results in heat accumulation, meaning that bricks store and release heat depending on the temperature and therefore help regulate the indoor climate (Egenvinding, n.d.; Mur og Tag, n.d.).

Wood (recycled)
Wood as an interior cladding contributes to the indoor environment through moisture buffering. Its materiality makes it great for acoustics (Dinesen n.d.)

LCA RESULTS

Construction materials:
As the actual amount of each construction material is not yet known, equal amounts of each material are analysed. The results (see pages 70-71) validate wood as the better building material when focusing upon climate change and CO_2 emissions. However, taking the other indicators into account, CLT and glulam construction wood are significantly higher than concrete, caused by the adhesives used in the production of the materials. All wooden elements are recycled in their end-of-life phase, resulting in no energy recovery through incineration. The choice of recycling lies upon the trees ability to absorb CO_2 from the atmosphere during its growth, which would simply be released back into the atmosphere if incinerated (Cesprini et al. 2019).

Insulation materials:
The analysis clarifies the advantages of implementing natural materials, especially when focusing upon global warming. The biggest differences lie in the straw panel, and what is important to note, is that the available environmental product declaration (EPD) for straw represents a whole construction element, including both wood and screws besides the straw. This construction unit performs better compared to Rockwool that represents the traditional insulation material, and only an insulation material.

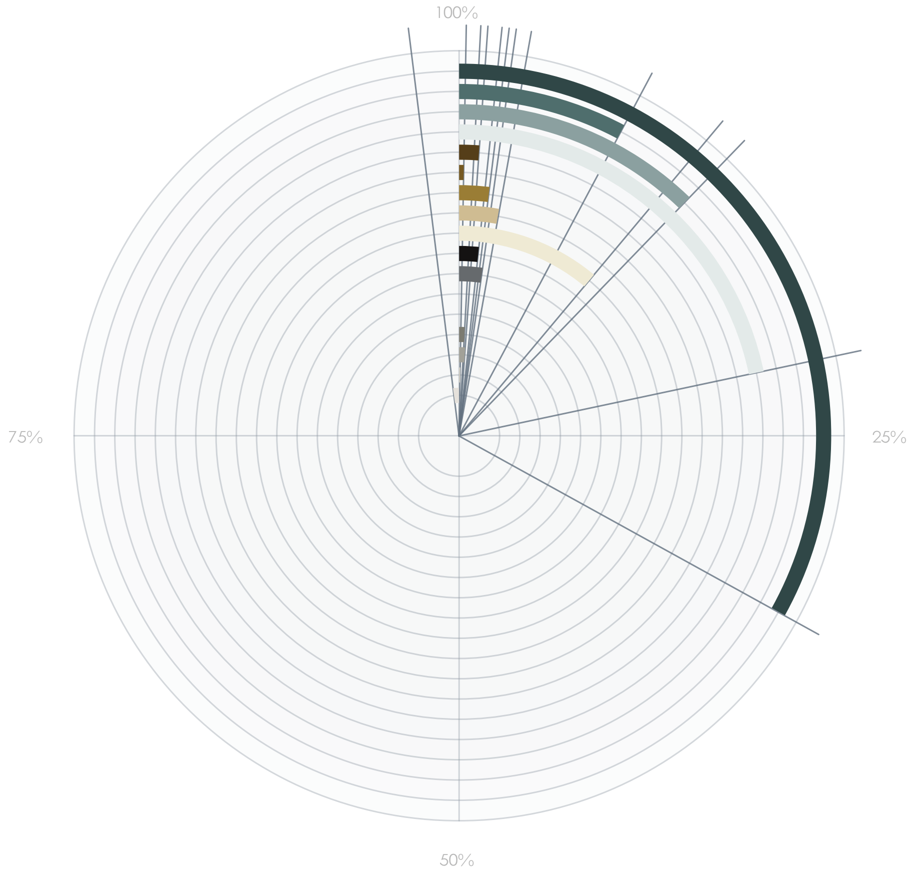
Façade materials:
The analysis of façade materials highlights the reused materials as better than natural material. This being due to low impacts in the production phase, as the materials are already produced and therefore require minimal work. The analysis also shows negative values for some of the indicators, which is a result of the natural materials that absorb CO_2 and other substances from the atmosphere. The fact that many of the materials are incinerated, lowers the energy used. However, many of the natural materials can be used for compost, which is more climate change friendly.

SYNTHESIS

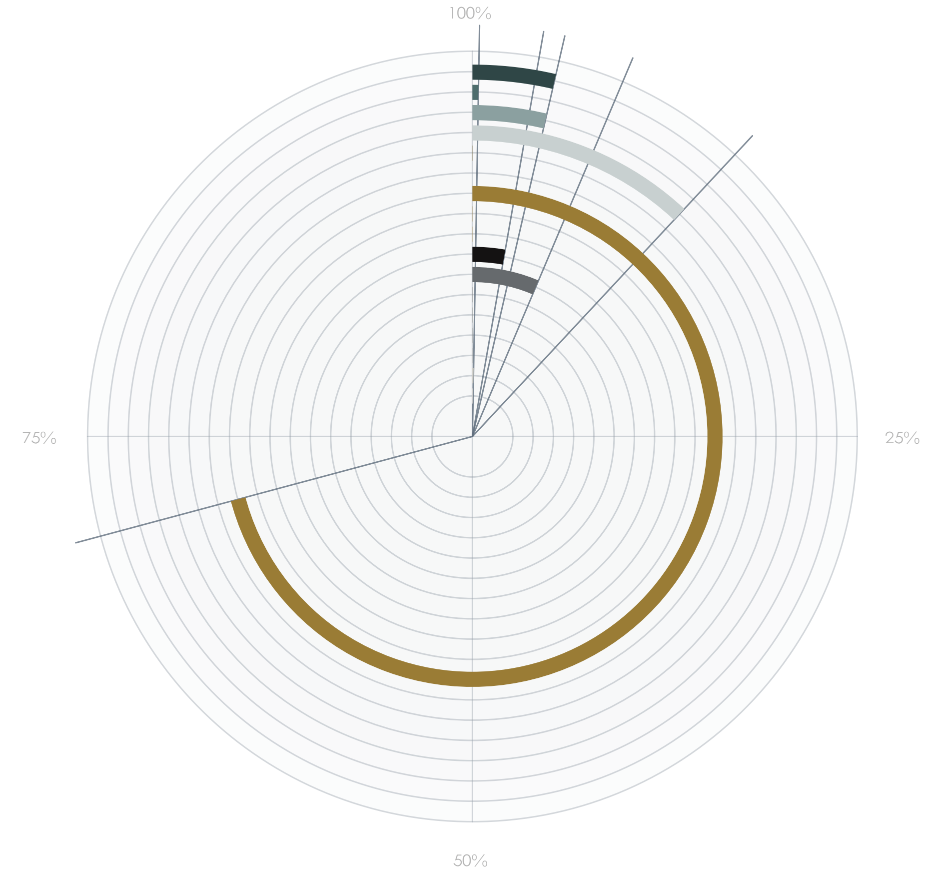
The material analysis validates this thesis' focus upon using solely natural materials, as they perform better than the more commonly used materials such as concrete and rockwool, clarified through the LCA analysis. Furthermore, the analysis showed that reused materials are preferable. In the analysis of insulation materials, a contradiction to the otherwise positive results of natural materials arose. The straw insulation performed comparably to rockwool and in some cases significantly worse. First and foremost, it is important to stress that the analysis of straw was performed based on data of a straw construction panel and not solely straw. Secondly, straw is an agricultural crop with a rather short timespan of regrowth. Therefore, the carbon storage potential which is removed once the material is harvested and utilized in buildings, can rather quickly be compensated compared to other natural materials such as wood, which have a longer timespan for regrowth. Straw is therefore more effective for short-term results in relation to climate changes. In extension, a large amount of the material is discarded during harvesting, making it an available waste material (Pittau et al., 2019). An analysis of the straw potential in Denmark showed that a large part of the produced straw is not harvested, and in extension, one of the areas with a lot of non-harvested straw is actually close to the project site of this thesis, making straw both a local and available waste material (Jessen, 2016). On the contrary, wood-based products are easily available on the market to a fair price, and also easy to assemble on-site, which makes it a quite interesting construction material (Pittau et al., 2018). Attention to the EOL of the natural materials is important, as incineration which is perhaps the worst but in fact the most common waste treatment for natural materials today, removes the advantages of carbon storage as it is released back into the atmosphere during incineration (Göswein et al., 2021).

LCA ANALYSIS

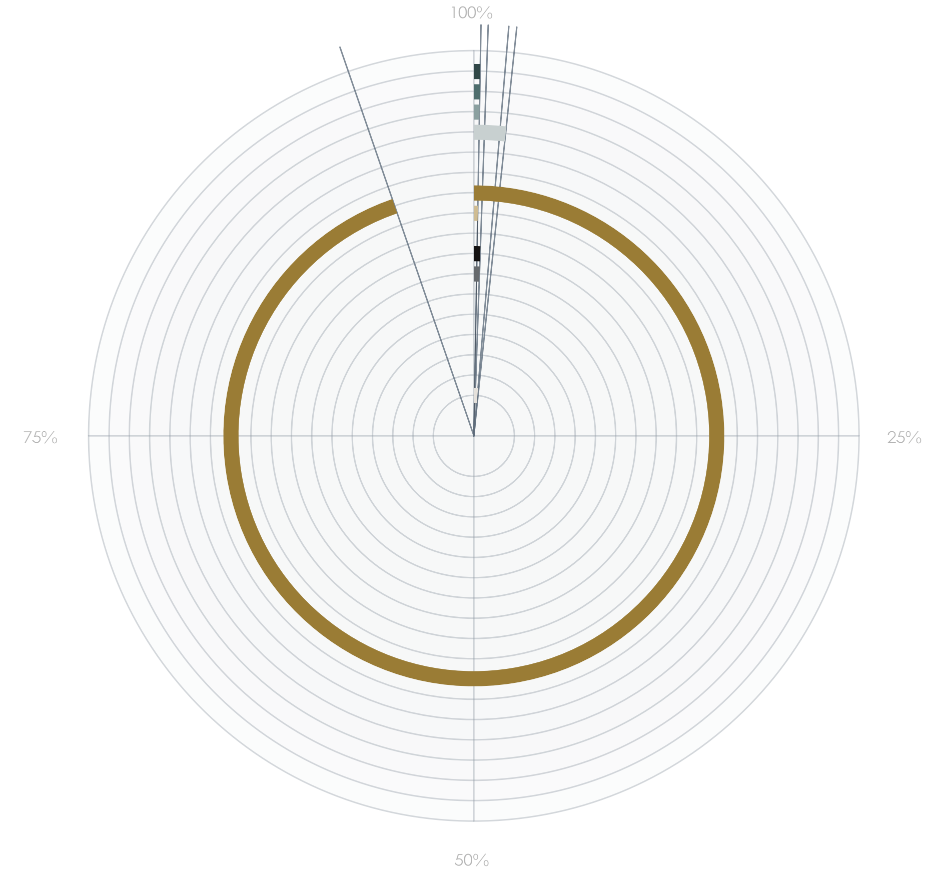
GWP - GLOBAL WARMING POTENTIAL.



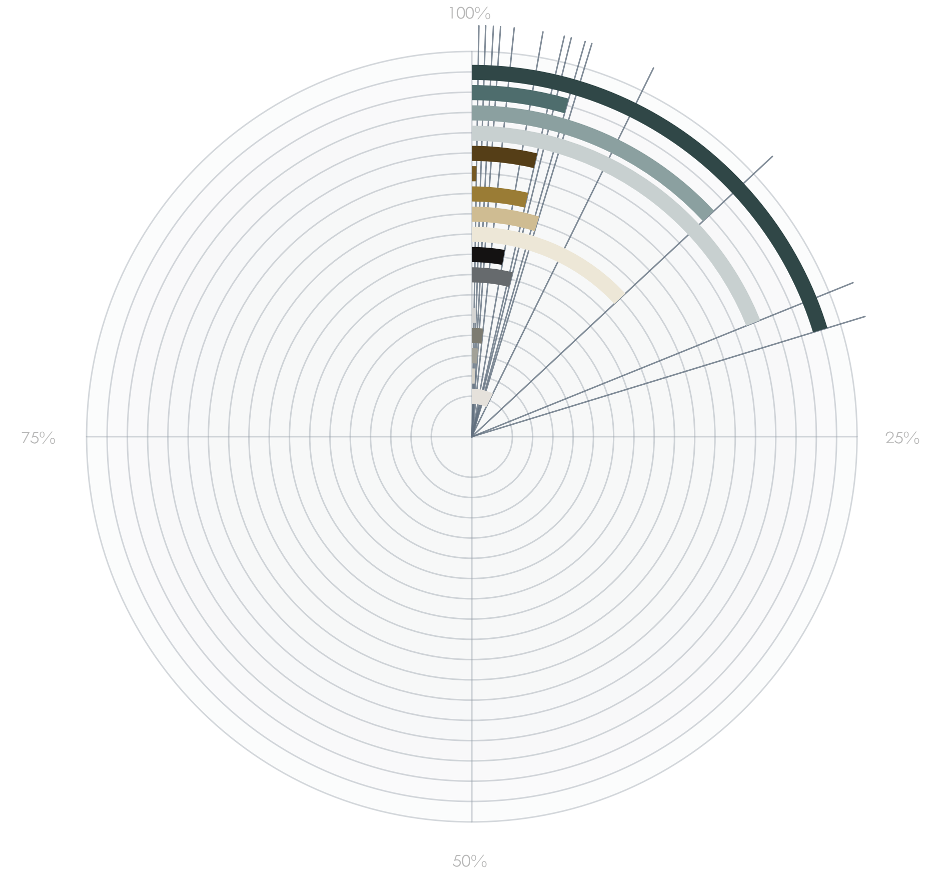
ODP - OZONE DEPLETION POTENTIAL.



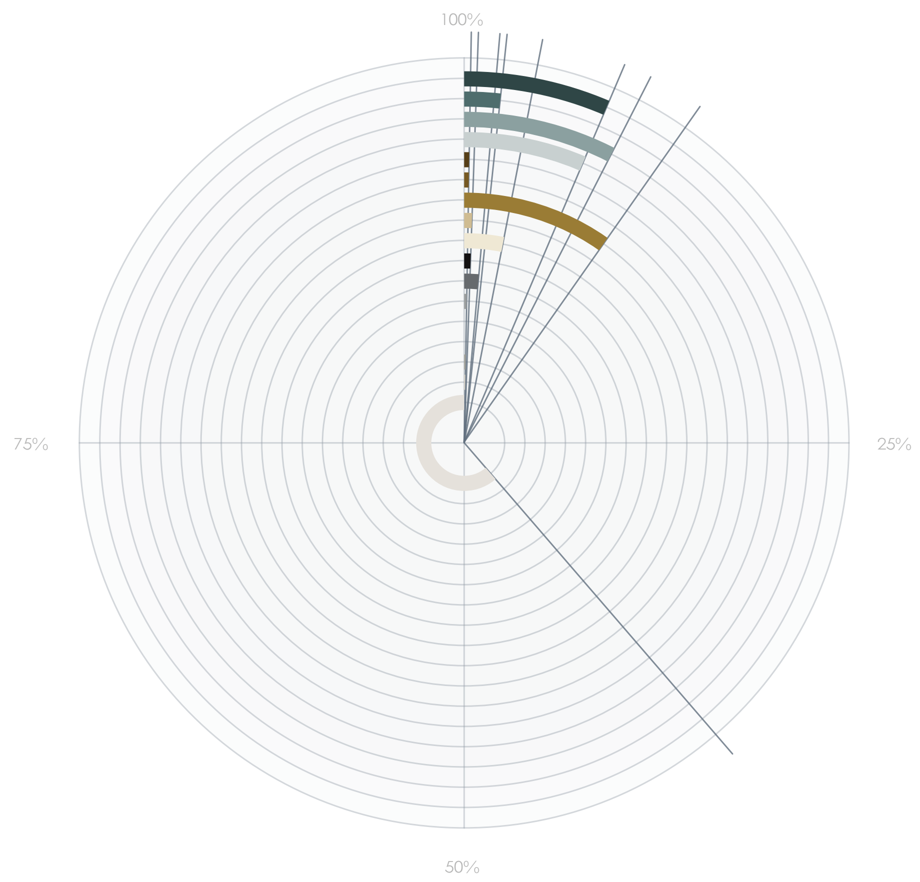
ADPE - ABIOTIC RESOURCE DEPLETION POTENTIAL FOR ELEMENTS.



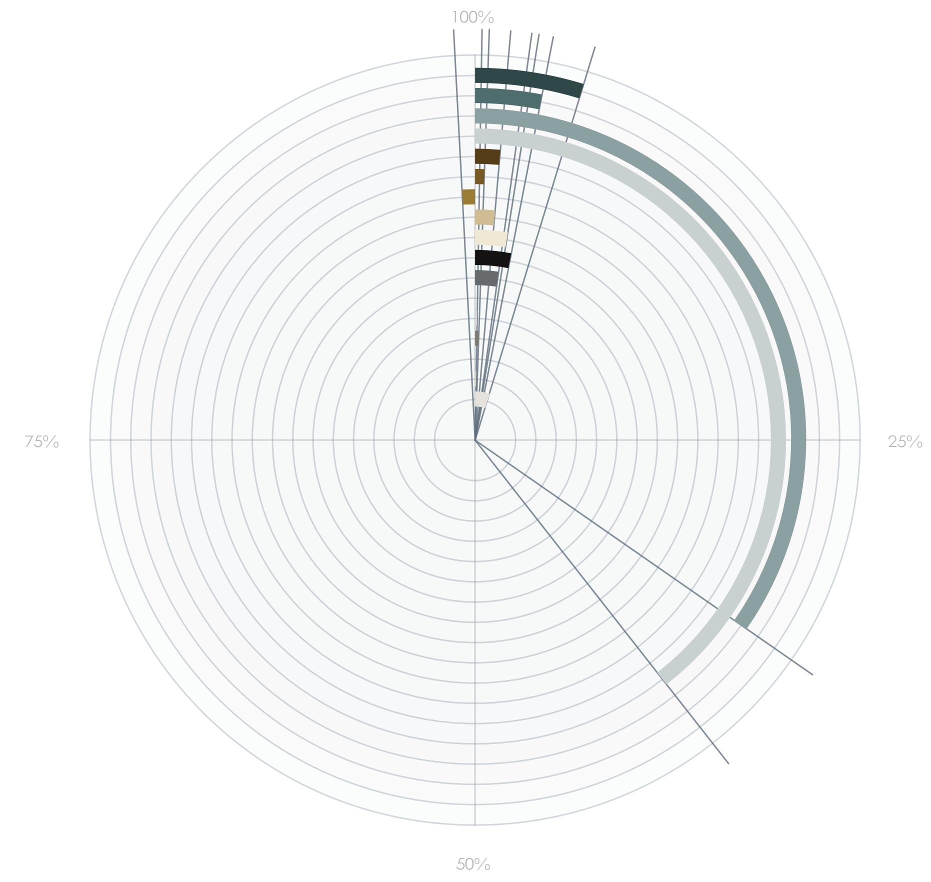
ADPF - ABIOTIC RESOURCE DEPLETION POTENTIAL FOR FOSSIL FUELS



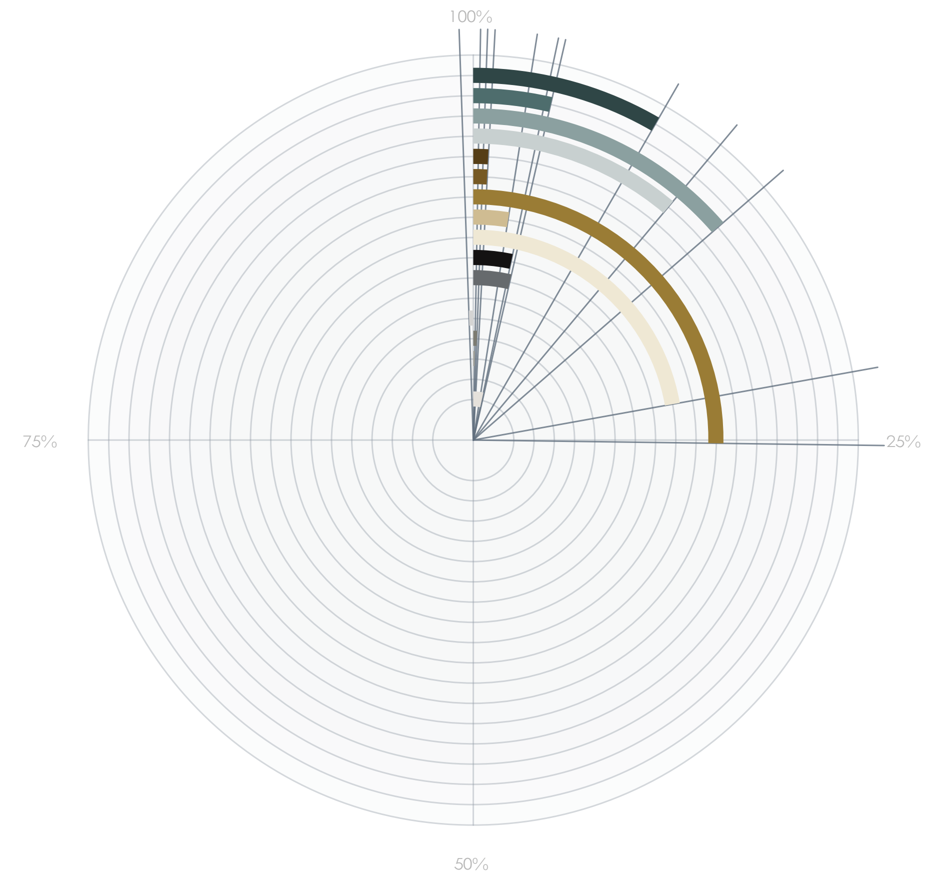
EP - EUTROPHICATION POTENTIAL.



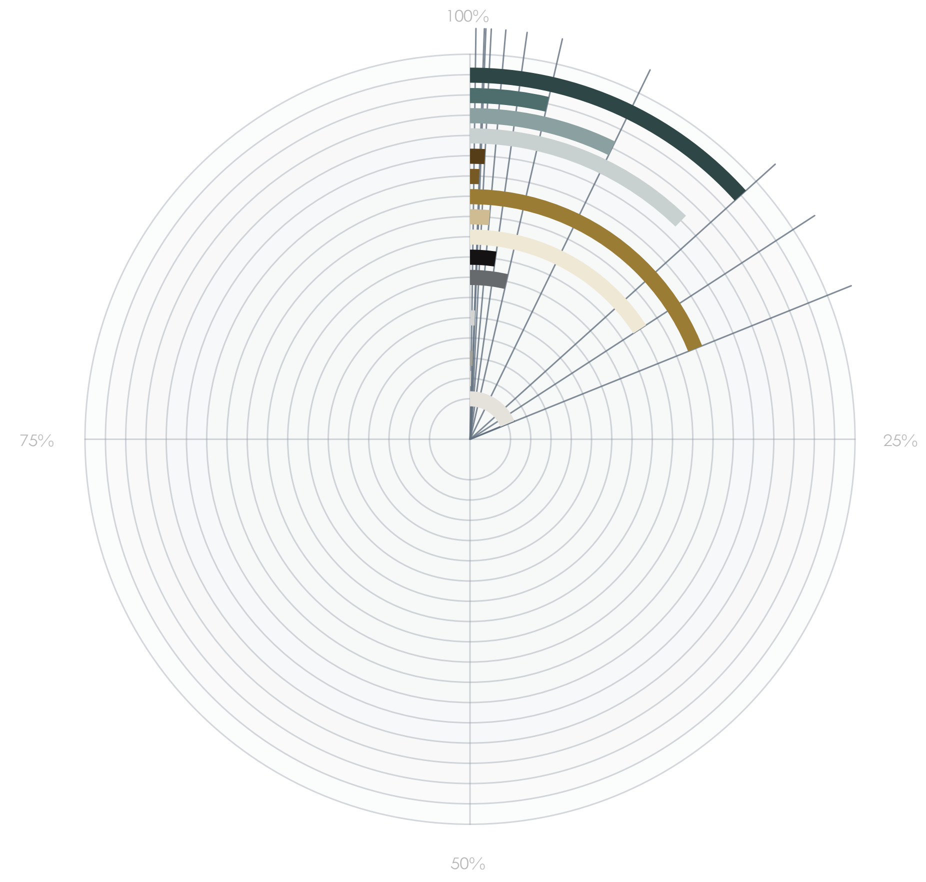
PETOT + SEK - PRIMARY ENERGY TOTAL & SECONDARY ENERGY.



POCP - PHOTOCHEMICAL OZONE CREATION POTENTIAL.



AP - ACIDIFICATION POTENTIAL.



INSULATION

Rockwool batts *Hemp* *Straw Panels* *Cellulose fibre loose* *Wood fibre batts*

CONSTRUCTION

Glulam *CLT* *Construction wood* *Concrete*

FACADE CLADDING

Reeds *Gypsum board* *Clay plaster* *Unfired clay bricks*

Reused bricks *Recycled wood* *Kebony* *Thermowood*

04.3.1 functions & users.

who are we designing for?

FIG. 45- Tirpitz museum (ThePlan.it, 2017)

FIG. 46- National Centre Thy (LOOP, 2019)

WHAT HAVE OTHERS DONE?

A tool to gather relevant and comprehensive information on the functional needs as seen by the users, is to study similar cases. The cases offer insight into the concept and layout of museums located along the danish west coast. The focus of the case studies is therefore how to grasp architecture in combination with the characterizing context, and how the interplay between the two approaches the audience and users.

CASE STUDY OF TIRPITZ MUSEUM

Architect: Bjarke Ingels Group (BIG)
Year: 2017
Location:Blåvand , Denmark
Area: 2850m2.

TIRPITZ showcase the historic world war II bunkers: a dominating element in the war history of the Danish West coast. The museum descends into the landscape with only 4 simple cuts in the topography that meet in a central clearing. The 4 pathways connect with existing trails in the dune landscape, and thus the museum is from the exterior perceived as a minimal impact on its environment (BIG.dk, n.d.). Simplicity is a key aspect of TIRPITZ. Studying the plan show an open foyer and cafeteria with access to all galleries as well as restrooms and other public functions, ensuring easy wayfinding for the visitors. Connected to the cafeteria is a lunchroom for field trips. The staff area lies in close relation to the rest of the museum, however still separated and private. Likewise, storage and technical rooms are located in close proximity to the museum. The concept of this west coast museum lies in its simplicity, respectful to its environment and content.

CASE STUDY OF NATIONAL PARK CENTRE THY

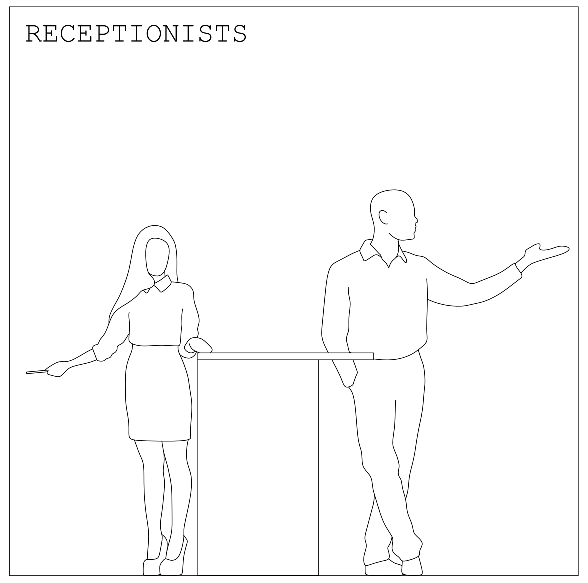
Architect: LOOP Architects, LB Consult, SLA & COAST
Year: 2021
Location: Nørre Vorupør, Denmark
Area: 682m2

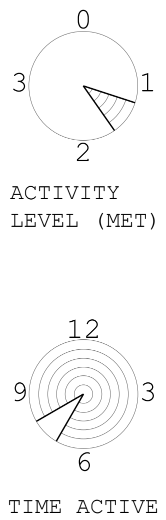
Nationalparkcenter Thy introduces its visitors to the nature and cultural history of the National park in Thy, being home to a large part of the Danish dune area. The centre is constructed inside a dune and therefore integrates in the surrounding nature. The users are led into the building by walls that cuts through the dune and lets sunlight into the centre, this being the only interaction with the dune. The technical installations are placed inside the building, which actually also benefits the installations as they are protected from the salty environment. This also leaves space for plenty of vegetation on top of the dune which helps to control rainwater runoff and combined with just a few windows, minimizes overheating and ensures mass for heat accumulation, just as it leaves space for human activities on top.

The plan is simple. The public areas are limited to just an entrance with access to restrooms and to just one open gallery space to which a meeting room and a storage room is connected. The open space allows flexibility in its use and the centre therefore has the abilities to be used for various purposes. Just behind the gallery lies the staff area, including office spaces, private restrooms and a small kitchen (LOOP Architects 2019).

TARGET GROUPS

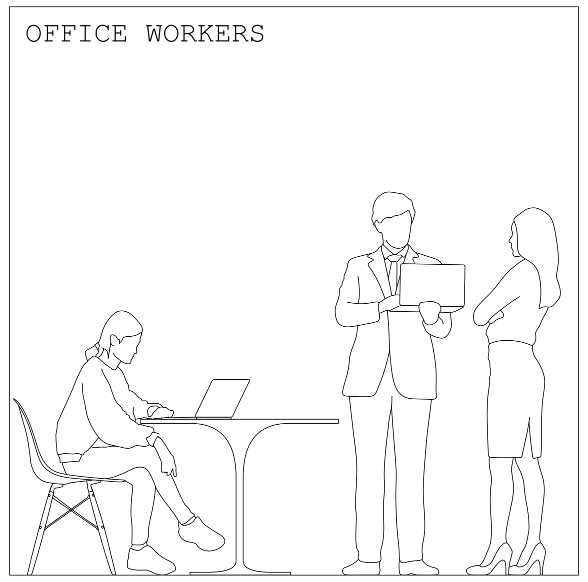
The users and user related functions are defined based upon the knowledge derived from the case studies as well as the previously mentioned statistics (see pages 16-17), stating that only 39% of the danish population feels well-informed about sustainability. Another report specifies how 88% of a user group survey, agree on the importance of educating children and young adults in climate change (Madsen, 2020), resulting in the following list of users and functions. The list is detailed but not limited to different people for each role, as one person can manage several roles.

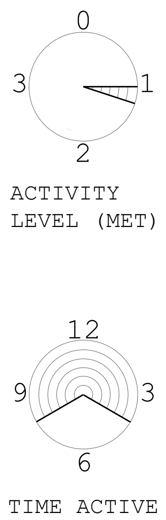




← RECEPTIONISTS

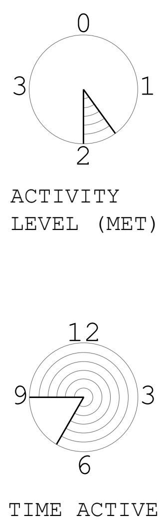
Working front desk and taking care of visitors as they enter the centre by providing information, selling tickets as well as shop articles and other costumer service-related tasks. A receptionist also often answers the phone, receives packages and keeps track on the centre calendar (Uddannelsesguiden 2021).





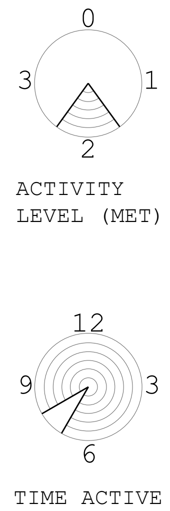
← OFFICE STAFF

General administration, coordination and management of the educational centre, ensuring that everything runs smoothly behind the scenes. The tasks include internal and external communication, organizing meetings and museum strategies, project managing, keeping track on budgets, human resources etc. (Museum Jobs n.d.).



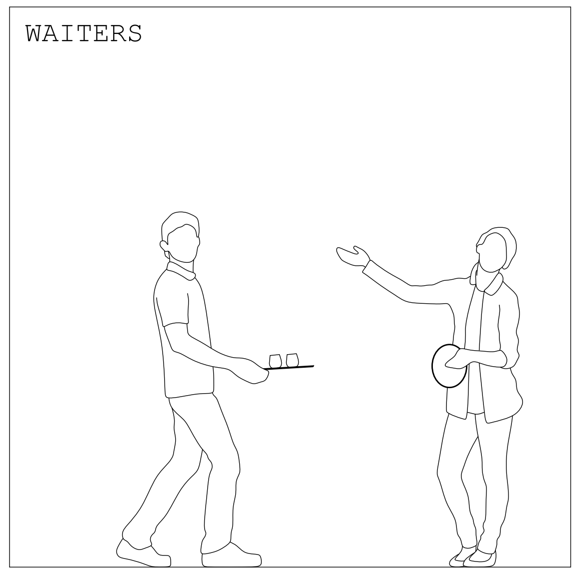
← GUIDES

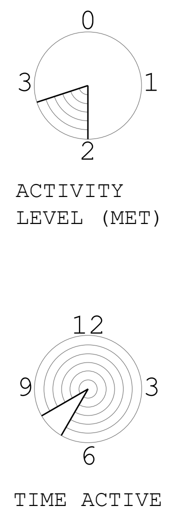
The guides communicate and teach visitors or school field trips relevant information related to the centre and exhibitions via tours or workshops. A part of the guides job is also to prepare teaching material and therefore work both in the centre and behind the scenes (UddannelsesGuiden 2019c).

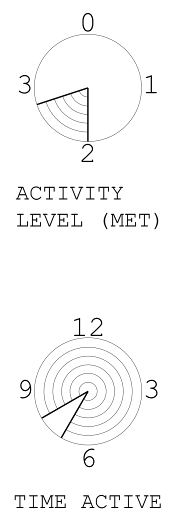


← KITCHEN STAFF (COOKS, WAITERS, DISHWASHERS)

The kitchen staff involves several job positions, being cooks, waiters and dishwashers. The cooks prepare the menu, buy the right groceries, prepares the food and sometimes also runs the kitchen (UddannelsesGuiden 2019a). Waiters welcome the visitors, take orders, bring food to the tables and cleans after the visitors as well (UddannelsesGuiden 2019d). The dishwashers clean the cutlery, plates etc. as well as cleans the kitchen (Uddannelsesguiden 2019b).

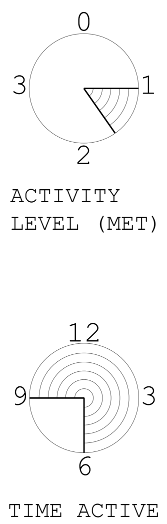






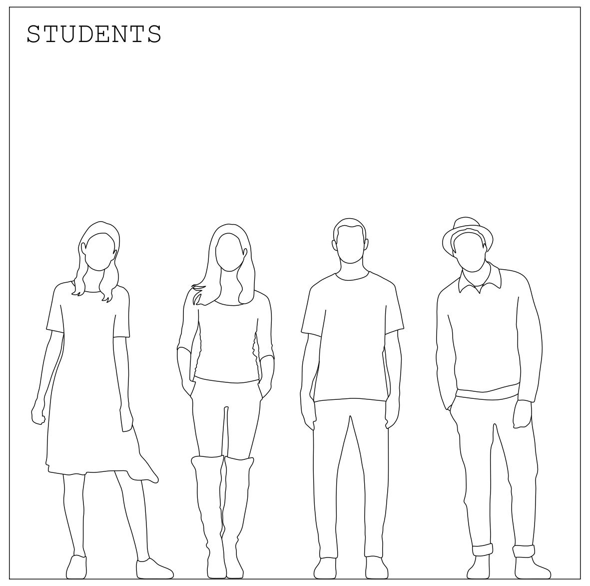
← CLEANING STAFF

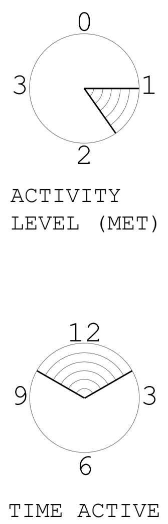
Daily cleaning of the centre either prior to or after opening hours. The cleaning staff finds their equipment in a separate room for this purpose.



← **VISITORS**

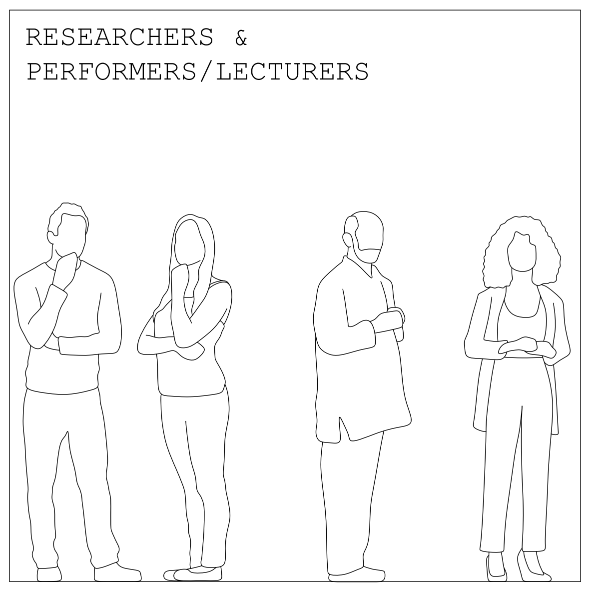
The target group for the educational centre. Explores the centre and its possibilities, visits exhibitions for learning. Leaves the centre feeling inspired and with new knowledge of climate change.

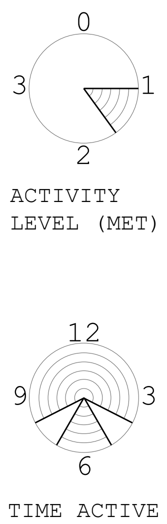




← **STUDENTS**

Utilizing the nature of the centre, being an educational centre and therefore learning through the exhibitions as well as the centre itself.

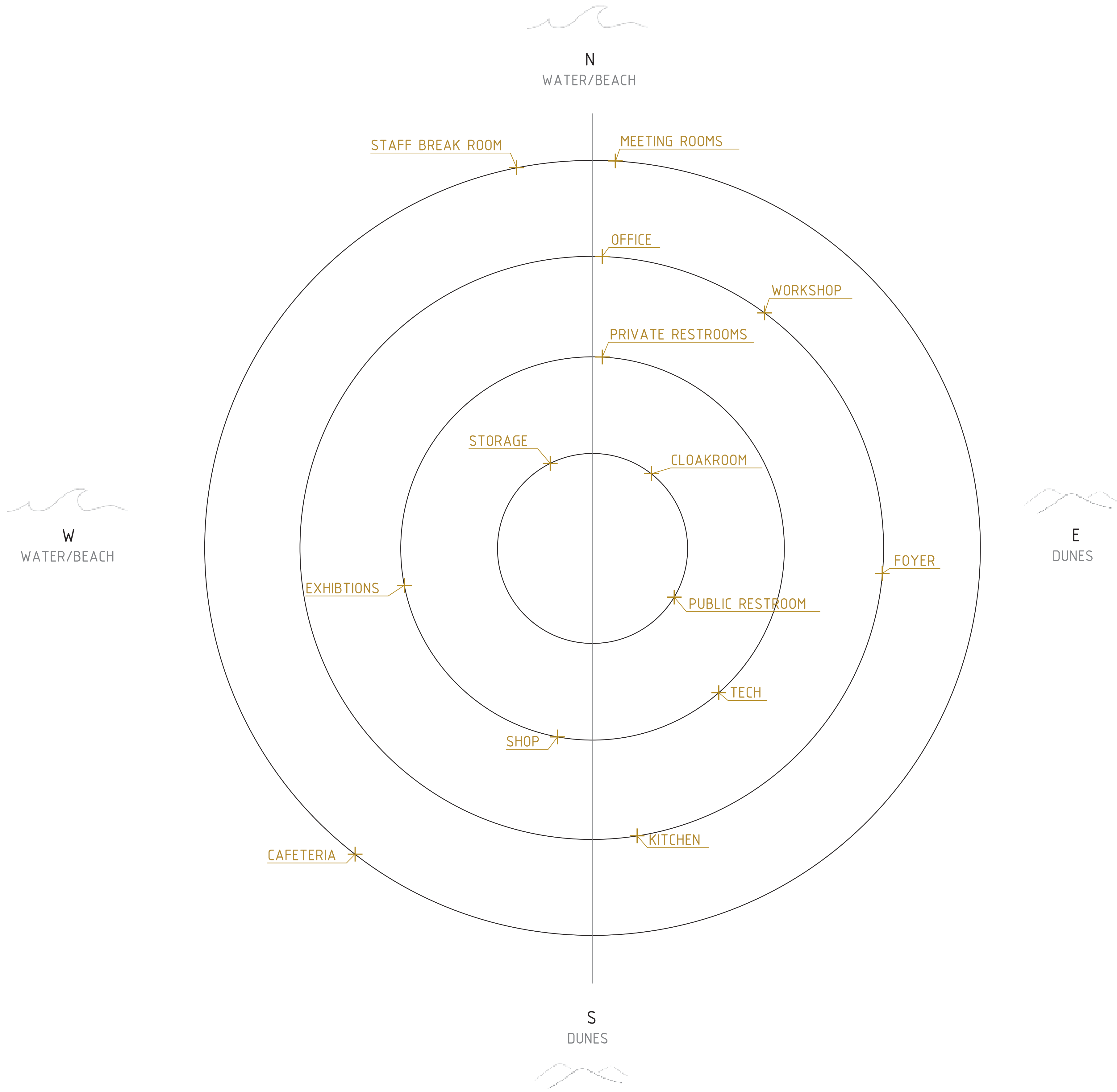




← **RESEARCHERS & PERFORMERS/ LECTURERS**

External researchers that come to the centre to deepen into their research, and occasional lectures or performances, utilizing the flexibility of the exhibition spaces.

FIG. 47- Target groups for the centre with their activity levels and schedules ↑



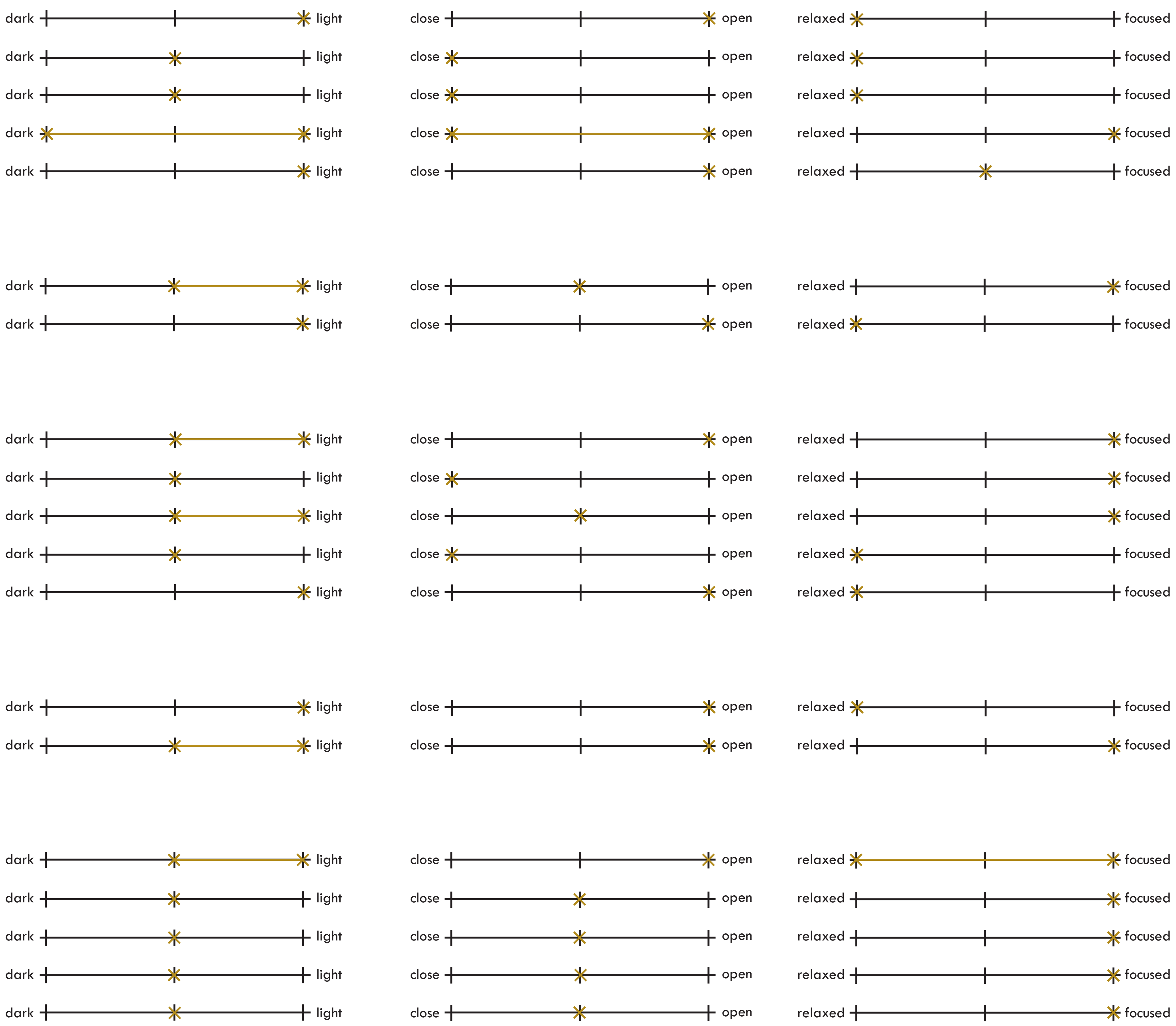
↑ *FIG. 48- Function diagram focusing on orientation of various functions and their distance to the exhibition space*

ROOM PROGRAM

		AREA m²	UNIT -	VISUAL daylight/artificial	AIR mechanical/natural	NOTES
MUSEUM	FOYER	200	1	D/A	M/N	RECEPTION AND SEATING
	CLOAKROOM	30	1	A	M	
	RESTROOMS	5	15	D/A	M/N	ONE ROOM WITH STALLS
	EXHIBITION	1500	1	D/A	M	CAN BE A SERIES OF ROOMS
	SHOP	50	1	D/A	M/N	
TEACHING	WORKSHOP	60	1	D/A	M/N	
	LUNCH ROOM	60	1	D/A	M/N	
OFFICE	OFFICE	50	1	D/A	M/N	
	OFFICE STORAGE	10	1	A	M	PRINTERS ETC.
	MEETINGROOMS	20	2	D/A	M/N	
	RESTROOMS	5	2	A	M/N	
	BREAKROOM	50	1	D/A	M/N	INCLUDING TEA-KITCHEN
CAFÉ	CAFÉ	100	1	D/A	M/N	
	KITCHEN	50	1	D/A	M/N	INCLUDING STORAGE
ADDITIONAL	HALLWAYS	100	-	D/A	M/N	
	EXHIBITION STORAGE	500	1	A	M	CAN BE SEVERAL ROOMS
	SHOP STORAGE	20	1	A	M	
	CLEANING	10	1	A	M	
	TECH	100	1	A	M	CAN BE SEVERAL ROOMS
	GROSS	2915m²				
	NET	2478m²				

ATMOSPHERE

dark/light — closed/open — relaxed/focused



05.0 RECAPITULATION

FIG. 49 - ATLAS OF PLACES

"This architectural thesis originates in an interdisciplinary approach to architecture, aspiring towards consensus between architecture and engineering. Our perception of successful architecture, roots in the corelation between building and context through awareness of atmospheres and environmental characters of the given place. Thus, the building should be an integral part of what already exists, and to be so, we believe that simplicity is key. Simplicity, found through harmony between the nature of the surroundings and the body of the architecture, defined and detailed according to the principles of the materials chosen to be compatible with the environmental context."

05.1 conclusion.

analytical conclusion

Climate change is an inevitable fact, only the extent to which it will impact is in question. The building industry is a great contributor to climate change, and therefore has just as great an opportunity to lower the global impacts and promote sustainability. Multiple approaches can be utilized, whereas this thesis primarily focus on materials, as seen from multiple perspectives. Firstly, natural materials have proven to be a better solution compared to traditional building materials, when analysing their direct environmental impact. Secondly, natural materials indirectly contribute further to sustainable development, as they provide the opportunity of a circular approach. Removing adhesives eases design for disassembly and thus, the materials can either return to the ecosystem or be reused in another context. This approach towards architecture compliments the atmosphere of the context in which this project will be placed. Located along the danish west coast, Blokhus has a significant but sensitive nature. In an area where vegetation grows wildly and not all roads are asphalt-paved, the environmental characteristics are enhanced in a building made out of natural materials.

Statistics have shown that 78% of the population are willing to change their habits to preserve the planet, only 39% feel informed about sustainability. As the population acknowledges the need for climate change and sustainable education, such a centre becomes even more crucial.

05.2 problem & vision.

This thesis visions to propose an Educational Centre for Climate Change, that in its existence takes responsibility for the environment by being an epitome for sustainable constructions and confronts and teaches the society sustainable action, in order to increase the general knowledge of our impact down to the very context we inhabit. The centre should therefore facilitate learning as well as dialogue and transparency related to the impacts of our actions, illustrated through implementation of passive strategies into the design of the building, to reduce its energy consumption. As a resource to exemplify limited impacts, the educational centre aims to be designed according to design for disassembly principles, ensuring the possibility to return the context back to its natural state prior to positioning a building. In extension, this project bases itself solely on natural materials, meaning that once served their lifetime, they can reciprocate to the ecosystem. Being located in a prominent feature of the Danish landscape should enhance the educational centre's motivation towards a sensitivity of landscape and nature through materialty, tactility and architectural composition. In conclusion, this report seeks to research and answer the questions:

'How far can we get with building with exclusively local, non-chemical materials?'

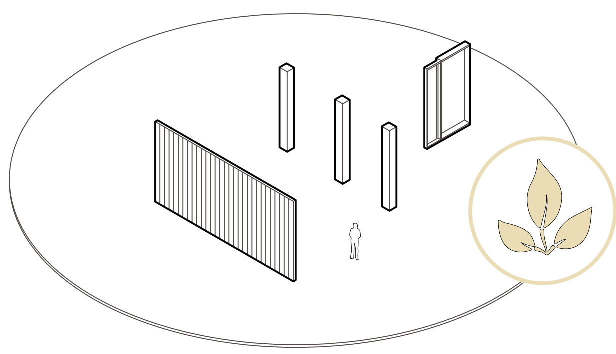
And

'Is it possible to create an educational centre for climate change which functions as an epitome for sustainability whilst inspiring visitors to alter their behavior in a more sustainable direction and motivate increased appreciation towards the danish nature?'

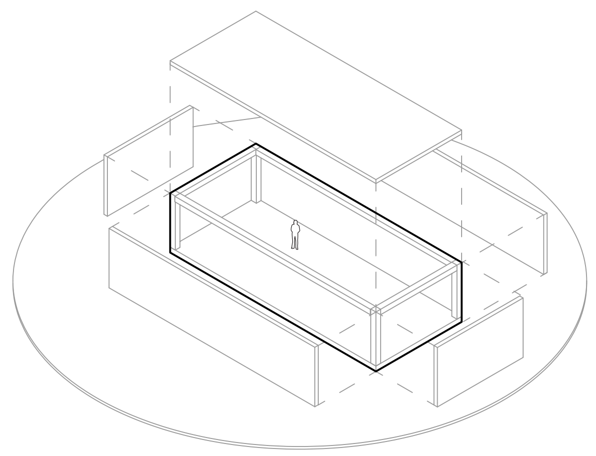
05.3 design initiators.

the driving design factors

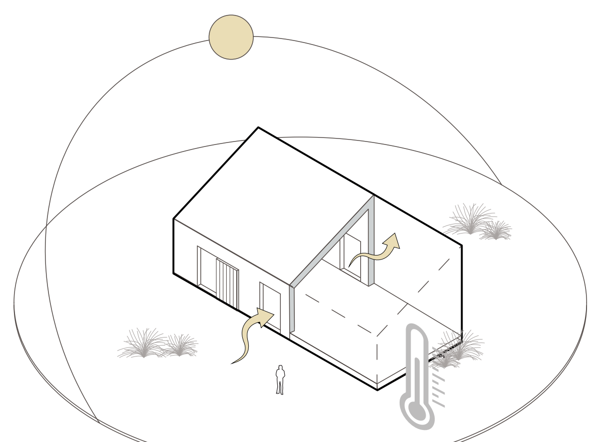
SUSTAINABLE



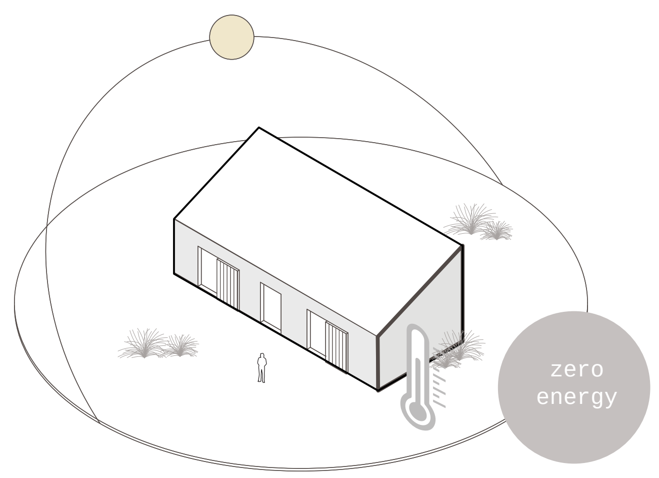
Strive to be made entirely of natural and non-chemical materials, considering the life cycle of various materials.



Should have a flexible and adaptable structure, by means of designing for disassembly

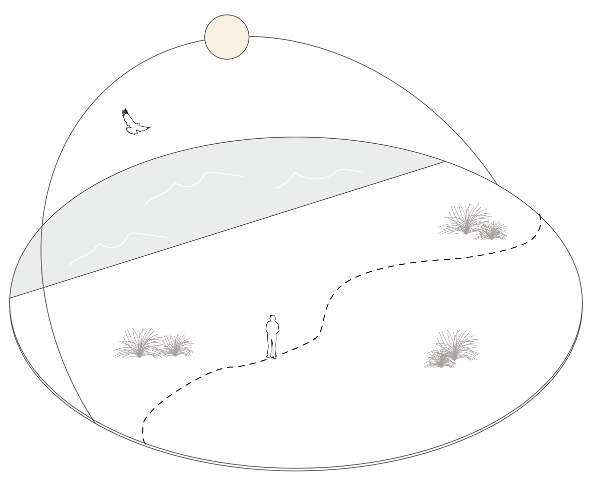


A good indoor environment. Considerations of the building envelope in relation to the microclimate.

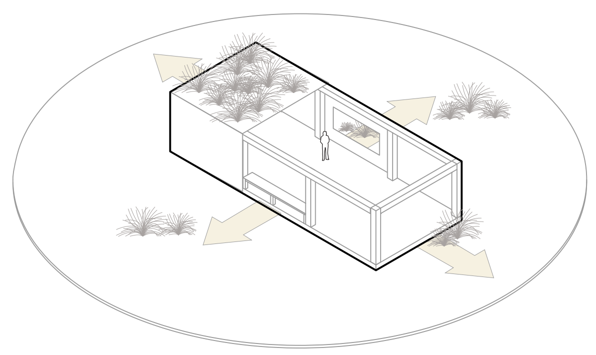


Reach a zero-energy level through predominantly passive means.

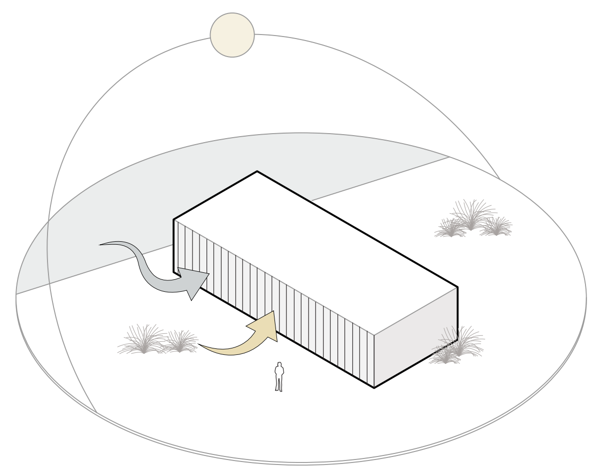
AESTHETIC



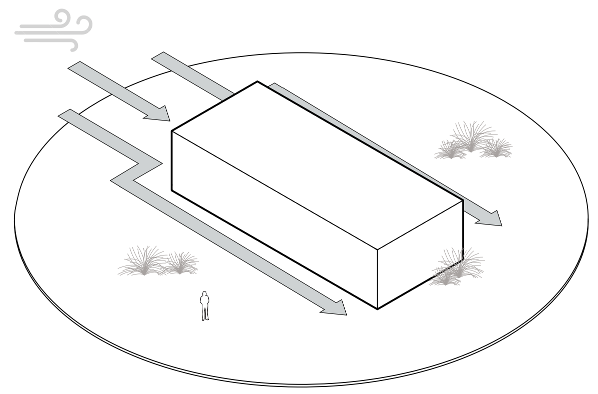
Microclimate to determine atmospheric experience of space, promoting a multi-sensory experience.



Construction, building, furniture and the surroundings complement each other and the educational experience.

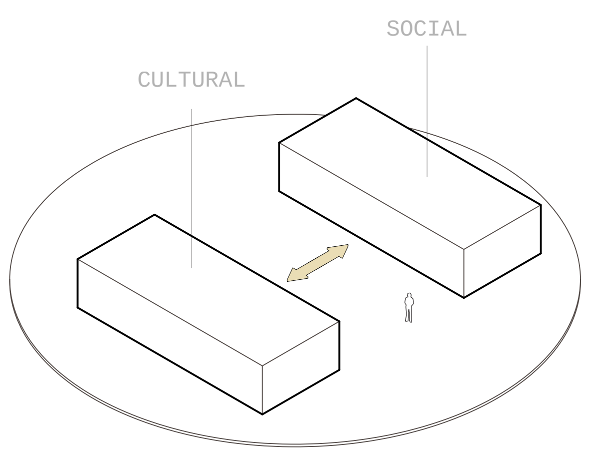


The choice of materials should be influenced by the context and the patinating of the rough sea setting.

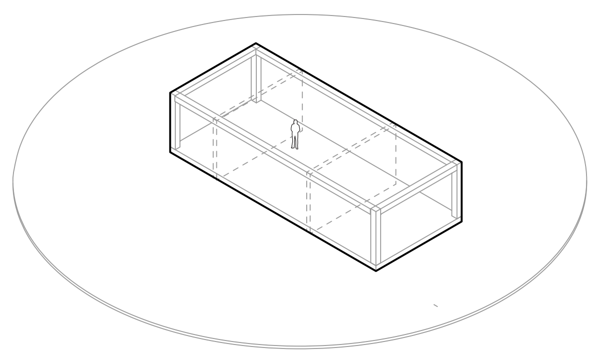


The building should incorporate the notion of critical regionalism by presenting architecture which is deeply rooted in the site whilst still participating in the global culture.

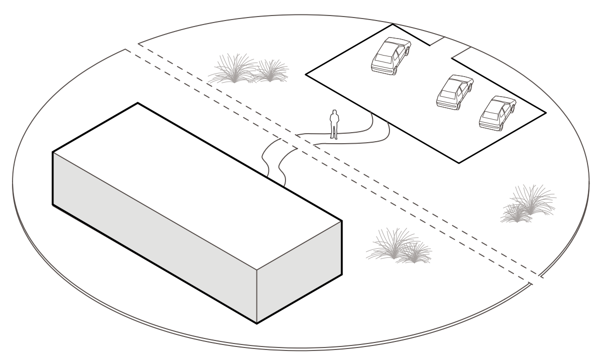
FUNCTIONAL



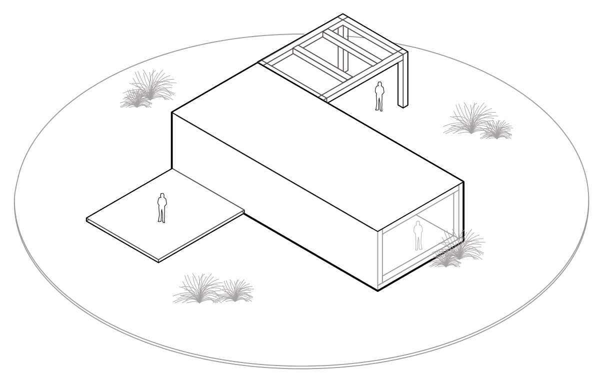
Functions should embrace social and cultural academic activities.



Flexibility in the exhibition area. Possibility of having themebased exhibitions and having changes over time.



The parking area should be separate and placed distant from the centre, in order to shift the mindset of the visitor to be completely emerged in the surroundings before entering the centre.



The centre should provide different ways in interacting with the surrounding nature to provide experiential reflections through different spaces and functions – both inside and outside the centre.

06 DUNESIDE

PRESENTATION

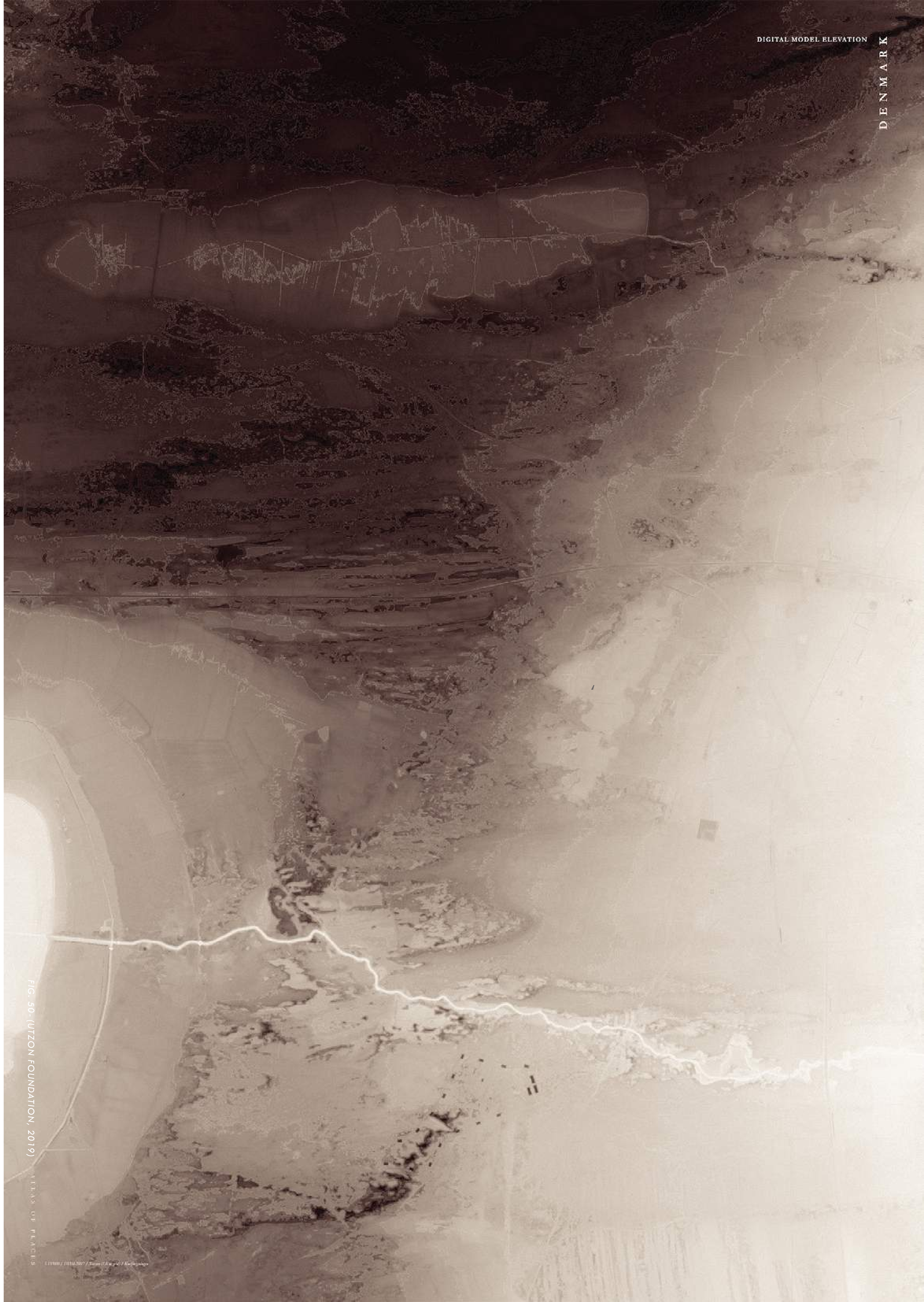


FIG. 50- (UTZON FOUNDATION, 2019)


N
PLAN IN 1:500

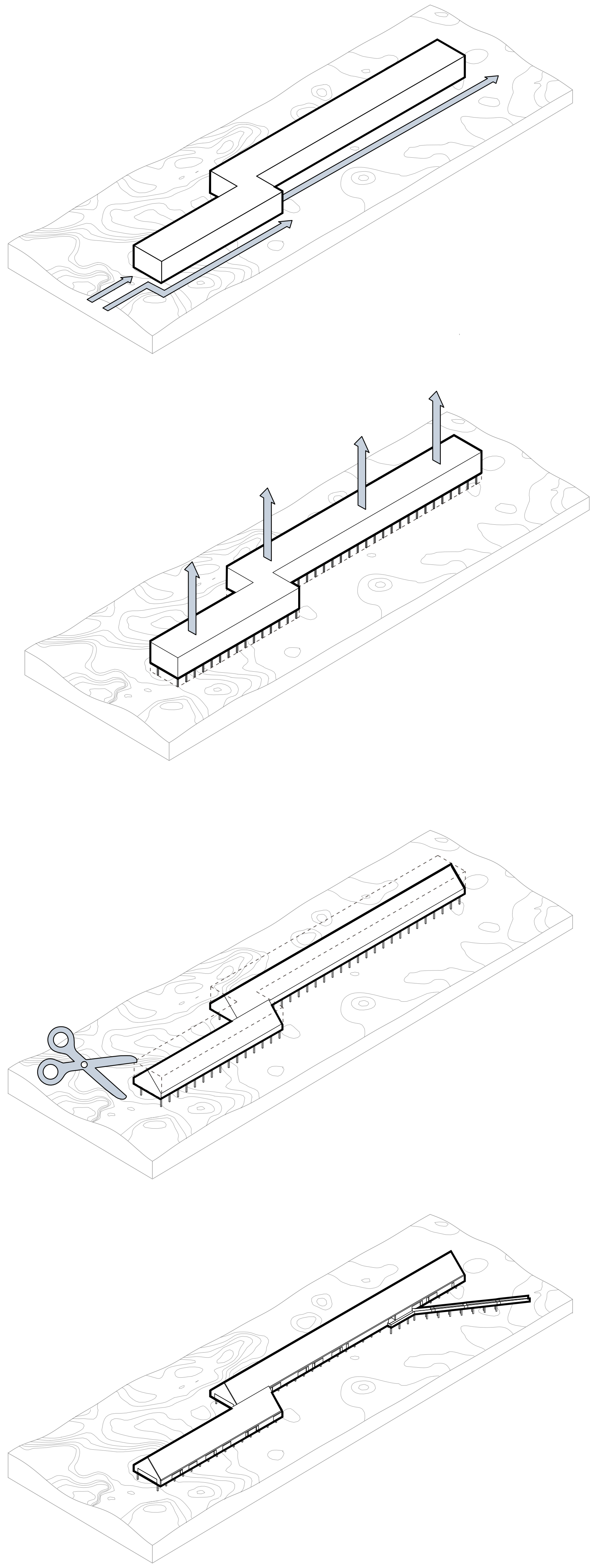
STROLLING THROUGH THE DUNES

DUNESIDE

IN A LANDSCAPE WHERE BEACH, OCEAN AND DUNES SEEM TO PROCEED ENDLESSLY, WHERE THE WIND CAUSES A CONTINUOUS MOVEMENT OF SAND AND TALL GRASS, AND WHERE A SOFT AND GENTLE ATMOSPHERE MAKES TIME STAND STILL, LIES 'DUNESIDE'. DUNESIDE STRIVES TO PUSH BOUNDARIES OF HOW TO DESIGN SUSTAINABLY IN THE BUILDING SECTOR. OPTING FOR THE USE OF COMPLETELY LOCAL, NATURAL NON-CHEMICAL MATERIALS, THE HUMBLE BUILDING TOUCHES THE CONTEXT GENTLY, WHILE FUSING THE TRADITIONAL WITH THE MODERN. COALESCING FLEXIBILITY, DESIGN FOR DISASSEMBLY, ACTIVE AND PASSIVE STRATEGIES WITH ATMOSPHERE, SIMPLICITY, AND TECTONICS, DUNESIDE SERVES AS A CATALYST FOR FUTURE SUSTAINABLE BUILDING METHODS.

DUNESIDE ARRIVAL

CONCEPT DIAGRAM



PLACING VOLUMES

respecting climate

LIFTING BUILDING ONTO POSTS

touching the earth lightly

ALTERING OVERALL SHAPE

regarding climate and indoor comfort

DETAILING BUILDING

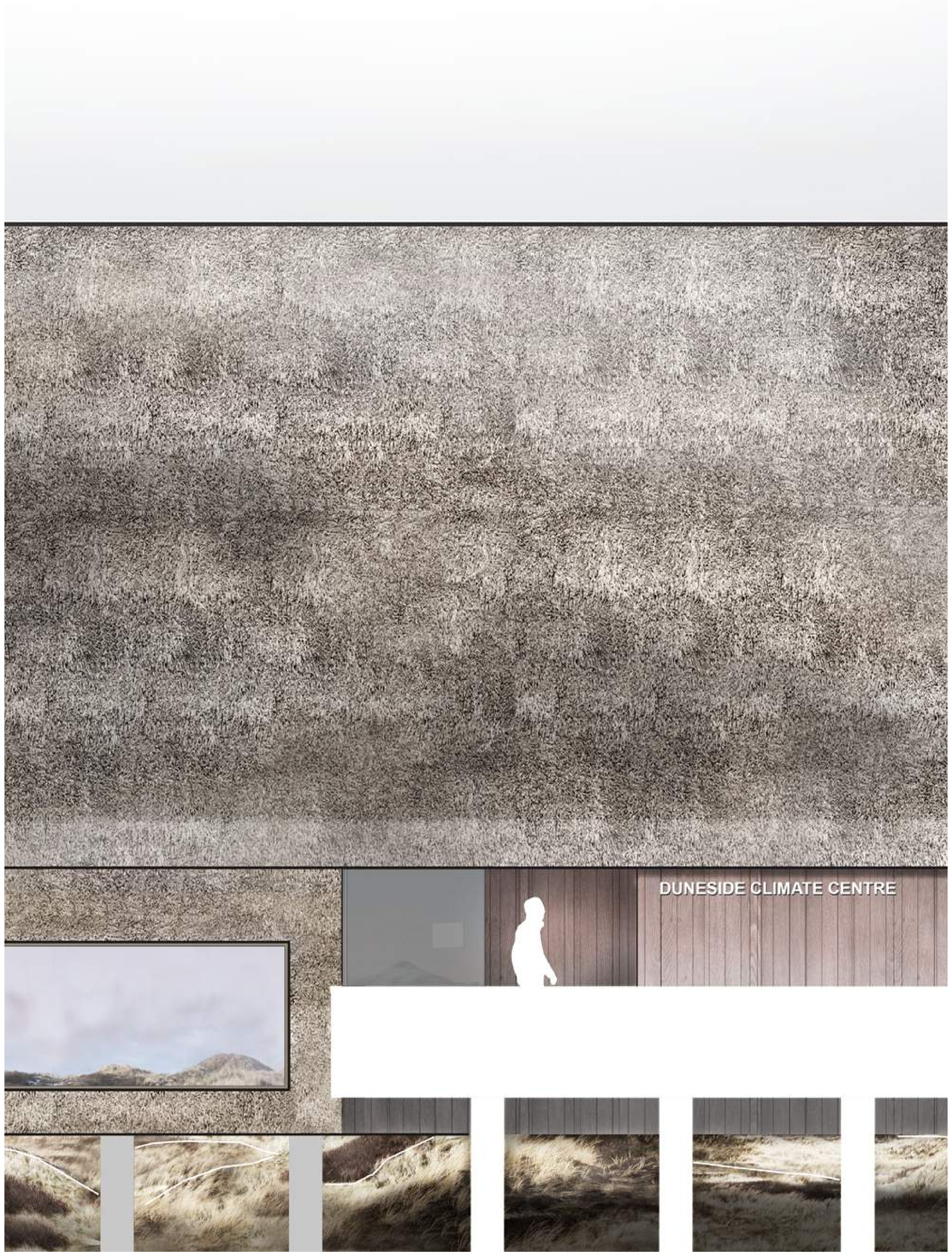
providing an experience

SOUTH FACADE IN 1:500

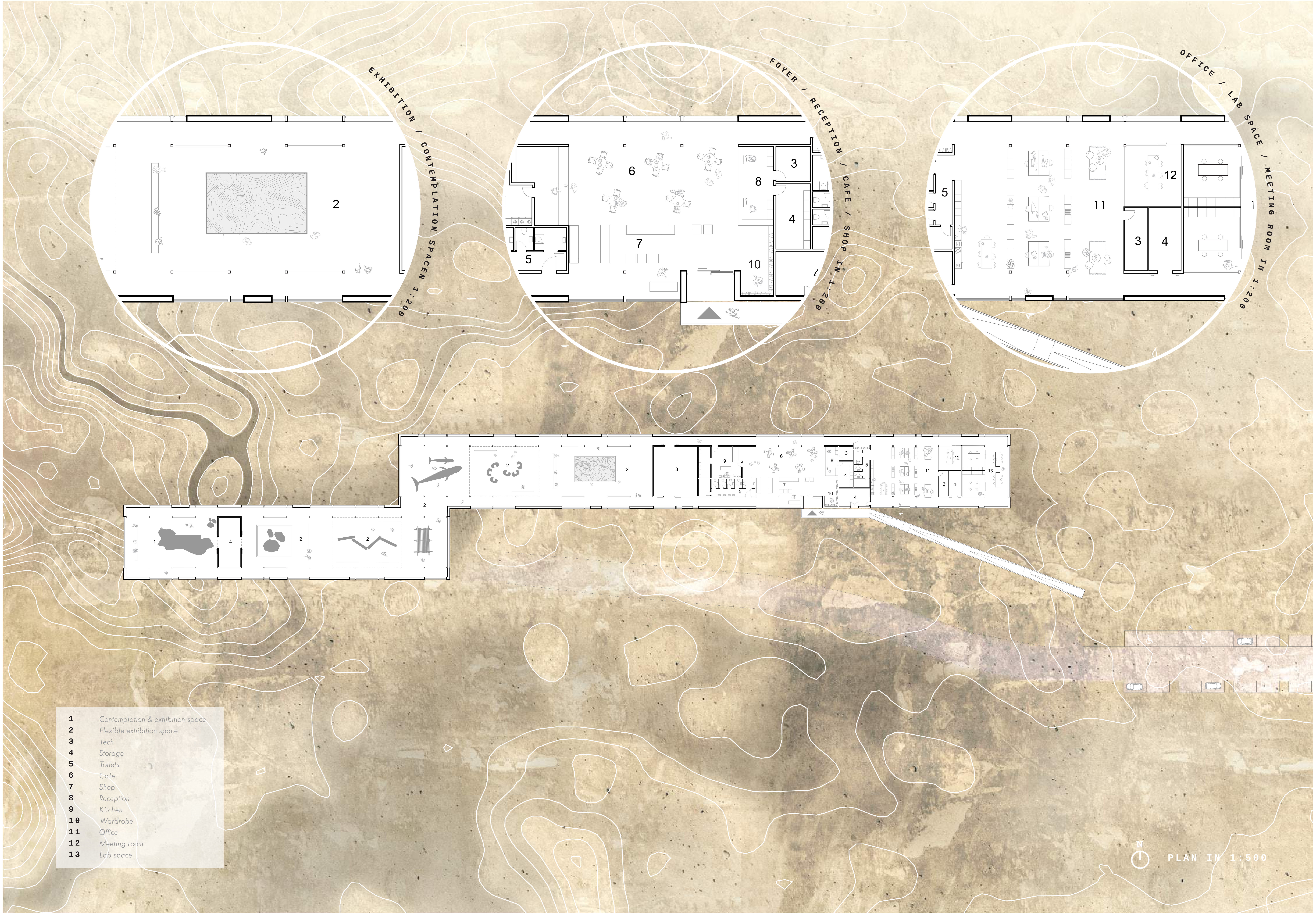
NORTH FACADE IN 1:500

WEST FACADE IN 1:500

EAST FACADE IN 1:500

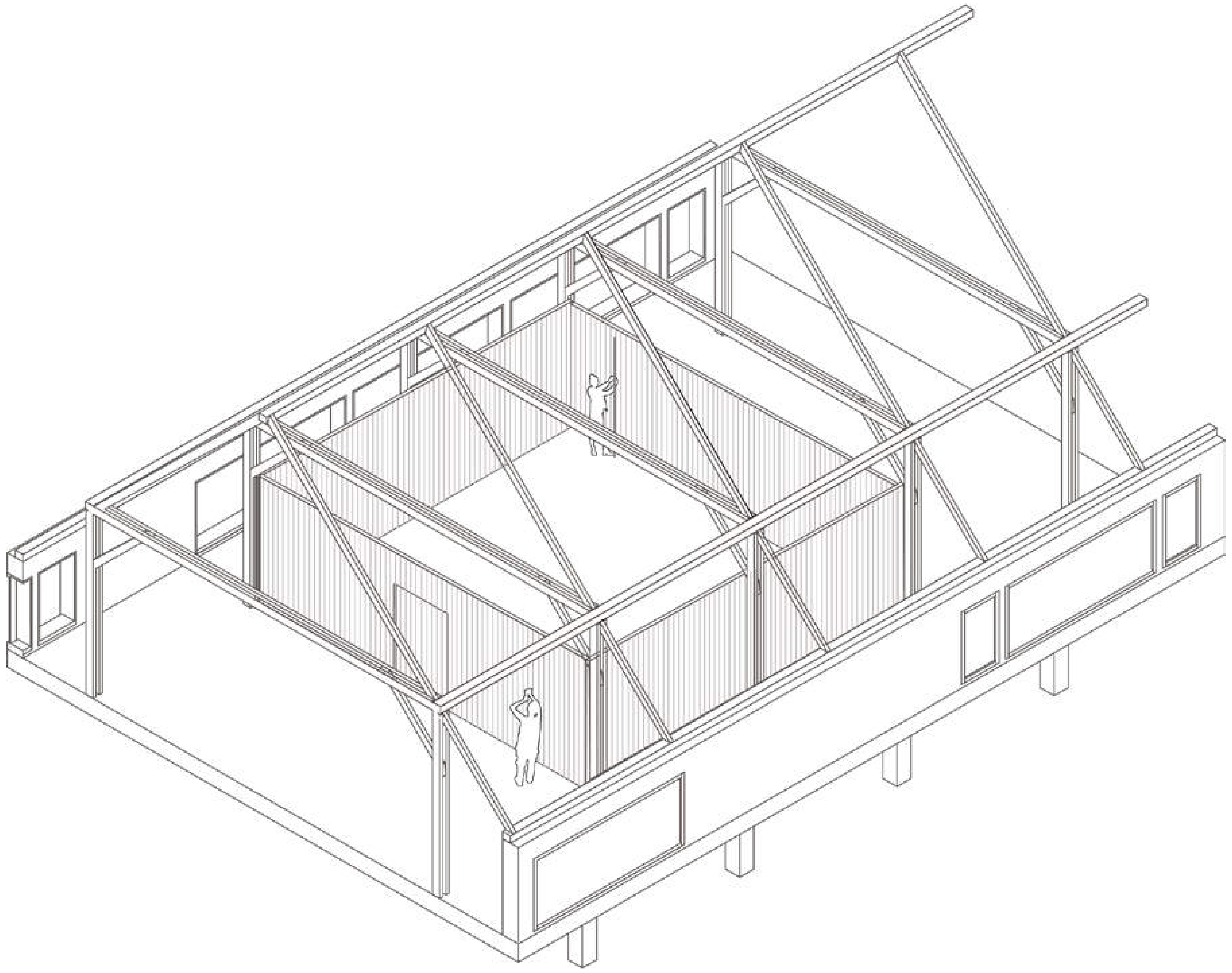


SOUTH ENTRANCE IN 1:50



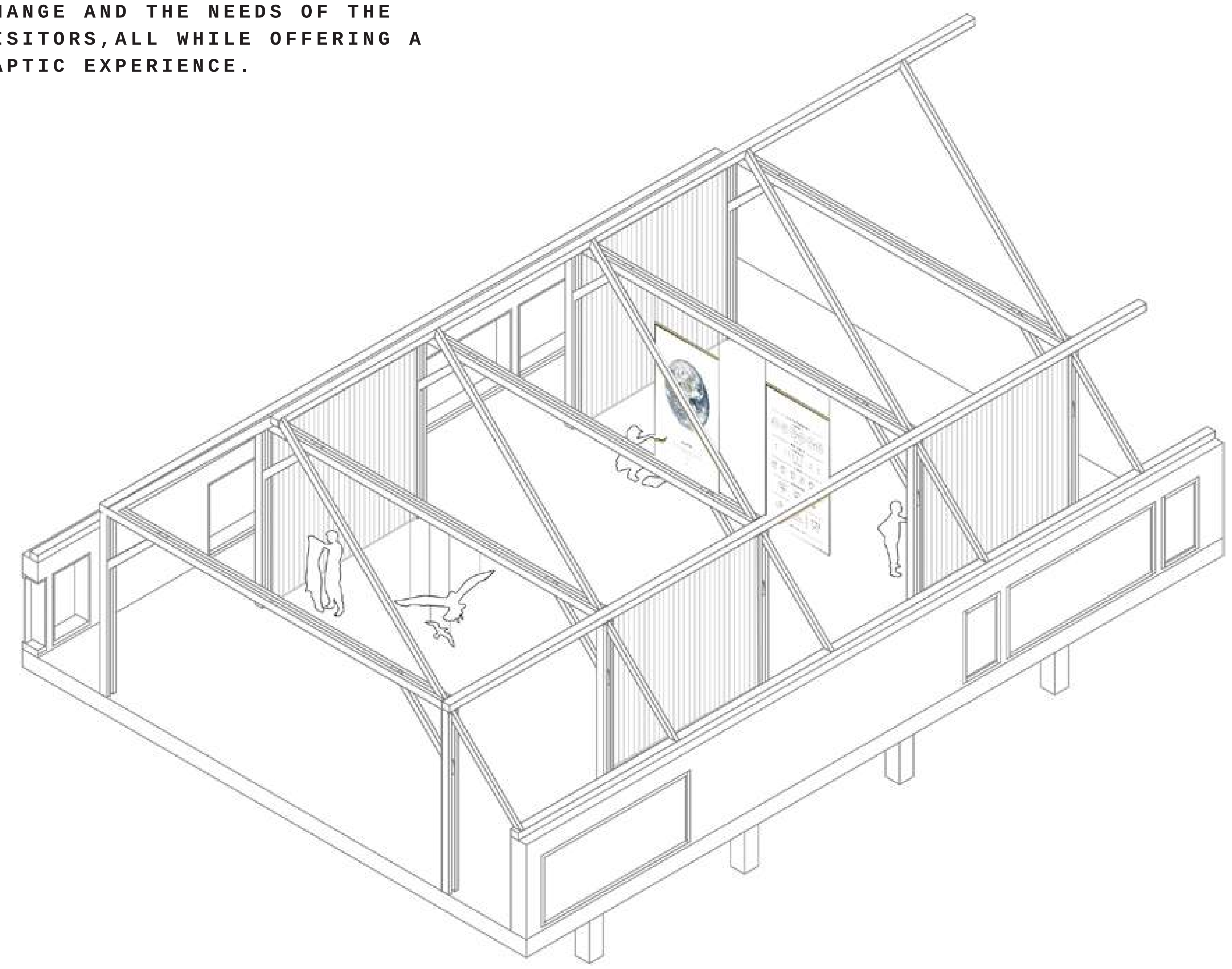
EXHIBITION / CONTEMPLATION SPACEN 1:200
FOYER / RECEPTION / CAFE / SHOP IN 1:200
OFFICE / LAB SPACE / MEETING ROOM IN 1:200
1 Contemplation & exhibition space
2 Flexible exhibition space
3 Tech
4 Storage
5 Toilets
6 Cafe
7 Shop
8 Reception
9 Kitchen
10 Wardrobe
11 Office
12 Meeting room
13 Lab space
N
PLAN IN 1:500

LONGITUDINAL SECTION IN 1:500



FLEXIBLE EXHIBITION SPACE

ADVOCATING FLEXIBILITY ENABLES EVOLUTION OF SPACES AND EXHIBITIONS TO FOLLOW THE PROGRESSION OF CLIMATE CHANGE AND THE NEEDS OF THE VISITORS,ALL WHILE OFFERING A HAPTIC EXPERIENCE.



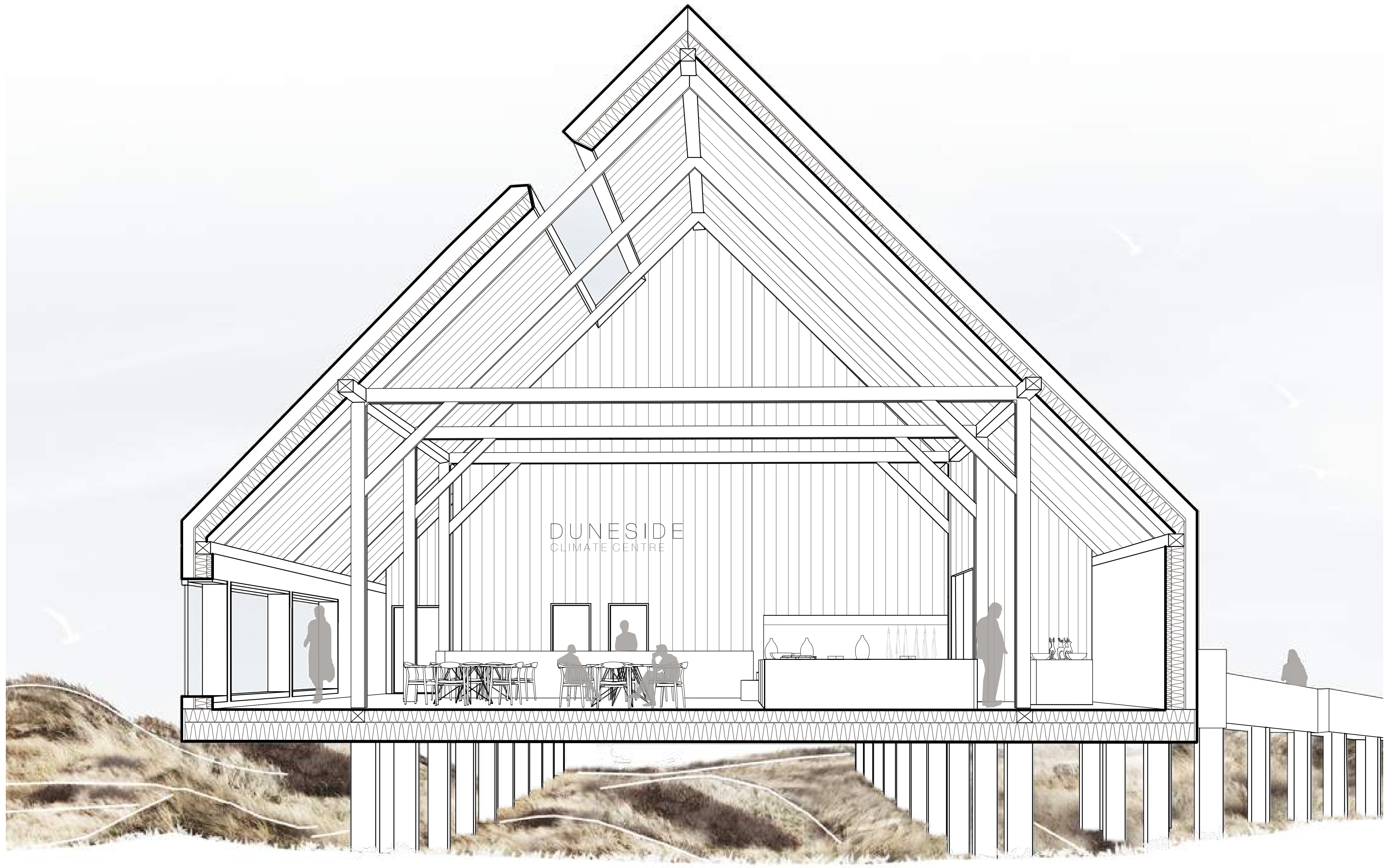
DARKROOM

IMAGINE A FULLY FLEXIBLE EXHIBITION SPACE, WHERE THE CONSTRUCTION ALLOWS VARIOUS POSSIBILITIES WHICH ARE EASY TO ASSEMBLE AND DISSASSEMBLE, SUCH AS A DARK ROOM FOR VIDOES AND DIVERSE MEDIA, OR POSTERS AND BOARDS IN AN OPEN SPACE.THE CONSTRUCTION CAN ALSO FUNCTION AS A BOUNDARY FOR THE EXIHIBITION, INITIATING CIRCULATION AROUND THE CENTRAL SPACE.

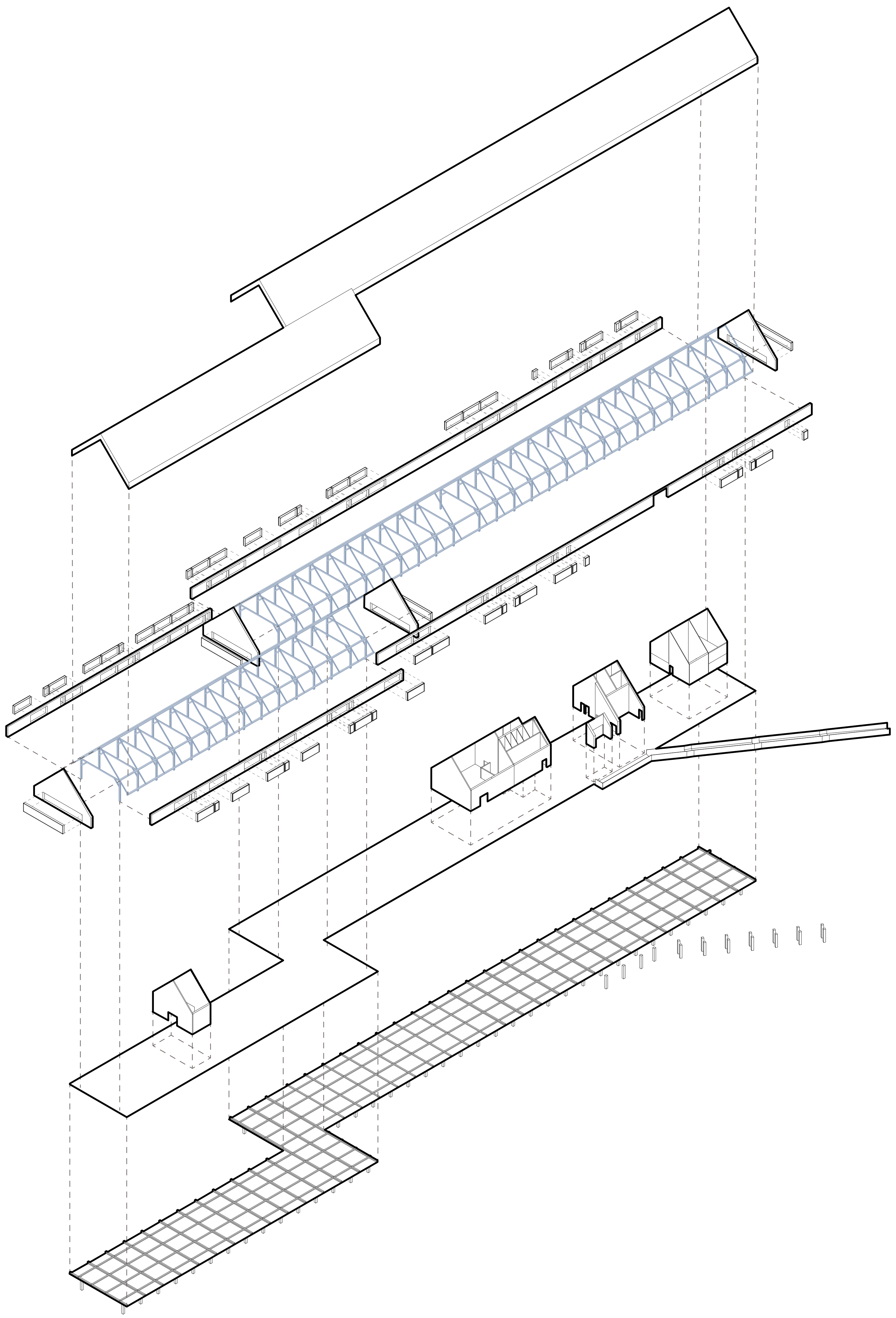
DARKROOM VISUALISATION

FLEXIBLE EXHIBITION / CONTEMPLATION SPACE

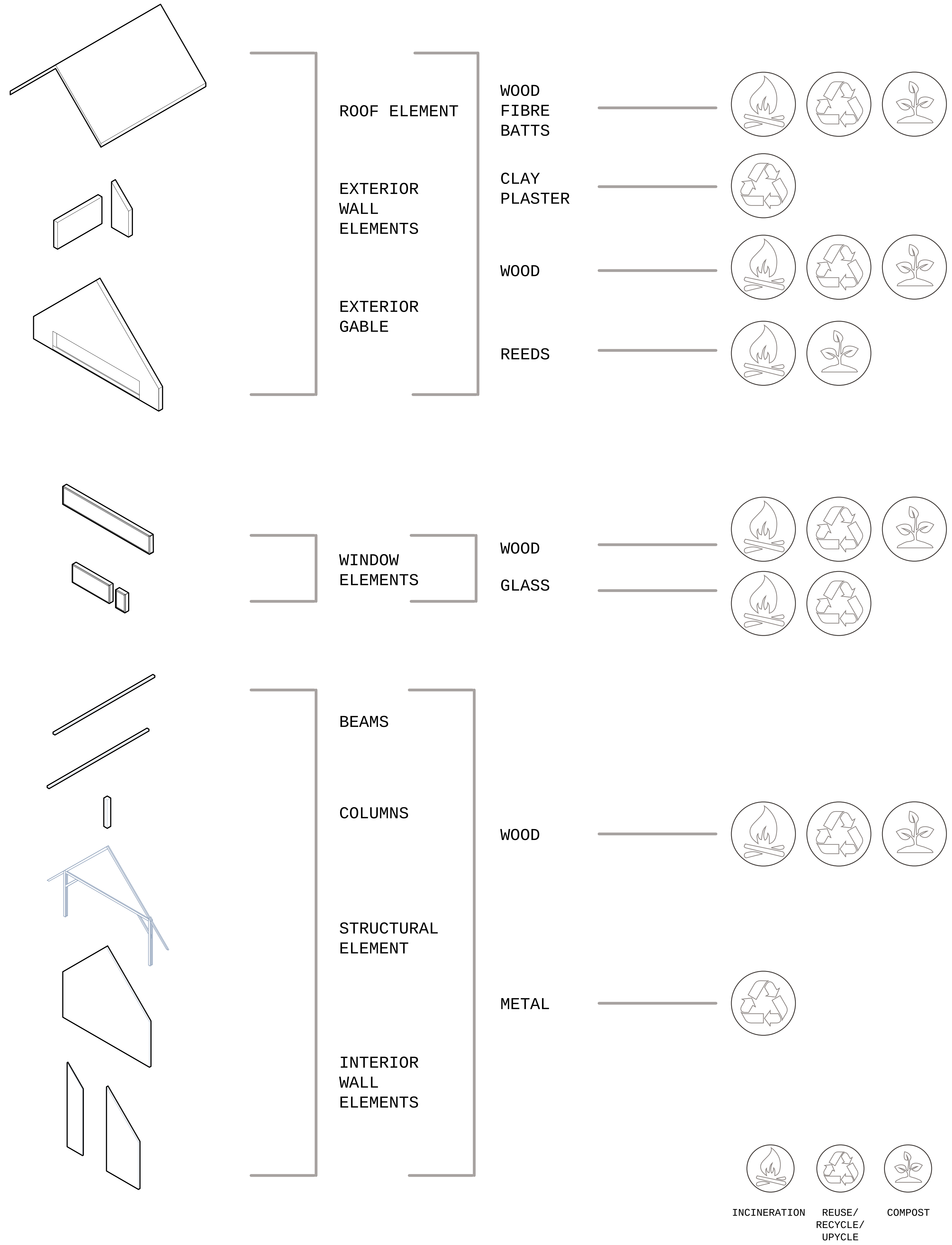
VISUALISATION OF RECEPTION / CAFE / SHOP



CROSS SECTION OF RECEPTION / CAFE / SHOP

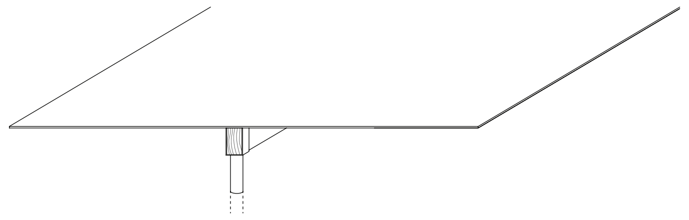


EXPLODED AXONOMETRIC DIAGRAM OF OVERALL CONSTRUCTION

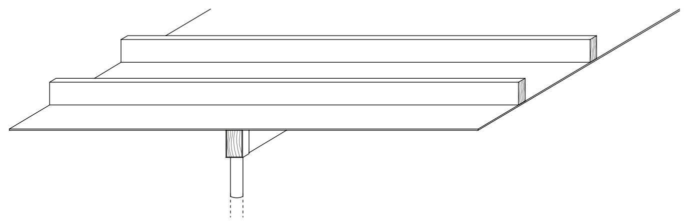


CONSTRUCTION ELEMENTS & DISPOSAL

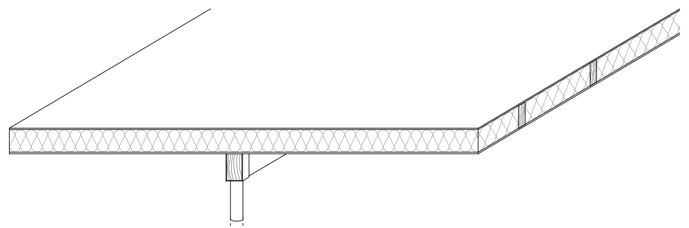
EXPLODED AXONOMETRIC DIAGRAM OF OVERALL CONSTRUCTION



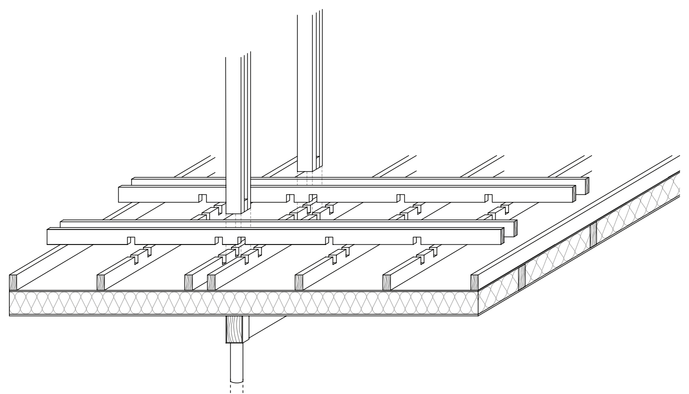
1 The deck is raised upon steel screw foundation pillars to have a level-free interior. The screw foundation accommodates design for disassembly.



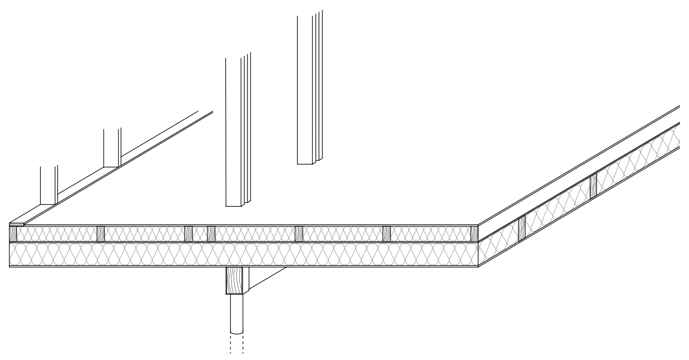
2 On top of longitudinal beams, a DHF board is placed to protect the construction against moisture. The construction consists of transverse load carrying wooden beams, that in combination with the longitudinal beams ensure stiffness.



3 Insulation is placed in-between the transverse beams, and an OSB board is placed on top to protect the insulation.



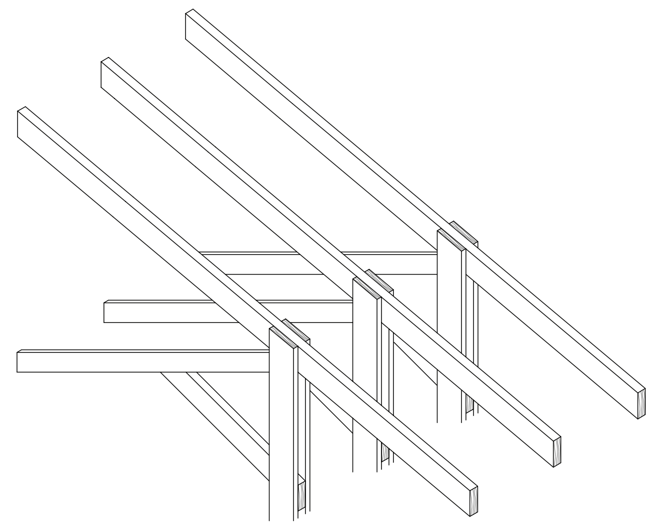
4 The load-bearing columns are designed to appear as standing directly on the floor. However, the columns are joint with beams using dowels, accommodating design for disassembly.



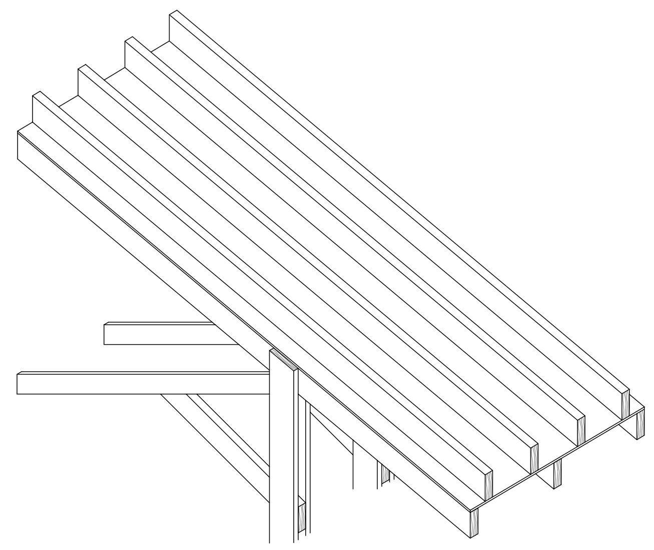
5 On top of the beams layer, an OSB board is placed, making the construction walkable and providing a surface on which the flooring can be attached.

EXPLODED AXONOMETRIC DIAGRAM OF OVERALL CONSTRUCTION

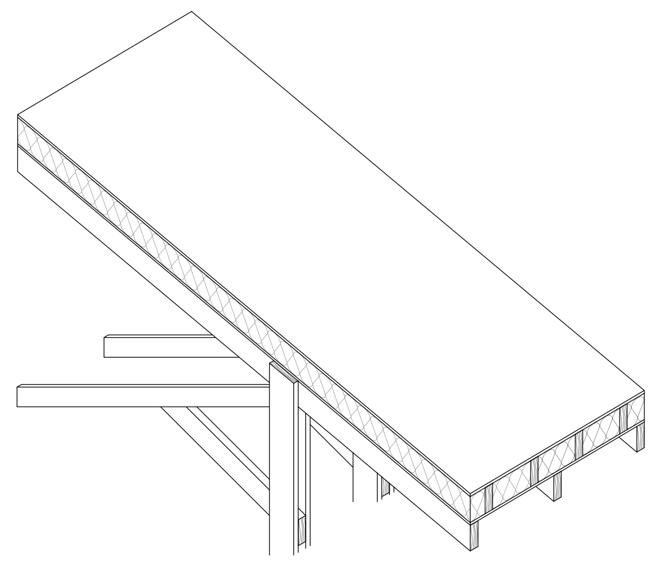
The load-bearing columns attach to wooden beams that are visible from the interior. The double column principle makes a dowel joint with the beams possible, easing design for disassembly. **1**

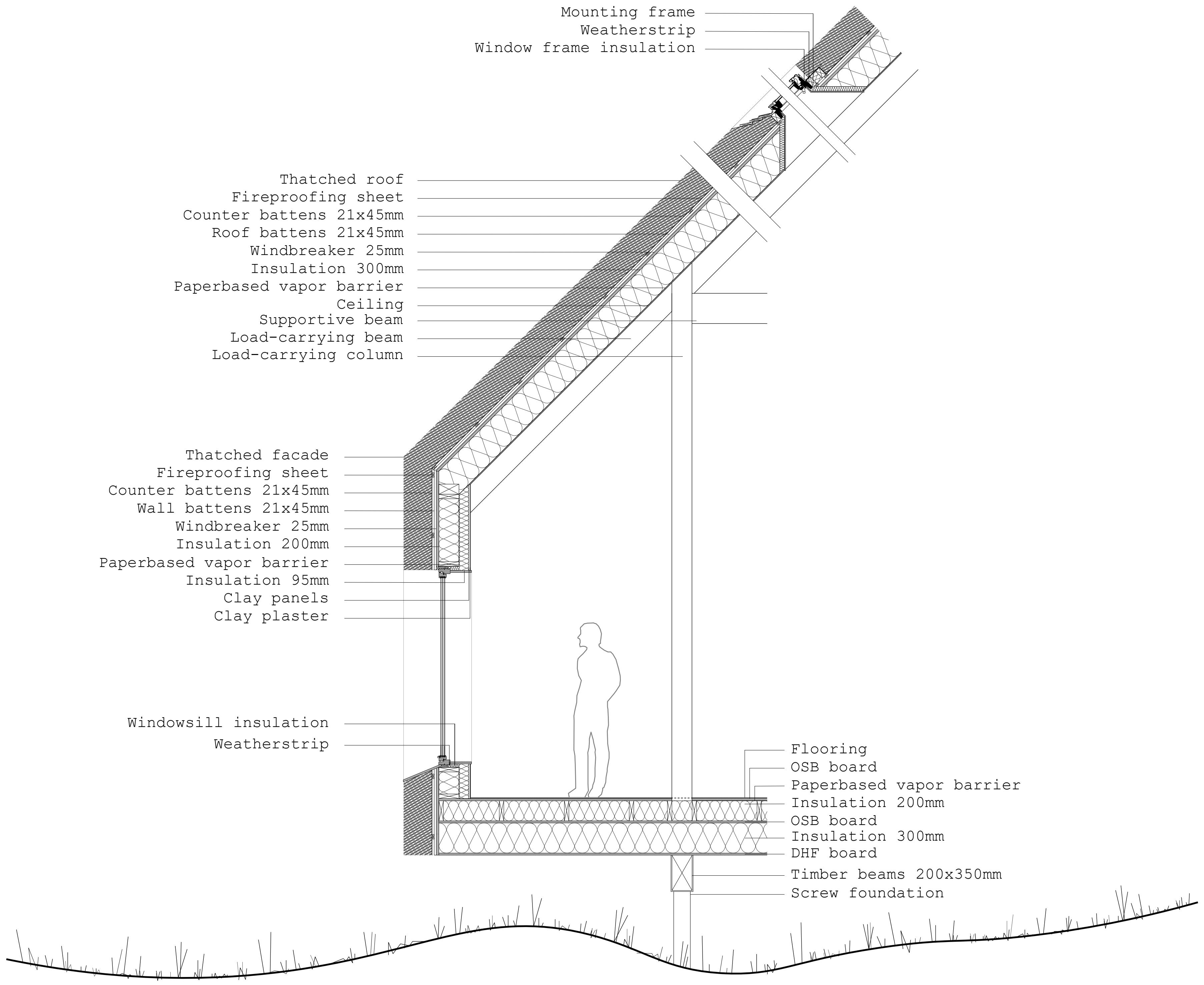


The ceiling is attached to the beams in a simple screw connection on which a layer of beams and insulation is added. **2**

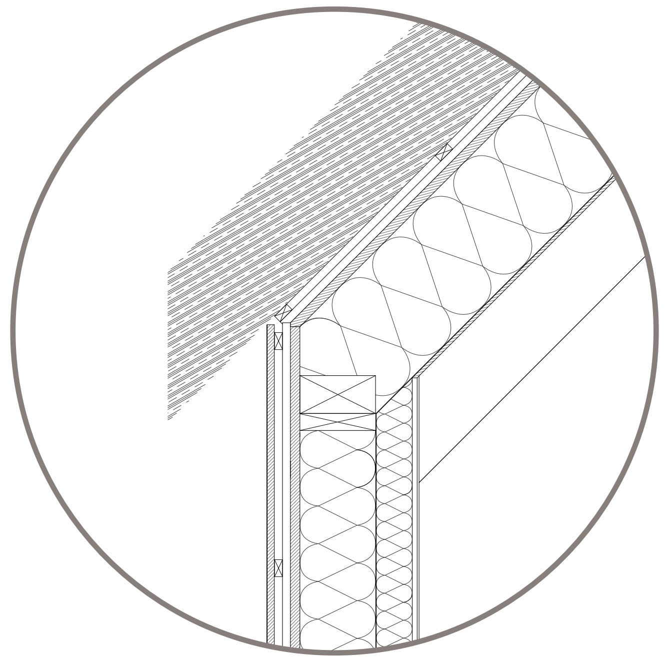


On top of the insulation layer a windbreaker is placed, keeping the construction airtight. The roof cladding will be placed upon the windbreaker using roof battens. **3**

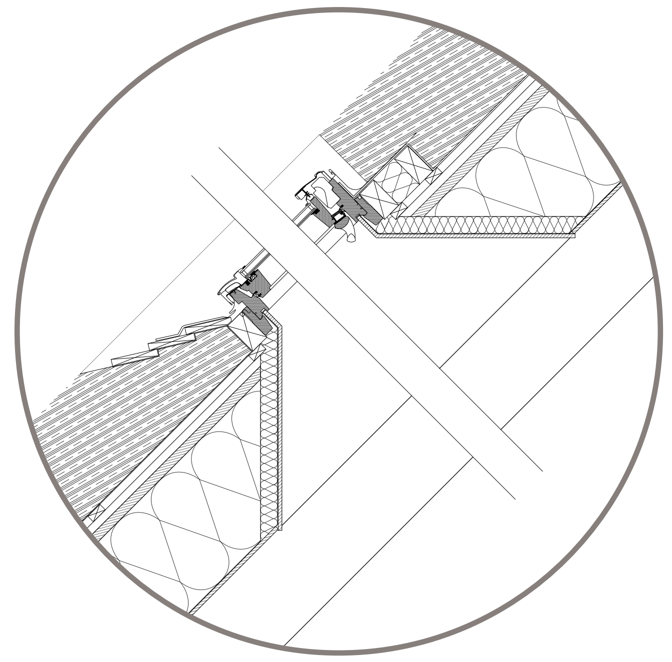




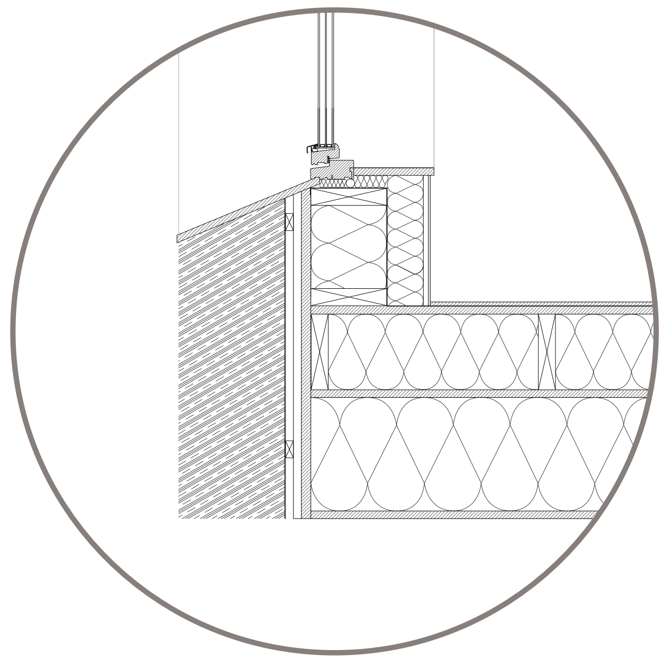
WALL DETAIL EXHIBITION IN 1:50



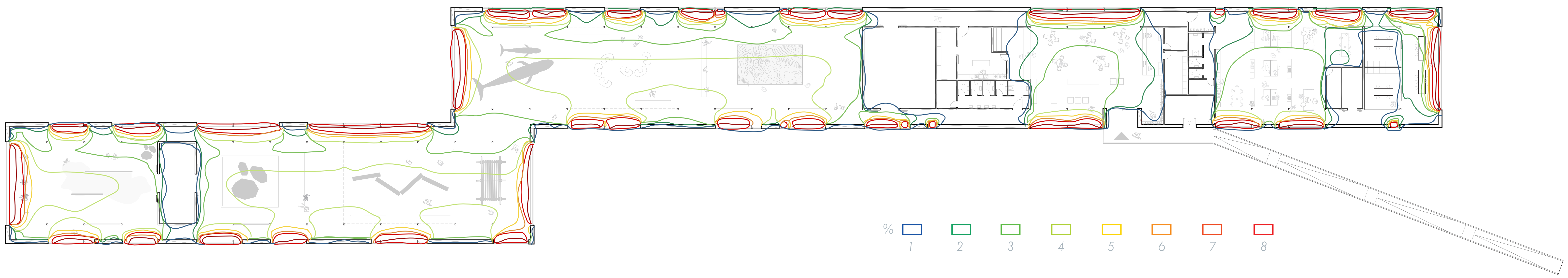
ROOF - WALL DETAIL OFFICE IN 1:20



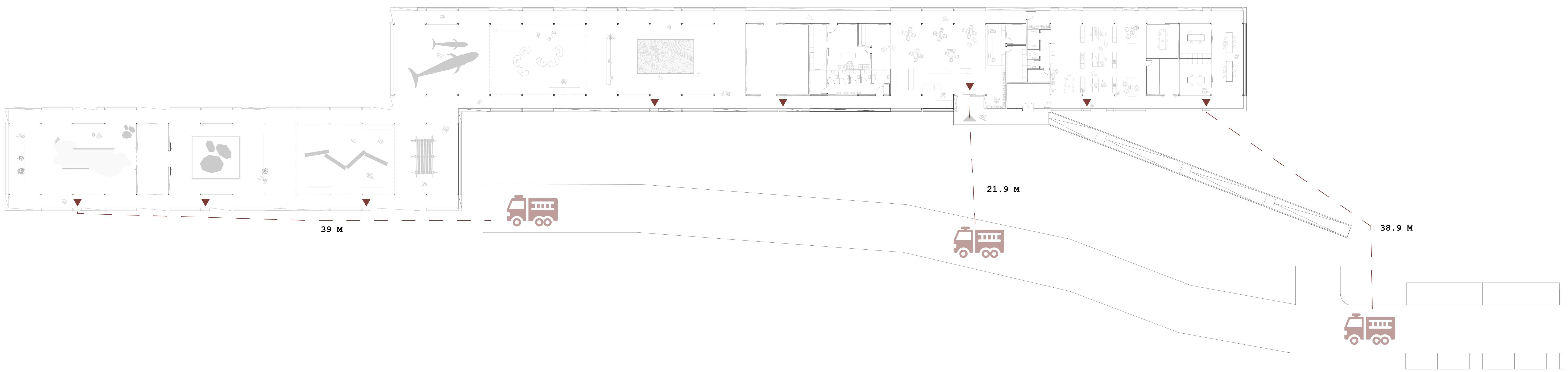
SKYLIGHT DETAIL IN 1:20



WALL- FLOOR DETAIL IN 1:20

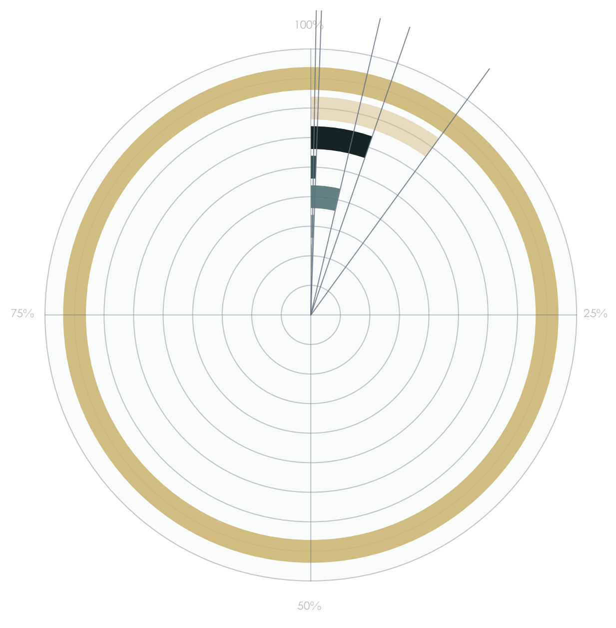


DAYLIGHT ANALYSIS

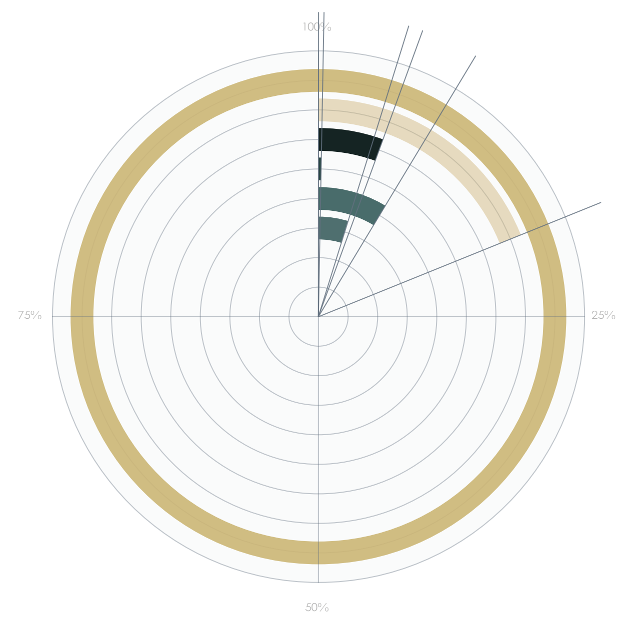


FIRE SAFETY

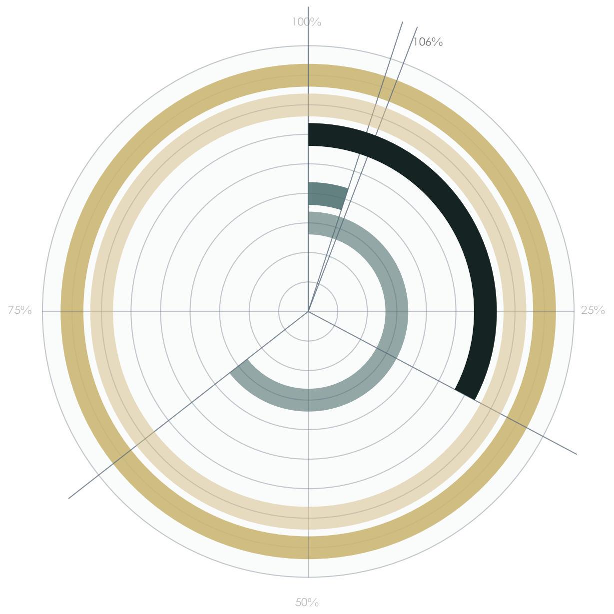
GWP - GLOBAL WARMING POTENTIAL.



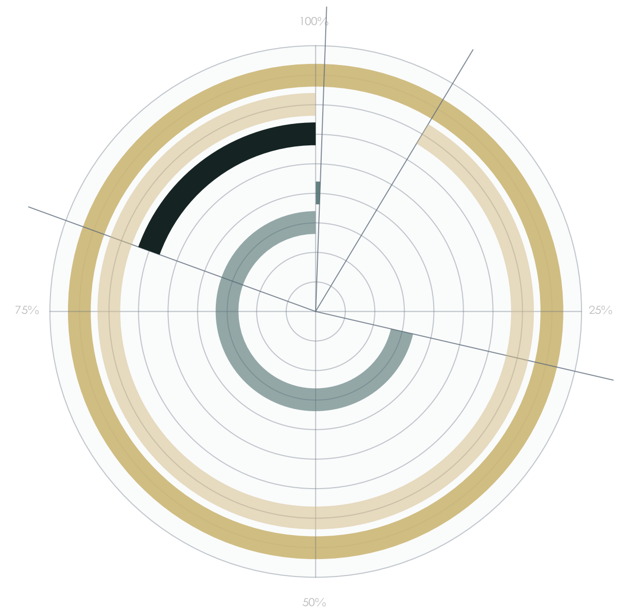
POCP - PHOTOCHEMICAL OZONE CREATION POTENTIAL.



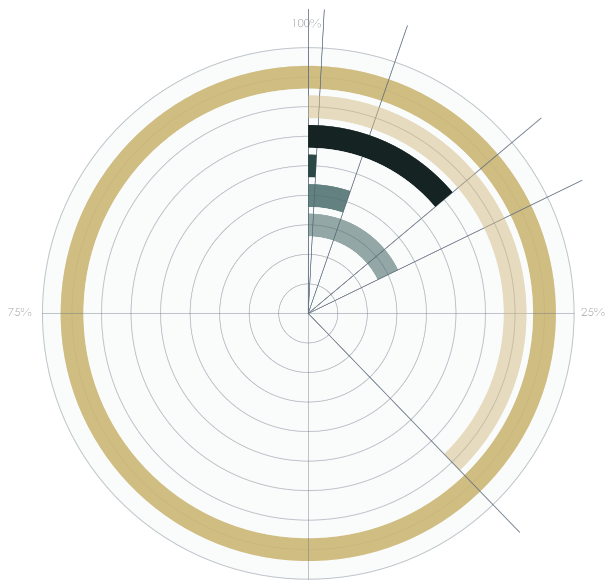
AP - ACIDIFICATION POTENTIAL.



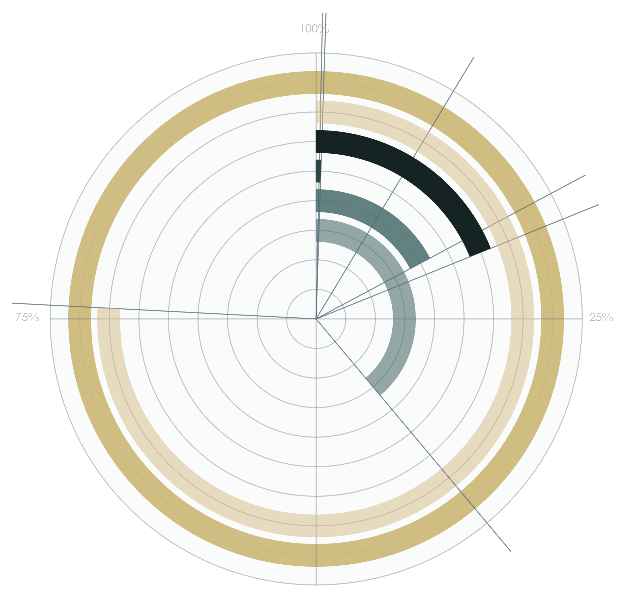
EP - EUTROPHICATION POTENTIAL.



ADPF - ABIOTIC RESOURCE DEPLETION POTENTIAL FOR FOSSIL FUELS



PETOT + SEK - PRIMARY ENERGY TOTAL & SECONDARY ENERGY.



LIFE CYCLE ASSESSMENT

The LCA provides a holistic evaluation of potential environmental impacts caused by the building. The re-suœts presented on the left are based on a simple method that includes the building's exterior and interior walls, the roof, the floor and the load-bearing construction. The analysis does therefore not include installations, ramps, inventory etc. (Green building counsil Denmark, 2020).

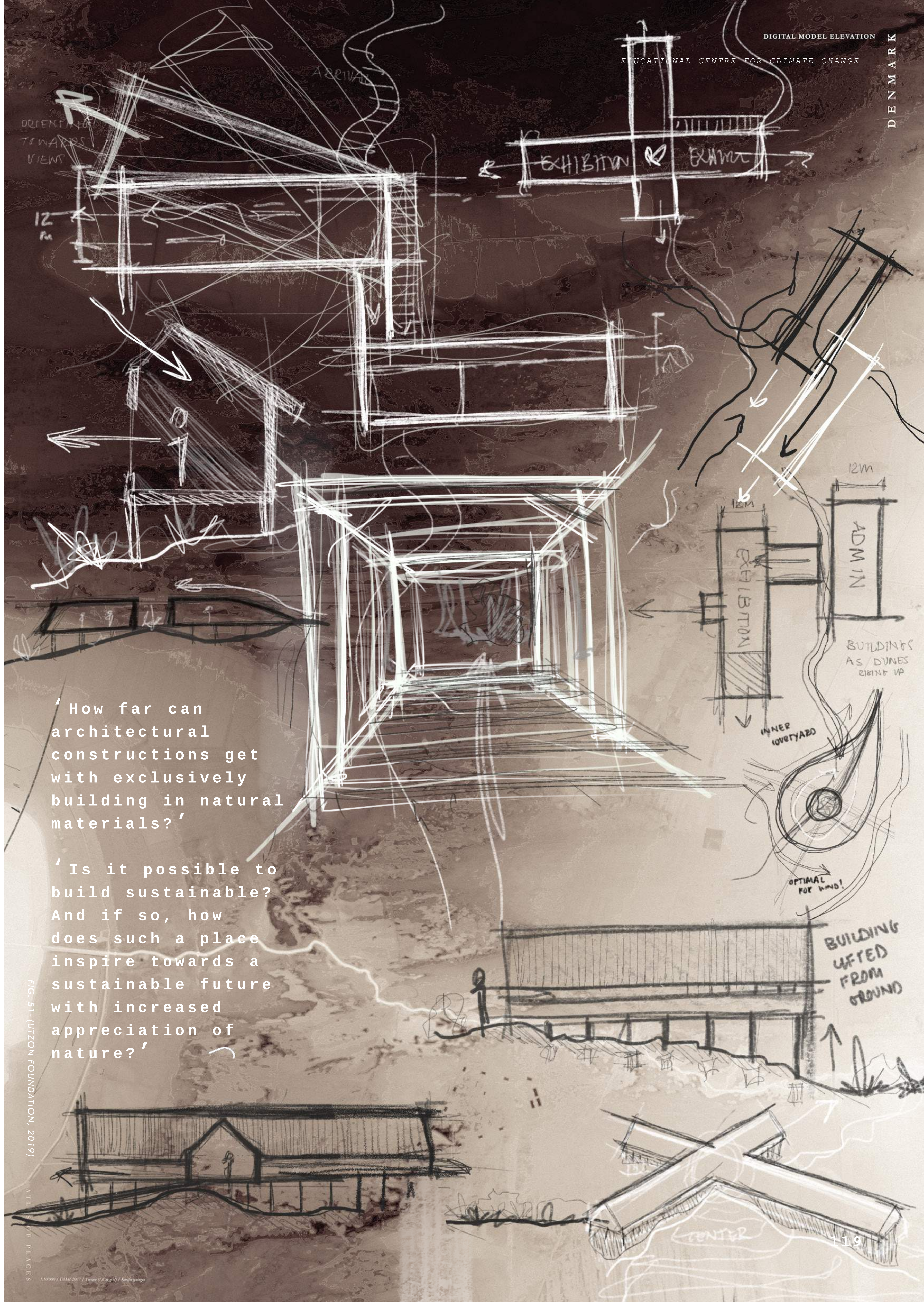
The results compare the building total with the DGNB reference values for six selected indicators of which reference values can be found in DGNB. Furthermore, the different constructions' contribution to the building total is illustrated. In general, the building performs better than the DGNB reference values, however, as not all aspects are included in the LCA, the results can't be directly compared but gives an overall insight into the building performance related to its environmental impact. One indicator that differentiates from the other is eutrophication (EP), where the result is negative. This is caused by reeds used as exterior material on the roof and façade, that absorbs phosphate during its growth.

KEY

DGNB total · *Building total* · *Exterior walls*

Interior walls · *Floor* · *Roof* · *Construction*

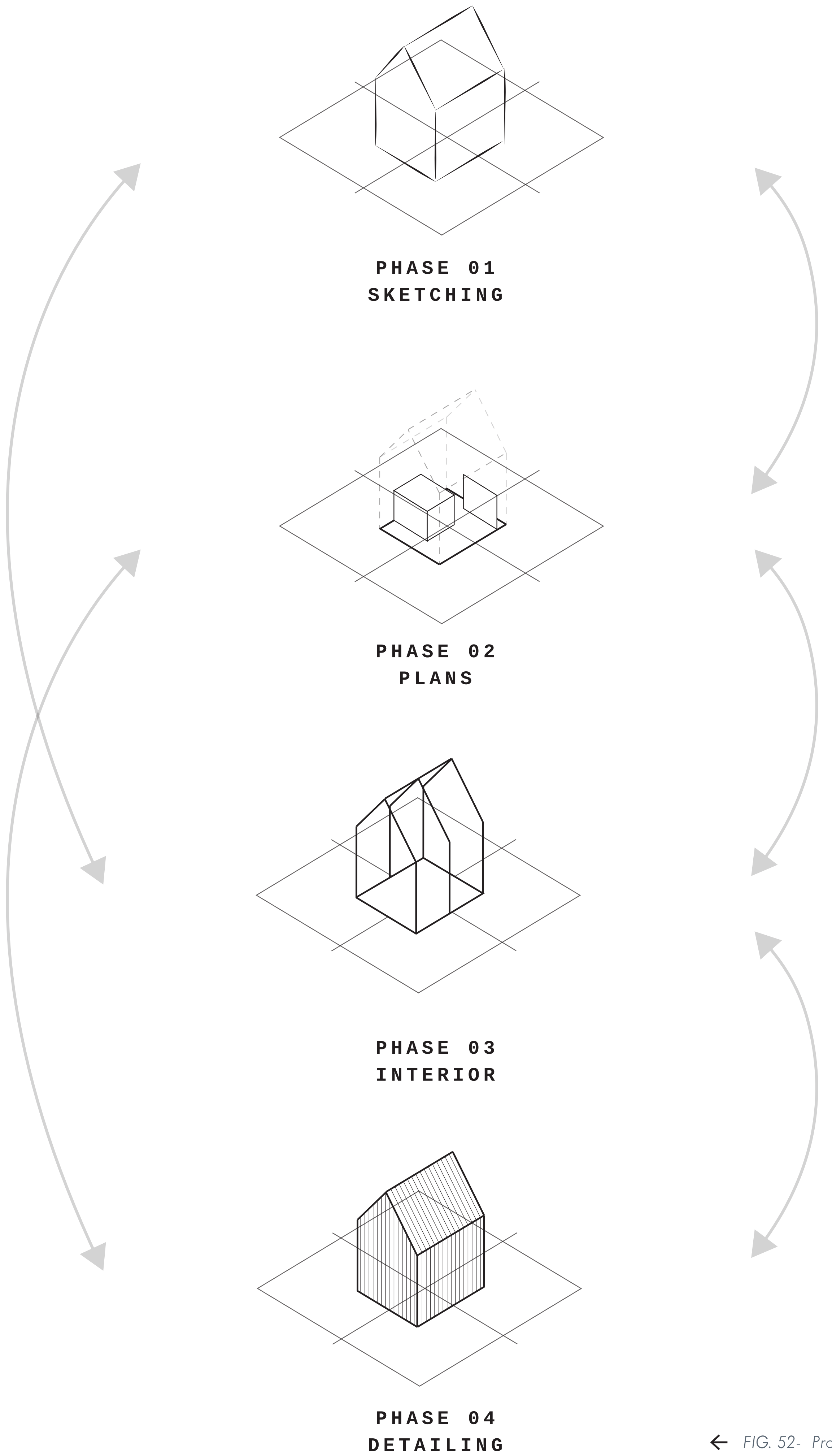
07 DESIGN DEVELOPMENT



'How far can architectural constructions get with exclusively building in natural materials?'

'Is it possible to build sustainable? And if so, how does such a place inspire towards a sustainable future with increased appreciation of nature?'

FIG. 51 [UTZON FOUNDATION, 2019]



← FIG. 52- Process diagram

07.00 preliminary.

FOLLOWING THE PROCESS The design process initiates in the presented analyses and continues to base itself upon underlying studies throughout the process. Thus, the concept and following adjustments and detailing will evolve in accordance with the vision of this thesis; to design a building that in its existence facilitates climate responsibility through dialogue and transparency.
The design process is presented somewhat chronologically but is in fact much more complex. The order of the design process seeks to communicate the investigations and decisions best possible, but as the process is iterative, many of the analyses are interdependent and decisions made simultaneously.

PHASE 01 SKETCHING →

CONTENT
+ Wind studies
+ Material >< site atmosphere
+ Initial construction
+ Functionality
+ Choice of design / concept
+ Placement on site

METHODS & TOOLS
+ Analogue sketching
+ Digital sketching
+ Digital modelling
+ Hand calculations
+ Robot structural analysis
+ Rhino
+ Computational fluid dynamics
+ Sketchup
+ Revit

PHASE 02 PLANS →

CONTENT
+ Plan iterations
+ Layout composition
+ User study
+ Implementation of LCA results
+ Joints
+ Design for disassembly

METHODS & TOOLS
+ Digital modelling
+ Rhino
+ Sketchup
+ Revit
+ Research article
+ Analogue sketching
+ AutoCad
+ LCA

PHASE 03 INTERIOR →

CONTENT
+ Exhibition placement
+ Interior materiality
+ Atmospheres of spaces
+ Indoor comfort
+ Room heights
+ Daylight percentage

METHODS & TOOLS
+ Digital modelling
+ Rhino
+ Research article
+ Analogue sketching
+ Photoshop
+ Collage
+ Moodboard
+ Velux Visualizer
+ Bsim
+ Be18

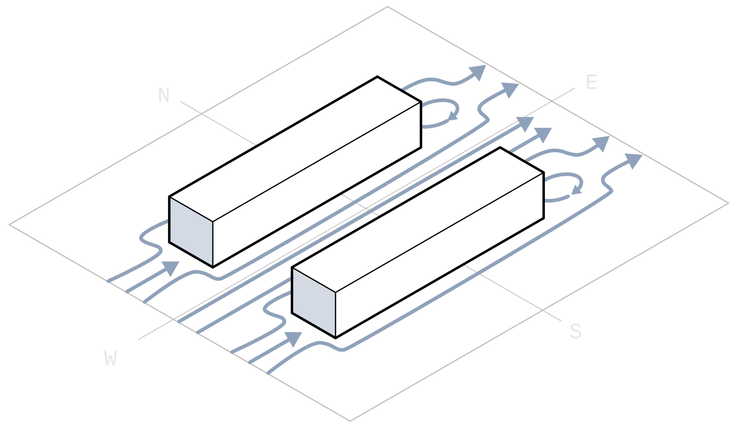
PHASE 04 DETAILING

CONTENT
+ Exterior expressions
+ Exterior shading
+ Passive strategies
+ Active strategies
+ Facade materials
+ Material compositions

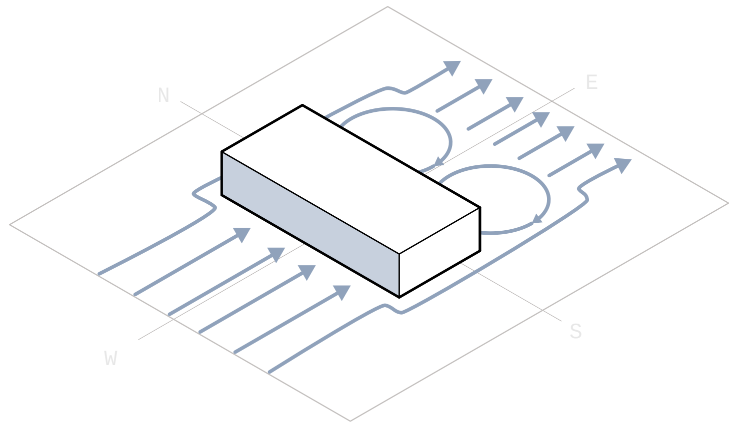
METHODS & TOOLS
+ Digital modelling
+ Rhino
+ Be18
+ Bsim
+ Collage
+ Photoshop
+ LCA

07.01 touching the earth.

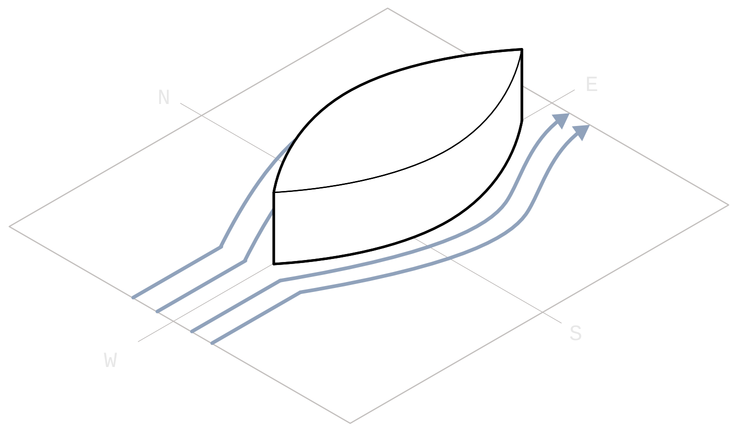
initial sketches & volume studies



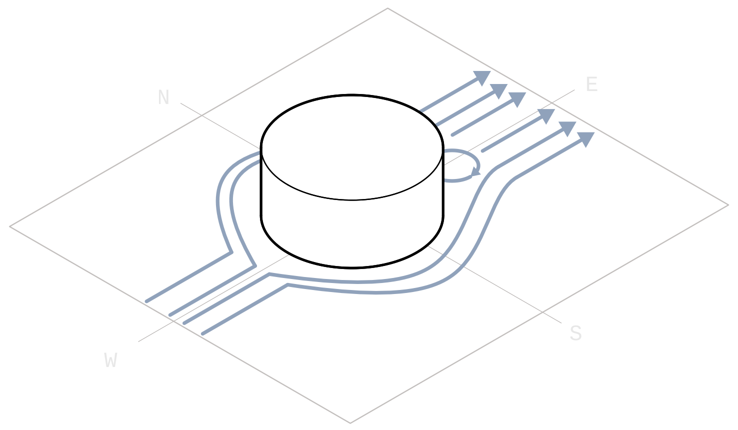
TRADITIONAL LONG HOUSE
Parallel buildings extending the same direction as the wind, causes minimal impact and therefore also little turbulence on the leeward side.



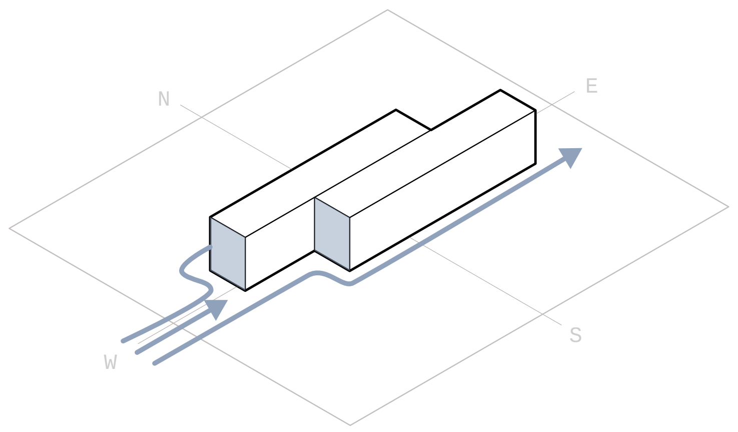
RECTANGLE
Buildings extending orthogonally on the wind direction causes greater impact and larger turbulence on the leeward side.



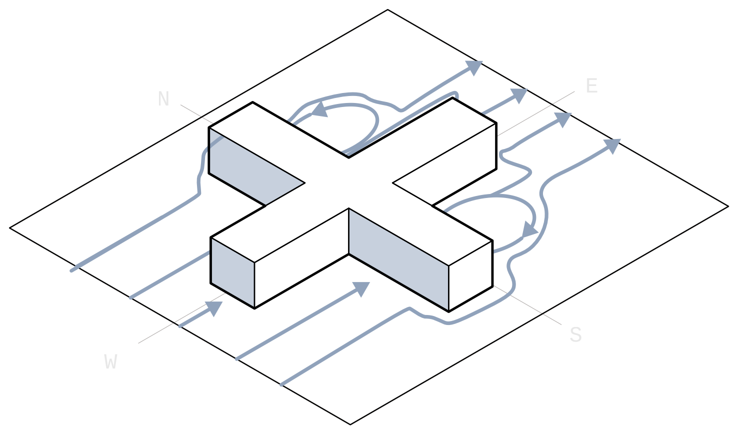
DIAMOND
The drop shape can ensure no turbulence on the leeward side, as the wind can follow the shape from windward to leeward side.



CIRCULAR
Rounded shapes and corners cause smaller turbulence areas on the leeward side, compared to a square shape of the same size.



SKEWED LONG HOUSE
Staggered buildings following the wind direction provides the same qualities as the parallel building, but also removes the risk of "corridor effect".

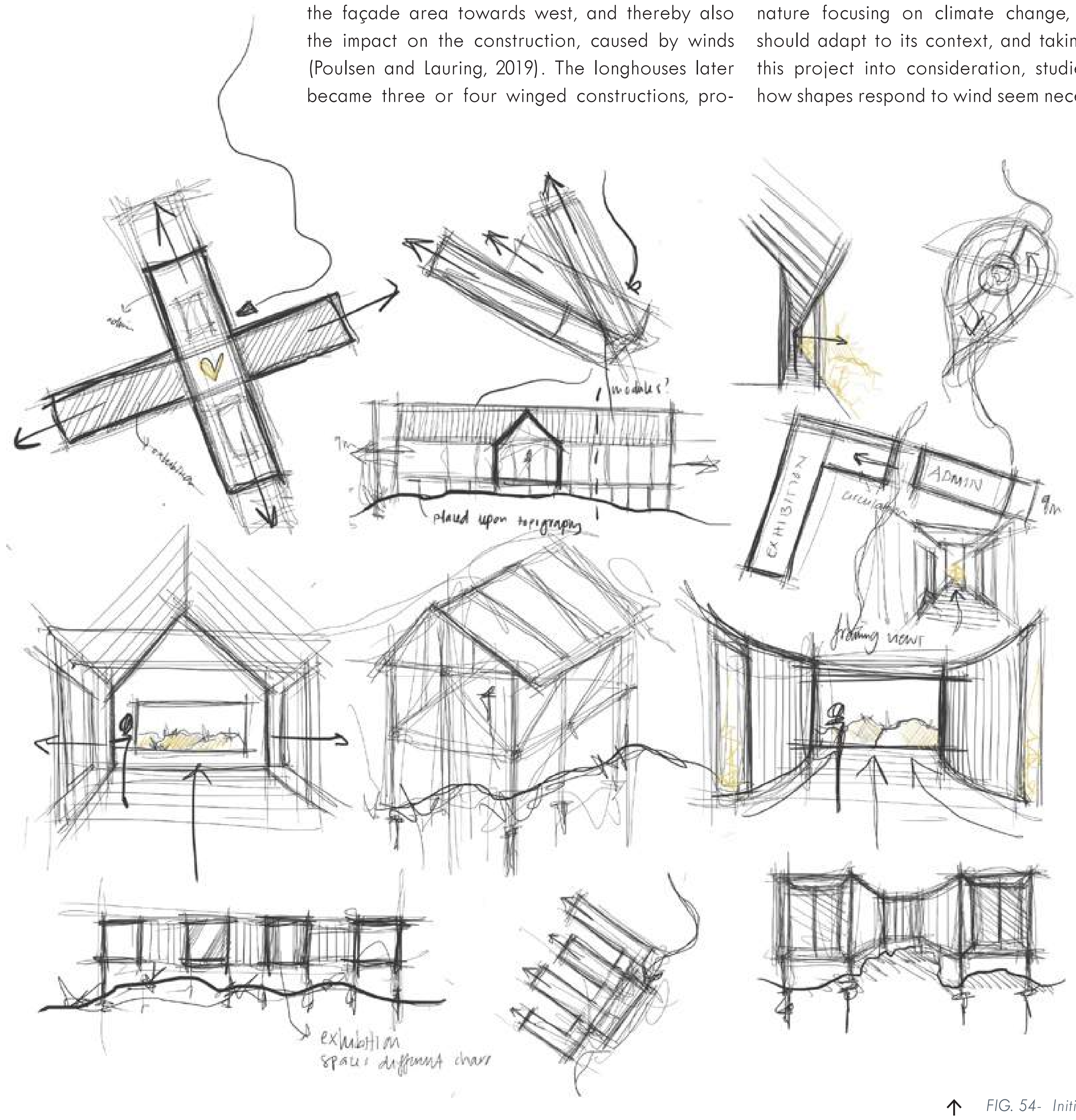


CROSS
Despite dividing the volume facing the wind, the shape still causes large turbulence areas on the leeward side.

FIG. 53- Wind study of different volumes in terms of pressure and turbulence (Bjerg, 2012) ↑

TRADITIONAL WEST COAST CONSTRUCTIONS

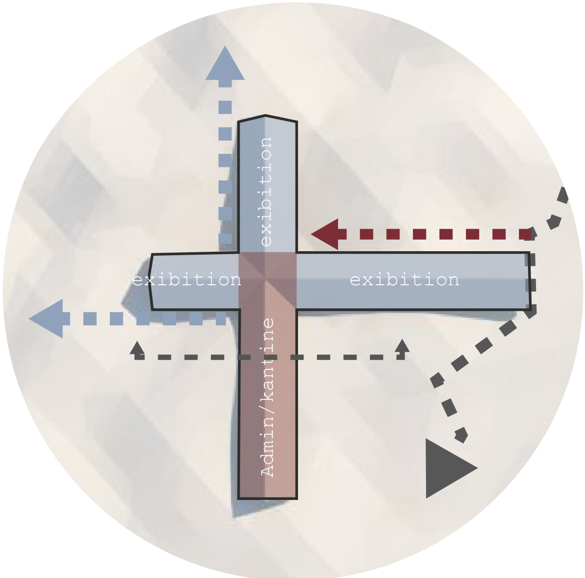
The Danish building tradition carefully considered the Danish climate, which, as previously stated, has predominating western winds. Thus, longhouses extending from east to west, were the main typology. This construction method both ensured a long façade facing the sun towards south and minimized the façade area towards west, and thereby also the impact on the construction, caused by winds (Poulsen and Lauring, 2019). The longhouses later became three or four winged constructions, providing lee from the wind. However, along the West coast, they continued to build east-west parallel longhouses, to avoid large façades towards the western winds (Poulsen and Lauring, 2019; Birkkjær and Kruse, 2016). Aiming towards a building that should increase the general appreciation towards nature focusing on climate change, the building should adapt to its context, and taking the site of this project into consideration, studies regarding how shapes respond to wind seem necessary.

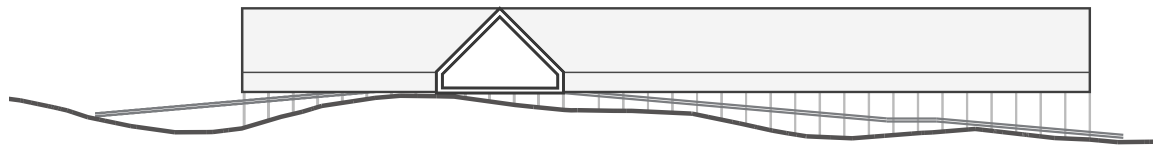


↑ *FIG. 54- Initial sketches*

07.02 spatiality.

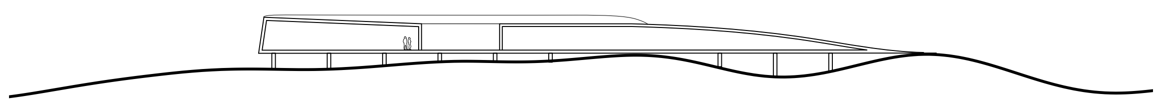
initial organisation of functions





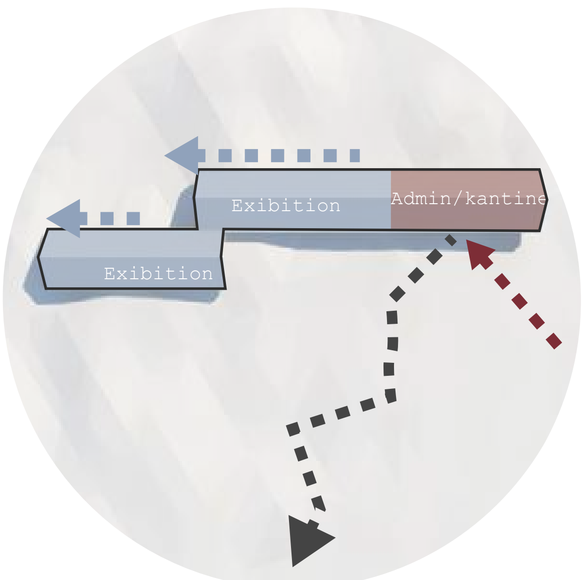
THE CROSS

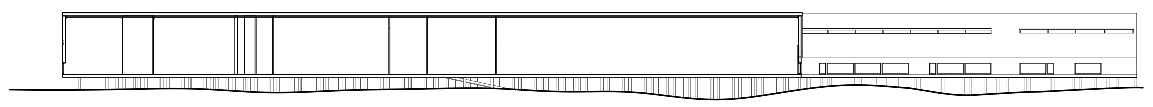
The cross has four wings stretching out towards north, east, south, and west, directing the visitor towards all the various views of the context. The volume sits on top of the context, with the eastern wing grabbing onto a path, leading the visitor up to the central heart of the building. The building allows for an unspecified flow, creating an intriguing journey throughout the center. However, the volume is not optimal in terms of wind, due to the large amount of facade towards the west, threatening the construction.



THE DROP

The drop creates an interior courtyard which allows for an outdoor space completely shielded from the wind. The organic shape is optimal in terms of wind and is the best option of the three. However, the organization of the functions was difficult, with rounded rooms and a narrow point towards the north. Additionally, the structure conflicts with the notion of design for disassembly and modular building and does not relate to the context to the same extent as the remaining two concepts.

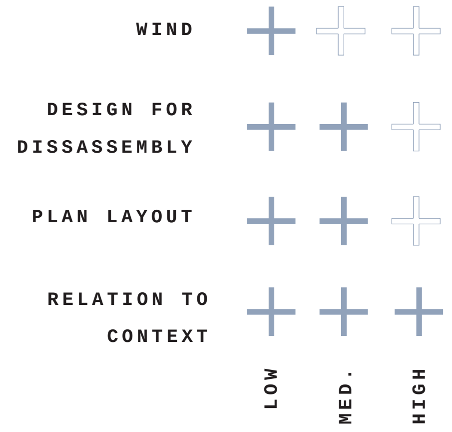


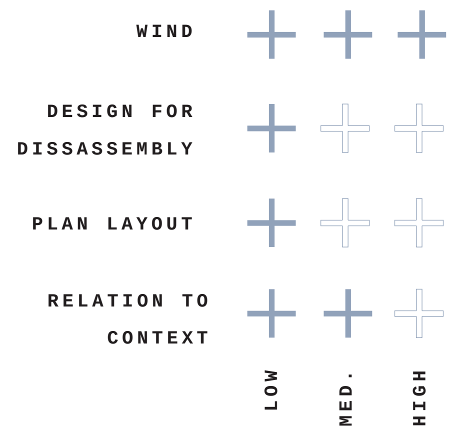


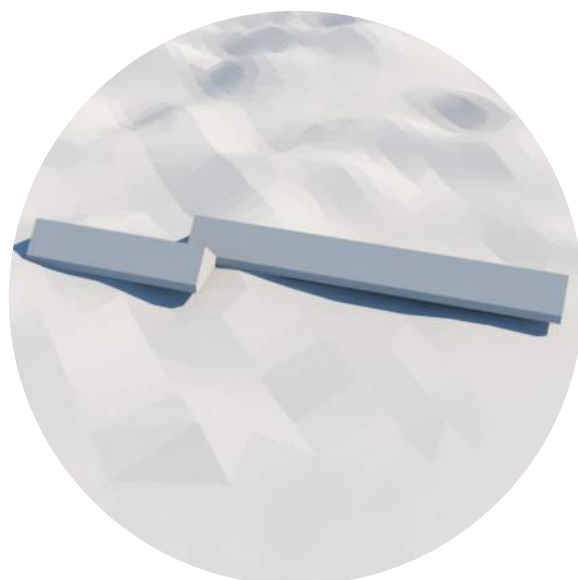
THE SKEWED LONG HOUSE

Inspired by the traditional danish housing, the two skewed volumes are placed on top of the terrain, directing the flow towards the west end of the buildings. The simple shape is optimal in relation to designing for disassembly, and modular building, whilst also cooperating with prevailing western winds. The buildings allow for the administration and offices to be in one end, and the exhibition spaces to be in another, creating clear flow, whilst having large facades towards north and south, initiating great possibilities for solar panels and natural daylight. These are some of the main factors considered when choosing this concept to elaborate on.

FIG. 55- Plans & sections of 3 main concepts ↑







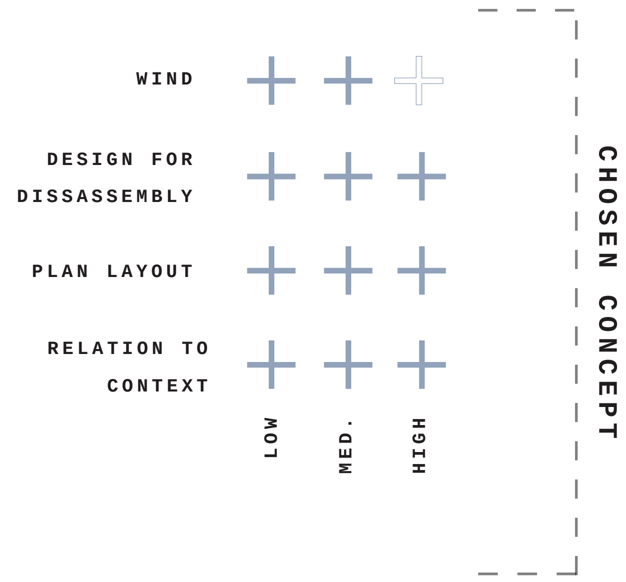
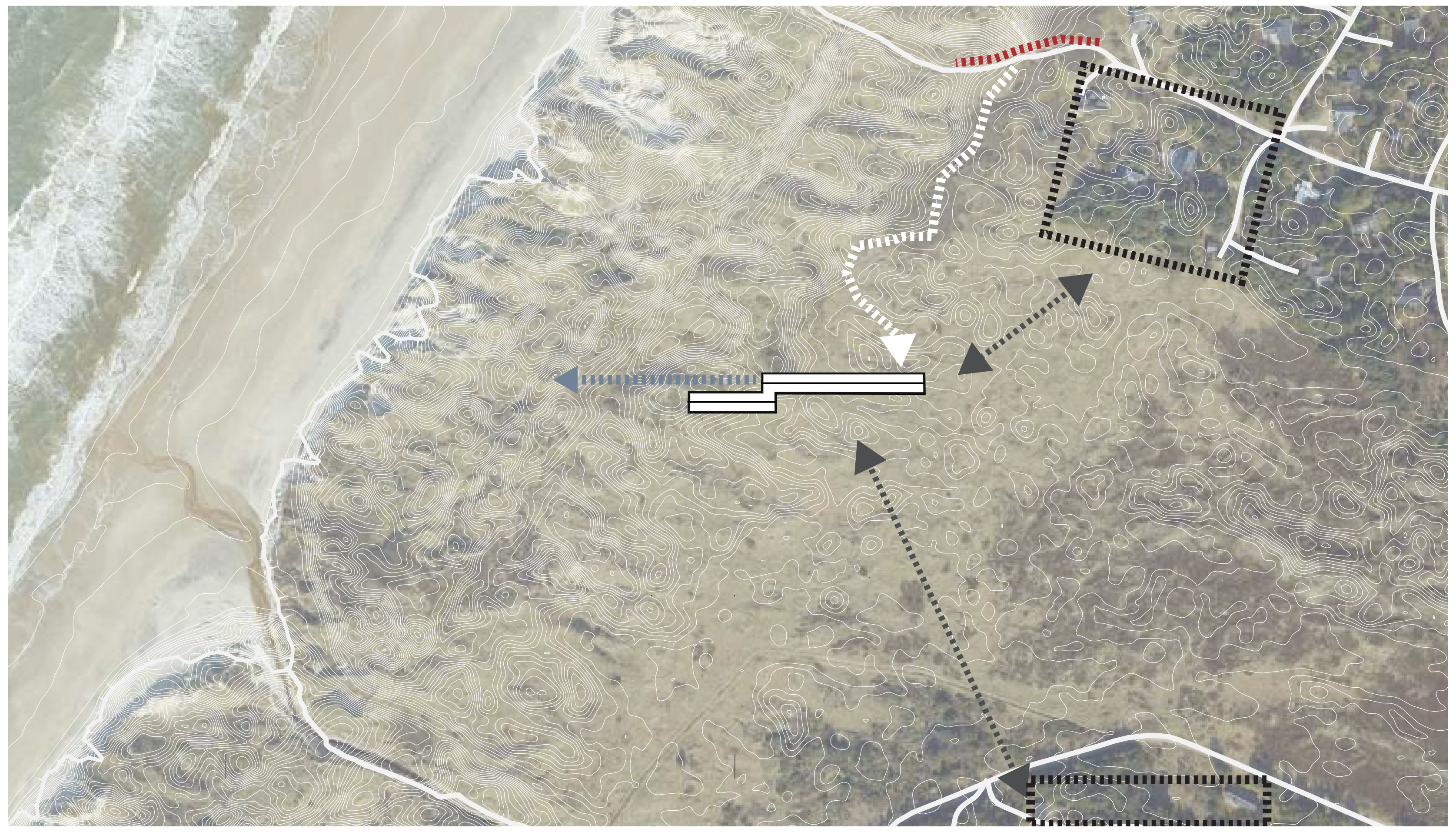


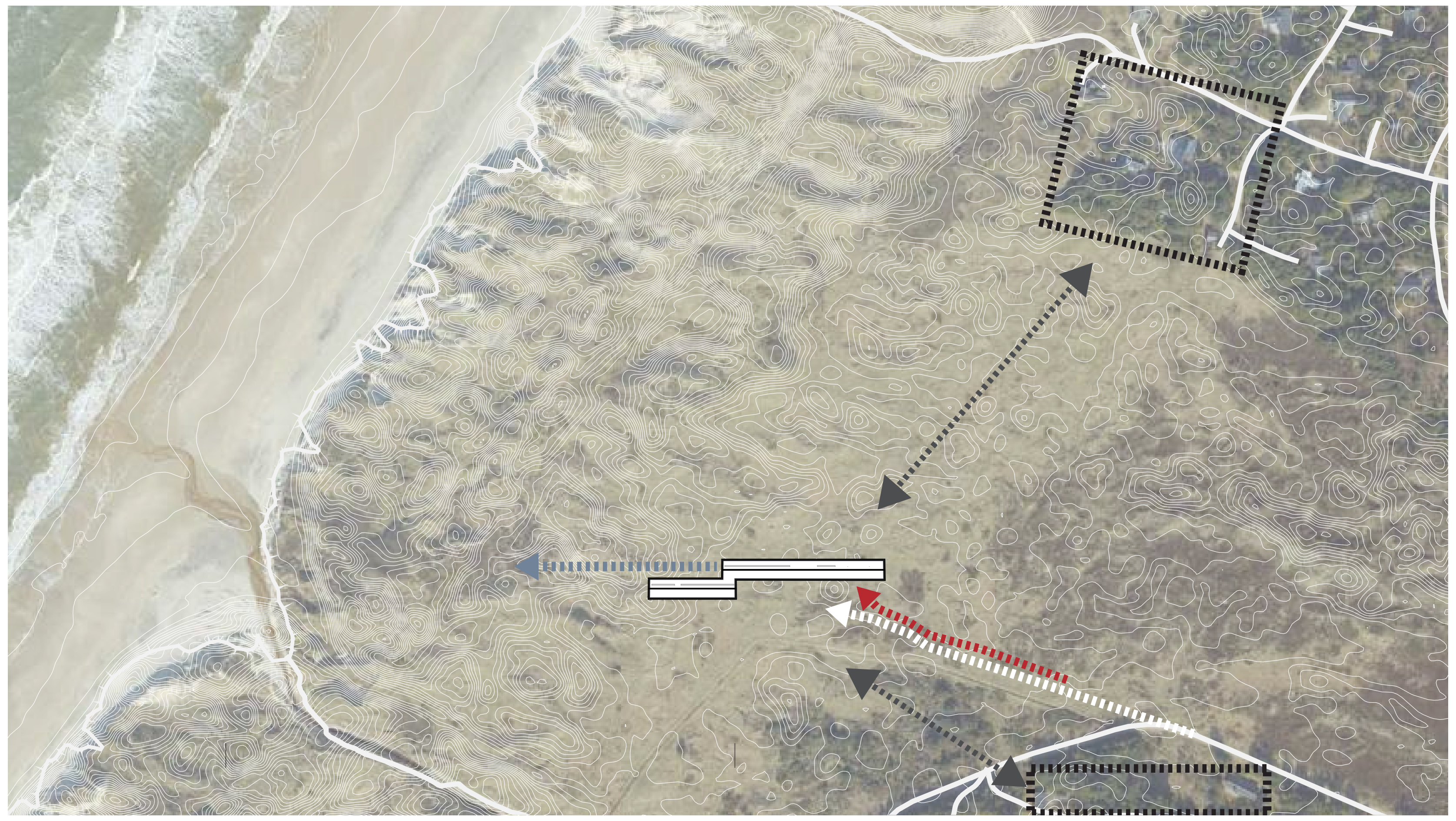
FIG. 56- 3D views of 3 main concepts ↑



↑ FIG. 57- Section of placement 01

views · residential area · parking · distance to residential area · path

CHOSEN PLACEMENT



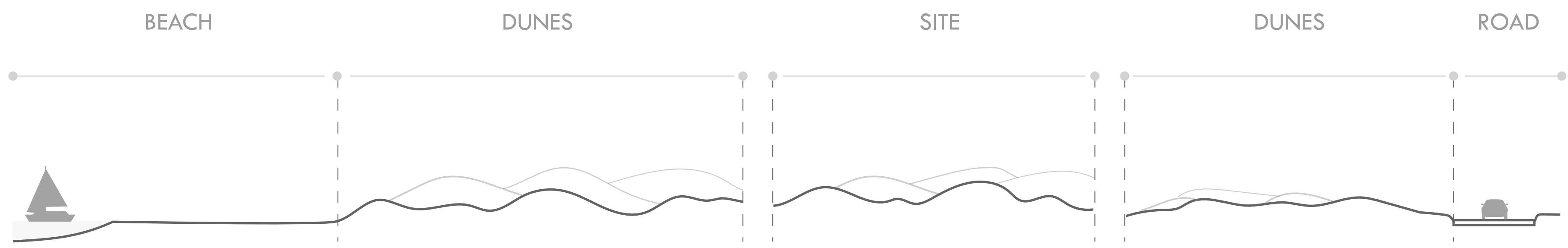
↑ FIG. 58- Section of placement 02

07.03 placement in terrain.

leaving a minimal footprint

PLACEMENT 01 : MORE REMOTE PLACEMENT

The first placement of the building was initially based on the experience of the landscape. The idea that the building is placed in the middle of the sand dunes generated a natural connection and allowed the experience of nature to be maximized. The visitors would arrive from north and walk along the outer edges of the sand dunes, where the building would peak in and out as one gets closer. This meant that a platform must be installed for the visitors which are not necessarily fit to walk on the rough terrain. Another obstacle this placement created was delivery of goods and material for the center, which would require establishing a road to the center. Doing this would damage the nature and the surrounding flora which defines this landscape.

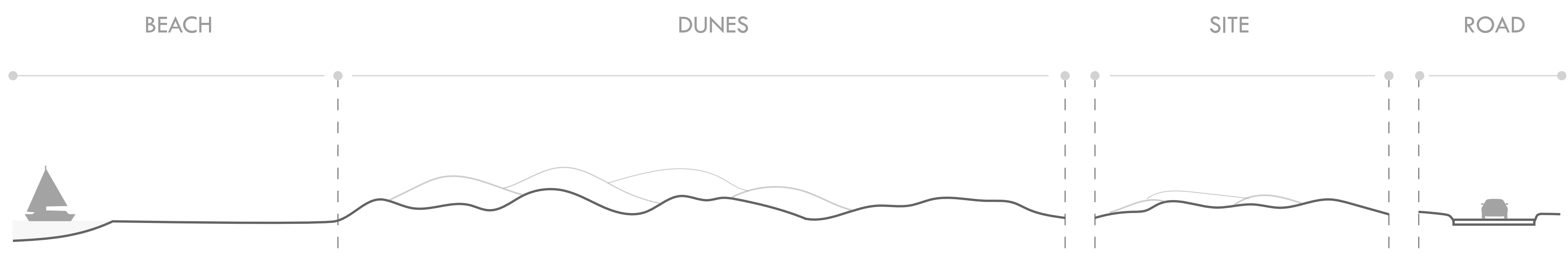


↑ FIG. 59- Section of placement 01

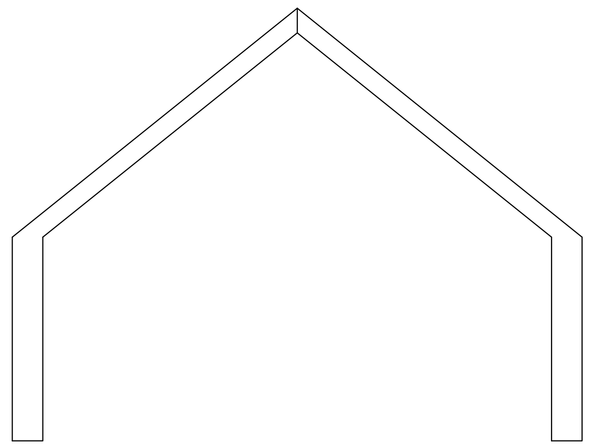
PLACEMENT 02 : CLOSER TO EXISTING INFRASTRUCTURE

The second placement is shifted south, where the building has a small distance to the sand dunes, moving the arrival point from north to east through a nearby road that curves away from the area. The road is made of gravel and has some connections to a few holiday homes nearby. This road is extended and will function as the primary arrival point, where parking and delivery also pass through, This connection provides solutions, such as the connection to the power grid and fire safety without damaging the nature.

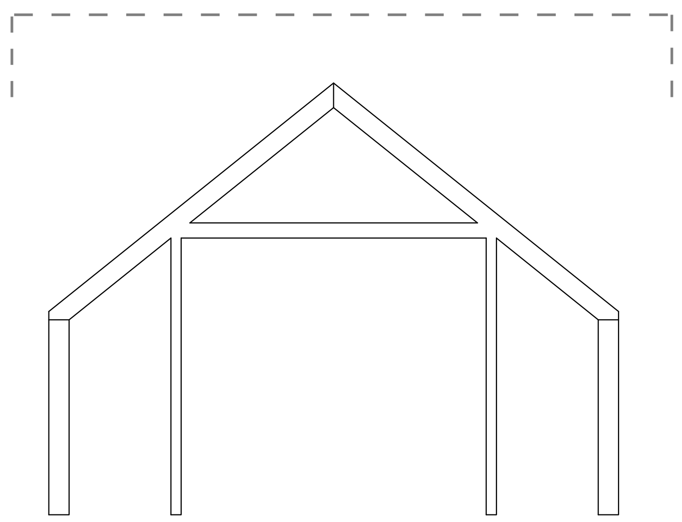
A concern for the placement of the building in this case was the experience of nature that is rooted deeply in the design criteria, and here the shape of the building creates a connection between the diverse types of nature. The arrival to the building is defined by tall grass land and the gravel road that leads to the emergence of the dune landscape along the building.



↑ FIG. 60- Section of placement 02

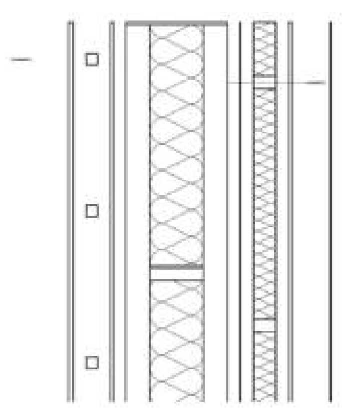


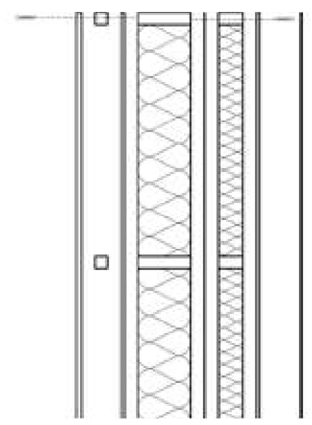
CHOSEN CONSTRUCTION



STRAW PANEL
If using the straw panel principle, the load-bearing construction will be placed in the exterior walls, making the wall thicker and less accessible when designing for disassembly.

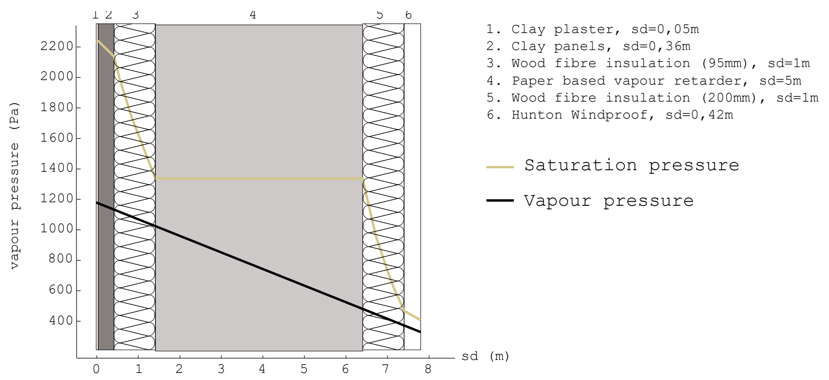
WOOD FIBRE
The straw panel stand as both insulation layer and load-bearing element, on which the remaining layers are mounted.

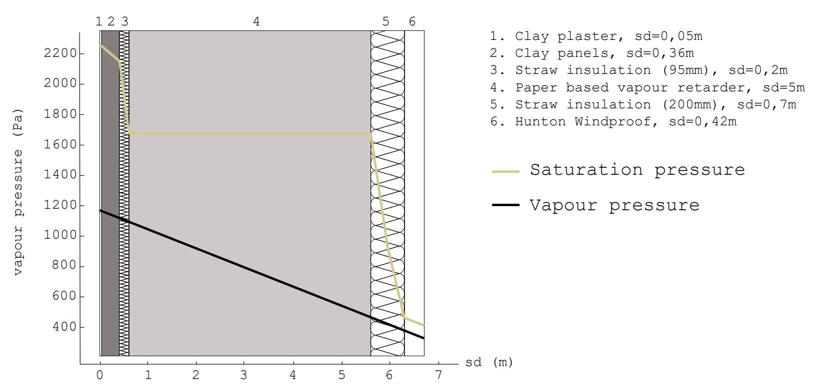




DETAIL
The wall has been designed to be diffusion permeable, meaning that moisture can transport itself through the construction. If the saturation pressure does not cross the line of

DETAIL
Placing the load-bearing construction on the interior and using wood fiber as insulation, allows for smaller walls and easier disassembly.





DIFFUSION DIAGRAM
The wood fiber insulation is placed within a wooden frame structure, whereas the other layers are the same as for the straw panel wall.

DIFFUSION DIAGRAM
A concern for the placement of the building in this case was the experience of nature that is rooted deeply in our design criteria, and here the shape of the building creates a

FIG. 61- Two different wall build-ups ↑

07.04 wall connections.

optimizing the overall structural composition

As a result of the preliminary LCA analysis (pages 70-71), two wall build-ups have been made. One of the walls uses the locally available material straw as insulation and is based upon the principles of the EcoCocon panels, that are both load-carrying and insulating (EcoCocon, n.d.). The other wall has wood fibre batts as insulation and uses a traditional construction technique with load-bearing beams and columns of construction wood, also chosen through the preliminary analysis. The two walls are evaluated based upon construction investigations and an LCA. The analysed walls therefore contain the layers as presented in the details (figure 61), whereas the wood fibre wall includes construction wood, representing the load carrying beams and columns.

The two walls both obtain recommended u-values for building class 2020 (Rockwool, n.d.) and are diffusion permeable (fig. 61). Both reeds and wood are considered as exterior façade materials, however in this case, wood is chosen as exterior material for both walls, as it therefore is ensured that the u-value is obtained regardless.

Both walls can easily be assembled and disassembled, just as they can easily be connected to floor and roof constructions. The LCA results clarify that the wood fibre wall is the better solution focusing on the majority of the environmental impact indicators. Focusing on the global warming potential being of interest when focusing on climate change, the wood fibre wall has an impact smaller than half of the EcoCocon wall. The results for the other indicators can be found in appendix 09.02.

Wood fibre   EcoCocon

↑ *FIG. 62- Global warming potential of two build-ups*

GLOBAL WARMING POTENTIAL (GWP)
Global Warming Potential. Expressed as CO_2 equivalents and refers to the global warming potential of CO_2 emitted into the atmosphere.

07.05 tectonic approach.

assessing different structural systems

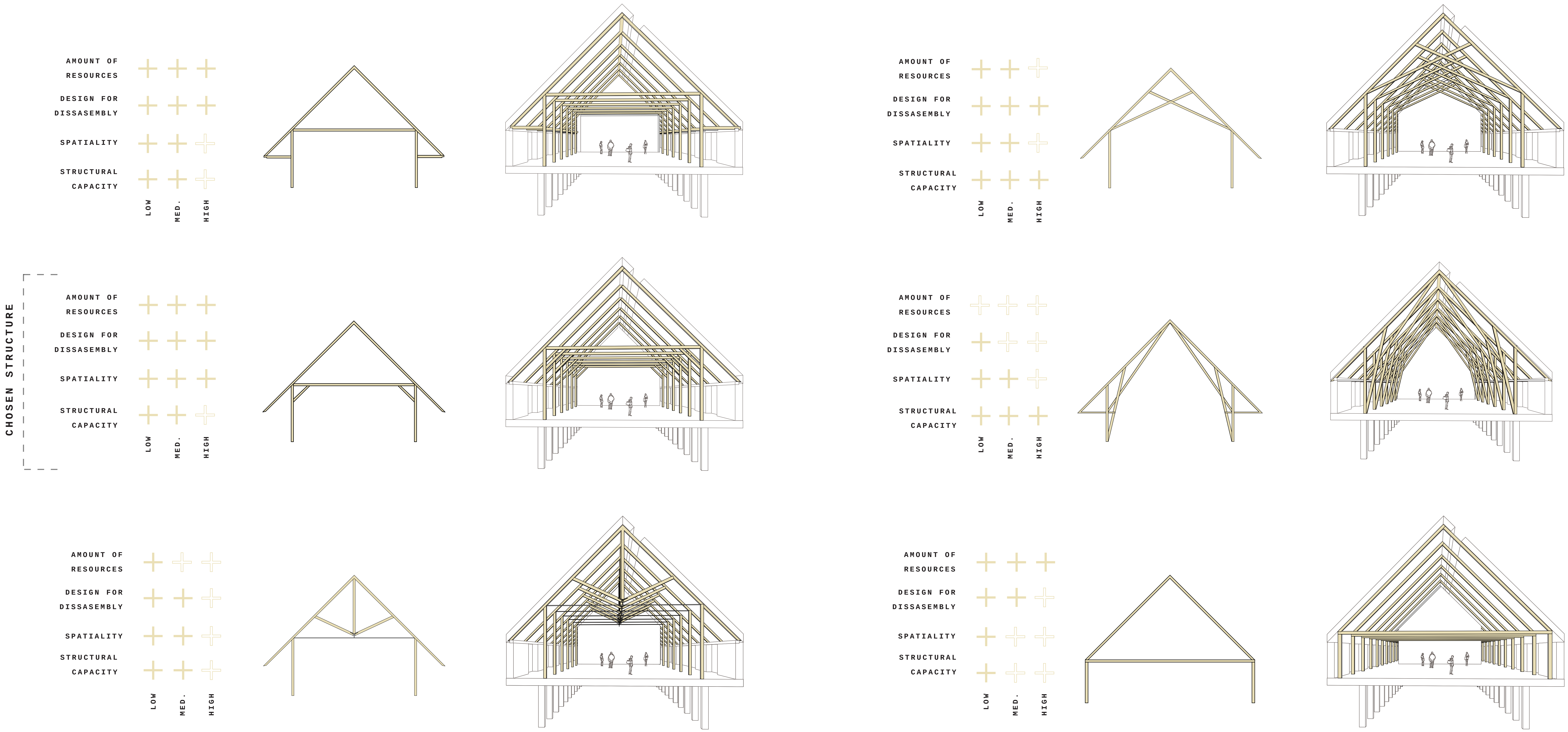


FIG. 63- Structural analysis ↑

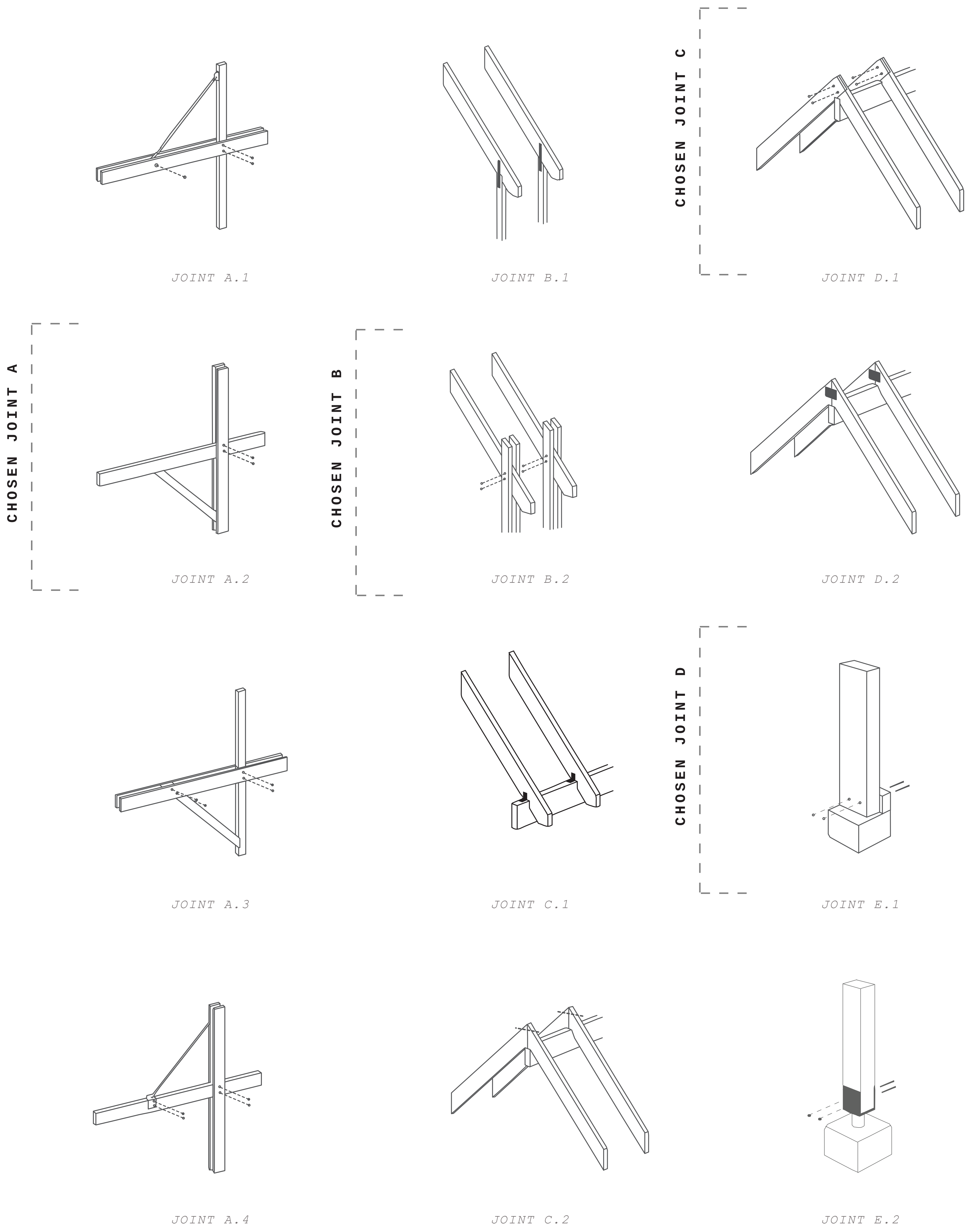


FIG. 64- *Various joints*

07.06 detailing joints.

by means of design for dissassembly

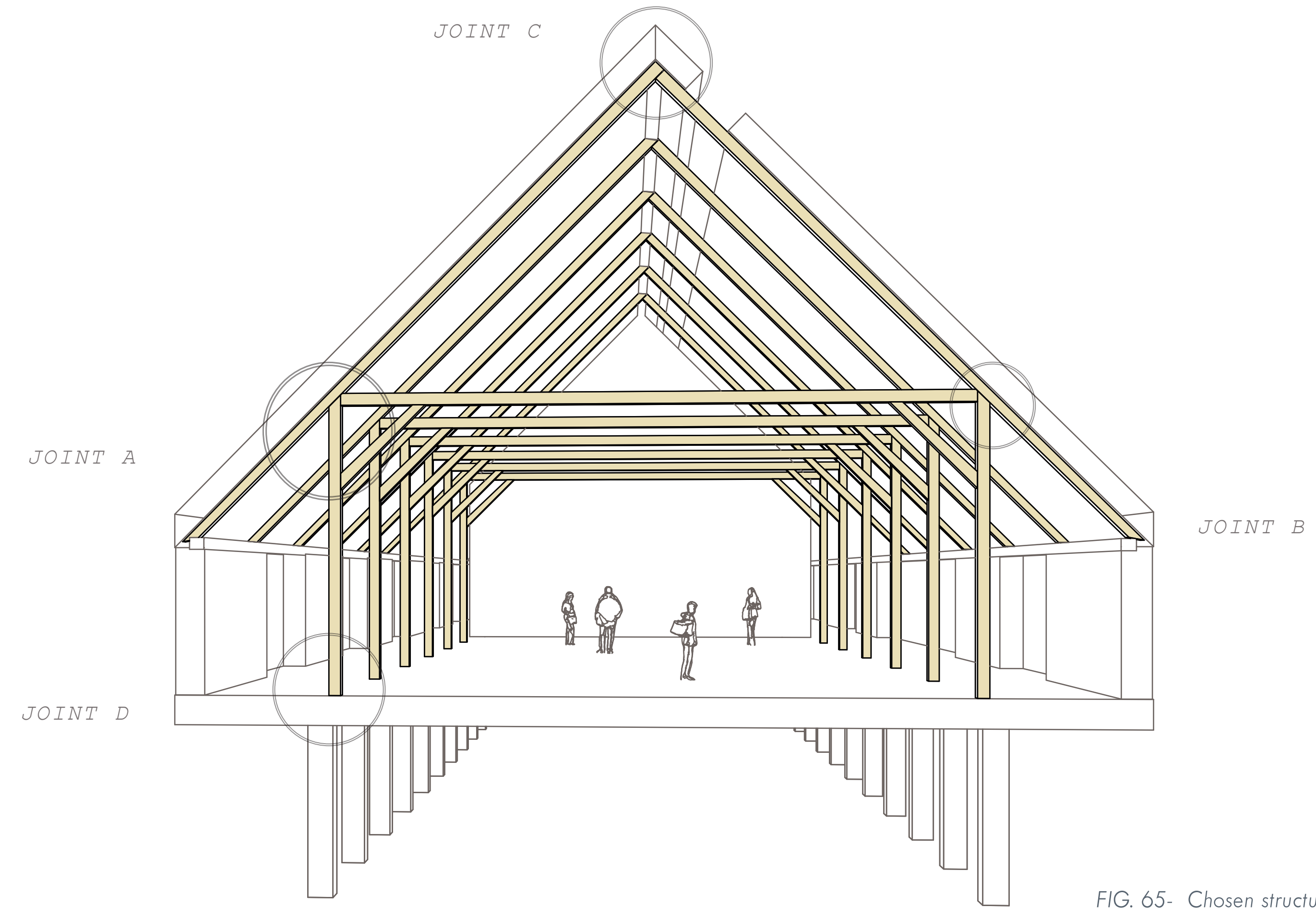


FIG. 65- *Chosen structure*

KEY NUMBERS

COLUMN SCENARIO 1:

Type of wood: C30

Cross section: 100x200mm

Load-carrying ratio: 0,40

COLUMN SCENARIO 2:

Type of wood: C30

Cross section: 63x125mm x2

Load-carrying ratio: 0,82

BEAM:

Type of wood: C30

Cross section: 100x225mm

Load-carrying ratio: 0,59

Buckling:

Permanent loads: 1mm<42mm

Variable loads: 23mm<26,25mm

EXPRESSING DESIGN FOR DISSASSEMBLY THROUGH JOINTS

Simultaneously with the joint studies, the load-bearing beams and columns was calculated with the aim to determine their dimensions. The full calculation can be found in appendix 09.01 and key numbers from the calculation are listed above. The calculation participated in an overall reflection of using only organic building materials down to timber dowels as opposed to metal screws in connections. It is important to note, that the calculations have not taken this into account, however a study argues that decreased stiffness using dowels should be expected, but not to an extent that would require a different calculation (Rumlová and Fojtík, 2015). Therefore, two types of column scenarios were tested, one prioritizing using as little material as possible with only one column, another prioritizing to not use any metal, however increasing the usage of material by having two columns on each side of the beam, acting as one column. Scenario one would visually require coherence between the width of beam and column which limits the choices in size of the column resulting in a rather low load carrying ratio and a column that is over dimensioned. On the contrary scenario two can be optimized to an optimal ratio, limiting the amount of unnecessary material. In extension, the area of the cross section of scenario two is smaller than in scenario one meaning that the amount of material is smaller despite having two columns compared to just one. Finally, the joint principle makes an only wood joint possible, following the initial vision to build using only organic materials.

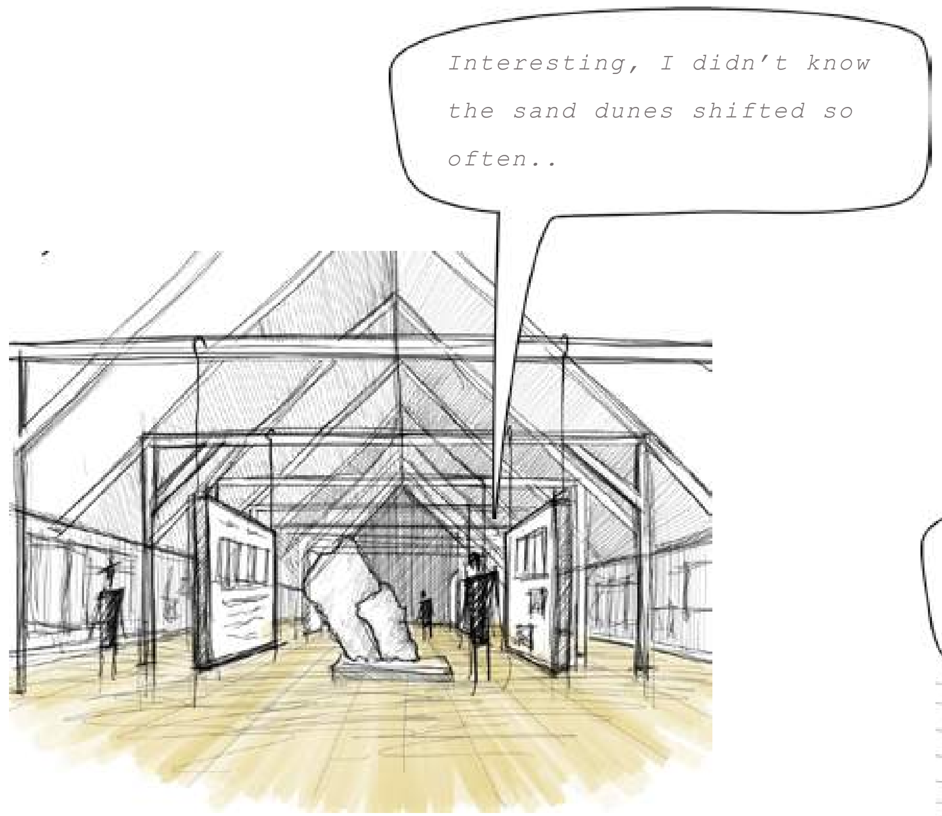


FIG. 66- Dark exhibition space

FIG. 67- Cafe space

FIG. 68- Light exhibition space

FIG. 69- End of exhibition space

07.07 detailing spaces.

envisioning different atmospheres

EXHIBITION EXPERIENCE

The user group study has until now clarified the needed functions of this centre, based on studies of similar existing cases. Although the case studies have provided information to map the functions and create plan layouts, the studies do not talk about how to create the right atmosphere, nor how to ensure that the centre and its content will have the influence on its visitors, as it is designed to. To ensure long-term memories and detail the museum experience, it is important to understand how it is influenced by various (design) factors.

Multiple studies of the museum experience have been conducted over time resulting in, for example, a description of the average museum visitor. However, the museum experience cannot be transferred to "an average." In fact, the museum experience is much more dynamic, and can be different for the same person on two different days. The reason, is that the visitor's motivation to go to the museum, is highly related to the post-visit experience. The motivation tends to be self-reinforcing, and the different identities can be categorised into:

EXPLORERS
People who have a general curiosity in the content of the museum. Explorers enjoy wandering and bumping into new exhibitions.

FACILITATORS
People who focus on the experience of others. Parents are therefore typically in this category.

PROFESSIONALS/HOBBYISTS
People who have a (un-)professional passion of the museum content. They are also typically people who would sign up for lectures.

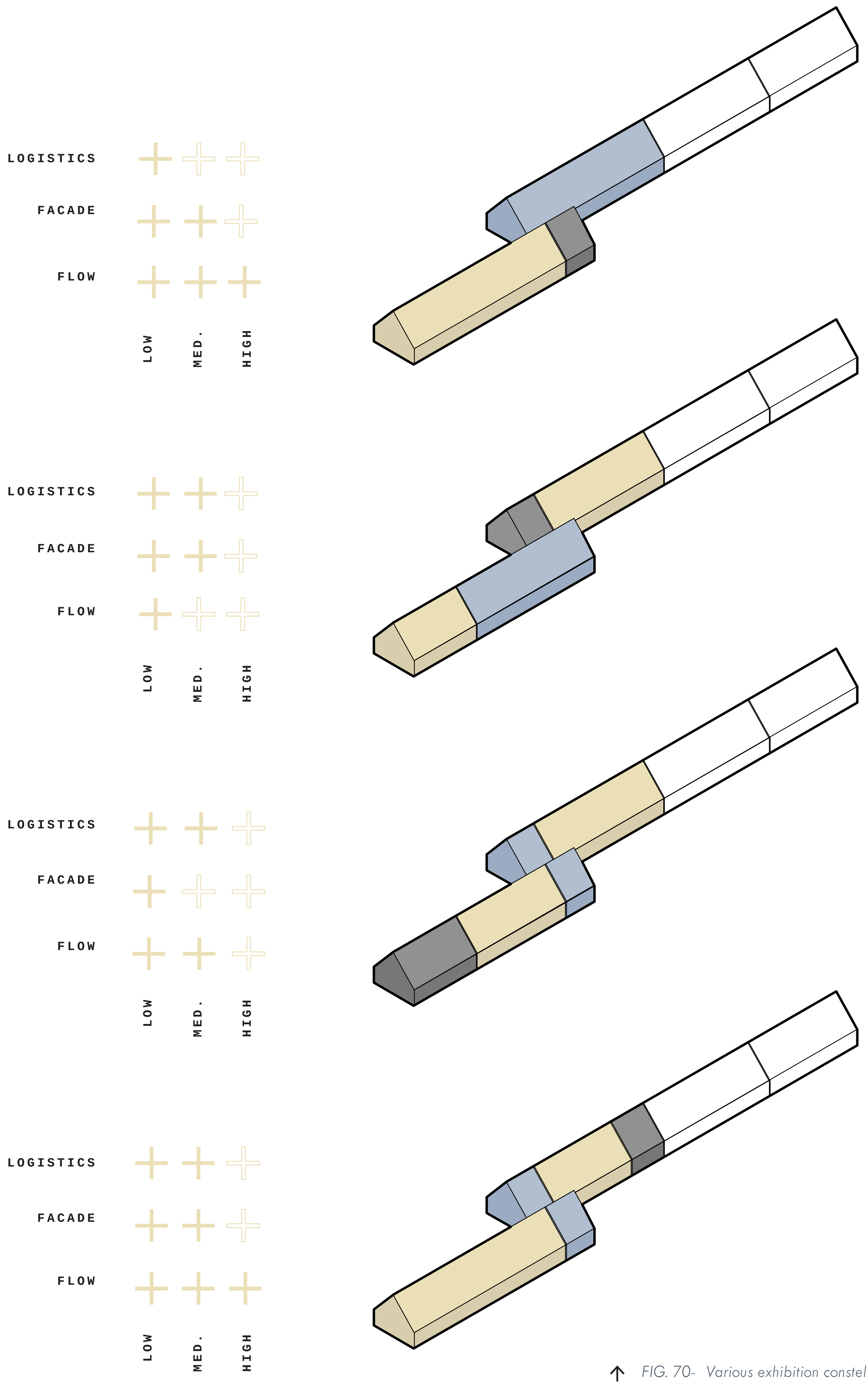
EXPERIENCE SEEKERS
People who see the museum as an important destination and to have "been there done that". Experience seekers value an enjoyable day highly.

RECHARGERS
People who see the museum as a refuge to have a restorative experience.
(Falk, 2006)

These users clarify a list of spatial demands, some of which that support already implemented functions based on previous analyses, such as a flexibility in the plan to facilitate lectures and the like, and a café to ensure an enjoyable visit. In extension, this study has highlighted a non-defined exhibition flow, various exhibition experiences and a place for contemplation as prominent features to accommodate all users.

Despite the different user categories, four factors are crucial to influence what is remembered from the museum visit. The first is things that support the visitors' motivation and interests, second and third are novel and things that have high emotional content for the individual, meaning experiences through exhibitions and things they interact with. Lastly are things that are supported by later experiences such as conversations, tv-shows or news articles (Ibid).

The four factors help defining atmospheres throughout the centre, as for example both dark and light exhibition spaces can awaken the senses and add to the museum experience. An in-house laboratory can contribute with new findings within the field of climate change, making the centre more attracting for both professionals and others. Lastly, a space for conversation about the exhibition content seems crucial to maximize the post-visit intended outcomes for all users.



flexible exihibtion
dark exhibition space
light exhibition space
core & administration

FIG. 70- Various exhibition constellations

CRITERIA:

LOGISTICS

The closer the flexible exhibition to the main access on the southeast side the better, for large pieces to easily enter the building. Easy transition between the various exhibition spaces is also optimal, preferring uninterrupted exhibition spaces.

FACADE

Considers views out and amount of daylight compared to the desired atmospheres. For example, unobstructed views for the light exhibition, lesser amounts of daylight in the dark exhibition space, etc.

FLOW

Focuses on awakening the sense and experience of the journey through the exhibition.

07.08 influencing flow.

examining various constellations

FULLY FLEXIBLE? Considering flow and the way in which the visitor moves through the building is vital when opting for an exhibition that leaves the visitor with a lasting impact and experience. Therefore, various compositions of the three main exhibitions spaces, light exhibition, dark exhibition, and flexible exhibition have been initiated and weighed against different criteria (see fig.70). However, during this process, the different constellations had such diverse advantages and complications, and it was therefore difficult to decide on one specific constellation. This raised the question of 'what if there didn't need to be a specific constellation, and the exhibition could be fully flexible?' This would grant the workers of the center a flexibility in which they themselves could decide the placement and layout of the different exhibition spaces providing them with an easy possibility of moving the different exhibition spaces around. If a dark space is needed for, for example videos or specific showcases, boxes which are easy to assemble and disassemble can be quickly built between the existing structure, initiating a simple transition and freedom.

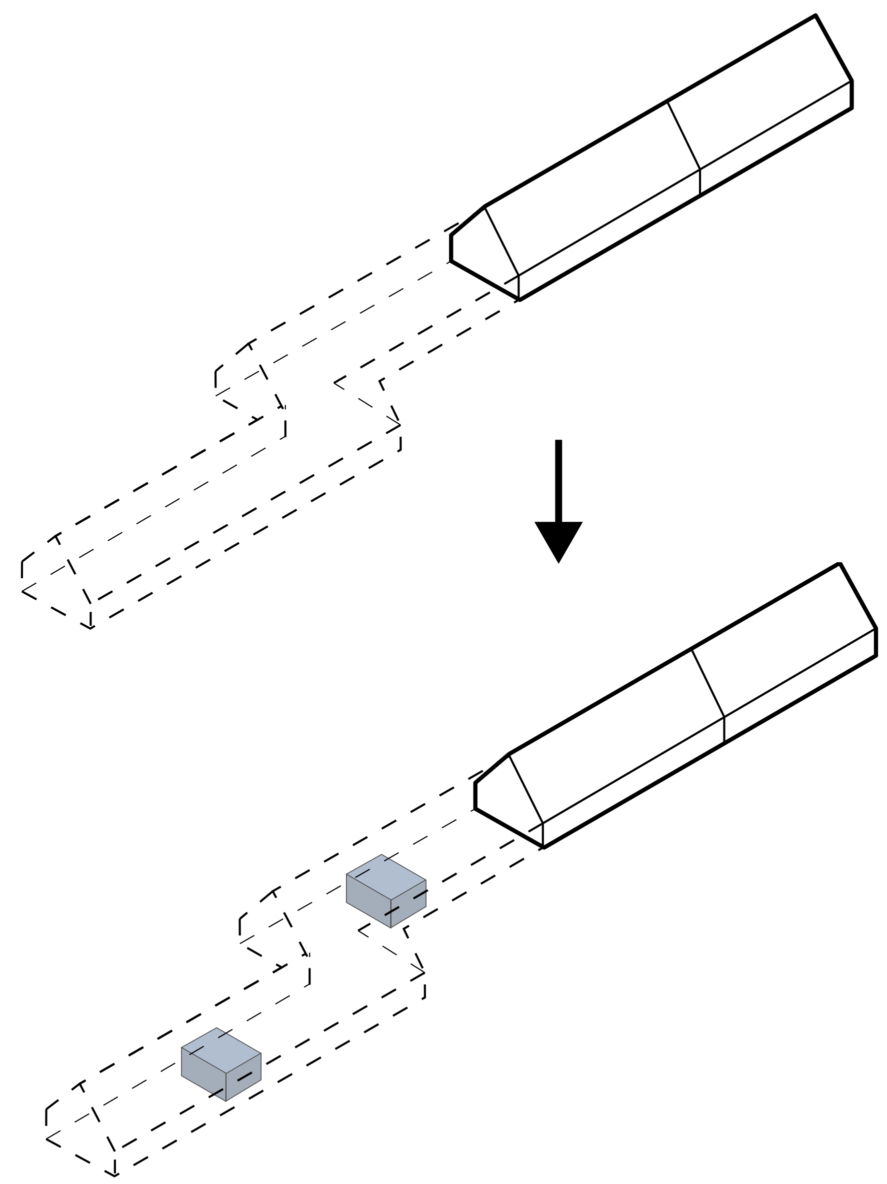


FIG. 71- Flexible exihibition

CHOSEN INTERIOR MATERIALS

FIG. 72- *Material composition 01*

CLAY PLASTER FLOOR, WOODEN CEILING, CLAY WALLS

The first iteration features the use of clay as a plaster and flooring combined with wood on the ceiling. The use of clay on the floor provides depth and acoustical properties to the room together with the clay plaster which is painted white on the walls. Clay also has high thermal mass, which is useful with passive heating in the building. The clay on the floor needs a lot of maintenance due to lack of durability and the color of it makes the distribution of the light difficult.

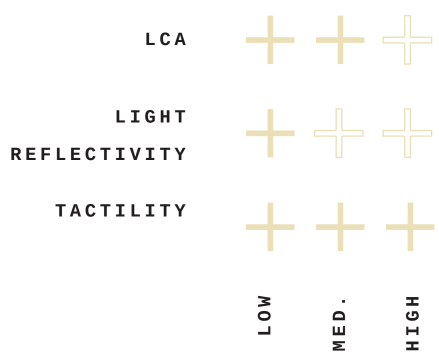


FIG. 73- *Material composition 02*

WOODEN FLOOR, WOODEN CEILING, CLAY WALLS

Similar to the first iteration, the second composition combines wooden flooring and ceiling with clay plastered walls. The substituted wooden flooring provides direction, leading the visitor through the exhibition space to the end of the room with the view out to the dunes. The acoustics of the wooden flooring provide a more haptic experience, relating to the traditional Danish houses.

07.09 materiality.

contemplating varied material compositions

PRELIMINARY Materiality encourages engagement through various senses and contributes immensely to the experience of a building. The activity in a room and the size of it have a high impact on the acoustics. Natural materials often have a tactility that absorbs sounds well, making it easier to have uninterrupted communication (Indeklimaportalen.dk, 2020). Simultaneously the appropriate choice of materials affects the overall life cycle of the building, and therefore both the aesthetic and environmental aspects have been used as the main validating factors. Hence, various material compositions have been examined through collages in photoshop, whilst the sustainable properties have been calculated in LCA and can be seen on page 70-71.

FIG. 74- *Material composition 03*

WOODEN FLOOR, WOODEN CEILING, WOODEN WALLS

The third iteration includes wood on all surfaces, creating an eminently warm environment. The wood on the ceiling provides extra height to the room through sense of scale, adding texture. In terms of design for disassembly the wood panels provide easy access and can be replaced. There is however not great contrast in materiality, and therefore does not accentuate where walls begin and end, leaving the atmosphere monotonous.

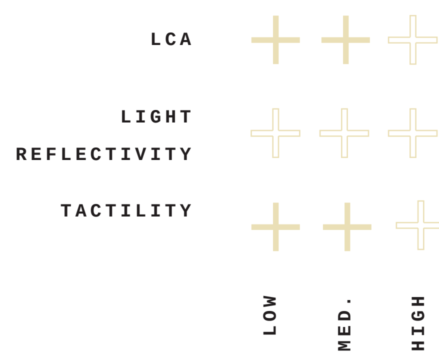
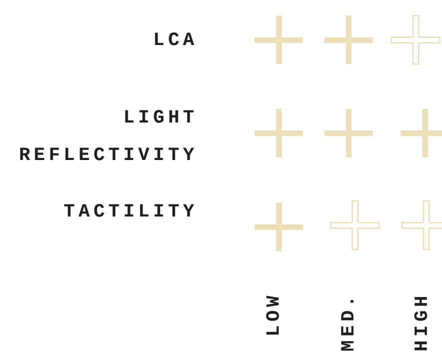


FIG. 75- *Material composition 04*

WOODEN FLOOR, WHITE CLAY RENDER CEILING, WHITE CLAY RENDER WALLS

Inviting in an extensive amount of daylight, the last iteration consists of light wooden flooring and white clay render ceiling and walls. Having such light surfaces does create a vast contrast to the warm exterior, however does not benefit the interior atmosphere, generating a more clinical perception, rather than a natural, raw one.



WITHOUT SKYLIGHT

Prior to adding skylight, the model has a total energy consumption of 42 kWh/ m^2 year. There are areas where the building does not reach the 3% daylight requirement, for example in the office area, where the average is 1%.

Be18 results:
Total energy consumption:
(42 kWh/ m^2 year)

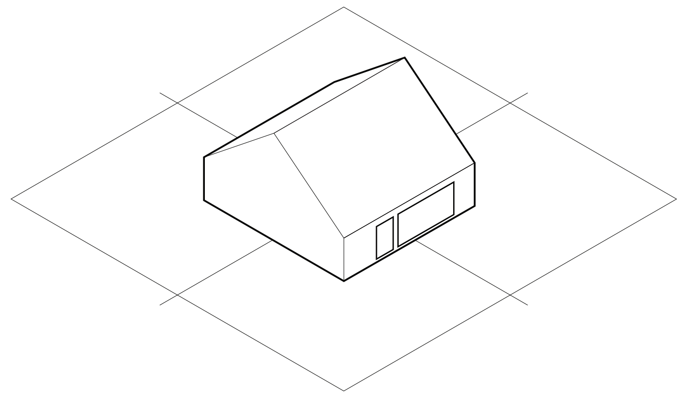


FIG. 76- Base model

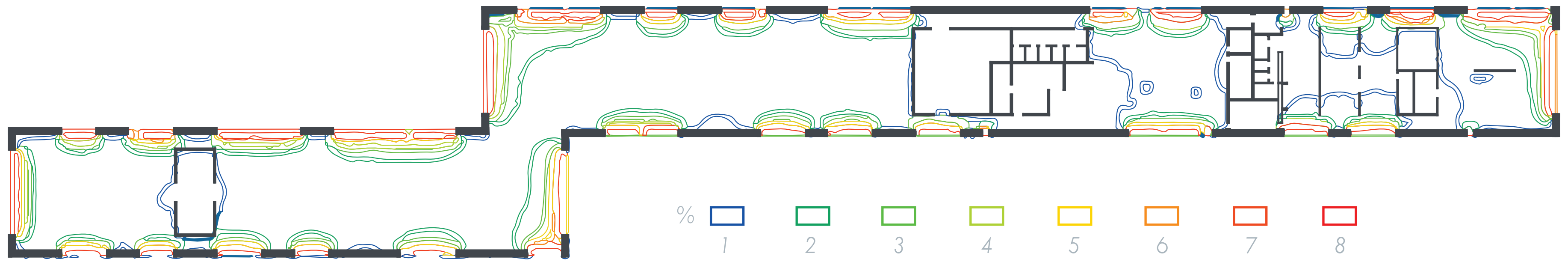


FIG. 77- Daylight analysis

WITH SKYLIGHT

Although adding skylights facing towards North increases the total energy consumption due to cold bridges, it is evident in the daylight analysis that it contributes positively towards the natural daylight factor in the building. For example, in the office space without skylight, the average daylight factor is around 1%, thus not fulfilling the minimum requirement of 3%. Here the skylight allows the average daylight factor to reach 6%, creating a more optimal workspace.

Be18 results:
Total energy consumption:
(45,3 kWh/ m^2 year)

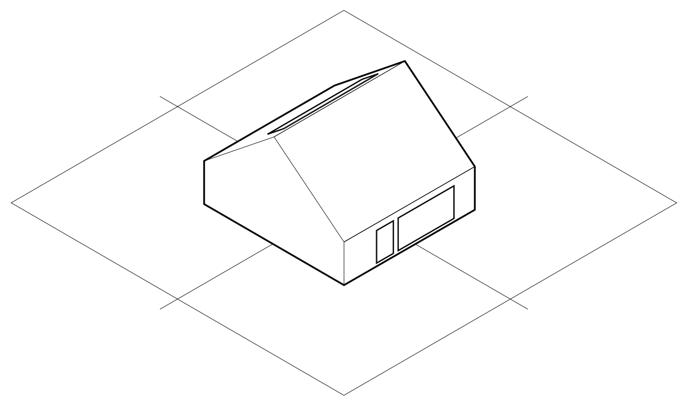


FIG. 78- Added skylight

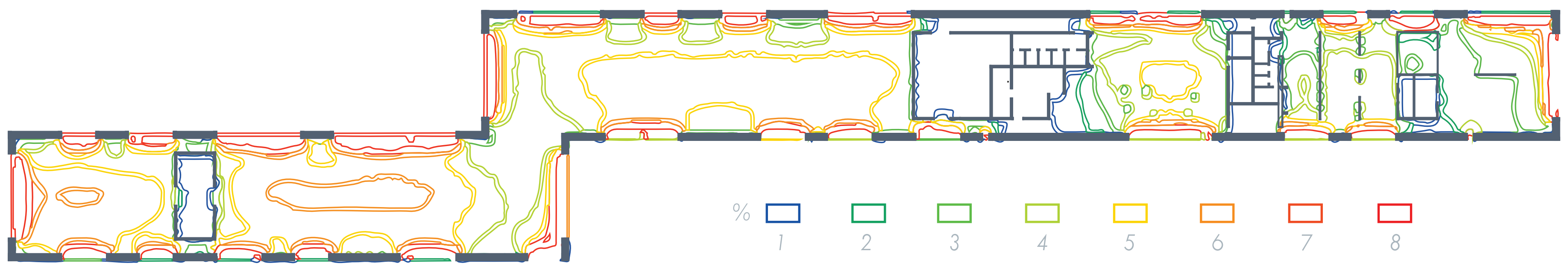


FIG. 79- Daylight analysis

07.10 indoor comfort.

providing an optimal indoor experience

PRELIMINARY

This building strives to reach zero energy standard, whilst ensuring an optimal indoor environment. The Danish building regulations set a minimum requirement for mechanical ventilation (Bolig- og Planstyrelsen, 2018) and thus can't be avoided. To minimize the need for mechanical ventilation, natural ventilation is introduced. Calculations of both mechanical and natural ventilation can be found in appendix 09.03 and 09.04 together with a ventilation plan.

30° CEILING

Two materials are considered as the exterior material: reeds and wood. A roof with wood as exterior material does not have any requirements as to what number of degrees the roof should be angled. The indoor comfort analysis clarifies a substantial number of overheated hours whereas the Danish building regulations have set a requirement of 100 hours above 26 degrees and 25 hours above 27 degrees (Bolig- og planstyrelsen, 2018).

Bsim results exhibition:
(hours > 26: 367)
(hours > 27: 263)
(hours < 20: 525)
Bsim results: office:
(hours > 26: 164)
(hours > 27: 75)
(hours < 20: 2327)

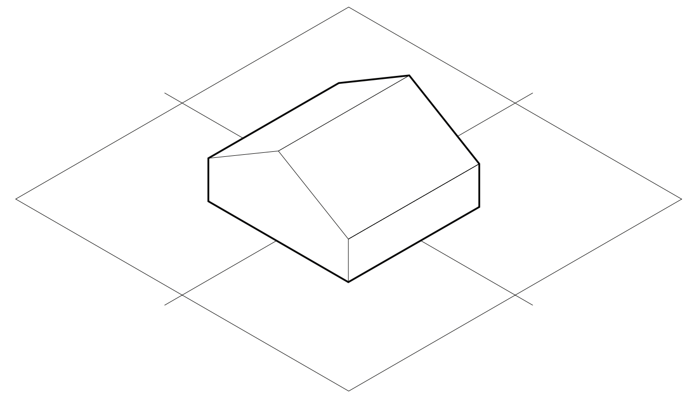


FIG. 80- Material composition 04

45° CEILING

Using reeds as the roof material requires an angle of 45 degrees, to have an optimal rainwater run-off and thereby also lifetime of the material (Vedsted-Jakobsen and Schmeichel, 2019). The angle results in an increased volume of the interior space, which benefits the indoor comfort, as the number of overheated hours is lowered. However, it should be stated that the number of hours above 20 degrees are lowered as well.

Bsim results exhibition:
(hours > 26: 207)
(hours > 27: 134)
(hours < 20: 1192)
Bsim results: office:
(hours > 26: 257)
(hours > 27: 133)
(hours < 20: 978)

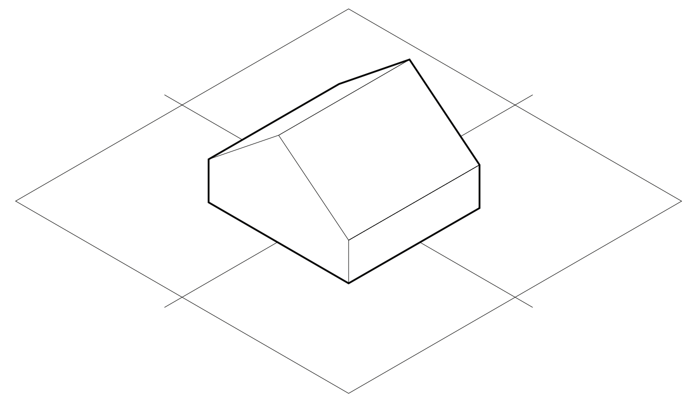


FIG. 81- Material composition 04

ADDING NATURAL VENTILATION

To decrease the overheated hours further, natural ventilation is applied to avoid increasing the energy usage. The natural ventilation reduces the overheated hours significantly, however not to the extent required by the building regulations. To reach the regulations changes to the façade such as overhangs, and shutters are tested in combination with a visual expression study.

Bsim results exhibition:
(hours > 26: 93)
(hours > 27: 50)
(hours < 20: 617)
Bsim results: office:
(hours > 26: 104)
(hours > 27: 57)
(hours < 20: 2349)

Be18 results:
Total energy consumption:
(39,5 kWh/ m^2 year)

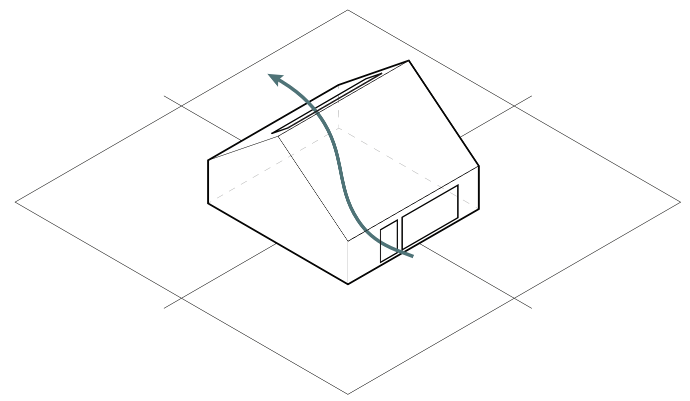


FIG. 82- Material composition 04

CHOSEN SECONDARY FACADE

FIG. 83. Facade 01

WOOD CLADDING & REED ROOF

The combination of a thatched roof and a wooden façade creates a dynamic expression. The wooden cladding stands in contrast to the window and the thatched roof, which is natural in tone and has depth combined with volume that stands out. This solution gives a quality that clearly separates the two entities that define the face of the building, through texture and the overhang that the roof provides. The use of wood cladding also provides easy use and maintenance, as each piece of wood can be separated and treated if damaged.

LCA
DESIGN FOR DISSASSEMBLY
MAINTENANCE
LIFETIME
LOW MED. HIGH

FIG. 84. Facade 02

REED CLADDING & REED ROOF WITH OVERHANG

This iteration features an overhang that provides protection to the façade. It also gives the roof more weight and separates the roof from the wall even though the roof and wall have the same material cladding. This solution challenges the form of the building as the context is wind dominated, which can cause the wind to catch the overhang and apply pressure to construction. The straw material is a natural material that grows in salty area and thereby has natural protection against it, enforcing a link to the context that the building is placed in.

LCA
DESIGN FOR DISSASSEMBLY
MAINTENANCE
LIFETIME
LOW MED. HIGH

CHOSEN MAIN FACADE

FIG. 85. Facade 03

REED CLADDING & REED ROOF

By removing the overhang and continuing the same cladding from roof onto the wall, the problem concerning the wind in minimized. The architectural expression is here a united element that defines the façade. The use of thatch on the wall gives the façade a different dimension and a connection to the elements and vegetation that inhabit the landscape. The reeds grow fast and in abundance, and as they grow absorb a lot of carbon dioxide which makes the material an ideal way to combat the climate crisis we now face.

LCA
DESIGN FOR DISSASSEMBLY
MAINTENANCE
LIFETIME
LOW MED. HIGH

07.11 facades.

materializing the outer shell

PRELIMINARY Various versions of facade claddings were created to provide an understanding of the aesthetic outcome, and its relation to the context. In addition, the main criteria considered were the performance in LCA, ease of design for disassembly, maintenance, and lifetime of the materials.

FIG. 86. Facade 04

WOODEN SHINGLES & REED ROOF

Combining reeds on the roof with wood shingles was also a solution that gave the façade a dynamic expression. The wood shingles protect the wood from rainwater which reduces the need for maintenance and thereby provides the façade with a longer lifespan. Together with the reed on the roof this solution gives a heavy expression that stands in contrast to the form of building.

LCA
DESIGN FOR DISSASSEMBLY
MAINTENANCE
LIFETIME
LOW MED. HIGH

FIG. 87. Facade 05

HORIZONTAL WOODEN ROOF & CLADDING

This iteration of the façade is made entirely of wood. The wooden roof is smaller and weighs less than a reed roof and has a longer lifespan depending on the treatment of material. Wood is also particularly good in terms of design for disassembly as the need for maintenance can easily be applied. In this case the wood elements are placed horizontally and overlap each other, functioning as a protection against rainwater and the strong wind.

LCA
DESIGN FOR DISSASSEMBLY
MAINTENANCE
LIFETIME
LOW MED. HIGH

FIG. 88. Facade 06

VERTICAL WOODEN ROOF & CLADDING

The vertical wood cladding is also an option that is easy to replace and maintain in term of design for disassembly, and here the form of building is enhanced by the verticality of the cladding. Opposite to the horizontal cladding the vertical elements give the façade a lighter expression that is desirable as the building is placed on poles. The wooden façade also changes over time and depending on the sort of the wood, a change in color and patina can give a value to the façade.

LCA
DESIGN FOR DISSASSEMBLY
MAINTENANCE
LIFETIME
LOW MED. HIGH

07.12 exterior expressions.

revitalizing the external composition

ASSESSING DIFFERENT EXPRESSIONS

Striving towards a welcoming center which harmonizes with the surroundings, investigations of various facade expressions were undertaken, concentrating on windows, shading, and entrance styles. For an integrated approach, the different investigations considered both the aesthetic aspect, as well as the technical aspect, focusing on indoor comfort and materiality. Indoor comfort calculations in BSim were initiated for the shading, concluding in side fins for the exhibition spaces, and shutters for the office area. Various versions of shutters were visualized in photoshop to understand the aesthetic facet, in which sliding shutters in wood on the exterior of the facade were chosen. The entrance was chosen in terms of the most welcoming and optimal transition, whilst the skylight windows the most subtle and complimentary to the overall form.

CHOSEN ENTRANCE

ENTRANCE

FIG. 89- Entrance versions →

WOOD AND REED ON INTERIOR, GLASS ON INTERIOR

WOOD ON EXTERIORS, GLASS ON INTERIOR

REED ON EXTERIOR, GLASS AND WOOD ON INTERIOR

CHOSEN SHADING

SHADING

FIG. 90- Shading versions →

FOLDING WOODEN SHUTTERS

INTEGRATED INTO REED FACADE

PLACED BEHIND REED FACADE

CHOSEN SKYLIGHT

SKYLIGHT

FIG. 91- Skylight versions →

CIRCULAR WINDOWS

VERTICAL BANDS

HORIZONTAL BANDS

SIDEFINS - EXHIBITION

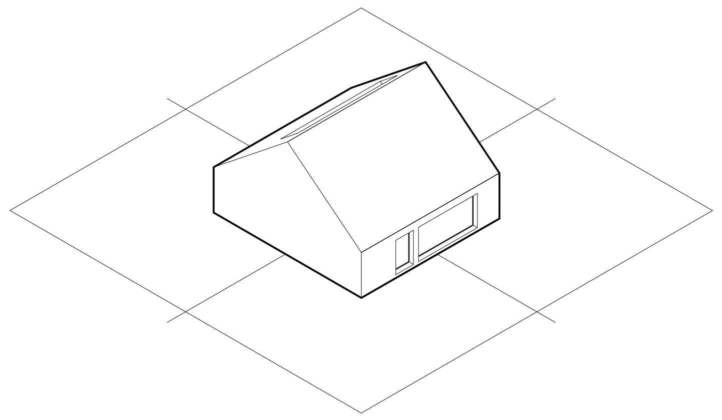


FIG. 92- Adding sidefins to exihibition space ↑

Bsim results exhibition:
(hours > 26: 62)
(hours > 27: 25)
(hours < 20: 718)
Bsim results: office:
(hours > 26: 104)
(hours > 27: 57)
(hours < 20: 2349)

Be18 results:
Total energy consumption:
(40 kWh/ m^2 year)

Applying reeds to both roof and façade provides the windows with an overhang and sidefins with the thickness of the reeds. While this solution proves to be sufficient in the exhibition area, the requirements are not obtained in the office.

ADDING SHUTTERS - OFFICE

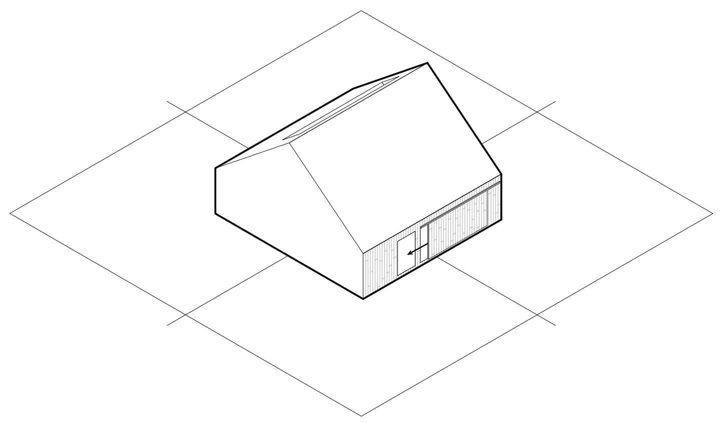


FIG. 93- Adding shutters to office area ↑

Bsim results: office:
(hours > 26: 59)
(hours > 27: 25)
(hours < 20: 1725)

Be18 results:
Total energy consumption:
(37.2 kWh/ m^2 year)

To obtain the requirements in the office area, the reeds façade is exchanged with a wooden façade, making shutters that are a discrete addition to the façade possible. The shutters lower the overheated hours to obtain the requirements and in addition, by making the shutters insulated, the increased insulation to the construction lowers the heat loss at night which solves the issue of hours below 20 degrees.

07.13 active strategies.

reducing overall energy usage

AIR-TO-AIR PUMPS

Air-to-air pumps are easy to install and assemble / disassemble but they require a lot of maintenance and are noisy. Additionally, the aesthetic aspect must be considered, as they are quite visible both on the interior and the exterior as multiple pumps would be necessary.

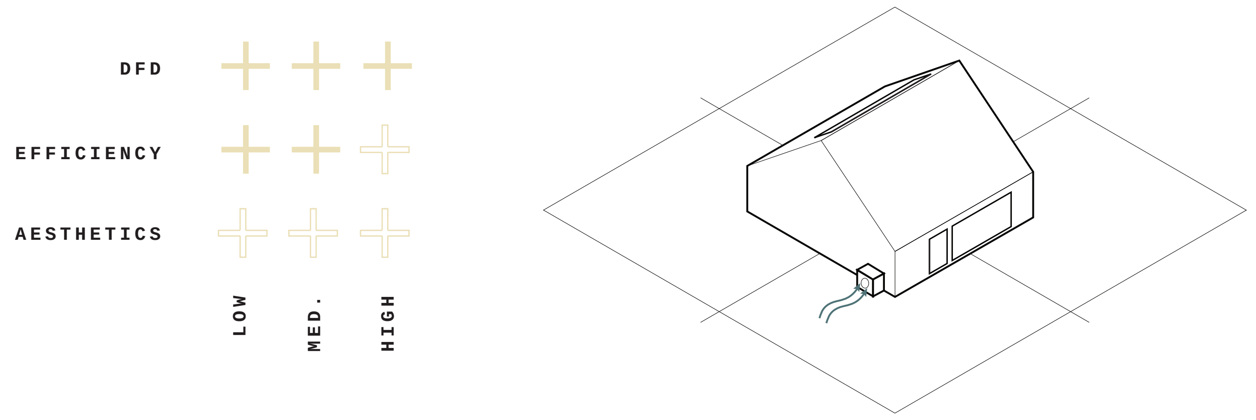


FIG. 94- *Air-to-air heat pump*

THERMAL HEAT COLLECTORS

Solar thermal collectors require the right position according to the sun and plenty space on the roof. They depend on the constant change of weather and are inefficient when the sun is not shining, where an additional system would be nescessary to provide energy.

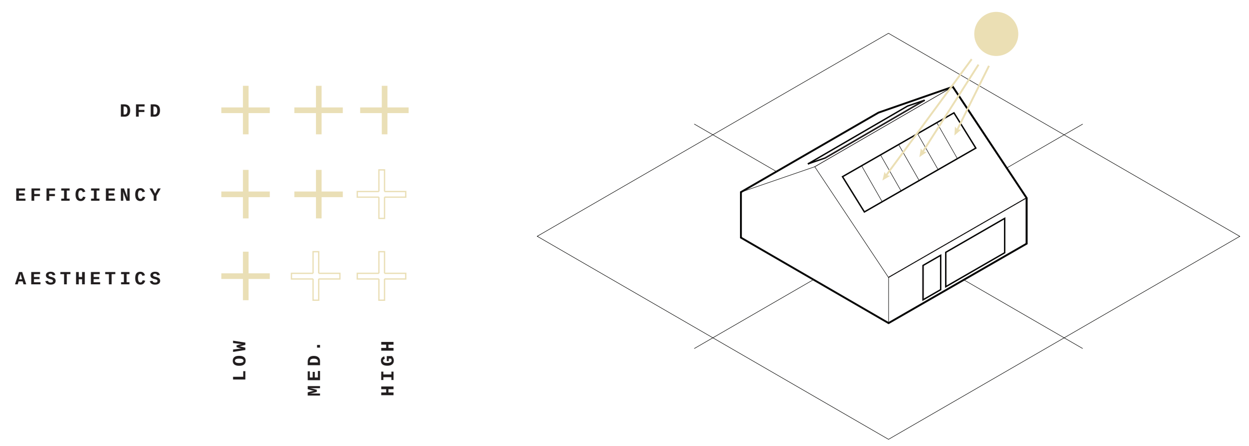


FIG. 95- *Thermal heat collectors*

GROUND SOURCE HEAT PUMPS

Ground source heat pumps withdraw heat from the ground through fluid filled pipes buried underground. The heat can be used for radiators, underfloor or warm air heating systems and hot water. The pipes can either be horizontal or vertical. Installing the pipes requires digging from a few meters up to 100 meters under the surface depending on the choice of horizontal or vertical pipes, affecting both the nature and the ease of disassembly. (energysavingtrust, 2020).

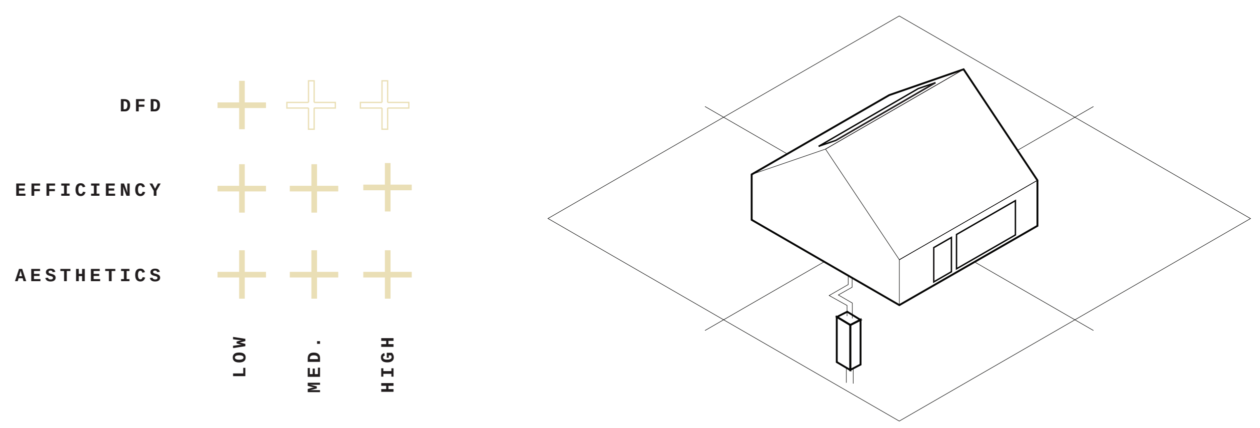


FIG. 96- *Ground source heat pumps (vertical)*

CLIMATE MITIGATION THROUGH ACTIVE STRATEGIES

Blokhus is placed on the outskirts of the town, and it is therefore beneficial to consider different active strategies to supply the center with renewable energy and heating. Accordingly, a quick investigation into the assorted technologies that are available, and their advantages and consequences has been made. Several factors such as aesthetics, efficiency, sustainability, and design for disassembly have been taken into consideration to reach the decision of using horizontal ground source heat pumps and solar panels, and their effect on the total energy consumption have been calculated in Be18.

ADDING HEAT PUMPS

Ground source heat pumps, either horizontal or vertical are considered the optimal solution regarding both efficiency and aesthetics bringing the energy requirements from the earlier iteration of 20.9 kWh/m^2 per year to -4.1 kWh/m^2 per year. However, it is important to consider that the pumps need to be dug into the ground, removing some of the delicate nature in Blokhus. Therefore, the pumps have been placed right underneath the already dug up road leading up to the building, minimizing the amount of destruction.

Be18 results:
Total energy consumption:
(20.9 kWh/ m^2 year)

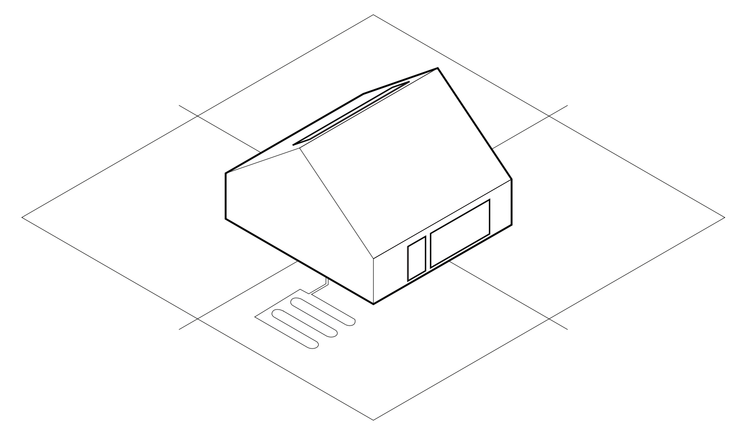


FIG. 97- *Ground source heat pumps (horizonal)*

ADDING SOLAR PANELS

Considering climate mitigation, solar panels have been implemented facing south. The solar panels cover 70m^2 of the southern facing roofs, and reduce the energy requirements from the earlier iteration of 20.9 kWh/m^2 per year to -4.1 kWh/m^2 per year. Monocrystalline solar cells are the chosen type as they are the most efficient, and due to their simple expression and colour. In terms of aesthetic considerations, the solar panels are built into the thermal envelope.

Be18 results:
Total energy consumption:
(-4.1 kWh/ m^2 year)

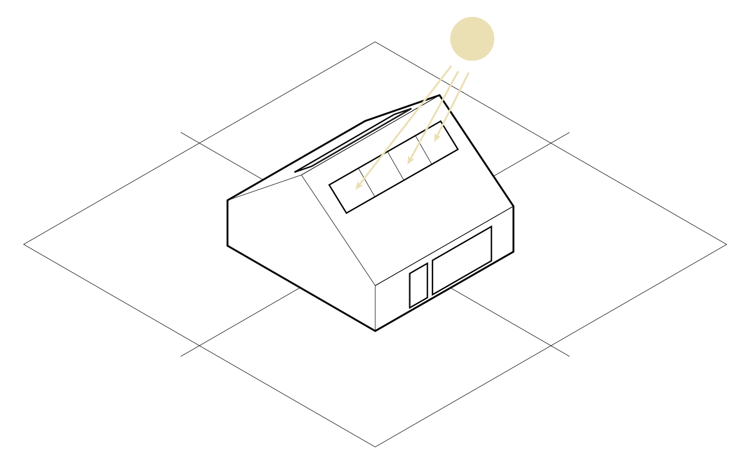


FIG. 98- *Solar panels*

07.14 conclusion.

a visitor centre of climate change

'Duneside' has been designed to push the limits of sustainable constructions and inspire towards a sustainable direction. The project is located at the Danish west coast, a place known for being exposed to strong winds and a distinctive nature, which have been taken into consideration in building design and placement. A building that teaches climate change and how to adapt to be more sustainable, should be just that. Working with climate adaptation has raised the building on pillars in order to minimize the physical impact on the surrounding nature, which also clarified a great contrast between the geometric shape of the building and the soft dune landscape, which in result emphasises both. Awareness of atmospheres and environmental characters, and how the building relates to it, have been a general theme throughout the project. Including life cycle assessments at various stages, both as preliminary research and in the following design process, clarified the environmental benefits of building with exclusively natural and local materials.

The focus upon building materials environmental impacts, was included as a tool to work with climate mitigation, just as the building has been adjusted to fit zero energy standard whilst still providing an optimal indoor environment for its users. The construction of the building roots in Danish building tradition with a visible construction that defines spaces in-between. As the material theory emphasised design for disassembly to be an important aspect of climate adaptation, the building has been designed with reversible connections making it possible to relocate the building or disassemble each material layer from another, providing the opportunity to dispose or recycle each material best possible. The natural materials not only benefit the climate, but is in harmony with the surrounding nature, and can be returned to the ecosystem, making the building an integral part of its context both now and in the future. Building with exclusively natural, non-chemical, materials doesn't compromise with architectural quality, and this project exemplifies how they can contribute to the architecture, through a building that uses traditional principles, that combined with the advantages and tactility of the local materials, gives a modern architecture that points towards the future.

Inspiring towards sustainable choices, is the very essence of the climate centre. Thus, the centre facilitates an exhibition area where visitors can find both light and dark exhibition spaces that inform and motivate to shift behavioural intentions to be more climate friendly. The exhibition area is designed to be flexible, as it is an open space that can be divided into smaller areas in-between the construction elements. The different settings have been implemented, as research clarified how various experiences that awaken the senses, will increase the impact and ability to recall the information. The exhibition has a non-defined flow, allowing visitors to create each their own experience, just as the flexibility of the space enables the possibility to host events. Several views of the surrounding nature are framed and used in the exhibition and in areas for contemplation as a tool to increase the general appreciation of nature. In extension, the centre provides an office and a laboratory that can facilitate external and in-house research, providing state-of-the-art information of sustainability and climate change to the exhibition.

In lee of the weather, visitors can explore and observe, in a building that with its one-level horizontality, makes it possible for everybody to move through the landscape. 'Duneside' provides its visitors a unique opportunity to experience the dune landscape, from a new perspective.

07.15 reflection.

contemplating our project & process

The Integrated Design Process (IDP) used in this thesis, is an approach that builds a project upon continuous research and analyses that utilise interdisciplinarity. Working on this thesis from an architectural and an engineering point of view, has concluded in a design proposal that builds upon compatibility between the two professions. Due to the global Covid-19 pandemic, this thesis has been written in a primarily digital setting, which has challenged the iterative process. Communicating through online platforms, require detailed information and drawings to avoid miscommunication. The various programs used to perform simulations and analyses throughout the project, fit a digital setting well, whereas analogue sketching has been challenged more. The greatest challenge lies within combining research and analyses with a design proposal, as it is the combination of the two that is the essence of the IDP.

Building with exclusively natural materials has been part of a circular approach, and therefore relates to both environmental impact, relation to site and design for disassembly. In terms of the environmental impact, this thesis bases itself on research articles which provide numerous possible natural materials. However, to evaluate them in relation to each other using a life cycle assessment, EPDs were necessary but difficult to find, narrowing the selection of materials. Natural materials seem to be represented in the field of research, but actual buildings which exemplify such constructions are still few and documentation of their performance can therefore be difficult to find. Nevertheless, the market showed to have quality products of such materials, making them easy to implement in the project. The cost of the materials, which has not been taken into consideration in this thesis, is expected to be of considerable influence and counteract the environmental benefits.

Building with exclusively natural materials has been achieved to a great extent, and the load-bearing construction has been fitted to attain this goal using dowel joints. However, mounting of other materials could have been investigated further, as they are assembled with screws. The screws were implemented as they provided an easy construction and ensured a reversable connection and can be reused, which fits the circular approach. An LCA of the two cases would clarify the better option and should be implemented along with further studies of joints.

The focus upon natural and local materials, resulted in a site-specific architecture using reeds as the primary external material. This choice not only ensured harmony between building and context, but the building benefitted from the environment, as the salty air protects the reeds, and limits the need for maintenance. Despite that using reed requires a certain angle on the roof, which increased the amount of material used, the beforementioned advantages and its locally availability made it the better choice. The benefits of using local materials can however be difficult to implement in the analysis of their impacts, as the data given in the EPD should be adjusted. How the data is adjusted, can be done in numerous ways, and depends on what is implemented in the data. In this thesis, the data has not been adjusted, and the LCA results might be better than what is presented.

The projects impact on its surrounding was also considered in terms of the physical impact, which raised the construction on screw foundation pillars, that can be removed more gently than concrete pillars. During the analysis phase, a problematic of trying to build sustainably occurred, as building in a natural environment would disturb the ecosystem. In extension, it seemed contradicting, trying to increase the appreciation of nature, but placing a building in it. However, as population growth continues to be a problem, building in such environments would eventually become necessary, and this project therefore exemplifies both how to build in such environments and how to adapt to and minimize the impact on our nature. Furthermore, framing such distinctive nature in combination with providing information of climate change, showed to be a tool that could increase the overall impact and goal of this centre, being to inspire towards changing behavioural intentions to be more climate friendly.

Climate adaptation and climate mitigation are two separate ways to work around climate change. This project includes both. The climate centre has been designed to have a load-carrying construction away from the exterior walls, which makes them quite flexible. An issue, that many buildings today face, is overheating caused by the amount of insulation in the walls. The implementation of design for disassembly principles, have made the façade flexible to the extent where the insulation could eventually be adjusted, according to adapt to climate changes. Other ways to prevent overheating is to use shutters and natural ventilation, both strategies that does not consume energy, both strategies that are implemented in the design proposal. These advantages also come with consequences, as shutters also disturb a direct view and the fact that natural ventilation might not be the optimal solution in an exhibition area, as the wind could cause unwanted movement. As an alternative to shutters, an overhang could limit the sun radiation inside the building and provide undisturbed views. However, an overhang was early in the process left out of consideration, as the site can be exposed to fierce winds, and an overhang would make the construction more fragile. Another issue related to not having an overhang is glare which could potentially be a problem. The solution in this project has been to choose wood as the façade material by the office area, which makes implementation of shutters more feasible, and to place the seating area for the café towards the northern façade. Thus, areas where visitors and users are in movement, glare is not considered to be of great inconvenience.

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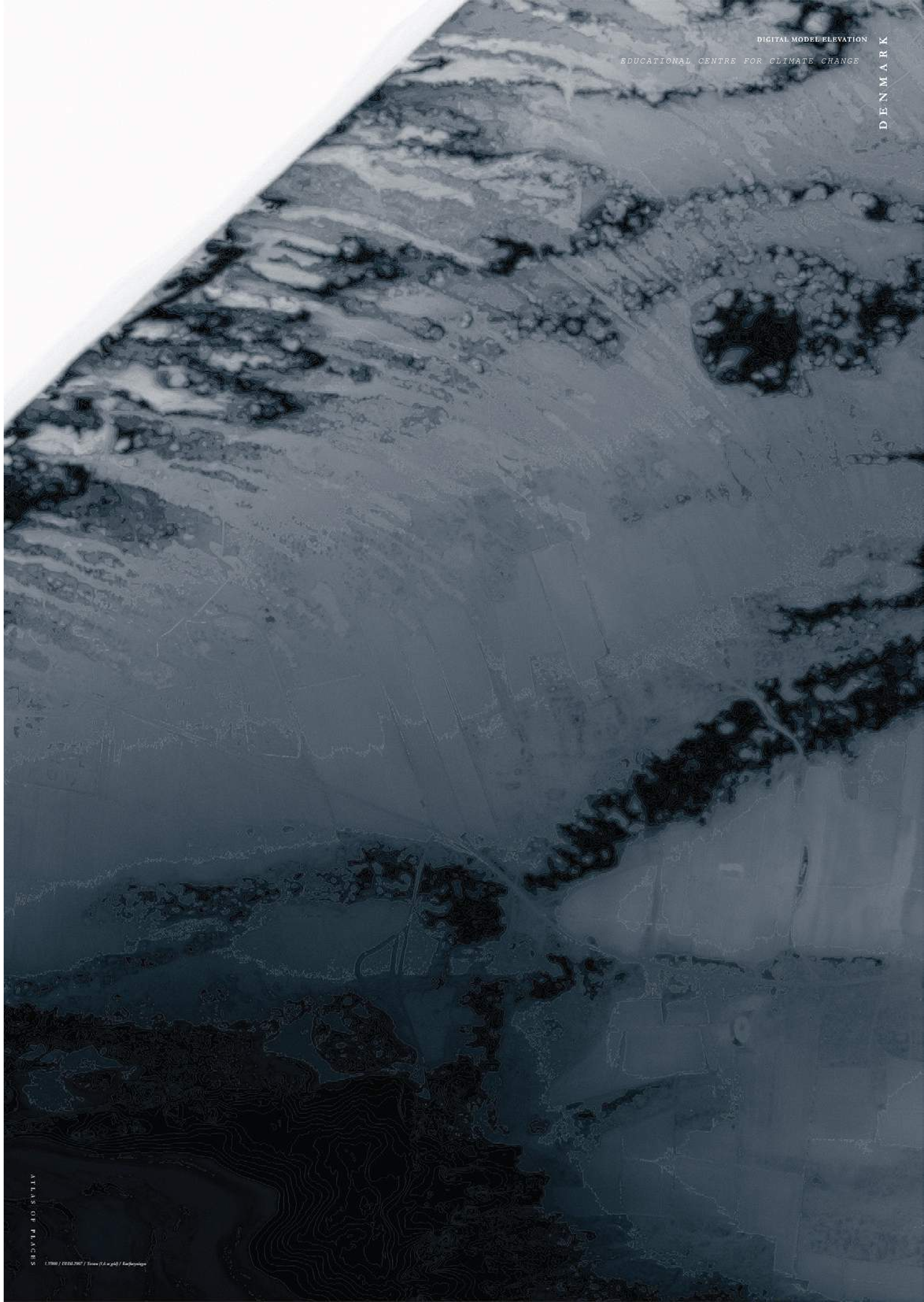

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08.02 illustrations.

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FIG.14 Murcutt, G., (2008). The Marika-Alderton House. [image] Available at: < https://www.ozetecture.org/marika-alderton-house > [Accessed 21 February 2021].

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09 appendix

CONSTRUCTION
LCA RESULTS
VENTILATION RATE
NATURAL VENTILATION

EDUCATIONAL CENTRE FOR CLIMATE CHANGE

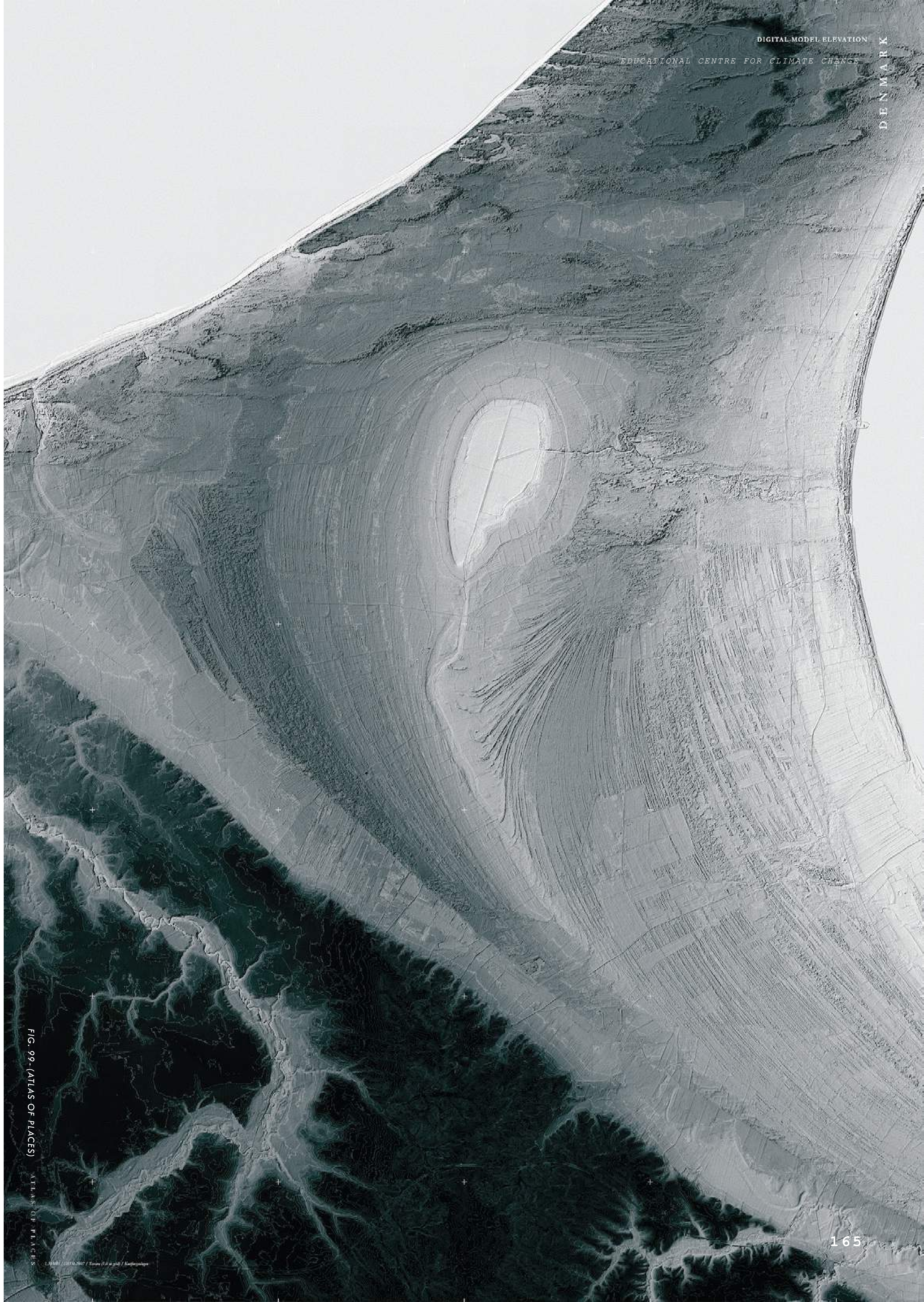

FIG. 99.-(ATLAS OF PLACES)

09.01 construction.

dimensioning of elements

LOADS

The following loads are included in the calculation.

Self-load

$$0{,}5kN/m^2$$

(Gammel, 2010)

Snow load

The snow load is calculated with following formula

$$s = \mu_i C_e C_t s_k$$

(5.1, Dansk Standard, 2015a)

μ_i = shape factor. For roofs with a slope between $30° - 60°$, the shape factor is calculated with following formula:

$$0{,}8 \cdot \frac{60° - \alpha}{30°} = 0{,}8 \cdot \frac{60° - 45°}{30°} = 0{,}4$$

(table 5.2, Dansk Standard, 2015a)

C_e = exposure factor, calculated used following formula:

$$c_e = c_{top} c_s$$

(table 5.1, Dansk Standard, 2015a)

Where c_{top} = topography factor, that can be found in Eurocode 1, table 5.1a.

$$c_{top} = 0{,}8$$

c_s = size factor.
Length of shortest side of building: $15m$
Length of longest side of building: $71m$
Height of building: $10m$

As $l_> \leq 10h \;\; \Rightarrow \;\; 15 \leq 10 \cdot 10$, the size factor can be set to 1.

$$c_e = 0{,}8 \cdot 1 = 0{,}8$$

C_t = thermal factor. This factor is set to 1, according to Eurocode 1, page 52.
s_k = characteristic terrain factor, set to $1{,}0\frac{\mathrm{kN}}{\mathrm{m}^2}$, according to Eurocode 1, 4.1.

The snow load is calculated:

$$s = 0{,}4 \cdot 0{,}8 \cdot 1 \cdot 1kN/m^2 \approx 0{,}32kN/m^2$$

Wind load

The basis windspeed v_b is calculated using following formula:

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$$

(4.1, Dansk Standard, 2015a)

c_{dir} = direction factor, which is set to 1 for wind from a western direction, cf. table 1a Eurocode 1.
c_{season} = season factor, which is set to 1 as the highest value from table 1b, Eurocode 1.
$v_{b,0} = 27m/s$, cf. Eurocode 1, page 75

$$v_b = 1 \cdot 1 \cdot 27m/s = 27m/s$$

The mean windspeed v_m in height z above terrain is calculated with:

$$v_m = c_r \cdot c_0 \cdot v_b$$

(4.3, Dansk Standard, 2015a)

c_r = roughness factor, calculated with:

$$c_r = k_r \cdot \ln\left(\frac{z}{z_0}\right)$$

(4.4, Dansk Standard, 2015a)

z = height of building, which is $6{,}85m$
z_0 = roughness length, found through table 4.1, Eurocode 1.
k_r = terrain factor, dependent on roughness length, and calculated with:

$$kr = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07} = 0{,}19 \cdot \left(\frac{0{,}003m}{0{,}05m}\right)^{0{,}07} = 0{,}156$$

(4.5, Dansk Standard, 2015a)

The roughness factor is calculated:

$$c_r = 0{,}156 \cdot \ln\left(\frac{6{,}85m}{0{,}003m}\right) \approx 1{,}206409$$

c_0 = orography factor set to 1, according to Eurocode 1, page 76

The mean windspeed is calculated:

$$v_m = 1{,}206 \cdot 1 \cdot 27m/s = 32{,}562m/s$$

Then, the wind turbulence intensity l_v, is calculated, using following formular:

$$l_v = \frac{k_l}{c_o \cdot \ln\left(\frac{z}{z_0}\right)}$$

(4.7, Dansk Standard, 2015a)

Where,
k_l = turbulence factor. The recommended value is 1, cf. Eurocode 1 page 80

$$l_v = \frac{1}{1 \cdot \ln\left(\frac{6{,}85m}{0{,}003m}\right)} \approx 0{,}129$$

The peak pressure q_p is calculated with following formular:

$$q_p = (1 + 7 \cdot l_v) \cdot \frac{1}{2} \cdot \rho \cdot v_m^2$$

(4.8, Dansk Standard, 2015a)

ρ = density of air: $1{,}25kg/m^3$

$$q_p = (1 + 7 \cdot 0{,}129) \cdot \frac{1}{2} \cdot 1{,}25\frac{kg}{m^3} \cdot (32{,}562\frac{m}{s})^2 \approx 1261{,}075\frac{N}{m^2} = 0{,}126\frac{kN}{m^2}$$

Now, the wind pressure on the external surfaces can be calculated, with following formular:

$$w_e = q_p \cdot c_{pe}$$

(5.1, Dansk Standard, 2015a)

c_{pe} = shape factor for external pressure, and can be found through table 7.4b, Eurocode 1 for the roof. The shape factor is set to $-1{,}4$, being the highest factor. As the value is negative, the wind load will be negative, and will therefore "help" the construction and should not be included in the load combinations. For the walls, the shape factor is found through table 7.1, and is set to $0{,}7$. The wind load on the façade is:

$$w_e = 0{,}126\frac{kN}{m^2} \cdot 0{,}7 = 0{,}0882\frac{kN}{m^2}$$

LOAD COMBINATIONS

Serviceability limit state (SLS)

$$\sum \gamma_{G,j} G_{k,j} + \gamma_{Q,1} Q_{k,1} + \sum \gamma_{Q,i} \psi_{q,i} Q_{k,i}$$

(6.10, Dansk Standard, 2013)

G = self-load
$Q_{k,1}$ = dominating variable load
$Q_{k,i}$ = additional variable loads
γ = partial coefficient
ψ = Load combination factor

Based on the calculated loads, 4 load combinations are calculated:
1. Self-load
2. Self-load and snow load
3. Self-load, snow load (dominating) and wind load
4. Self-load, wind load (dominating) and snow load

Combination 3 and 4 are only relevant for the column calculation, as the wind load on the roof is not included.

The load is calculated as line loads. Each beam and column have a center-to-center distance of 5m.
Self-load:

$$0{,}5\frac{kN}{m^2} \cdot 5m = 2{,}5\frac{kN}{m}$$

Snow load:

$$0{,}32\frac{kN}{m^2} \cdot 5m = 1{,}6\frac{kN}{m}$$

Wind load:

$$0{,}0882\frac{kN}{m^2} \cdot 5m = 0{,}441\frac{kN}{m}$$

The load combination factors can be found I table A.1.1, Eurocode 0.
For dominating snow load:

$$\psi = 0{,}3$$

For dominating wind load:

$$\psi = 0{,}0$$

The partial coefficients can be found in table A1.2 (B+C), Eurocode 0.
For self-load in load combination 1:

$$\gamma_G = 1{,}2 \cdot K_{FI}$$

K_{FI} is a factor that takes the consequence class into account. This project lies within consequence class 2, which according to table A.1.2 gives:

$$K_{FI} = 1{,}0$$

The partial coefficient for self-load in load combination 2, 3 and 4:

$$\gamma_G = 1{,}0 \cdot K_{FI} = 1{,}0 \cdot 1{,}0 = 1{,}0$$

The partial coefficient for dominating load:

$$\gamma_{Q,1} = 1{,}5 \cdot K_{FI} = 1{,}5 \cdot 1{,}0 = 1{,}5$$

The partial coefficient for additional load:

$$\gamma_{Q,i} = 1{,}5 \cdot \psi \cdot K_{FI}$$

- For dominating wind load: $\gamma_{Q,i} = 1{,}5 \cdot 0{,}0 \cdot 1{,}0 = 0{,}0$
- For dominating snow load: $\gamma_{Q,i} = 1{,}5 \cdot 0{,}3 \cdot 1{,}0 = 0{,}45$

Load combination 1:

$$\sum 1{,}2 \cdot 1{,}0 \cdot 2{,}5kN/m$$

The load is:

$$P_{d.SLS.P} = 1{,}2 \cdot 1{,}0 \cdot 2{,}5kN/m = 3kN/m$$

Load combination 2:

$$\sum 1{,}0 \cdot 1{,}0 \cdot 2{,}5kN/m + 1{,}5 \cdot 1{,}0 \cdot 1{,}6kN/m$$

The load is:

$$P_{d.SLS.K} = 1{,}0 \cdot 1{,}0 \cdot 2{,}5kN/m + 1{,}5 \cdot 1{,}0 \cdot 1{,}6kN/m \approx 4{,}9kN/m$$

Load combination 3:

$$\sum 1{,}0 \cdot 1{,}0 \cdot 2{,}5kN/m + 1{,}5 \cdot 1{,}0 \cdot 1{,}6kN/m + \sum 0{,}45 \cdot 0{,}3 \cdot 0{,}441kN/m$$

The load is:

$$P_{d.SLS.K} = 1{,}0 \cdot 1{,}0 \cdot 2{,}5kN/m + 1{,}5 \cdot 1{,}0 \cdot 1{,}6kN/m + 0{,}45 \cdot 0{,}3 \cdot 0{,}441kN/m = 4{,}96kN/m$$

Load combination 4:

$$\sum 1{,}0 \cdot 1{,}0 \cdot 2{,}5kN/m + 1{,}5 \cdot 1{,}0 \cdot 0{,}441kN/m + \sum 0{,}0 \cdot 0{,}0 \cdot 1{,}6kN/m$$

The load is:

$$P_{d.SLS.K} = 1{,}0 \cdot 1{,}0 \cdot 2{,}5kN/m + 1{,}5 \cdot 1{,}0 \cdot 0{,}441kN/m + 0{,}0 \cdot 0{,}0 \cdot 1{,}6kN/m = 3{,}16kN/m$$

Ultimate limit state (ULS)

$$\sum G_{k,j} + Q_{k,1} + \sum \psi_{0,i} Q_{k,i}$$

(6.14b, Dansk Standard, 2013)

Load combination 1:

$$P_{d.ULS.P} = 2{,}5\frac{kN}{m}$$

Load combination 2:

$$P_{d.ULS.K} = 2{,}5\frac{kN}{m} + 1{,}6\frac{kN}{m} \approx 4{,}1\frac{kN}{m}$$

DIMENSIONING OF BEAMS

In order to determine the dimension of the beams, it is necessary to document the bending strength, shear strength and pressure perpendicular on the fibres in the wood.
To find the forces affecting the beam, the structural analysis program Robot is used. From Robot, following forces are found:

Bending force: $M = 10kNm$
Shear and normal force: $F_z = f_x = 7{,}73kN$
The shear and normal forces are the same, as the roof is angled 45 degrees, and equal forces are found in horizontal and vertical direction.

The bending strength is checked with following formular:

$$\frac{\sigma_{m,d}}{f_{m,d}} \leq 1$$

σ_m = bending stress, and found with:

$$\sigma_m = \frac{M}{W}$$

M was given by Robot.
W = the cross section resisting moment, which for rectangular cross sections are found with:

$$W = \frac{1}{6} \cdot b \cdot h^2 = \frac{1}{6} \cdot 100mm \cdot (225mm)^2 \approx 843750mm^3$$

The bending stress is calculated:

$$\sigma_m = \frac{10 \cdot 10^6 N/mm}{843750mm^3} \approx 11{,}85185\ N/mm^2 = 11{,}85MPa$$

$f_{m,d}$ = the calculated strength of the material which can be found through Teknisk Ståbi page 304 for construction wood C30 (Jensen, 2013).

$$f_d = \frac{f_k \cdot k_{mod}}{\gamma_M}$$

f_k = characteristic strength
k_{mod} = modification factor that takes load duration and the influence of moisture in the construction into account and can be found in Eurocode 5.

- Permanent loads: $0{,}6$
- Short-term loads: $0{,}9$

γ_M = partial coefficient for the material properties, which is found through Eurocode 5, table 2.3.

$$\gamma M = 1{,}35 \cdot \gamma_3$$

$\gamma_3 = 1$, cf. Eurocode 5, page 25

$$\gamma_M = 1{,}35 \cdot 1{,}0 = 1{,}35$$

The calculated bending strength is:

$$f_{m,d} = \frac{30MPa \cdot 0{,}9}{1{,}35} = 20MPa$$

The calculated shear strength is:

$$f_{v,d} = \frac{4{,}0MPa \cdot 0{,}9}{1{,}35} = 2{,}667MPa$$

The calculated strength against pressure perpendicular on the fibres is:

$$f_{c.90,d} = \frac{2{,}7MPa \cdot 0{,}9}{1{,}35} = 1{,}8MPa$$

The bending strength can now be tested:

$$\frac{11{,}85MPa}{20MPa} = 0{,}5925$$

As $0{,}59 < 1$, the beam withstands bending forces.

The shear strength is tested with:

$$\frac{\tau_d}{f_{v,d}} \leq 1$$

Shear in the cross section is found with:

$$\tau_d = \frac{3}{2} \cdot \frac{V_p}{A}$$

The area of the cross section is:

$$100mm \cdot 225mm = 22500mm^2$$

Which gives:

$$\tau_d = \frac{3}{2} \cdot \frac{7{,}73 \cdot 10^3 N}{22500} = 0{,}515MPa$$

The shear strength is tested:

$$\frac{0{,}515MPa}{2{,}66MPa} 0{,}193609$$

As $0{,}19 < 1$ the beam withstands shear forces

The pressure perpendicular on the fibres is tested with;

$$\frac{\sigma_{c.90.d}}{k_{c.90} \cdot f_{c.90.d}}$$

$\sigma_{c.90.d}$ = the calculated compression stress found with:

$$\sigma_{c.90} = \frac{V_d}{A_{vederlag}}$$

The area that the beam and its support have in common is called "vederlaget". The beam is supported by a column with following dimensions: 100x225mm:

$$A_{vederlag} = 100mm \cdot 225mm = 22500mm^2$$

The compression stress is:

$$\sigma_{c.90} = \frac{7{,}73 \cdot 10^3 N}{22500mm^2} \approx 0{,}343556MPa$$

k_c is a factor that takes risk of split and the size of the compression into account. $k_{c.90}$ is set to 1, cf. Eurocode 5 page 39.

The pressure perpendicular on the fibres is tested:

$$\frac{0{,}3435MPa}{1 \cdot 1{,}8MPa} \approx 0{,}1908$$

As $0{,}19 < 1$ the beam withstands compression.

This proves that the beam with cross section 100x200mm in C30 will not break. However, it is also needed to document that it lies within a certain range of buckling.

The max buckling for this construction is found through following expression:

- Permanent loads

$$u_{fin} = \frac{l}{250} = \frac{10{,}5m}{250} = 0{,}042m = 42mm$$

- Variable loads

$$u_{fin} = \frac{l}{400} = \frac{10{,}5m}{400} = 0{,}02625\ m = 26{,}25mm$$

(Table 7.2, Dansk Standard, 2015b)

The deformation of the beam is found through Robot.
The deformation for the permanent load only is: $1mm$
The deformation for load including snow-load is: $23mm$

The buckling is tested:

$$1mm < 42mm$$
$$23mm < 26{,}25mm$$

As both are true, it is concluded that the beam will not exceed the allowed buckling.

DIMENSIONING OF COLUMNS

Finally, the column is dimensioned. As for the beam, the bending and compression stress have to be tested. The forces applied to the column is also found through Robot, and only the bending force and compression parallel to the fibres are relevant.
Bending force:

$$M = 0{,}65kNm$$

Compression force:

$$F_z = \pm 22kN$$

Two types of columns are tested based on the joint investigations. The first is the scenario of one column. The compression stress is found with:

$$\sigma_{c,d} = \frac{F_{c,0,d}}{A_{ef}}$$

The area of the cross section is chosen based on table 7.4 in Teknisk Ståbi, and chosen to have the same width as the beam:

$$100mm \cdot 200mm = 20000mm^2$$

The compression stress is calculated:

$$\sigma_{c,d} = \frac{22 \cdot 10^3 N}{20000mm^2} \approx 1{,}1MPa$$

The bending stress is found with:

$$\sigma_{m,y,d} = \frac{M_d}{W_y}$$

$W_{y,z}$ = the cross section resisting moment in two directions, and found in Teknisk Ståbi for the cross section

$$W_y = 677 \cdot 10^3 mm^3$$
$$W_z = 333 \cdot 10^3 mm^3$$

(table 7.4, Jensen, 2013)

The bending stress is calculated:

$$\sigma_{m,y,d} = \frac{0{,}65 \cdot 10^6 Nmm}{677 \cdot 10^3 mm^3} \approx 0{,}97MPa$$
$$\sigma_{m,z,d} = \frac{M_d}{W_z} = \frac{0{,}65 \cdot 10^6 Nmm}{333 \cdot 10^3 mm^3} \approx 1{,}95MPa$$

As the column has to withstand wind-load affecting the column perpendicular, following must be obtained:

$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$
$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$k_m = 0{,}7$, cf. Eurocode 5 page 39
$k_{c,y}$ is a factor found with:

$$k_{c,y} = \frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}}$$

$\lambda_{rel,y}$ = relative slenderness ratio found with:

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05}}}$$

Where λ_y is the slenderness ratio found with:

$$\lambda_y = \frac{l_s}{i_y} = \frac{l_s}{h} \cdot \sqrt{12}$$

l_s is the critical length of the column
h= height of cross section

$$\lambda_y = \frac{5000mm}{200mm} \cdot \sqrt{12} \approx 86{,}6$$

Which gives:

$$\lambda_{rel,y} = \frac{86{,}6}{3{,}14} \cdot \sqrt{\frac{23MPa}{12000mm^2}} \approx 1{,}21$$

k_y is calculated with:

$$k_y = 0{,}5\left(1 + \beta_c\left(\lambda_{rel,y} - 0{,}3\right) + \lambda_{rel,y}^2\right)$$

β_c is set to $0{,}2$, cf. Eurocode 5 page 44

$$k_y = 0{,}5 \cdot (1 + 0{,}2 \cdot (1{,}21 - 0{,}3) + 1{,}21^2) \approx 1{,}32$$

Which gives:

$$k_{c,y} = \frac{1}{1{,}32 + \sqrt{1{,}32^2 - 1{,}21^2}} \approx 0{,}54$$

The calculated strength is found with:

$$f_{c,0,d} = \frac{f_{c,0,k} \cdot k_{mod}}{\gamma M}$$

k_{mod} is a modification factor taking load duration and moisture into account, and can be found in Eurocode 5.
γM is a partial coefficient taking the type of material into account, and can be found in Eurocode 5 table 2.3:

$$\gamma M = 1{,}35 \cdot \gamma_3$$

$\gamma_3 = 1$, according to Eurocode 5 page 25

$$\gamma M = 1{,}35 \cdot 1{,}0$$

The calculated strength for compression parallel with fibres:

$$f_{c,0,d} = \frac{23MPa \cdot 0{,}6}{1{,}35} \approx 10{,}22MPa$$

For bending:

$$f_{m,d} = \frac{30MPa \cdot 0{,}6}{1{,}35} \approx 13{,}33MPa$$

And finally:

$$\frac{1{,}1MPa}{0{,}54 \cdot 10{,}22MPa} + \frac{0{,}97MPa}{13{,}33MPa} + 0{,}7 \cdot \frac{1{,}95MPa}{13{,}33MPa} = 0{,}37$$
$$\frac{1{,}1MPa}{0{,}54 \cdot 10{,}22MPa} + 0{,}7 \cdot \frac{0{,}97MPa}{13{,}33MPa} + \frac{1{,}95MPa}{13{,}33MPa} = 0{,}40$$

As $0{,}37 < 1$ and $0{,}40 < 1$, the column withstands the loads.

Next, the scenario of two columns on each side of the beam is tested.
The area of the cross section for both columns is:

$$125mm \cdot 125mm = 15625mm^2$$

The compression stress is tested:

$$\sigma_{c,d} = \frac{22 \cdot 10^3 N}{15625mm^2} \approx 1{,}4MPa$$

The bending stress is tested with:

$$\sigma_{m,y,d} = \frac{M_d}{W_y}$$

$W_{y,z}$ = the cross section resisting moment in two directions, which is found in Teknisk Ståbi for the cross section

$$W_{y,z} = 326 \cdot 10^3 mm^3$$

(table 7.4, Jensen, 2013)

The bending stress is tested:

$$\sigma_{m,yz,d} = \frac{0{,}65 \cdot 10^6 Nmm}{326 \cdot 10^3 mm^3} \approx 1{,}99MPa$$

As the column has to withstand wind-load affecting the column perpendicular, following must be obtained:

$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$
$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$k_m = 0{,}7$,
$k_{c,y}$:
The slenderness ratio:

$$\lambda_y = \frac{5000mm}{125mm} \cdot \sqrt{12} \approx 138{,}56$$

The relative slenderness ratio:

$$\lambda_{rel,y} = \frac{138{,}56}{3{,}14} \cdot \sqrt{\frac{23MPa}{12000mm^2}} \approx 1{,}93$$

k_y:

$$k_y = 0{,}5 \cdot (1 + 0{,}2 \cdot (1{,}93 - 0{,}3) + 1{,}93^2) \approx 2{,}53$$

Which gives:

$$k_{c,y} = \frac{1}{2{,}53 + \sqrt{2{,}53^2 - 1{,}93^2}} \approx 0{,}24$$

The ratio is tested:

$$\frac{1{,}4MPa}{0{,}24 \cdot 10{,}22MPa} + \frac{1{,}99MPa}{13{,}33MPa} + 0{,}7 \cdot \frac{1{,}99MPa}{13{,}33MPa} = 0{,}82$$

As $0{,}82 < 1$ the column withstands the loads.
In extension, this ratio is better than the ratio for one column, which means that this solution also has a better utilization of the material.

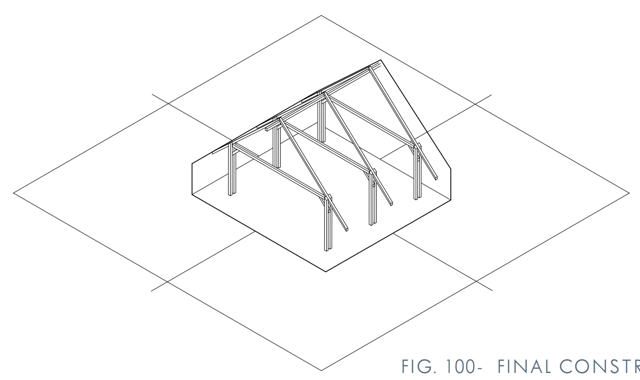

FIG. 100- FINAL CONSTRUCTION

LITERATURE

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Gammel, P. (2010) Statik og konstruktiv forståelse. Ahus: Arkitektskolens Forlag

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09.02 LCA results.

results from the deisgn process

WALL CONNECTIONS

	GWP	ODP	POCP	AP	EP	ADPe	ADPf	Petot	Sek
EcoCocon wall	3,67E-01	1,31E-06	1,09E-03	1,37E-02	4,33E-03	2,81E-04	5,92E+00	-1,86E+00	9,80E-03
Woof fibre wall	1,69E-01	3,25E-09	2,60E-05	4,09E-04	1,06E-04	1,06E-07	3,13E+00	1,58E+00	2,74E-01

FINAL RESULTS

	GWP	ODP	POCP	AP	EP	ADPe	ADPf	PEtot	Sek
DGNB reference	9,19E+00		4,72E-03	2,33E-02	3,15E-03		9,37E+01	3,87E+01	
Building total	9,13E-01	2,10E-08	9,15E-04	2,46E-02	-3,65E-02	1,31E-05	3,56E+01	2,94E+01	6,33E-01
Exterior walls	4,98E-01	6,67E-09	2,72E-04	7,92E-03	-7,85E-03	6,00E-06	1,30E+01	7,31E+00	6,32E-02
Interior walls	5,20E-02	5,97E-13	8,14E-06	5,54E-05	9,30E-06	6,38E-09	8,29E-01	2,43E-01	0,00E+00
Floor	3,38E-01	8,76E-09	4,12E-04	1,27E-03	2,42E-04	1,85E-06	4,85E+00	6,70E+00	2,37E-01
Roof	4,75E-03	5,53E-09	2,20E-04	1,53E-02	-2,89E-02	5,24E-06	1,68E+01	1,50E+01	3,32E-01
Construction	2,05E-02	6,20E-11	2,33E-06	3,62E-05	9,47E-06	9,54E-09	9,46E-02	1,08E-01	0,00E+00

09.03 ventilation rate.

a calculation of mechanical ventilation

VENTILATION RATE SENSORY

The aim for the ventilation rate is to reach category B from the Danish Standard DS/CEN/CR 1752. The following calculation exemplifies how the ventilation rates have been calculated, using the office as an example.

The area of the room: $219m^2$
People in room: 6

To calculate the ventilation rate for sensory comfort, following formula is used:

$$Q_c = 10 \cdot \frac{G_c}{C_{c,i} - C_{c,0}} \cdot \frac{1}{\varepsilon_v}$$

(A.2, DS/CEN/CR 1752)

Q_c = ventilation rate (l/s)
G_c = The pollution (olf)
$C_{c,i}$ = Desired indoor air quality (decipol) set to $1{,}4dp$ cf. table A.5
$C_{c,0}$ = Perceived outdoor air quality (decipol)
ε_v = Ventilation effectiveness

The following loads are used:
People
- $1\ olf/person$

(table A.6, DS/CEN/CR 1752)

Building
- $0{,}1olf/m^2$

(table A.8, DS/CEN/CR 1752)

The perceived outdoor air quality is set to $0{,}01dp$ cf. table 1.7, GKB.
The ventilation efficiency is set to 1.

The ventilation rate is calculated:

$$Q_c = 10 \cdot \frac{6 \cdot 1olf/person + 219m^2 \cdot 0{,}1olf/m^2}{1{,}4dp - 0{,}01dp} \approx 200{,}72l/s$$

This ventilation rate is based upon occupation all hours of the day. In order to take into account that the room is only occupied some hours of the day, the average ventilation rate is calculated. The danish building regulations has set a minimum requirement for ventilation rates to $0{,}3\frac{l}{s}pr.m^2$. The average ventilation rate is calculated:

$$Q_c = \frac{10h \cdot 200{,}72l/s + 14h \cdot (0{,}3l/s\,pr.m^2 \cdot 219m^2)}{24h} \approx 121{,}96\ l/s$$

VENTILATION RATE HEALTH

To calculate the ventilation rate for health following formula is used:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,0}} \cdot \frac{1}{\varepsilon_v}$$

(A.3, DS/CEN/CR 1752)

Q_c = ventilation rate (l/s)
G_h = The pollution (l/s)
$C_{h,i}$ = Desired indoor air quality (ppm)
$C_{h,0}$ = Perceived outdoor air quality (ppm)
ε_v = Ventilation effectiveness

To fulfill the category B, the maximum CO_2 pollution must not exceed 660ppm over the outdoor CO_2 concentration. The typical outdoor CO_2 concentration is $350ppm$ cf. DS/CEN/CR 1752.
The CO_2 pollution caused by humans can be calculated with following formula:

$$q_{v,CO_2} = 17 \cdot M$$

(8.4 Terpager Andersen, Heiselberg and Aggerholm, 2002)

M is the activity level (met), which for office work is set to $1{,}2met$ (DS/CEN/CR 1752)

$$q_{v,co_2} = 17 \cdot 1{,}2met = 20{,}4l/h$$

To fulfill the category B, the maximum CO_2 pollution must not exceed 660ppm over the outdoor CO_2 concentration. The typical outdoor CO_2 concentration is $350ppm$ cf. DS/CEN/CR 1752.
The CO_2 pollution caused by humans can be calculated with following formula:

$$q_{v,CO_2} = 17 \cdot M$$

(8.4 Terpager Andersen, Heiselberg and Aggerholm, 2002)

M is the activity level (met), which for office work is set to $1{,}2met$ (DS/CEN/CR 1752)

$$q_{v,co_2} = 17 \cdot 1{,}2met = 20{,}4l/h$$

The ventilation rate is calculated:

$$Q_h = \frac{6 \cdot 20{,}4l/h}{((660ppm + 350ppm) - 350ppm) \cdot 10^{-6}} \approx 185454{,}5l/h = 51{,}5l/s$$

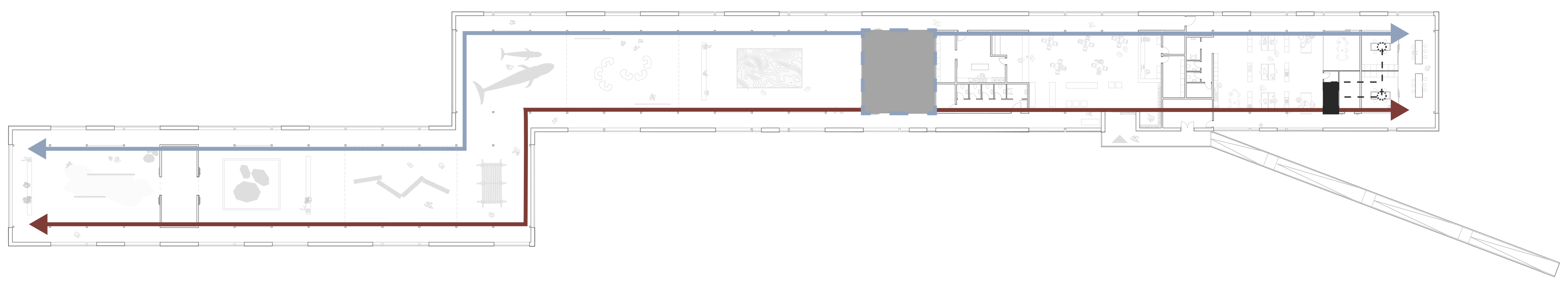
The average ventilation rate is calculated using same principle as for sensory ventilation:

$$Q_c = \frac{10h \cdot 51{,}5l/s + 14h \cdot (0{,}3l/s\,pr.m^2 \cdot 219m^2)}{24h} \approx 59{,}78\ l/s$$

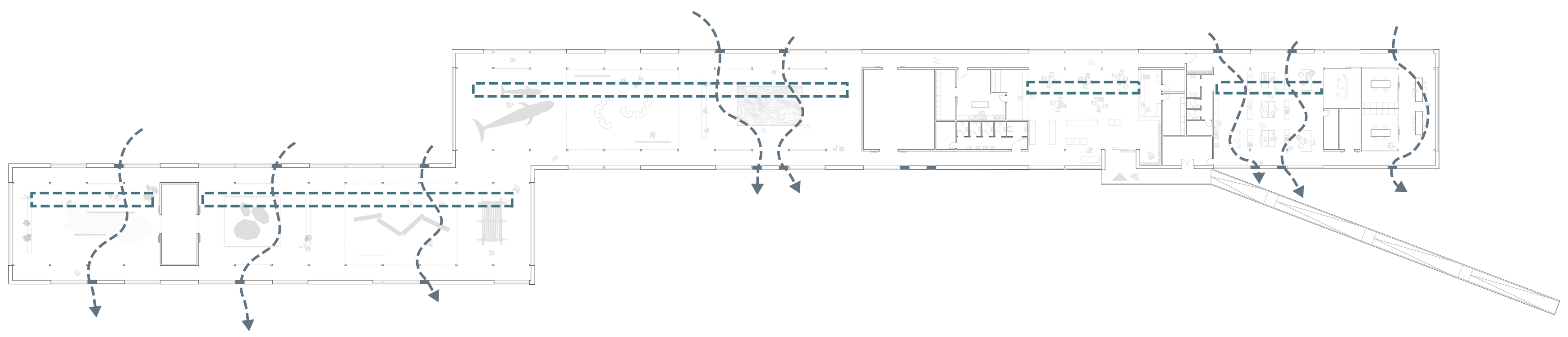
LITERATURE

Terpager Andersen, K., Heiselberg, P. and Aggerholm, S., 2002. By og byg anvisning 202 - Naturlig ventilation i erhvervsbygninger. Hørsholm: Statens Byggeforskningsinstitut.

Danish Standard Association, 2001. DS/CEN/CR 1752. København: Danish Standards Association.



MECHANICAL VENTILATION



NATURAL VENTILATION

09.04 natural ventilation.

a calculation of the ventilation rate

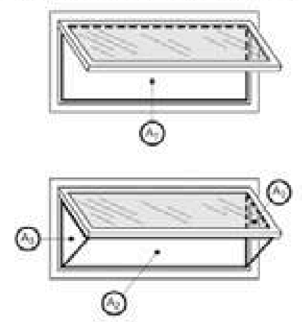
Natural ventilation can be calculated using two principles: wind induced and thermal buoyancy. The calculations are based upon SBi 202, (Andersen, Heiselberg and Aggerholm, 2002), in which all formulas can be found.

THERMAL BUOYANCY

Inlet window
Area: $2{,}4m^2$
Opening area (A_{eff}):

$$\left(\frac{1}{A_{eff}}\right)^2 = \left(\frac{1}{C_{d,1}A_1}\right)^2 + \left(\frac{1}{C_{d,2}A_2 + 2C_{d,3}A_3}\right)^2$$

The discharge coefficient, $C_d = 0{,}7$, cf. SBi 202 page 58.
A_1 is the area of the window frame opening, A_2 is the area between window and window frame when the window is opened and A_3 is the area of the triangles that appears when the window is open.



(Andersen, Heiselberg and Aggerholm, 2002, page 59)

The windows can be opened to 20 degrees, which gives following opening area:

$$\left(\frac{1}{A_{eff}}\right)^2 = \left(\frac{1}{0{,}7 \cdot 2{,}4}\right)^2 + \left(\frac{1}{0{,}7 \cdot 0{,}83 + 2 \cdot 0{,}7 \cdot 0{,}25}\right)^2$$

$$A_{eff.1} = 0{,}814m^2$$

The opening height $H_1 = 1{,}1m$
Temperature inside $24{,}5°C$

Outlet window
Area: $2{,}5m^2$
Opening area: $0{,}621m^2$
Opening height: $7{,}5m$
Temperature outside: $21°C$

To calculate the natural ventilation, the air flow rates for both inlet and outlet windows are calculated. Following formula is used:

$$Inlet: Q_1 = C_{d1}A_1\sqrt{\frac{2|\Delta p_1|}{\rho_u}}^{\frac{1}{2}} \qquad Outlet: Q_2 = C_{d2}A_2\sqrt{\frac{2|\Delta p_2|}{\rho_i}}^{\frac{1}{2}}$$

(9.2)

C_d = outflow coefficient
A = area of window
Δp = pressure of inlet and outlet air
ρ = Air density set to $1{,}225\ kg/m^3$

The pressure of inlet and outlet air is calculated with following formula:

$$Inlet: \Delta p_1 = \rho_u \cdot g \cdot (H_0 - H_1) \cdot \frac{T_i \cdot T_u}{T_i} \qquad Outlet: \Delta p_2 = \rho_i \cdot g \cdot (H_0 - H_2) \cdot \frac{T_i \cdot T_u}{T_i}$$

(9.18, 9.19)

ρ_u, ρ_i = density of outside and inside air. Outdoor: $1{,}225\ kg/m^3$, indoor $1{,}18\ kg/m^3$.
g = gravitational acceleration $9{,}82\,\frac{m}{s^2}$
H_0 = Height of neutral plane
H_1, H_2 = Height of inlet and outlet window
T_i, T_u = Temperature inside and outside

The neutral plane is found with following formula, as the outflow coefficient is the same for both inlet and outlet:

$$H_0 = \frac{A_1^2 H_1 + A_2^2 H_2}{A_1^2 + A_2^2}$$

(9.20)

$$H_0 = \frac{2{,}4^2 \cdot 1{,}1 + 2{,}5^2 \cdot 7{,}5}{2{,}4^2 + 2{,}5^2} \approx 4{,}430558m$$

The pressure of inlet and outlet air is:

$$\text{Inlet: } \Delta p_1 = 1{,}225\frac{kg}{m^3} \cdot 9{,}82\frac{m}{s^2} \cdot (4{,}43m - 1{,}1m) \cdot \frac{24{,}5°C - 21°C}{24{,}5°C} \approx 5{,}572Pa$$

$$\text{Outlet: } \Delta p_2 = 1{,}18\frac{kg}{m^3} \cdot 9{,}82\frac{m}{s^2} \cdot (4{,}43m - 7{,}5m) \cdot \frac{24{,}5°C - 21°C}{24{,}5°C} \approx -5{,}081Pa$$

The air flow rates are calculated:

$$Q_1 = 0{,}7 \cdot 0{,}81m^2 \cdot \sqrt{\frac{2 \cdot |5{,}5Pa|}{1{,}18\,kg/m^3}}^{\frac{1}{2}} \approx 0{,}99m^3/s$$

$$Q_2 = 0{,}7 \cdot 0{,}62m^2 \cdot \sqrt{\frac{2 \cdot |5{,}08Pa|}{1{,}225kg/m^3}}^{\frac{1}{2}} \approx 0{,}736m^3/s$$

WIND INDUCED

To calculate wind induced natural ventilation, following formula is used:

$$Inlet: Q_1 = C_{d1}A_1\sqrt{\frac{2|\Delta p_j|}{\rho_u}} \qquad Outlet: Q_2 = C_{d2}A_2\sqrt{\frac{2|\Delta p_j|}{\rho_i}}$$

p_j is the wind pressure calculated with:

$$P_{wind} = C_p \cdot \frac{1}{2} \cdot \rho_u \cdot v_{ref}^2$$

C_p = pressure coefficient. For wind coming from southwest, the coefficient will be $0{,}25$, and from east $-0{,}8$.

v_{ref} is the reference wind speed, corresponding to the building height, and is calculated with:

$$v_{ref} = v_{meteo,10} \cdot k \cdot h^a = 6m/s \cdot 0{,}68 \cdot 6{,}85m^{0{,}17} = 5{,}658m/s$$

$v_{meteo,10} = 6\,m/s$

k, α = terrain factor (Table 6.3)

h = height of building

$$P_{wind} = 0{,}25 \cdot \frac{1}{2} \cdot 1{,}225kg/m^3 \cdot (5{,}658m/s)^2 \approx 4{,}901Pa$$

To calculate p_j, the internal pressure has to be calculated.

$$p_i = \frac{1}{2} \cdot \rho_u \cdot v_{ref}^2 \cdot \frac{A_{in}^2 C_{p,in} + A_{out}^2 C_{p,out}}{A_{in}^2 + A_{out}^2} \tag{9.14b}$$

$$\frac{1}{2} \cdot 1{,}225 \cdot 5{,}658 \cdot \frac{2{,}4^2 \cdot 0{,}25 + 2{,}5^2 \cdot (-0{,}8)}{2{,}4^2 + 2{,}5^2} \approx -1{,}02725Pa$$

p_j is calculated:

$$\Delta p_j = \frac{1}{2} \cdot C_{pj} \cdot \rho_u \cdot v_{ref}^2 - p_i \tag{9.13}$$

$$\text{Inlet: } \Delta p_j = \frac{1}{2} \cdot 0{,}25 \cdot 1{,}225\,kg/m^3 \cdot 5{,}658m/s - (-1{,}027Pa) \approx 1{,}893381Pa$$

$$Outlet: \Delta p_j = \frac{1}{2} \cdot (-0{,}8) \cdot 1{,}18kg/m^3 \cdot 5{,}658m/s - (-1{,}027Pa) \approx -1{,}643576Pa$$

The air flow rates are calculated

$$Q_1 = 0{,}7 \cdot 0{,}81m^2 \cdot \sqrt{\frac{2 \cdot 1{,}89Pa}{1{,}18\frac{kg}{m^3}}} \approx 1{,}0148\frac{m^3}{s} = 1014\,l/s$$

$$Q_2 = 0{,}7 \cdot 0{,}62m^2 \cdot \sqrt{\frac{2 \cdot 1{,}64Pa}{1{,}225\,kg/m^3}} \approx 0{,}710\frac{m^3}{s} = 710\,l/s$$

LITERATURE

Terpager Andersen, K., Heiselberg, P. and Aggerholm, S., 2002. *By og byg anvisning 202 - Naturlig ventilation i erhvervsbygninger*. Hørsholm: Statens Byggeforskningsinstitut.