Badehotel Havvejen

Master's Thesis

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Title Page

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Ill. 2 *The Cement factory*

Abstract

This project focuses on the architectural transformation of an existing 114-year-old cement factory on the Danish island Samsø into a new beach hotel, integrating Samsø's culinary heritage, tourism, and sustainable identity whilst emphasising the historical context and purpose of beach hotels and the ways of transforming buildings. The design process outlines the various aspects and challenges associated with, specifically, repurposing an industrial site into a hospitality function while simultaneously highlighting the originality of the existing building's industrial identity, analysing the design considerations, structural modifications, and spatial reconfigurations required for the conversion to a beach hotel. Additionally, focusing on the Life Cycle Assessment as a technical aspect that outlines the sustainable goal for the transformation project.

These design key points frame a design proposal that revives the historical identity of a beach hotel, honouring the original building, and highly brings guests and users closer to the nature.

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Ill. 3 *Vesborg Fyr*

Reading Guide

This thesis consists of different phases based on the Integrated Design Process and Double Diamond Design Process containing program, design development and presentation. The program includes a set of analysis and interpretation of the contextual conditions and subjects. The design process presents the overall design approach and iterations from specific analysis, functional, and technical demands. The presentation, the last phase, is a set of illustrations to visualise the final design in which is a product of the previous phases as an integrated design process.

Introduction

The following thesis explores transformation architecture that highly includes the identity of Samsø that will contribute to a unique experience for guests and users of the beach hotel. This will be represented by a transformation design of the cement factory on Samsø, an island located off the east coast of Central Jutland.

An existing design proposal for the project that converts the building to a luxurious spa hotel is designed by LOOP Architects. Their approach of transformation for the whole building is by demolishing the existing building and rebuilding the same volume footprint with brand new materials. Additionally, reusing and upcycling old materials for the interior such as wooden boards as countertops, timber to benches and wooden beams for the flooring (Samsø Strandhotel, 2022).

Several goals in transforming the 114-year-old cement factory into a beach hotel is set for the project to achieve a unique architectural quality through preserving the existing building as much as possible to highlight its industrial identity, and parallelly reach a high sustainable design quality through Life Cycle Assessment and reach an energy frame classification BR18.

Motivation

Transforming existing buildings and repurposing their functions presents several benefits, touching all subjects regarding sustainability such as economic, social, and environmental (Planradar, 2022). This approach includes a high quality of architectural sustainability and the preservation of a cultural heritage of the context or the building itself, which will be focused on for this thesis.
This also frames the motivation for the project and explores design opportunities of creating authentic transformation architecture that highly reflects on the unique characteristics of the original building, natural context, and helps to contribute unique experience for the local community and tourists by implementing a touch of Samsø's cultural heritage into the design and other beach hotel facilities to be open all-year-round and will benefit the increasing tourism rate, not only in Denmark but also for Samsø.

Ill. 4 *Issehoved*

Strategy and Process

The Double Diamond Design Process, DDDP, and the Integrated Design Process, IDP, are used in combination to define the course of the project. DDDP is a general design process developed for project management that focus on when to gather information, create ideas, opportunities and when to downscale and conclude on the procured data. IDP is the general design method for development of architectural designs. It provides specific tools used in different phases to guide towards a final design concept.

The Double Diamond Design Process

The Double Diamond Design Process was developed by the British Design Council in 2005 to graphically map the divergent and convergent phases of a design process split into four phases; Discover, Define, Develop, and Deliver. The purpose of the design process is to showcase the different modes of thinking that designers use. Splitting the design process into singular diamonds, the first diamond representing the discover and define phases is where the right thing to design is discovered and defined. The second diamond representing the develop and deliver phases is where the design is developed and delivered in the right way (Council, 2005).

Discover

The first phase of the design process starts with an initial idea or inspiration based on a discovery. In this phase it is important to understand the extent of the problem which requires divergent thinking and investigation of different research areas.

Define

In the second phase the scope of the problem is defined. When all data has been discovered in the discovery phase it is then analysed through convergent thinking to filter and elaborate on the different components of the project.

Develop

This phase marks the "start" of the design process where the defined problem transforms into a realised product. Different design methods and multi-disciplinary strategies are used to investigate different design concepts and ideas to realise a solution of the problem.

Deliver

The final phase is the delivery of the final product where the final testing has been made to ensure no issues remains and where the discovered problem has reached its completion.

The Integrated Design Process

The Integrated Design Process is an iterative process divided into five different phases: Problem, Analysis, Sketching, Synthesis, and Presentation. This design process combines technical and architectural relations to define an aesthetically holistic design. The different phases follow a loop of analysing and sketching when new knowledge is acquired to improve and update the design that ensures an understanding of the project from initial problem to final design (Knudstrup & Hansen, 2005).

Problem

The first phase is formulating the problem and project idea, through initial research and analysis, the scope of the project is defined, and a problem statement is formulated.

Analysis

The analysis phase gathers and processes information of multiple investigations before the sketching of the design can begin.

Sketching

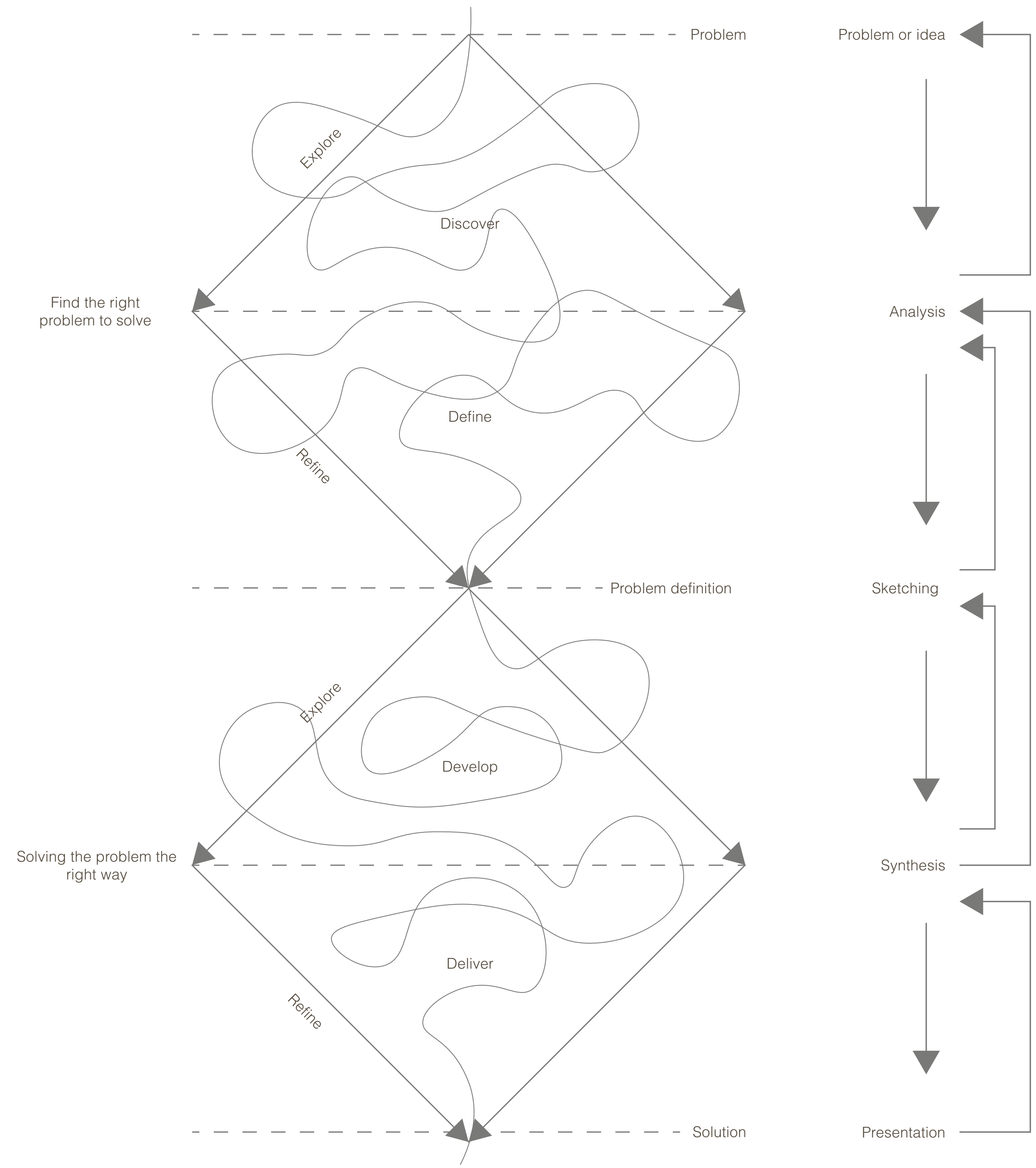
The sketching phase is where the design ideas are visualised as an iterative analysis following the analysis phase. Multiple visualisation software's are used to generate 2D- and 3D models along with in-hand sketches and drawings. Physical models are another tool used to communicate the ideas of the project.

Synthesis

The synthesis phase is where the project takes form, and the final design is developed. This phase iteratively returns to the analysis phase to assess and solve possible issues.

Presentation

The last phase is the presentation of the design where the final concept is showcased with a thorough written report together with final design drawings, renders, and physical models to illustrate the thought process of the final product.



Ill. 5 *Double Diamond and Integrated Design Process*

Methodology

Quantitative- and qualitative research are used in combination as a holistic framework, taking a stand in a problem statement and analysing quantitative data through qualitative research (Williams, 2007).
The following describes the different methodologies used throughout the project to acquire information and gain knowledge of the problem.

Accumulation of Knowledge

Literature Studies

Literature studies functions as the basis foundation of accumulating knowledge from all types of research. If the literature is well conducted it can enhance the ability to further generate design ideas and set the course for a particular field (Snyder, 2019).
Literature studies are often used in the early phases of a project to develop basic knowledge of the design topic. By using the Integrated Design Process and the Double Diamond Design Process as a combined iterative process, allows for the gathering of information throughout the entire design process with the benefit of evaluating the acquired data to gain new inspiration for the development of the project.
Tools: Books, Peer reviewed articles, Databases.

Case Studies

Using case studies as a research approach to conduct knowledge in the early design phase functions to seek patterns and observe behaviour of relevant topics to provide evidence for the design to live up to its intended potential.
Case studies can be made with the purpose of elaborating specific topics with a broader perspective as common use of a building or as a more in-depth analysis of specific details regarding design functions.
Tools: Literature, Architectural magazines, Databases.

Idea Generation

Sketching

The initial phases of a design process are made through sketching to showcase the early idea generation process. Sketching is always used side by side with the analysis phase throughout the entire project as an iterative process.
Tools: Analogue sketching, Digital sketching.

Volumetric Study

To supply and further develop the idea generation, physical models can greatly increase the understanding of an idea by converting 2D sketches into 3D volumes. Volumetric studies can unveil potentials and difficulties of a design proposal.
The volumetric studies can be made both physically and digitally and is used as a method to quickly showcase multiple design ideas and help gain a common understanding of scale and perspective of the design proposal throughout the entire design process.
Tools: Rhino, Enscape, Foam, Cardboard models.

On-/off Site Study

Mapping

Mapping is a tool used to gain an understanding of the sites environmental relations and its surroundings. Mapping provides an indication of scale and can show potential difficulties that might occur during the use of the site.
Mapping is used throughout the analysis phase to collect data of microclimate analysis showing potential inconvenient issues regarding the building. Mapping of the surrounding vegetation shows possibilities for outdoor activities enhancing the use of the site.
Tools: Dataforsyningen.

Genius Loci

Genius Loci is a study performed on-site and studies the sensorial aspects of site ultimately addressing it as a space rather than place. The study is performed as observations through the human senses and noting the experiences of what can be seen, heard, smelled, etc. The observations are documented through photographs and sketches to communicate the subjective experiences.
Tools: Photographs, Sketching, Site visit.

Technical

Simulation

Technical simulations are important to support design iterations throughout the entire design process. Early simulations of the daylight were conducted using the Rhino plug-in Ladybug to investigate if room conditions receive enough daylight. Iterations of the energy frame of different design proposals are also important to showcase energy savings and benefits of renovation projects compared to new built projects through Be18. The same ideology is applied when investigating indoor climate through dynamic simulations in BSim where adjustments and optimisations quickly can be applied.
The material use is investigated through LCAbyg to analyse iterations of the environmental impacts of different building components giving the opportunity to make the design as sustainable as possible.
Tools: BSim, Be18, LCAbyg, Ladybug.

Presentation

Report

The entire project is documented through a written report covering all subjects addressed in the design process. The report allows the reader to gain insight in the thought process of the writers and the design development showcasing difficulties and challenges aswell as solutions.
The report summarises everything from early design concept ideas, initial sketches, and turn points to the final illustrations and renders of the presented project.
Tools: InDesign, Word.

Illustrations

Illustrations are used to visualise concepts and further enhance the understanding an explanation of a subject that can't be written in words. Illustrations are used through the entire process of a project from early design ideas to finished design concepts.
Tools: Illustrator, Photoshop, Rhino.

Renders

Renders are used as photorealistic visualisations of the final design to display exterior and interior spatiality and communicate their atmospheres and functions.
Tools: 3ds Max, Corona, Rhino, Enscape, Photoshop.

Infographics

Infographics aims to help explain a large amount of numeric data graphically for the reader to quickly gain an overview and enhanced understanding of the relevant topic.
Tools: Excel, Photoshop, Illustrator, Analogue drawings.

Ill. 6 *The Cement Factory*

The Existing Building

The History
Site Location
Plan and Form
Materials
Structural System
Thermal Envelope

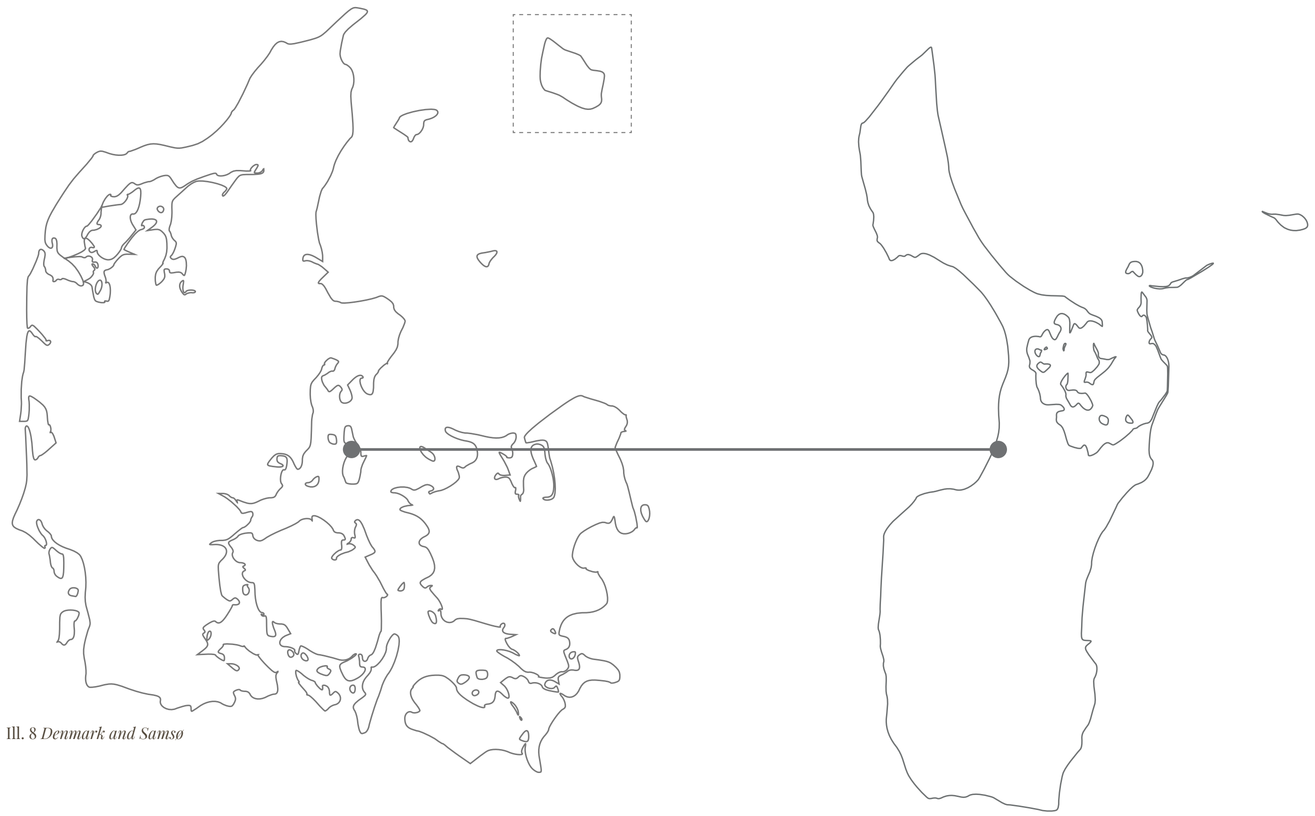
Ill. 7 Photo Credit: Styrelsen for Dataforsyningen og Infrastruktur

The History

The cement factory was originally founded by local farmers who produced concrete bricks and concrete roof tiles, which then made the location ideal, due to the accessibility of raw material, for the production (Cementvarefabrikken Sælvig, n.d.).
The factory was first built in 1908 as a masonry warehouse and has through time expanded with multiple extensions and undergone numerous renovations and transformations, the latest being the transformation of a warehouse into staff facilities in 1993 (Cementvarefabrikken Sælvig, n.d.). The cement factory is now deemed to be a preserved building that indicates modifications or renovations that detract from the original appearance must be avoided (DinGeo Boliga, n.d.) (Kulturministeriet, n.d.).
The company that is still in function to this day is planned to move somewhere else in Samsø together with their tools, machineries, vehicles, and silo.

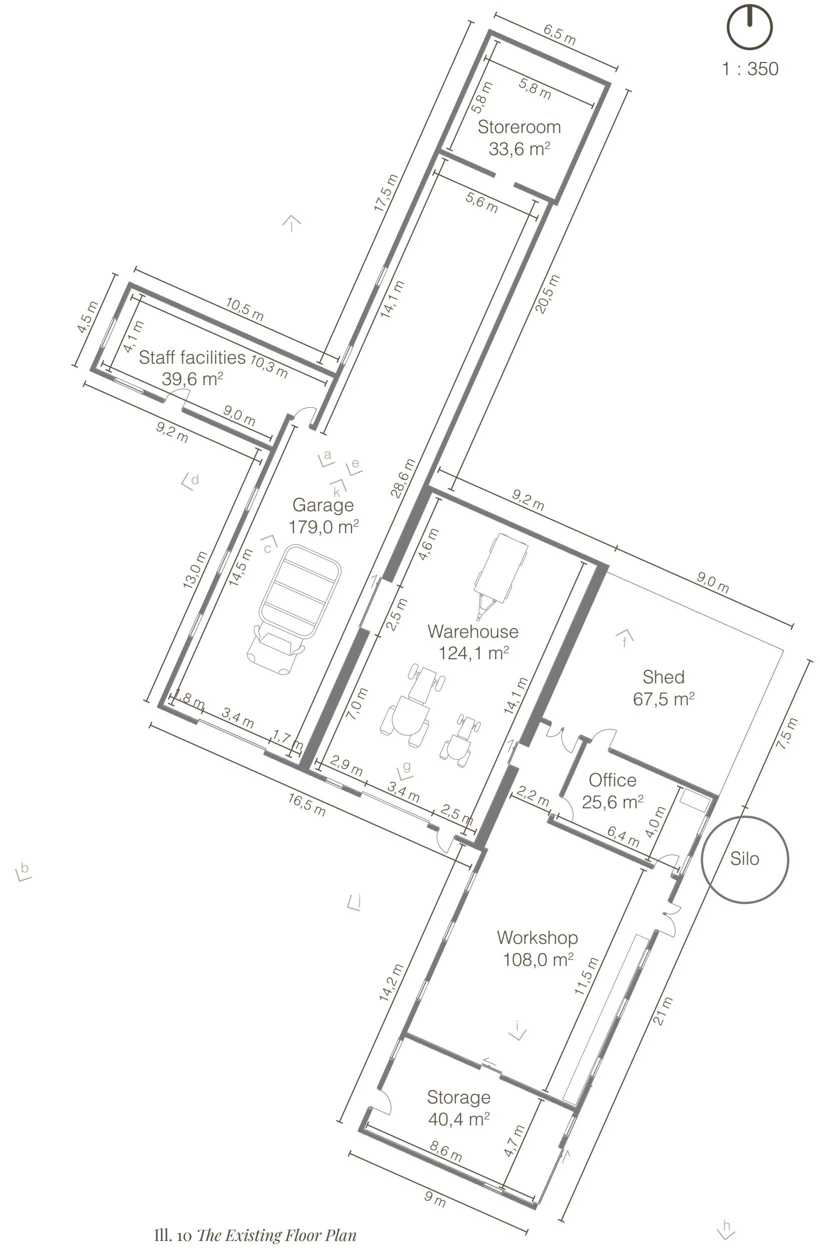
Site Location

The project site is located on the Danish Island, Samsø. Samsø is in the middle of Denmark which makes Samsø accessible both from Jutland and Zealand. There are three different ferry options: Two from Jutland to Zealand and one from Zealand to Ballen with, respectively, a distance of 4 and 10,5 km from the cement factory.
The entrance to the site is from the east therefore the most optimal placement for the entrance facilities will be towards east. The facilities for the guests at the beach hotel will be placed towards west and north to get the view of the ocean and towards south to utilise the sun for outdoor areas therefore the staff facilities should be placed towards northeast.



Ill. 8 *Denmark and Samsø*

Ill. 9 *The Topography on the Site*



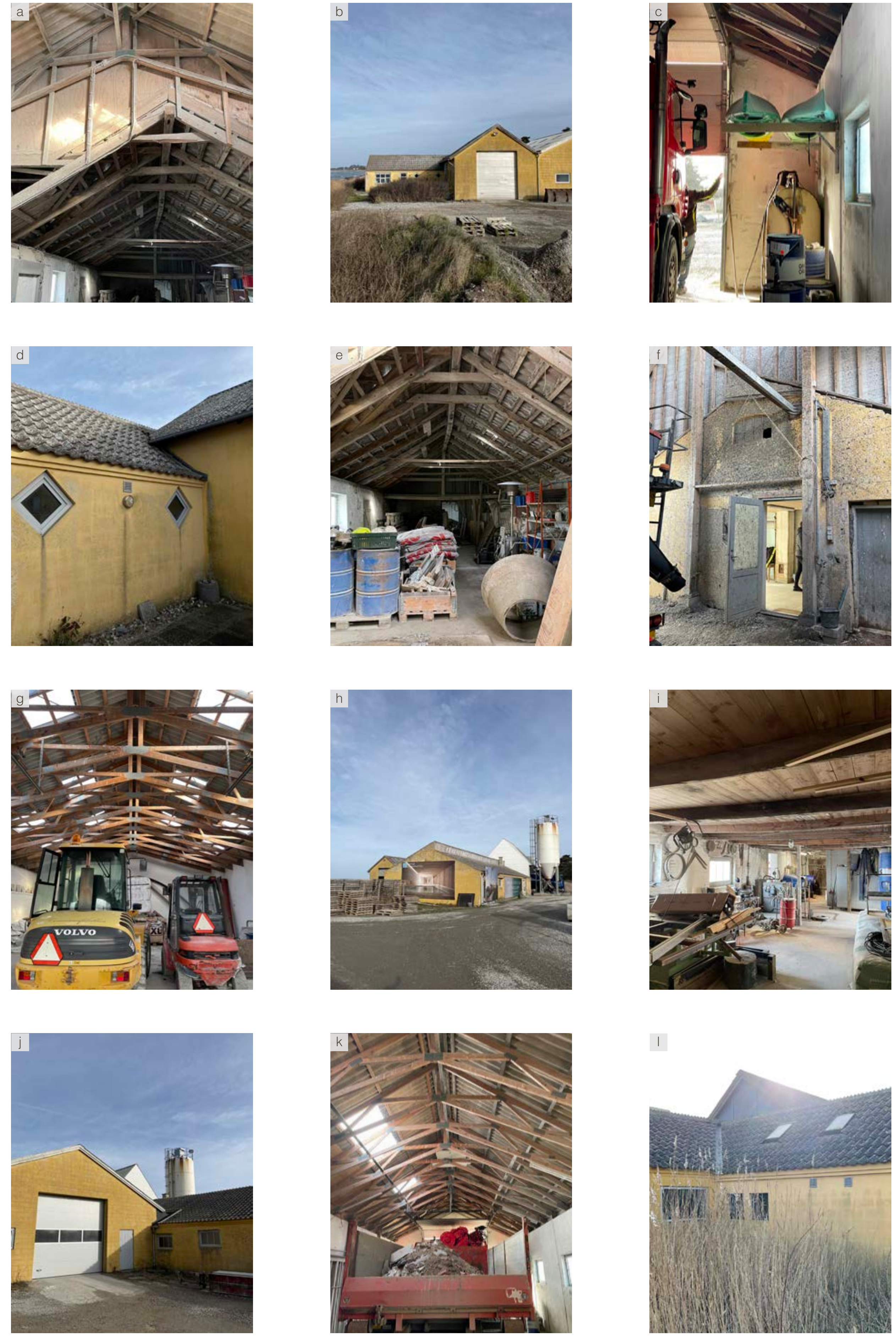
Ill. 10 *The Existing Floor Plan*

Plan and Form

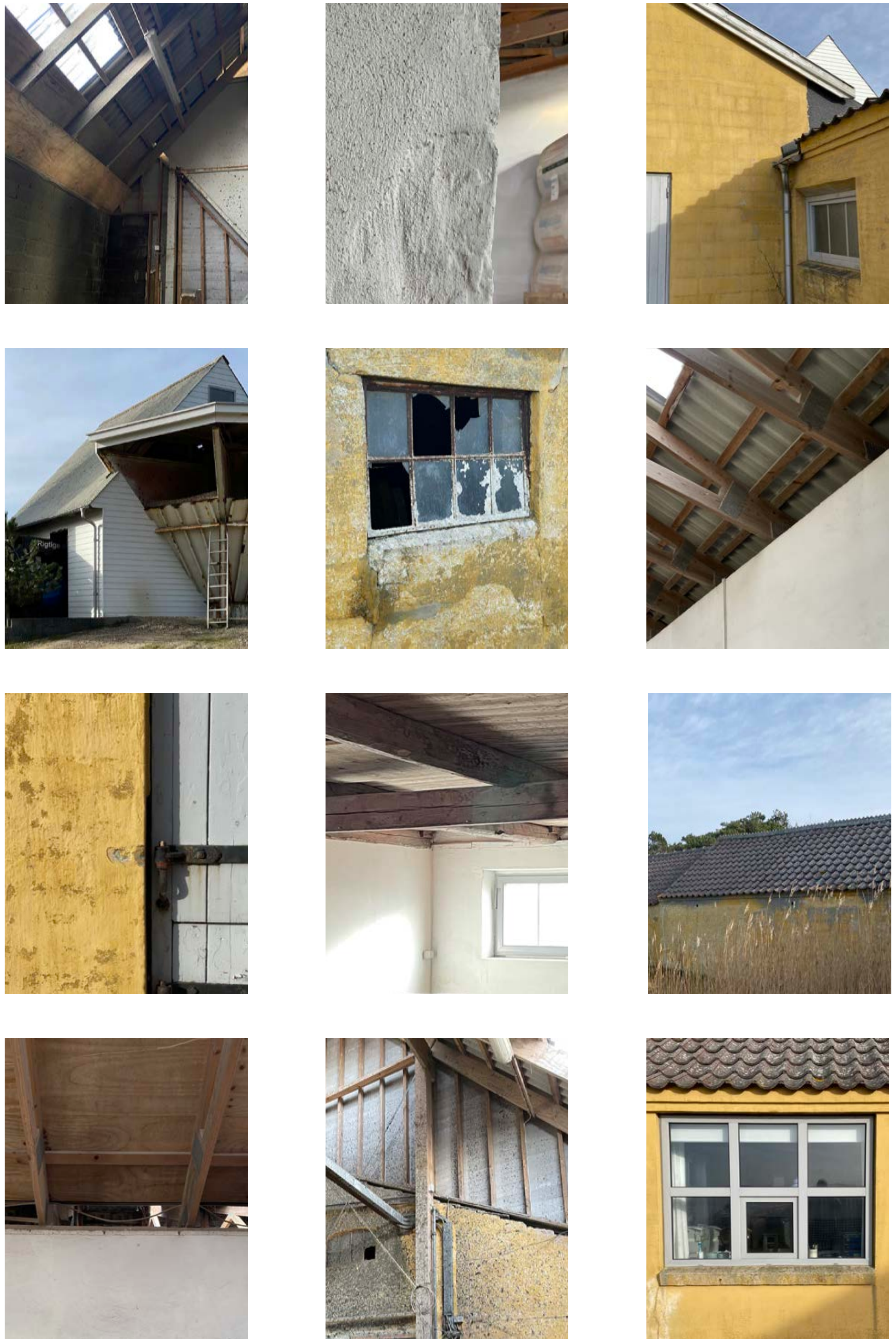
The cement factory consists of seven rectangular buildings that are interconnected through its indoor circulation. The workshop, storage, a shed for the concrete mixer, warehouses, garage, staff facility, and storeroom can be accessed through the main entrance.

All buildings have pitched roofs with the ridge running in a north-south direction, except for the existing staff facility which runs in an east-west direction. The garage and warehouse have a full height interior with visible lattice trusses, while the other rooms have a flat-cladded ceiling with partly visible beams.

The outdoor areas are mostly open areas used as storage and feature various types of pavements including gravel, stones, tiles, and asphalt by the entrance area.



Ill. 11 *The Cement Factory*



Ill. 12 *The Cement Factory*

Materials

The outer expression of the cement factory has an exterior facade that quickly catches the eye with its bright, patina, yellow-plastered walls that is further complemented by the traditional red clay roofing tiles that were originally red, but after a long period of time changed its expression to be dark grey. Additionally, white, wooden-framed windows as a contrast to highlight openings on the facade.

Stepping inside through the main entrance, which is located at the oldest part of the building, will quickly give a rustic expression of its identity and history through the visible wooden beams, complimented by its white-plastered walls and the low-height wooden ceiling. Some of these key features continue in the newer part of the building, but with a more industrialised expression of the visible wooden beams and wavy fibre-cement ceiling tiles. Several skylights are implemented in the warehouse bringing more natural light into its large space.

Structural System

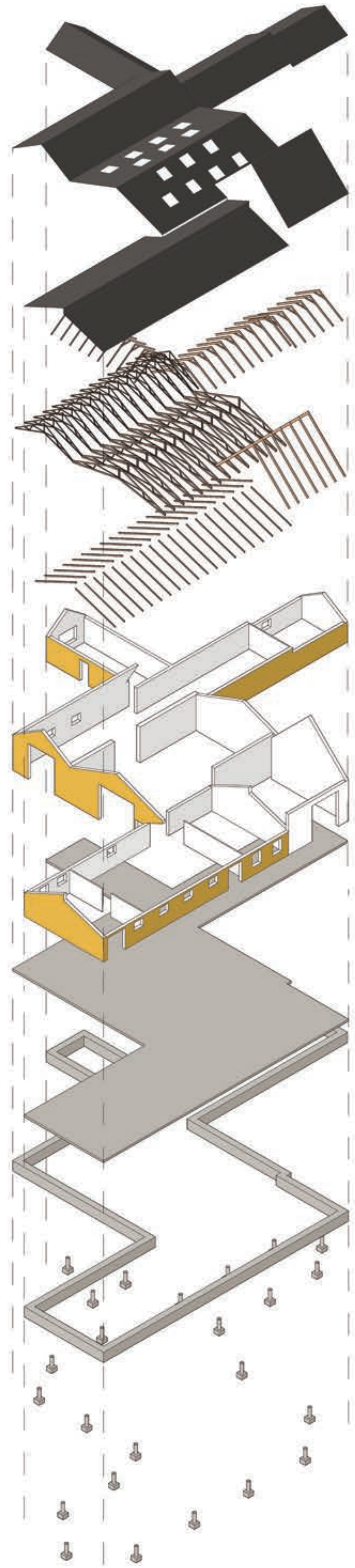
A structural analysis includes examining the various components of the existing overall loadbearing structure such as beams, columns, and walls to ensure stability for the loads and stresses of the transformation, but also other natural loads such as the wind and snow. The analysis is based on two different limit states: Ultimate Limit State (ULS) and Serviceability Limit State (SLS). The ULS analysis evaluates the structural component's ability to withstand the maximum loads and stresses that occur without failure, while SLS examines the ability to maintain the buildings functionality and comfort under normal use condition.

The analysed structure is located in the existing garage where it is assumed to be the most critical structure due to its total roof area of 195 m² and largest span of 9 m. The wooden beams are made up of construction wood of C30 arrayed 1 m from each other and sits on top of reinforced concrete wall with a thickness of 300 mm. The added loads that will affect the structure are the wooden beams' self-weight, snow load, wind load, and the reinsulated part of the roof, which is calculated on 2 versions: a light and heavy roof.

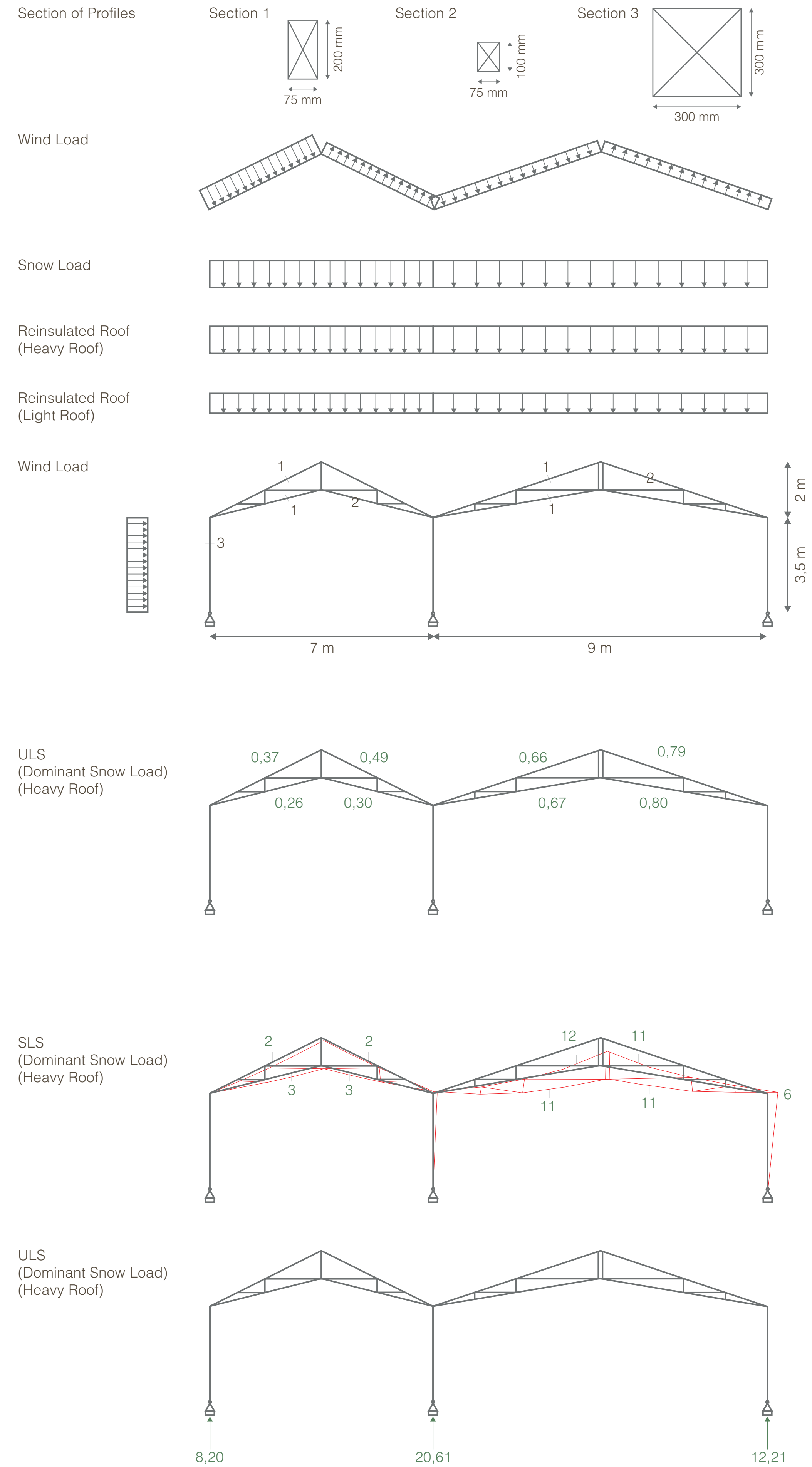
Through the structural simulations, the most critical situation occurs with snow load as the dominant load combined with a heavy roof and shows that the maximum utilisation ratio to be 0,8 and deformation to be 12 mm. Optimally, the utilisation ratio needs to be below 1 and a deformation to be below 1/500th the length of a beam, in this case, 24 mm.

Additionally, the concrete walls are also affected by the before-mentioned loads and therefore a rough calculation is also done to get an insight of stability after transformation. The columns' strength quality is assumed to be at least C25 and through the simulations, the most critical concrete column is in the middle with a vertical reaction of just over 20 kN on a section area of 300 mm x 300 mm. This results with a utilisation ratio under 1.

It is therefore to be concluded, that the wooden beams are able to uphold stability even after the renovation and reinsulating the roofs and with the most critical loads calculated with a heavy roof, it is assumed that a lighter version of the roof will result in a better result.



Ill. 13 *Exploded Structural System*



Ill. 14 *Structural System*

Thermal Envelope

Walls

Main Building (Workshop, Storage, Office) 1908

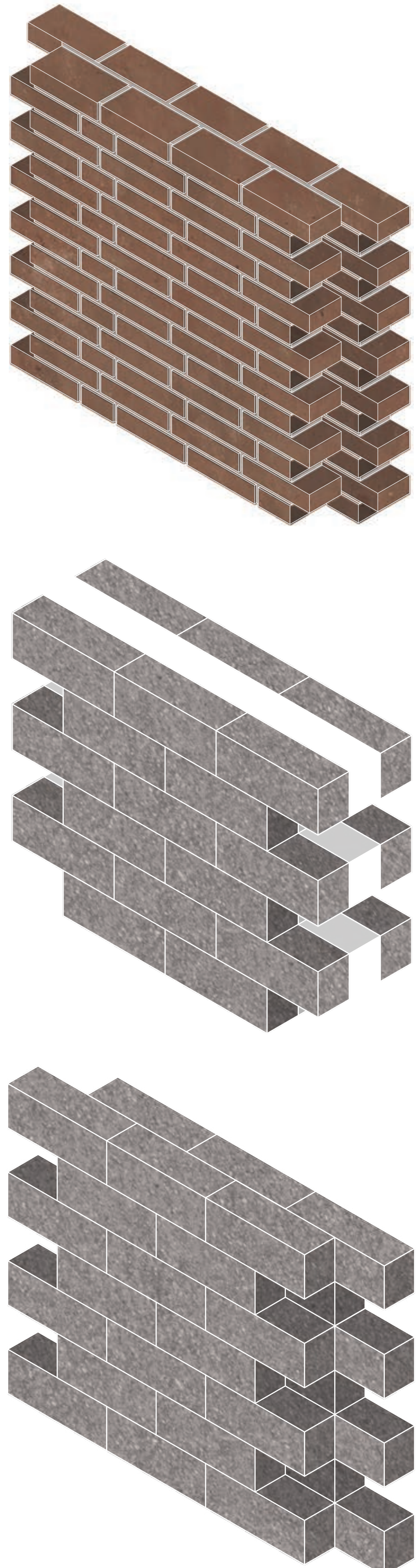
The cement factory on Samsø was originally built in 1908 and has through its course had multiple renovations and building added to the construction. Today only a minor warehouse building is left from the original cement factory.
The 1908 main building is assumed to be built with two layers of clay bricks with no insulation. With the two layers of bricks and an outer layer of lime render, the warehouse wall is estimated to have a U-value of 1,9 W/m^2K, which means the buildings heat loss and risk of condensation will be too high.

Warehouse, 1978

In 1978 a building permit for a new larger warehouse were applied for. The walls in the warehouses should be built with an inner layer of 100 mm Leca blocks and a 100 mm layer of expanded polystyrene insulation. The outer layer of the wall should be cladded with aluminium sheets, but due to the cladding not fitting in with the existing cladding of the surrounding buildings the permit could only be granted if the building expression would fit into the existing context (Byggesagsarkivet 1978-79).
Through analysis and site visit it is assumed that the exterior wall construction consists of two layers of Leca blocks with a 100 mm layer of expanded polystyrene insulation in between and an outer cladding of lime render. The U-value is estimated to be 0,25 W/m^2K.

Staff Facilities, 1993

It is registered in the building archive that in 1993 one of the older warehouse buildings was transformed into new staff facilities. The outer walls should be replaced with new ones built by 200 mm Leca blocks assumed without insulation. This gives the walls a U-value of 0,9 W/m^2K.



Ill. 15 *Existing Walls*

Floor and Roof

Floor

The existing floor in the cement factory consists of a concrete deck on top of a capillary layer of gravel. The thermal performance of the concrete floor is not suitable to be used as a habitable area with a U-value of 2 W/m^2 K.

Roof

The roof consists of a series of lattice trusses with a cover of clay tiles and sheathing. There is no insulation in the roof construction, due to the building isn't built as a heated area and therefore, a new roof construction is needed to be built in the renovation project.

Strategy

To accommodate todays building regulations for residence the existing buildings must be renovated and reinsulated. The buildings must follow the Danish building regulations and fit into one of the renovation categories by following the below listed regulations from BR18.
Renovating a building also must be profitable and as a rule of thumb it is worth renovating a building if the existing layer of insulation less than 125 mm thick (Rockwool, 2021). Through the previous analysis of the existing buildings the largest thickness of insulation present in some of the walls is 100 mm, which makes the whole cement factory suitable for renovation.

U-Value Wall	U-Value Floor	U-Value Roof	Energy Demand Window	Renovation Class 1	Renovation Class 2
0,018 W/m^2K	0,1 W/m^2K	0,12 W/m^2K	0,1 W/m^2year	52,5 + 1650/HFA kWh/ m^2year	70 + 2200/HFA kWh/ m^2year

(Energistyrelsen, 2018)

Ill. 16 *Vesborg Fyr*

Theoretical Position

Sustainability

Sustainability can be divided into three categories, social-, economic-, and environmental sustainability, each category aspires to be equally balanced between each other, where environmental sustainability will be the main focal subject in this thesis. Therefore, a sustainable building environment is about thinking ahead and observe the entire lifecycle of a building, it's about thinking broadly of the local, regional, and global consequences, and it's about thinking deeper into analysing and documenting the environmental, social, and economic aspects. This means that regulations and projections of the buildings demands broad and long-term thinking with incorporation of respective knowledge and integrated design (Birgisdottir, et al., 2013).

Environmental Sustainability

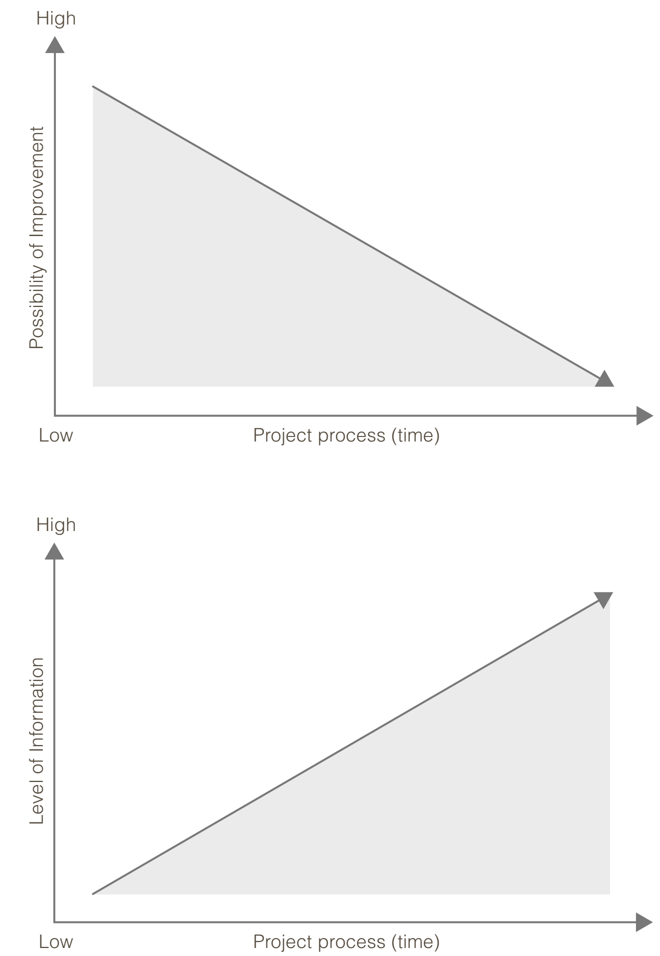
The environmental aspect of sustainability concerns the environmental impact of the construction sector and how to reduce the negative influence caused by energy consumption and material use. The construction sector is responsible for 39% of the total climate impacts, which of 28% is caused by the energy consumption of the buildings and 11% is caused from material use and this puts the construction sector in a position to significantly contribute to the sustainable development of the future (Realdania, 2022).
Today the construction sector is in a period of transition, driven forward by the global focus on climate change (Realdania, 2022). To reduce the emissions from construction restorations and transformations of old buildings have through multiple studies shown to be more climate-friendly than building new ones, but to restore old buildings and buildings with a historic identity is a balancing act under which preservation values, aesthetics, present use, finances, the climate, and the environment must be weighed against each other (Realdania, 2022).
This thesis aims to preserve the identity of the cement factory by preserving the structural identity of the building and maximise the use of original design features. The investigations of the environmental impacts of this process to provide quantitative data will be assessed through Life Cycle Assessment, LCA, to show qualitative results of the benefits of renovation and transformation in the built environment.

Life Cycle Assessment

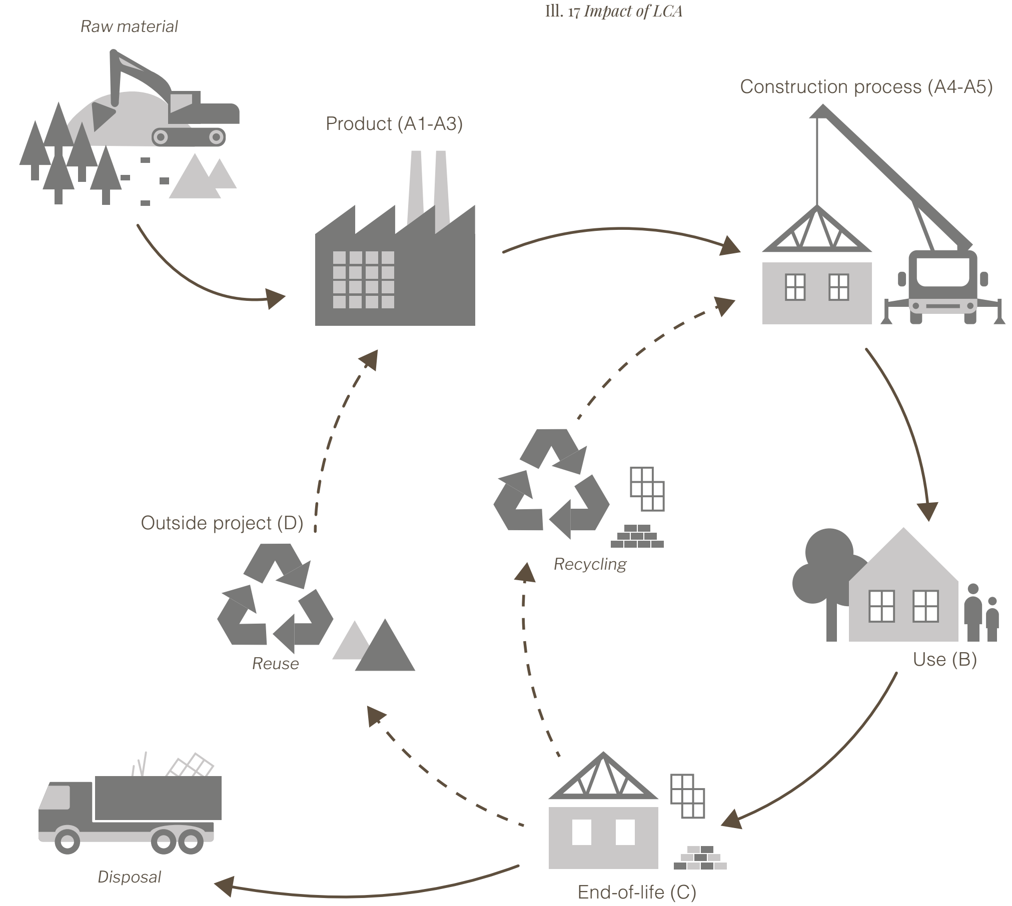
Life Cycle Assessment is a method used to assess the potential environmental impacts and use of resources in the built environment. The buildings is assessed through different phases from early resource extraction to the demolition of the buildings after their end of life.
A building is assessed through different phases. The first phase is the production phase (A1-A3) where the environmental impact of each material used in the building is assessed from extraction of raw material to manufacturing of the final product ready to be used on the building site. Then the construction phase of the building (A4-A5) is assessed through transportation of all building materials and assembly of the building. When the building is built it is assessed through the usage phase (B) where energy consumption throughout the lifetime of the building and replacement of building components are assessed. The energy consumption can be calculated as an estimate through the software Be18. After the usage phase the building is assessed through the End-of-Life phase (C) where considerations of disposal, demolition, and reuse of materials and building components are made. Another phase outside of the project framework (D) is assessed and informs of building materials' potential of reuse or recycle. This phase is assessed separately as it will benefit the LCA of a new building built with reused or recycled materials (Kanafani & Birgisdottir, 2021).
Renovating or transforming a building renews the lifecycle of the building and the LCA method can be applied though with minor alterations. The construction of the existing building components are excluded in the new LCA due to the uncertainty of obtaining valid data of previous owner's emissions during construction rather than including estimates (Realdania, 2022). Also, the phase for potential of reusing building components after their end-of-life cannot be included in the final LCA. This is because of the risk of double counting if a future contractor also includes the benefits of reuse and of the fact that one cannot be certain of obtaining a potential CO_2 saving in the future (Realdania, 2022).

LCA in Practice

A building with a low climate impact is best achieved if the knowledge regarding Life Cycle Assessment is implemented from the start of a project when working integrated and iterative throughout the design process.
Incorporating LCA in the early phases of a project is important to have the climatic impact function as a decisive factor throughout the project. It is assumed that all activities, material use, and energy consumption affects the building's climatic performance.
During the design process there will be many decisions to consider and more and more choices regarding the design will be made before reaching the final design. This is done by continuously sharing and improving data from different studies throughout the design phases (Kanafani & Birgisdottir, 2021).
One way of implementing LCA in the project is to compare different building components that will be more difficult to replace later in the process, e.g., foundation and loadbearing elements. Taking a stand in existing buildings the LCA can be made as a comparison of different renovation scenarios or demolition and building new (Kanafani & Birgisdottir, 2021).



Ill. 17 *Impact of LCA*



Ill. 18 *Typical Phases of a Building's Life Cycle*

Transforming Buildings

In architecture, transformations refer to changes made to existing buildings and/or structures. These changes can range from simple modifications, such as updates to systems or finishes, to more extensive renovations, and additions. Transformations can be driven by a variety of factors, including changes in use, technology, building codes, and cultural values. The main goal of an architectural transformation can be to improve functionality, increase energy efficiency, or adapt to changing needs, while also preserving the historical, cultural, and aesthetical values of the building or structure. The approach of transforming a building can vary a lot, depending on the context and the desired outcome, and can involve a delicate balance between preservation and change (Asefi, 2012).

Transformation, 19th century

Since the mid-19th century, people have been intrigued by the relationship between old buildings and their preservation. Two key figures in this field were French architect and theorist Eugène Viollet-le-Duc and English art historian John Ruskin. These two are considered to be polar opposites in classical restoration theory, representing respectively a maximal and minimal approach to preserving existing structures (Andersen, 2015).
Viollet-le-Duc believed that architects needed to have a complete understanding of an existing building in order to make changes to it. He advised to restore buildings to their original form, regardless of whether the design had ever been fully realised. (Milosevic, n.d.).
Ruskin, on the other hand, strongly opposed Viollet-le-Duc's focus on style. For Ruskin, the most important elements of an old building were its original materials and signs of aging. Believing that preserving the way in which the building had aged and the way in which its materials had been worked was crucial. He felt that restoring a building would be like destroying it, since its wear and decay were so important to its character. "The Arts and Crafts Movement", co-founded by Ruskin and William Morris (1834-1896), a poet, writer, designer, aimed to raise the standards for British Architecture. This movement had a significant impact, not only in England but also served as a source of inspiration for Danish association "Landsforeningen Bedre Byggeskik". Morris also established "The Society for the Protection of Ancient Buildings" which opposed the then-widespread restoration methods that returned buildings to a certain style (Andersen, 2015).

Transformation, 20th century

Venice Charter, 1964, is a crucial document for the 20th century restoration practices and modern transformation architecture. It addresses the fields of conservation and restoration and sets the principles for preserving and restoring historical monuments, while at the same time respecting both art and historical evidence. The principle that in modern thought and practice has had the greatest impact on how the architect should relate to the existing (Andersen, 2015).

> *"Replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence." (ICOMOS, 1965)*

A widely accepted principle in the 20th century was that new additions to a building should be distinguishable from the original materials. Nowadays, the focus is on finding a balance between old and new. Additionally, David Chipperfield Architects and Julian Harrap follows a philosophy of "gentle building evolution" values the historical structure and contents of the building, resulting in a new construction that preserves the original proportions, but with updated materials and simple forms. (Cardno, 2015).

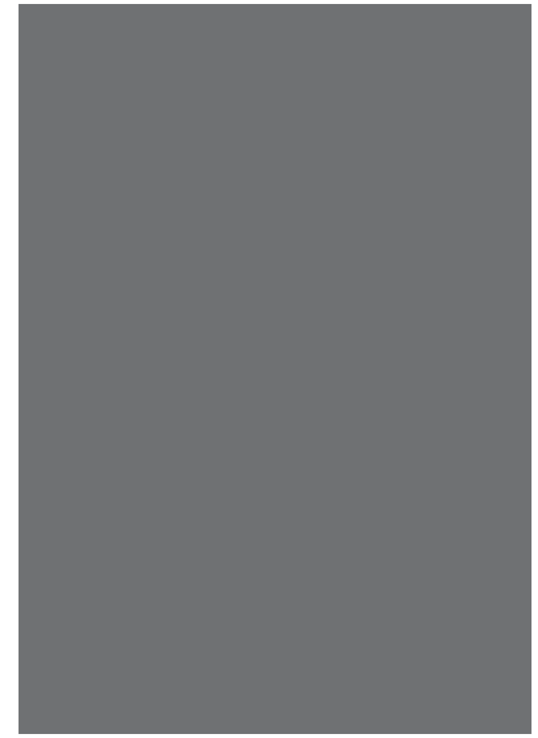
> *"An architect working extensively on old buildings who is not just a repairer, but cares about design and dares to practice it. (...) Caring about the little things, Harrap believes, does not mean ignoring the wider issues." (Powell, 1999)*

Architectural transformations can range from simple modifications to extensive renovations and are driven by various factors, such as changes in use and technology. The main goal is to improve functionality and preserve the historical and cultural values of the building. Two key figures in the field, Eugène Viollet-le-Duc, and John Ruskin, represent a maximal and minimal approach to preserving existing structures, respectively. In the 20th century, it was widely accepted that new additions should be distinguishable from the original materials as their philosophy is to value the historical structure and contents while preserving the original proportions with updated materials and simple forms, showcasing history within a modern context. These philosophies are therefore crucial knowledge in regard to how transforming an existing cement factory into a new beach hotel, and by knowing each their own key design principles will help the overall transformation design development.

Venice Charter
Transform with Respect

Ill. 19 *Transform with Respect*

John Ruskin
Preserve the Original

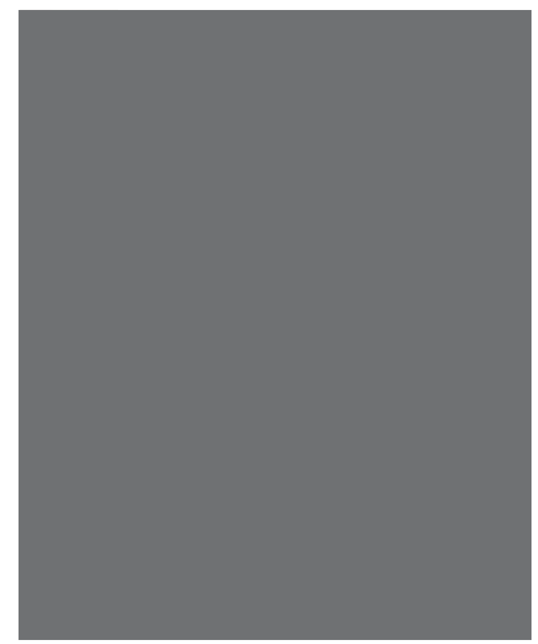


Ill. 20 *Preserve the Original*

Violet Le Duc
Restore the Form

Ill. 21 *Restore the Form*

D. Chipperfield
Transform and Evolve

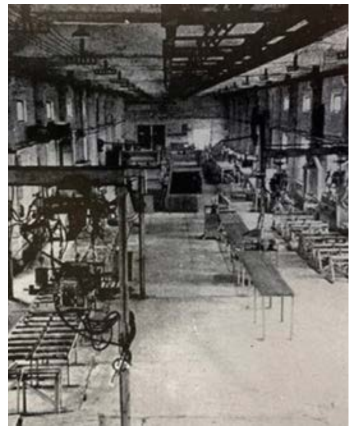


Ill. 22 *Transform and evolve*

Case Study

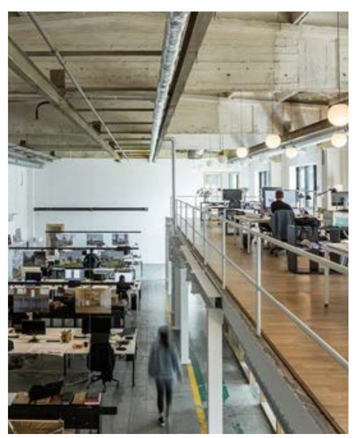
Betono Fabrikas by DO Architects

Betono Fabrikas is a transformation project of an old industrial concrete factory into a multifunctional use with creative and living spaces. The concrete factory is located in Vilnius, Lithuania and was a highly industrial area through the Soviet period. It was dedicated to making several concrete elements for housing units, however after the fall of the Soviet Union the whole area got abandoned and after the closure of this former industrial factory, it has been remodeled without consideration of its building history.
The overall transformation design of the factory is based on a goal to re-design and reimagine the entire building's identity and history to preserve what was once the original existence of the space, yet with a modern approach.
The main fundamental architectural approach of the project was to use all of the historical key features of the building's identity such as the construction elements, industrial machinery, visible structures, and large existing open ports that altogether creates a seamless relation into its industrial history whilst fitting into the modern understanding of spaces, functionality, and sustainability (ArchDaily, 2023).


Ill. 23 *Photo Credit: DO ARCHITECTS*

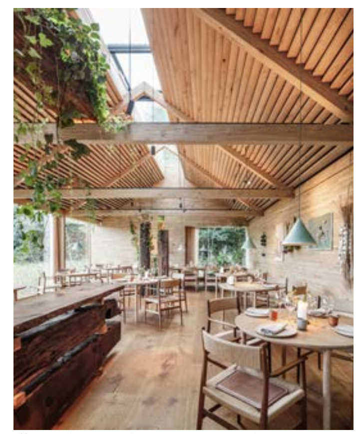

Ill. 24 *Photo Credit: Lukas Jusas DO ARCHITECTS*


Ill. 25 *Photo Credit: Lukas Jusas DO ARCHITECTS*


Ill. 26 *Photo Credit: Lukas Jusas DO ARCHITECTS*


Ill. 27 *Photo Credit: Rasmus Hjortshøj*


Ill. 28 *Photo Credit: Rasmus Hjortshøj*

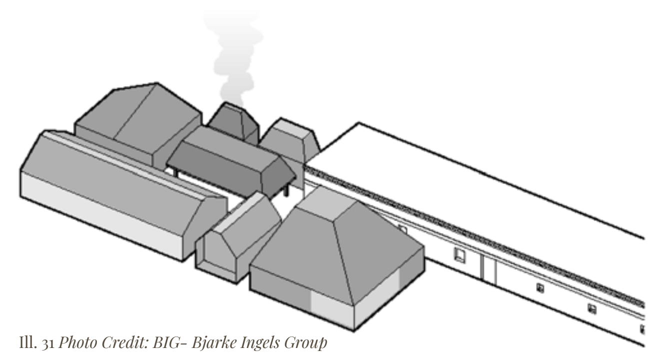

Ill. 29 *Photo Credit: Rasmus Hjortshøj*


Ill. 30 *Photo Credit: Rasmus Hjortshøj*

Case Study

Noma 2.0 by BIG

Noma 2.0, one of the world's most renowned restaurants, has a new home designed by BIG in Copenhagen's Christiania community. The cluster of buildings is situated in between two lakes on the site of a former military warehouse that once stored mines for the Royal Danish Navy. With interiors completed in collaboration with Studio David Thulstrup, the project is envisioned as an intimate culinary garden village that are separated yet connected (BIG, 2018).
Every part of the restaurant experience; the arrival, the lounge, the barbeque, the wine selection, and the private company are clustered around the chefs and guests. With the chef's central position, they are set to allow guests to follow what would traditionally happen behind the scenes. Each building within the buildings is connected by glass covered paths for guests to follow the changes of the weather, daylight, and seasonal changes – including the natural environment as an integrated part of the culinary experience.
The main dining room has a highly natural interior with timber and natural bricks that creates a warm experience for users, while on the other hand the service kitchen for chefs is with black timber surrounding with natural wooden kitchen islands; this encapsulates and highlight the chefs and their work from the viewpoint of the guests. Guests are generally able to explore each surrounding buildings and experience Nordic Materials and building techniques; the lounge, f.eg. appears to be a massive stone interior that feels cold but together with its fireplace gives comfort and coziness (ArchDaily, 2018).
Overall, Noma 2.0 is a unique and immersive dining experience that seamlessly integrates nature, architecture, and culinary art harmoniously together through its choice of materials. Implementing these key-points into the design of a new beach hotel will greatly increase the overall quality of the building and the guests' experience whilst further promoting Samsø's culinary identity.


Ill. 31 *Photo Credit: BIG- Bjarke Ingels Group*

Ill. 32 Issehoved

Project Scope

The Identity of Samsø
The Identity of a Beach Hotel
District Plan

The Identity of Samsø

Seasons

Samsø has many activities throughout the year with the summer period being the most attractive season. All seasons offers different experiences of the island, each applying to the phenomenological senses (Visitsamsoe, n.d.).
In the summer Samsø is visited by thousands of tourists, who seek to enjoy their holiday either in a cottage or a hotel, and some tourists stay at campsites around the island. The island offers a wide variety of activities throughout the summer like going to the beach, hiking, bike riding and golfing, etc. There are still multiple opportunities for outdoor activities during the other seasons.
In autumn it is possible to experience the landscape dominated by melancholy colours, where the roads are empty of tourist that calls for meditative walks in the nature with possibilities of being accompanied by free-ranging animals.
Spring follows the same properties as autumn, the colours of the landscape are warmer and the temperature is rising, which gives the perfect opportunity to go for a hike in the hills or take a bike ride along the island to buy fresh crops.
Winter is the season with the least number of visitors but there are still multiple activities to participate in. This season is marked by indoor activities rather than outdoors, where it is possible to gather with the family in front of the fireplace with a hot beverage and play games. Though it is still possible to enjoy the outdoor environment by walking along the coastline, go ice skating or take a swim in the ocean. With more than 100 km of coastline there is great opportunity to submerge into the cold water (Feriepartner.dk, n.d.).


Ill. 33 *Photo Credit: Visit Samsø*


Ill. 34 *Photo Credit: Visit Samsø*


Ill. 35 *Photo Credit: Visit Samsø*


Ill. 36 *Photo Credit: Visit Samsø*


Ill. 37 *Photo Credit: Visit Samsø*


Ill. 38 *Photo Credit: Visit Samsø*


Ill. 39 *Photo Credit: Visit Samsø*


Ill. 40 *Photo Credit: Visit Samsø*

Tourism

Samsø is a popular tourist destination in Denmark that is known for its culinary experience, natural landscape, beautiful beaches, historical sites, and its natural cultural heritage (Feriepartner.dk, n.d.). Samsø is well-visited by tourists, not only from Denmark, but also from other countries, and has a thriving tourism industry with a range of attraction and several accommodation options (Jetzen, et al., 2018).
Denmark's National Strategy for tourism aims to grow the number of overnight-stays by a third by 2025, but this will impact a specific focus on sustainability, despite Denmark's reputation for being highly environmentally conscious (Holland, et al., 2019).
In 2022, the number of overnight-stays in hotels, resorts, hostels, campsites, and marina was 39,6 mil. in Denmark. This is an increase of around 4,3 mil. in 2019 pre-COVID-19. and 10 mil. in 2021 post-COVID-19 and sets as a new record for the highest number of overnight-stays in Denmark, in which 65% are Danish guests. Hereby, 11,6 mil. of the total stays are Danes who stayed in hotels, such as beach hotels, which is the highest ever (Danmarks Statistik, 2023).
To design a beach hotel that not only meets the needs and desires of potential guests but also positively contributes to Samsø's local community and environment. This will be crucial to carefully consider and incorporate a variety of important qualities and features that aligns with Samsø's unique and natural landscape, rich cultural heritage, and diverse range of activities close to nature. Prioritising these elements in the design of a new beach hotel will not only help to attract more tourists to Samsø, but also contribute to the sustainable growth of the local economy and community in a beneficial way.

Ill. 41 *Sustainable Energy on Samsø*

Ill. 42 *Windmills outside Samsø*

Ill. 43 *Samsø Energiakademi*

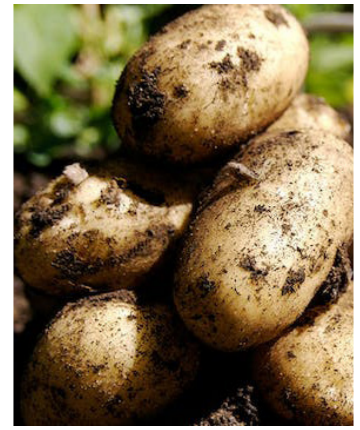
Ill. 44 *Photo Credit: Lasse Skovgaard / TV2 Øst*

Ill. 45 *Photo Credit: FBG Medier/Morten Damsgaard*

Sustainable Energy

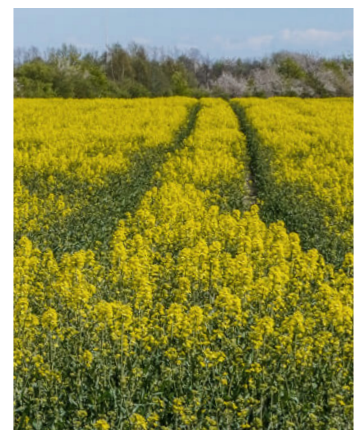
In 1997 Samsø initiated a process to become self-suppliant of their own renewable energy through windmills, 11 at land and 10 at sea. More inhabited areas of the island are connected to four district heating plants, which generate heat from combustion of straw and by 2030 Samsø wants to become independent from fossil fuels. More distant areas, factories and transport still depend on fossil fuels (Nielsen & Jørgensen, 2015).

Samsø was also once named Denmark's Sustainable Energy Island and now produces 160% of its electricity needs and 70% of its heat from sustainable sources, mainly from windmills offshore. The excess amount of electricity is transported to the rest of Denmark, which makes Samsø one of the net exporters of electricity in the Danish power network (Nielsen & Jørgensen, 2015).



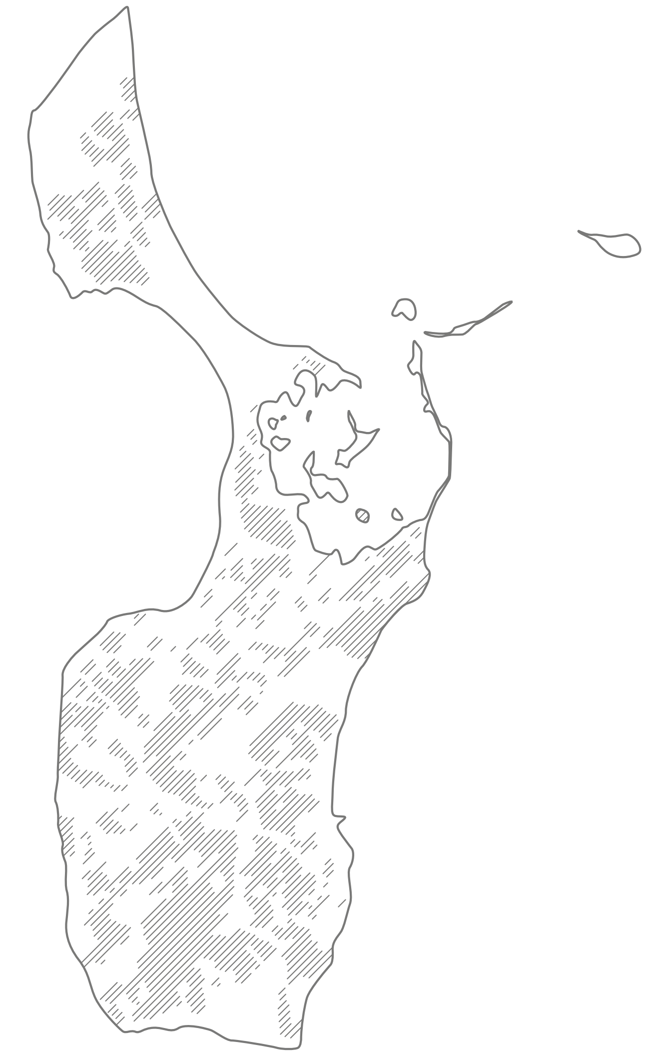
Ill. 46 *Photo Credit: Lotte Bjarke*

Ill. 47 *Photo Credit: Visit Samsø*



Ill. 48 *Photo Credit: Kristina Møller*

Ill. 49 *Photo Credit: Visit Samsø*



Ill. 50 *Agriculture on Samsø*

Culinary Agriculture

Samsø's main occupation of income is the tourism industry followed by the agriculture industry, which also is an attraction for tourists. Today 68% of the land on the island is utilised for agricultural purposes and Samsø is especially known for their production of potatoes and vegetables. Due to the favourable weather conditions the potatoes are harvested earlier in the season compared to the rest of Denmark (Eggert, et al., 2020). Though the production of grains is dominating the agricultural industry on Samsø by utilising 45% of the land, whereas 10% of the land is utilised for growing potatoes, compared to national level where only 1% is utilised for growing potatoes (Møller & Dalgaard, 2020).

In general, all chefs on Samsø use locally harvested crops and meats for their restaurants and even some of the chefs have special arrangements with the farmers to cultivate specific crops (VisitDenmark, 2023).

The Identity of a Beach Hotel

The History of a Beach Hotel

The definition of a beach hotel is: A hotel located by the water. The first beach hotels in Denmark were built in the late 19th century and offered walks along the waterfront, fresh air, and with the opportunity to swim in the ocean. In the past, the ocean was seen as a dirty place where fishermen fished and belonged but over time it was found that the salty water, combined with the fresh air, had a positive effect on people's health. It was usually the rich people from the capital of Denmark, Copenhagen, or other city dwellers who were advised by doctors to get away from the polluted cities and out in the fresh air and go swim in the sea. As more and more of the rich city dwellers came to the small towns by the beaches, the need for holiday homes and beach hotels increased. Initially, only the richest went on holiday by the oceanside, but with the "Holiday Act" in 1938, where everyone was entitled to two weeks of paid holiday, more and more people with diverse social classes joined. Today, some beach hotels have expanded their facilities to offer spa and wellness together with different treatments (Opholds Guiden, n.d.).

Ill. 51 *Photo Credit: Saxild Arkiv*

Ill. 52 *Photo Credit: Lokalarkivet i Hørsholm*

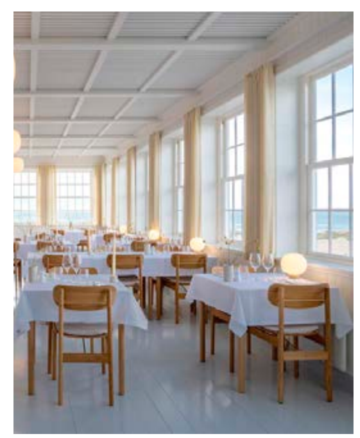
Ill. 53 *Photo Credit: Nordjyllands Kystmuseum, Lokalhistorisk Arkiv Sæby*

Ill. 54 *Photo Credit: Nordjyske*

Ill. 55 *Photo Credit: Silke Grane*

Ill. 56 *Photo Credit: Torben Eskerod*

Ill. 57 *Photo Credit: OpdagDanmark*



Ill. 58 *Photo Credit: Jens Lindhe*

Architectural Position

Danish beach hotel architecture has a rich history that dates to the late 19th-century and early 20th-century when Denmark experienced a surge in tourism. The Danish architects of this time were highly inspired by the architecture of other European countries and began to incorporate classicism elements, Jugendstil and functionalism into beach hotel architecture (DAC, 2023).
Key features of Danish beach hotel architecture are its use of natural materials, which are often locally sourced such as wood and red/yellow clay bricks. Implementing large windows increases the natural atmosphere inside the beach hotels and takes advantage of the costal views and allow guests to enjoy the natural comfort within their rooms. These design features are due to the Scandinavian architectural movement in Europe in the early 20th-century that highly encompasses the relation to nature (Thomann, 2022).

Samsø's Existing Beach Hotels

Information about the two existing beach hotels on Samsø has been obtained to get an idea of their location, opening period, and facilities.

Samsø Badehotel – Ilse Made is situated in the far countryside and offers a scenic view of the ocean. Although the hotel is around 440 m away or 1 km on foot from the ocean and has no direct access to the beach from the hotel, which makes it rather inconvenient to visit. On the other hand, Ballen Badehotel is located in the town and does not offer any ocean view, but it provides an easier access to the yacht harbor and beach, which is around 200 m away on foot from the hotel. Both beach hotels are seasonal and are open in varying periods, ranging from 6 to 8,5 months during the spring, summer, and autumn months of the year.

The facilities offered at both the beach hotels are very similar. Each hotel provides a restaurant that serves both guests staying at the hotel and also for those who are not, as well as event spaces for hosting private gatherings (Ballen Badehotel, n.d.) (Samsø Badehotel - Ilse Made, n.d.).

Each hotel also offers various sizes of rooms ranging from a one-person room to a villa that includes rooms enough for 8 people (Samsø Badehotel - Ilse Made, n.d.).

	Ballen Badehotel	Samsø Badehotel Ilse Made
Location	City View to other buildings Close to the beach	Countryside Sea view Long distance to ocean
Open months during the year	6 months April - September	8,5 months Mid-March - November
Facilities	Restaurant Assembly room Conference rooms 21 rooms 2 tents	Restaurant Assembly room Conference rooms 8 rooms with 4 beds 23 rooms with 2 beds 1 room with 8 beds

Ill. 59 *Ballen Badehotel*

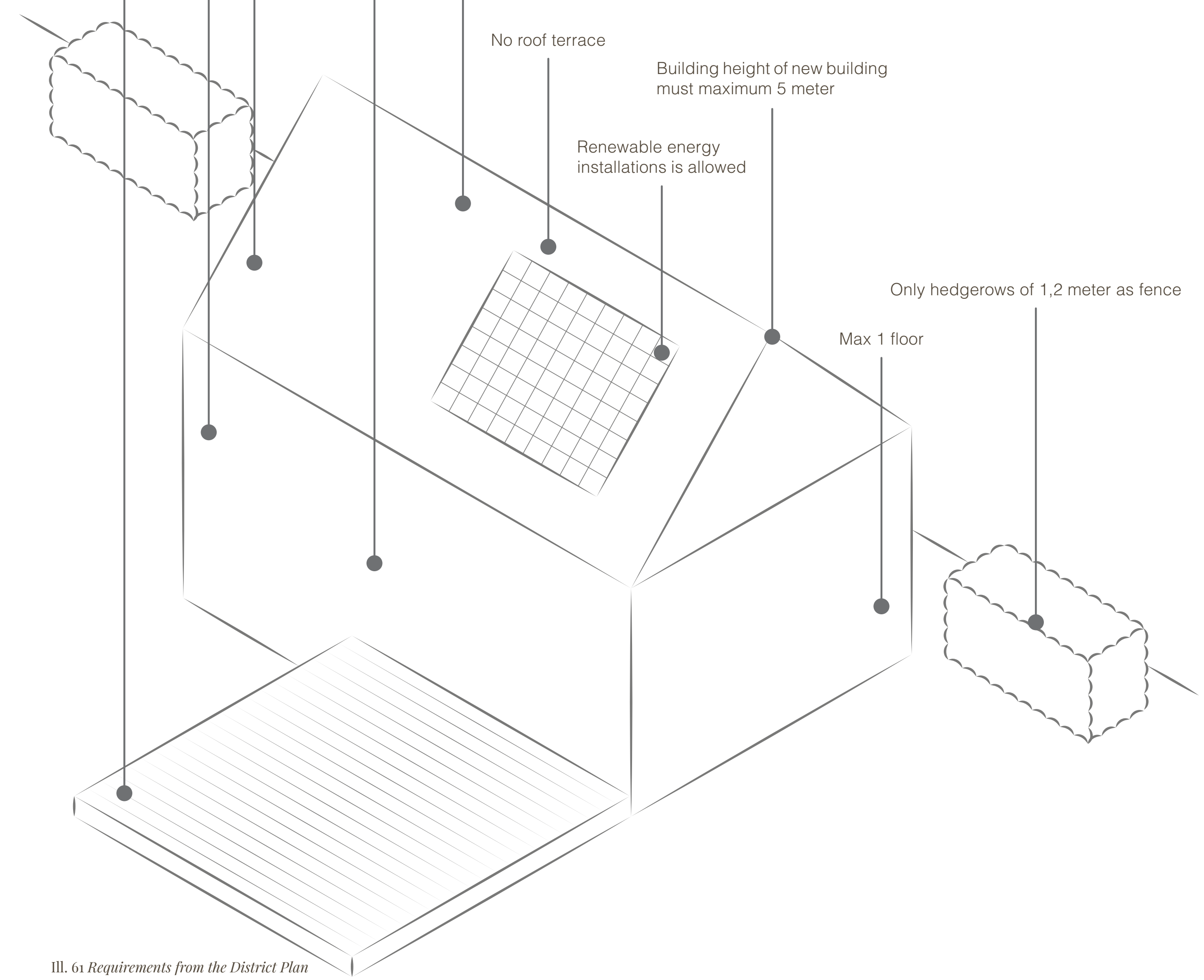

Ill. 60 *Samsø Badehotel Ilse Made*

District Plan

The beach hotel is situated near two summer house areas, and it is therefore assumed to follow the Local Plan 83 to ensure that the beach hotel adheres to the criteria for the surrounding summer houses.

The district plan says that to maintain the harmony with the surroundings, any new constructions that can impact the visual contact to the coastal landscape are not allowed to exceed a building height of 5 m. Additionally, only one floor is permitted, and the outer wall's height on at least one side must not exceed 3 m. However, it is possible to make minor changes and additions to existing structures while keeping the original building height and floors.

To ensure that the new buildings blend in with the existing structures in the local area, their appearance must not differ significantly. The exterior building facade must be made out of wood, brick, or plaster in either white, black, or natural colours. However, other smaller building parts can be made of glass or other materials. Roofs must be design with a symmetrical pitched roofs with a maximum slope of 45 degrees and must be made out of non-reflective roofing material. While renewable energy installation may be installed, they must not cause any glaze to close neighbours. It is not permitted to establish a roof terrace, and free-standing terraces must not be higher than 0,5 m above the natural terrain. Fendin must be as hedges with a maximum height of 1,2 m and must be planted on the owner's plot at least 30 cm from the site boundary (Samsø Kommune, 2018).



Ill. 61 *Requirements from the District Plan*

Ill. 62 *Besser Rev*

Recapitulation

The Setting

To promote an all-year round operation for the beach hotel, it is important to include facilities, activities, and attractive outdoor areas that altogether encourage guests to visit the beach hotel regardless the season. Bicycles, paddleboards, kayak, etc. and a bathing pier should also be available for guests to enjoy activities on Samsø.
To make the beach hotel a peaceful and relaxing place to go get away from the busy everyday life the user group of the beach hotel is focussed on adults.
To maintain the overall identity of a beach hotel it is important to implement calmness, comfortability, and provide unique experience into the transformation of the cement factory as it should be a space for guest to retreat to. All rooms should be able to have a clear view of the ocean and easily access the outside natural landscape and to accommodate diverse user groups, the hotel should also offer different room configurations. Other rentable facilities should be also included for private gatherings and celebrations. Additionally, a restaurant will be used as a clear connection to Samsø's agricultural industry through its sensory experience and create a closer connection between the guests and the chef.
Several architectural key points stated in the district plan such as the facade material and height clearance are to be integrated into the design to fit into the island's overall expression. Samsø is also known as "Denmark's Sustainable Energy Island" by using renewable energy and therefore also implemented into the design.

Ill. 63 *The Setting*

Seasonal Atmosphere

Winter

Autumn

Spring

Ill. 64 *The Seasonal Atmosphere*

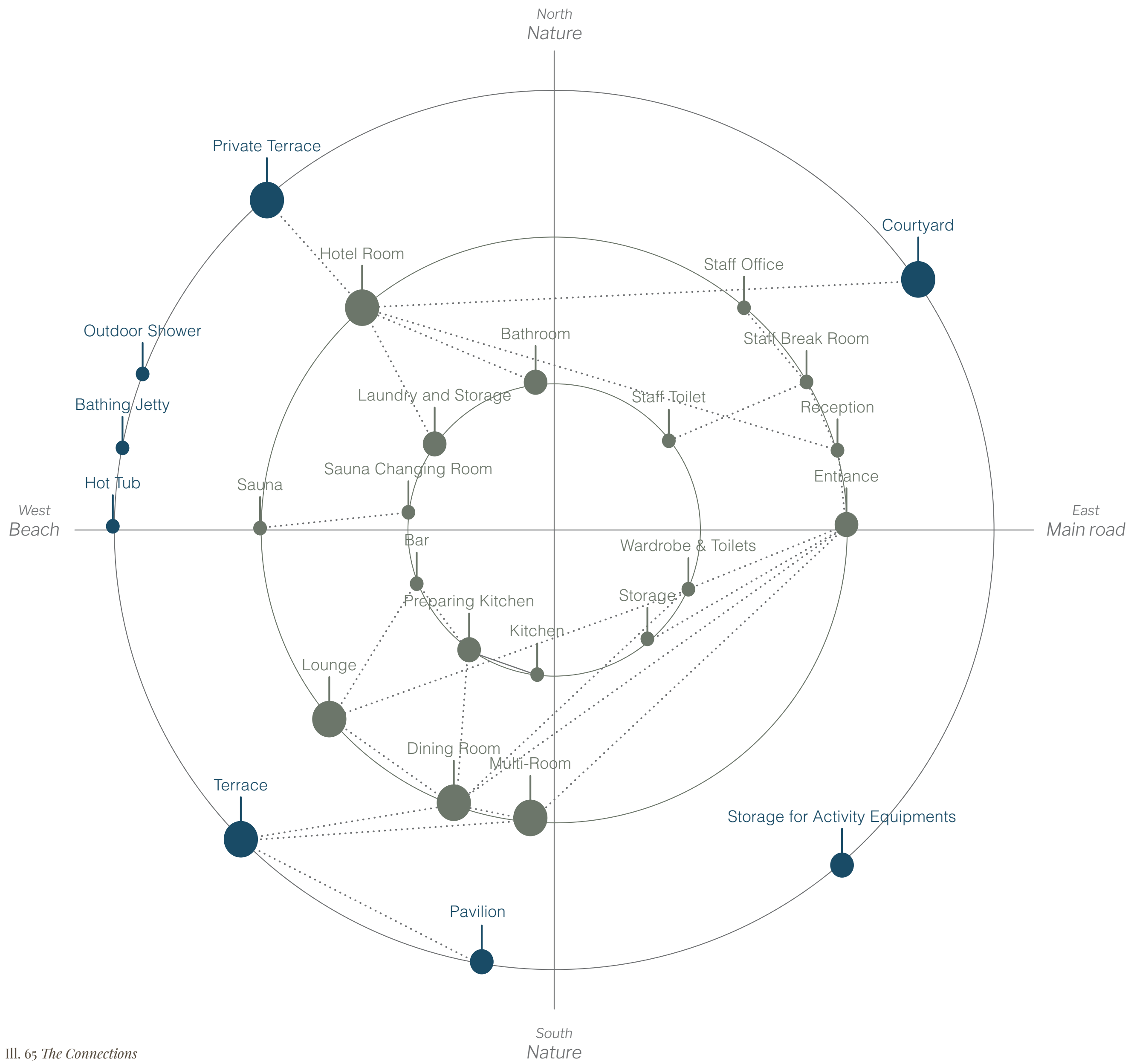
Summer

Room Program

Room	Quantity	Area	Total Area	Capacity	User	Orientation	Primary Season	Special Characteristics
		m^2	m^2	Persons	* H / R / S			
Gathering Space								
Entrance	1	51	51	10	H / R / S	East	All Seasons	Direct view to the ocean
Reception	1	13	13	4	H / S		All Seasons	
Toilets	3	3	9		H / R		All Seasons	
Total	5		73					
Restaurant								
Kitchen	1	20	20	3	S		All Seasons	
Preparation Kitchen	1	31	31	8	S		All Seasons	Open connection to the kitchen
Bar	1	10	10	3	S		All Seasons	
Dining Room	1	70	70	25	H / R / S	South	All Seasons	
Lounge	1	79	79	20	H / R / S	South / West	All Seasons	
Multi-Room	1	74	74	40	H / R / S	South	All Seasons	Multi-functional floor planning
Storage	1	3	3		S		All Seasons	Direct connection with the terrace
Toilet	3	5	15		H / R		All Seasons	
Total	10		146					
Hotel Rooms								
Bedroom	8	16	128	16	H	West / North	All Seasons	View to the ocean
Bathroom	8	4	32	16	H		All Seasons	
Terrace	8	9	72	16	H	West / North	Sp / Su / A	
Laundry and Storage	1	10	10		S		All Seasons	
Total	25		242					
Administration								
Office	1	13	13	2	S		All Seasons	
Break Room	1	33	33	10	S	North / East	All Seasons	
Toilet	2	6	12		S		All Seasons	
Technical Room	2	3	6		S		All Seasons	
Total	6		64					
Urban Area								
Terrace	1	176	176	60	H / R / S	South / West	Sp / Su / A	
Pavilion	1	42	42	15	H / R	South	Sp / Su / A	
Courtyard	1	274	274	16	H	East	Sp / Su / A	
Storage for Activity Equipment	1	63	63		H / S		All Seasons	Easy access to the water and exit
Sauna	1	24	24	8	H	West	All Seasons	Directly admittance to outside
Sauna Changing Room	1	10	10	3	H		All Seasons	
Hot Tub	2	6	12	8	H	West	All Seasons	
Outdoor Shower	2			2	H	West	All Seasons	
Bathing Jetty	1				H	West	All Seasons	
Total			564					
Gross Area			840					

* H: Hotel Guests
R: Restaurant Guests
S: Staff

Functional Program

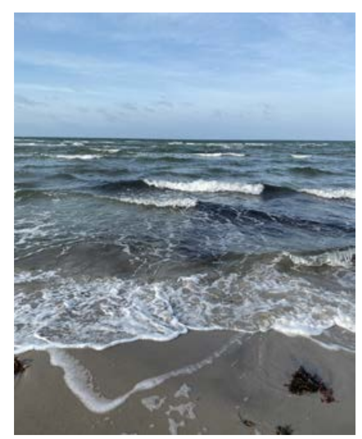


Ill. 65 *The Connections*

Ill. 66 *Photo Credit: Safretti*

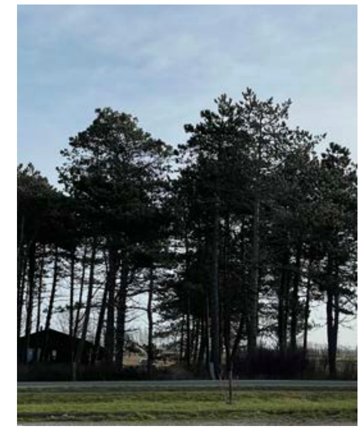
Ill. 67 *Photo Credit: Kristina Møller*

Ill. 68 *Photo Credit: VICA Danmark*

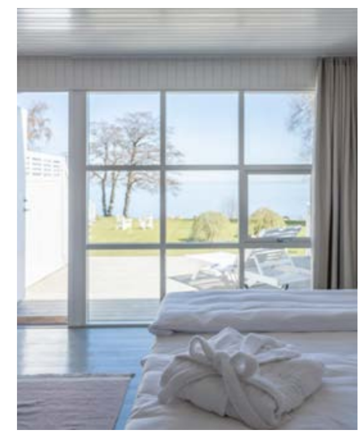


Ill. 69 *Photo Credit: Project Site*

Ill. 70 *Photo Credit: BoShop*



Ill. 71 *Photo Credit: Project Site*

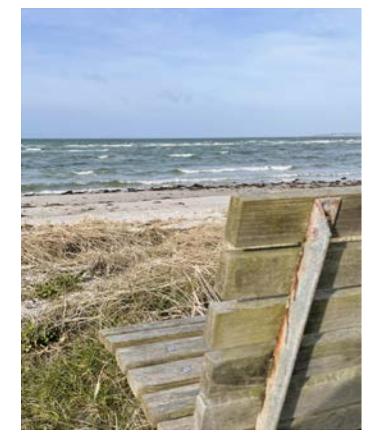


Ill. 72 *Photo Credit: Melsted Badehotel*

Ill. 73 *Photo Credit: Rasmus Hjortshøj*

Ill. 74 *Project Site*

Ill. 75 *Photo Credit: Rasmus Hjortshøj*



Ill. 76 *Project Site*

Ill. 77*Photo Credit: Vildmarksbad i grantræ, Sølund Huse (2023)*

Ill. 78 *The Cement Factory*

Problem Statement

How can a beach hotel through the architectural transformation of an old cement factory be designed to accommodate and support the agricultural identity of Samsø to further enhance the traditional beach hotel typology with the primary focus of being environmentally sustainable?

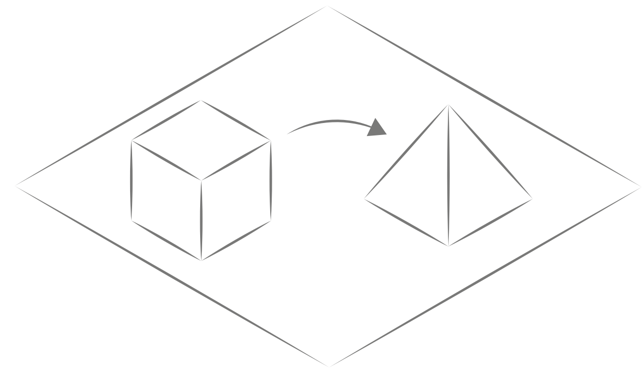
Vision

The vision of this thesis is to propose a sustainable transformation of an old, existing cement factory into a beach hotel that emphasises the environmental benefits of renovation compared to building a new building while preserving the historic identity of the cement factory, and simultaneously aligning with Samsø's agricultural heritage.

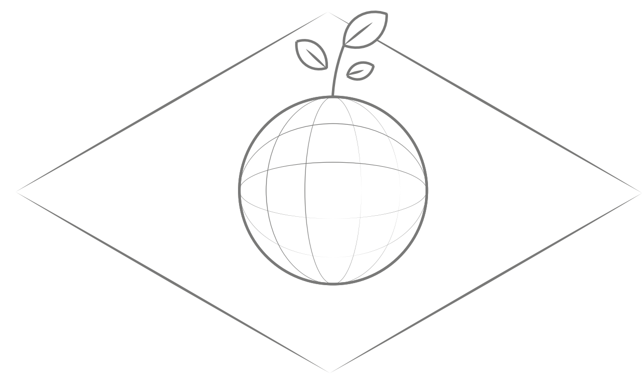
The beach hotel shall facilitate a space for comfort and a unique culinary and historical experience, capturing the essence of an authentic, traditional beach hotel. This implementation aims to encourage a year-round establishment to positively impact and be a part of Samsø's increasing tourism rate. Additionally, the architectural composition of the thesis will solely be based on the use of natural materials, chosen through Life Cycle Assessment analysis to further extend the sustainable aspect of the project.

Located in a Danish rural landscape where tall grass and dunes are the prominent feature, will deepen a close relation to nature and enhances the motivation for the thesis towards a sustainable transformation architecture, through materiality, identity, and experience. In conclusion, this thesis seeks to examine and answer the following problem statement.

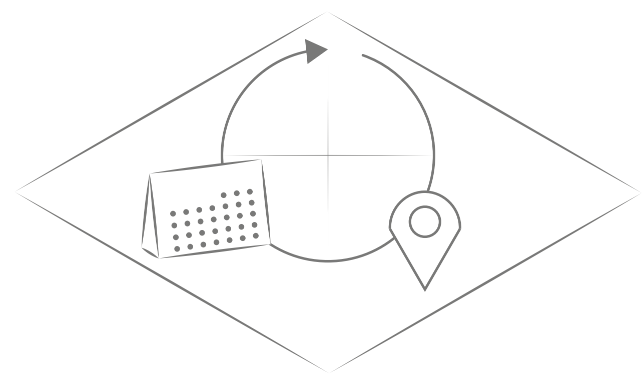
Design Parameters



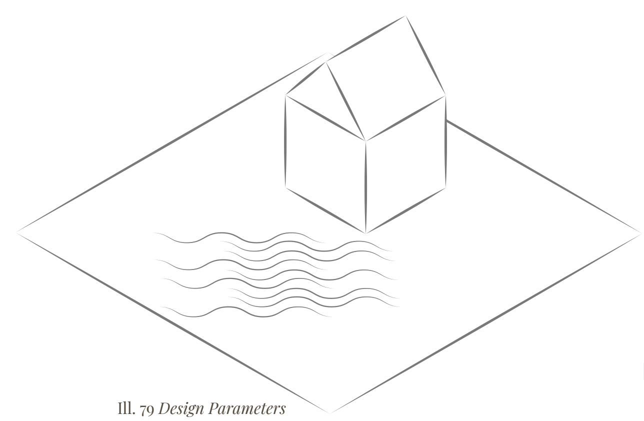
Transform architecturally both exterior and interior with respect of the existing building identity.



Implement sustainable strategies to lower environmental impact.



Incorporate Samsø's culinary- and tourism identity through facilities that can be used and open all year round.



Revive the original identity of a beach hotel.

Ill. 79 *Design Parameters*

Ill. 80 *Brundby Stubmølle*

Microclimate

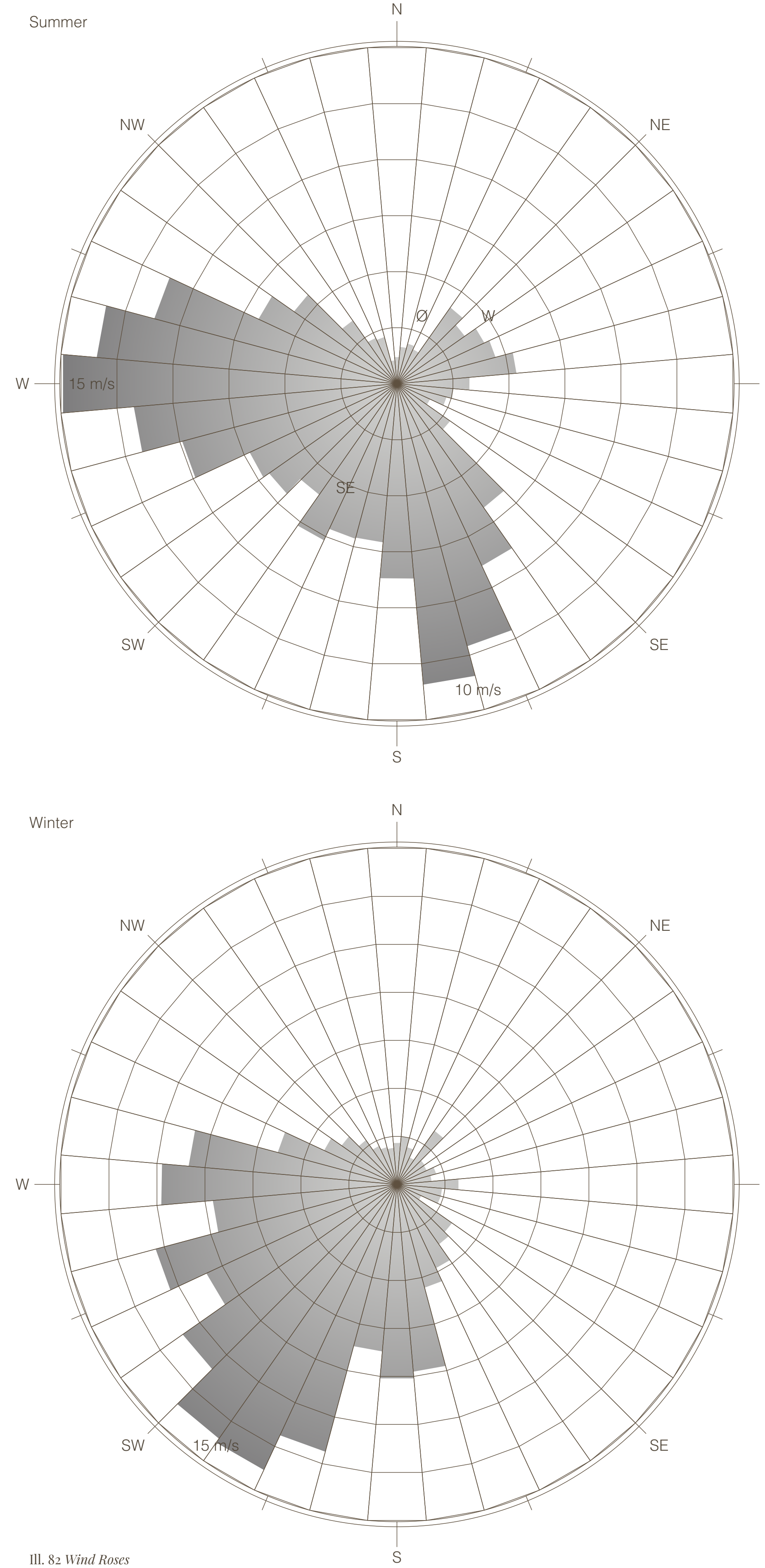
Wind Exposure
Shadow
Blue Spot
Sea Level

Ill. 81 *Wind Exposure*

Wind Exposure

The wind rose depicts the average wind exposure from April to September and October to March 2007 – 2021 in Røsnæs, Denmark. This lighthouse in Røsnæs is chosen since it is the lighthouse with the right orientation closest to the project site. The wind exposure on the site is important to consider for both the outdoor spaces for stay and natural ventilation in the building. It is expected that the guests have longer stay outdoors in the period from April to September which is why the wind rose is divided into two.

In the summer half year, the wind mainly comes from west and south, with occasional exposure from southwest. The most optimal outdoor areas are due to the wind rose towards northwest, north, east, and northeast but due to the building's location on the site, the most idyllic and relaxing outdoor area is to the west and southwest but since the wind comes from here wind shelter solution must be considered. Furthermore, the windows of the building can be advantageously oriented to the west, southwest and south to utilise the wind for natural ventilation.



Ill. 82 *Wind Roses*

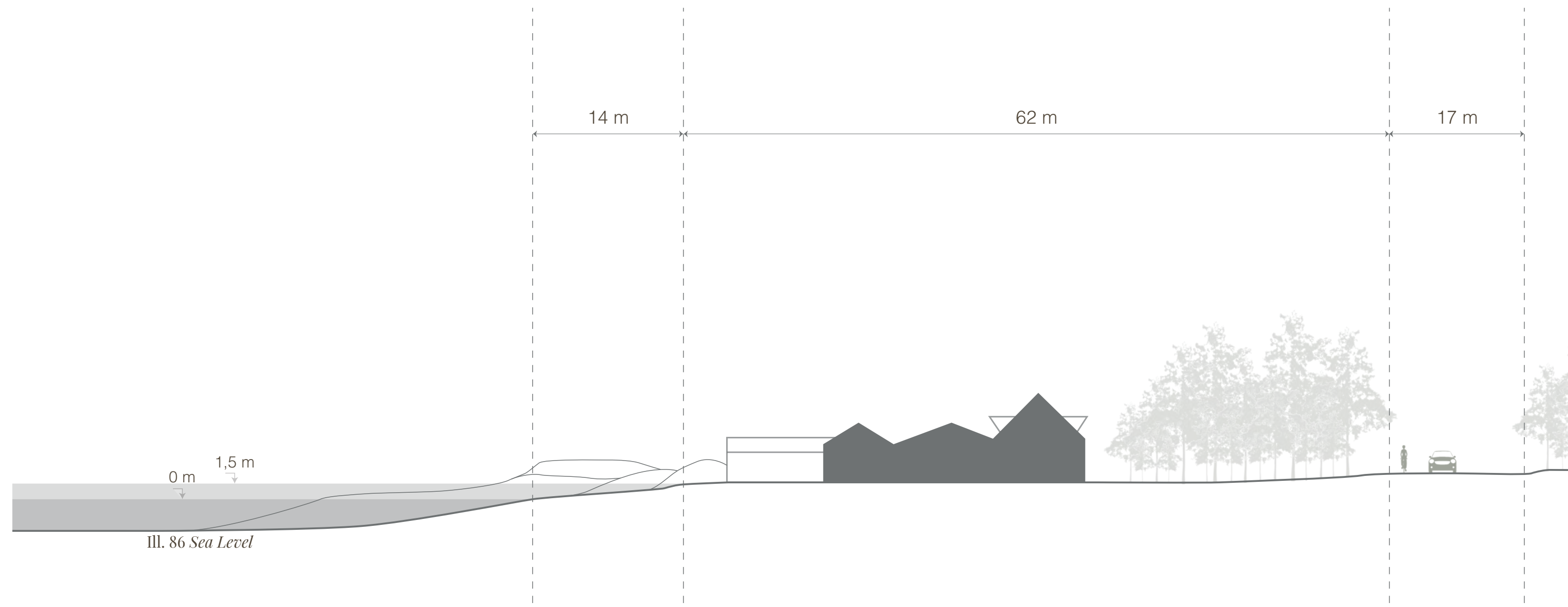
Ill. 83 *Shadow Summer*

Ill. 84 *Shadow Winter*

Shadow

To gain an understanding of how the shadows fall from the cement factory, two separate analyses were done for the winter and summer season. To gain an understanding of how the shadows fall from the cement factory, two separate analyses were made for the winter and summer season. The results indicate that during the summer mornings, shadows will be cast on the southwestern side of the project site towards the sea. Throughout the day, the shadows will then shift with evening shadows moving towards the south-eastern part of the site. During the other hand, during winter, shadows will primarily fall towards north. Based on the analysis in the summer, it is recommended to place outdoor areas and facilities in the southwestern part to gain take advantage of the sun as it changes throughout the day. In winter, it wouldn't be optimal to place winter facilities towards north, as it would be the area with least sunlight.

Ill. 85 *Blue spot*



Ill. 86 *Sea Level*

Blue Spot

To accommodate the rainy days in Denmark, a blue spot analysis is done to identify areas on the project site that are mostly vulnerable of being flooded during a heavy rainfall. Heavy rainfall is defining exceeding 15 mm within a 30-minute period, and in this analysis outlines the potential impact of a rainfall for both 15 mm and 30 mm scenarios. This information is crucial to determining the risk for buildings on the site, as well as to determine opportunities for vegetation and natural water supply (Miljøministeriet, 2019).

The results indicate that the largest blue spot areas are located towards south and southwest. When considering a new building volume, it would be most optimal to be places in the northern eastern and partially southeastern areas of the project site.

Sea Level

The project site's close proximity to the ocean indicates a significant risk to the building and surrounding outdoor areas. The main purpose of this analysis is to give an insight on how close the water gets towards the site in high-tide and low-tide cases as well as rare incidents such as storms and abnormal high-tides.

Studies have shown that the yearly amount of downpour has had a 15% increase in the period 1874-2019 and there will be a further increase of 14% until the year 2100 (Miljøministeriet, 2021) (DMI, 2012).

The tidal strength varies depending on the location, with the difference between low and high tide typically being less than a meter on the open sea but can largely affect the coastal regions around the world. In Denmark this varies of around a couple of meter and data from Aarhus, which is located close to Samsø towards west, shows that the sea level here can increase around 1 m and in rare cases 1,5 m (DMI, 2022).

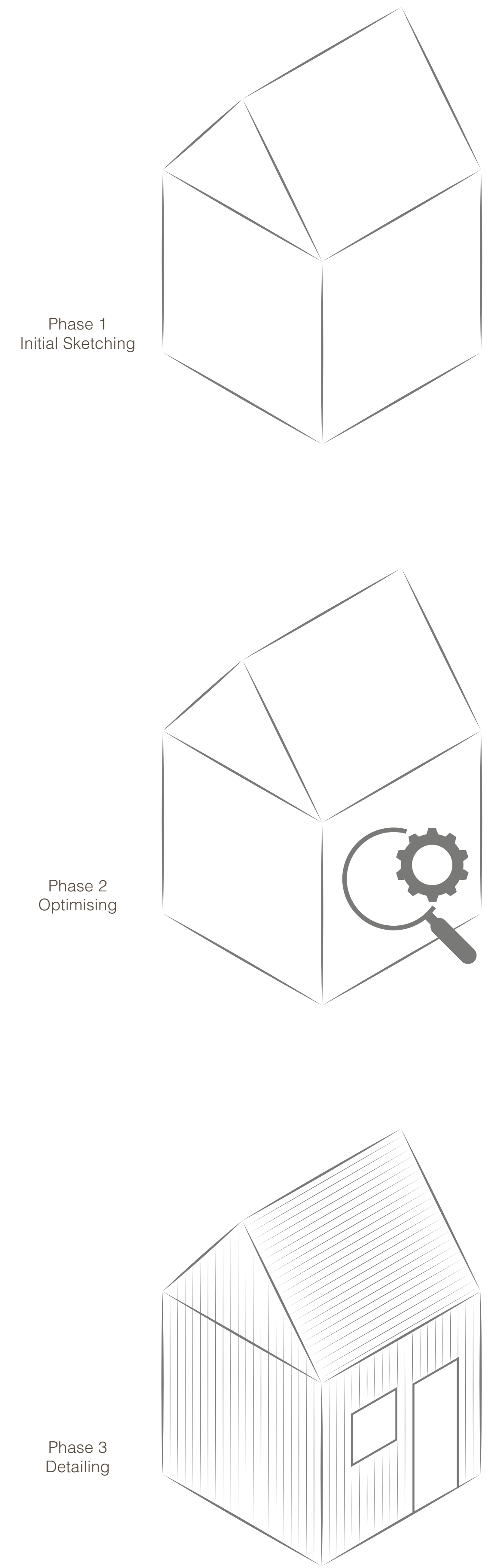
The analysis is also visualised on the project site and shows how the site changes when the water rises with 1,5 m above the normal sea level and due to the rather flat landscape, the water can get relatively close to the building. Also the analysis underlines the problematics from the blue spot analysis.

Ill. 87 *Vesborg Fyr*

Design Development

Design Strategy

The design development represents an integrated design process in between the underlying design studies and analysis which are used to apply critical adjustments that align with the project's vision. Although this is presented in a chronological order, the process is complex and iterative involving multiple decision-making steps through continuous assessment that results in several design iterations. The design development includes various subjects such as optimising volumes, interior planning, and urban planning in a small scale etc. as well as the technical aspects such as energy performance, structural and the overall sustainability. Ultimately, the goal is to communicate the best possible decisions for the project in an effective way that culminates a final design that harmonises with the project goal.

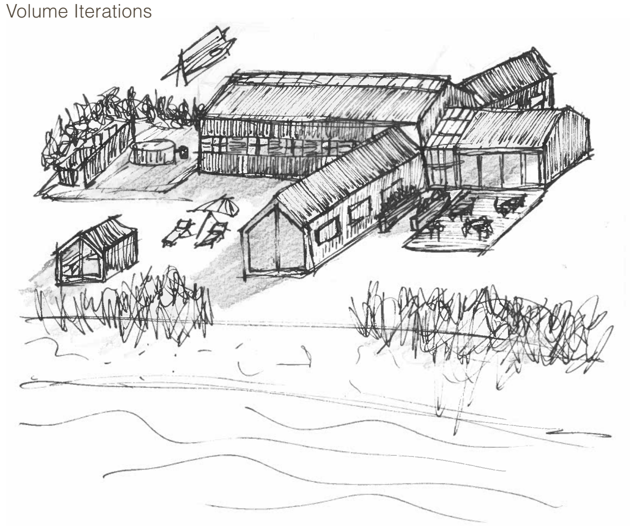


Ill. 88 *Design Phases*

Sketch Exercise 1

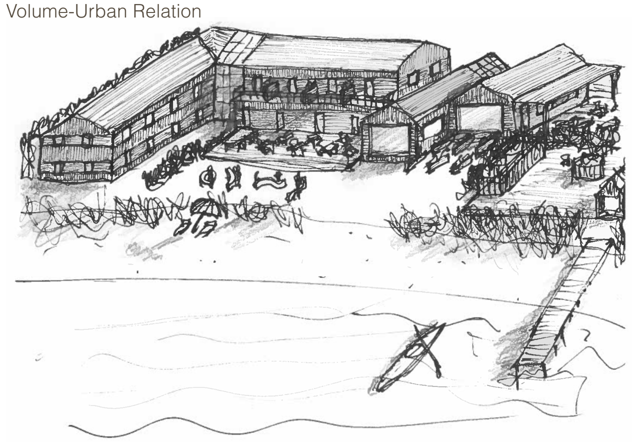
This early phase is to visually explore and communicate ideas without considering the project's hard constraints in regard to transforming an existing building. Quick freehand sketches without any predetermined plans or rules, other than the project's subject and site, will help determine each other's ideas in a more organic and spontaneous way, while also being a short but beneficial phase to guide the project through the next phases.

Volume Iterations

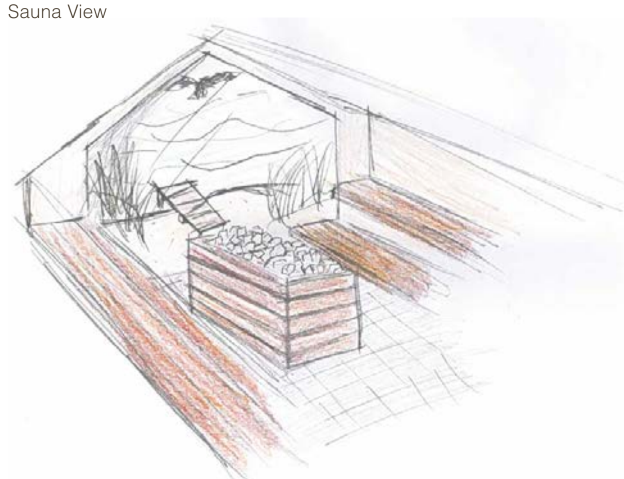


Maximising Views

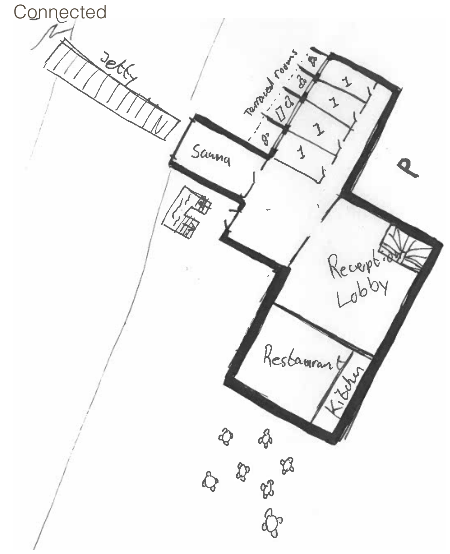
Volume-Urban Relation



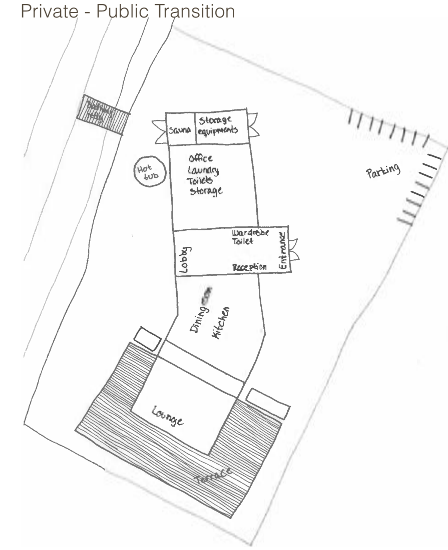
Sauna View



Connected

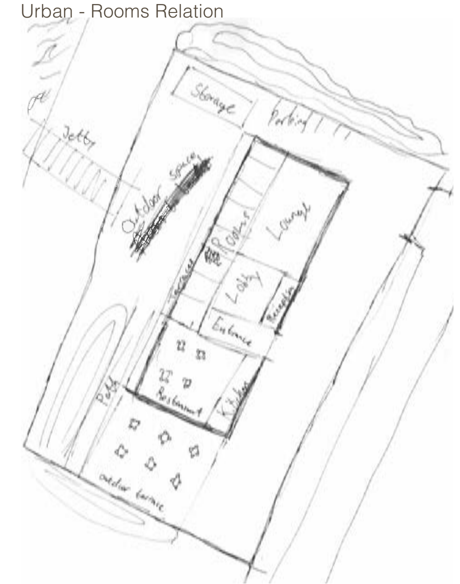


Private - Public Transition

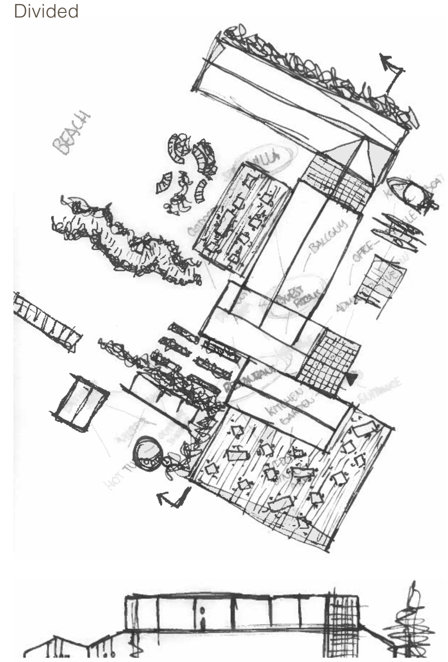


Central Separation

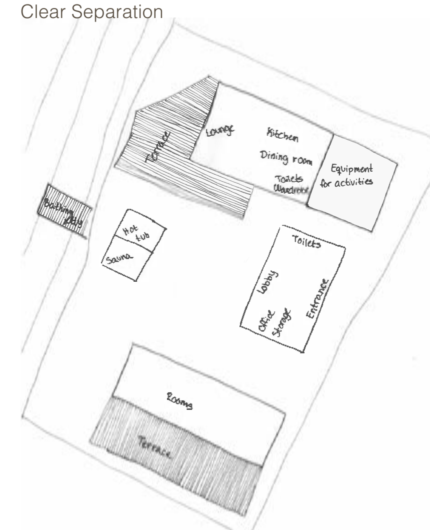
Urban - Rooms Relation



Divided



Clear Separation



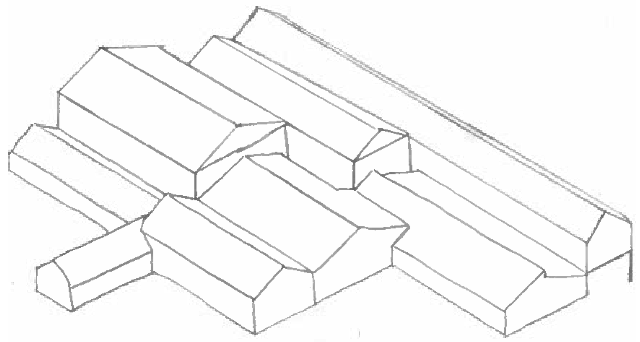
Ill. 89 *Sketch Exercise 1*

Sketch Exercise 2

In case of preserving and renovating the existing building, volume and floor plan sketches are made with the existing building in mind. This study helps to get an idea of where it is possible to place different facilities for the beach hotel and where to place facilities in the in the existing building to be beneficial for the guests. This study showed that the capacity for the restaurant compared to the amount guests differed too much and there was a need for additional space to make more rooms to host guests for the beach hotel.

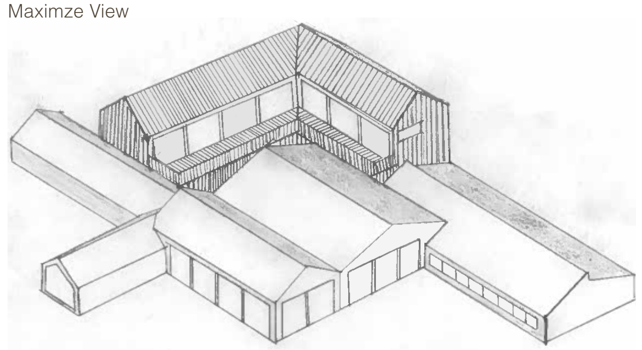
Beach View

Similar Roof Typology

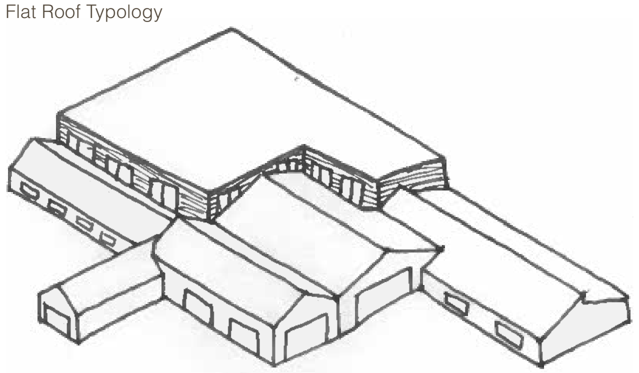


Arrival View

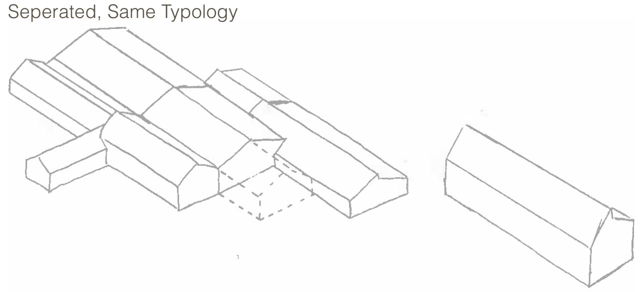
Maximze View



Flat Roof Typology

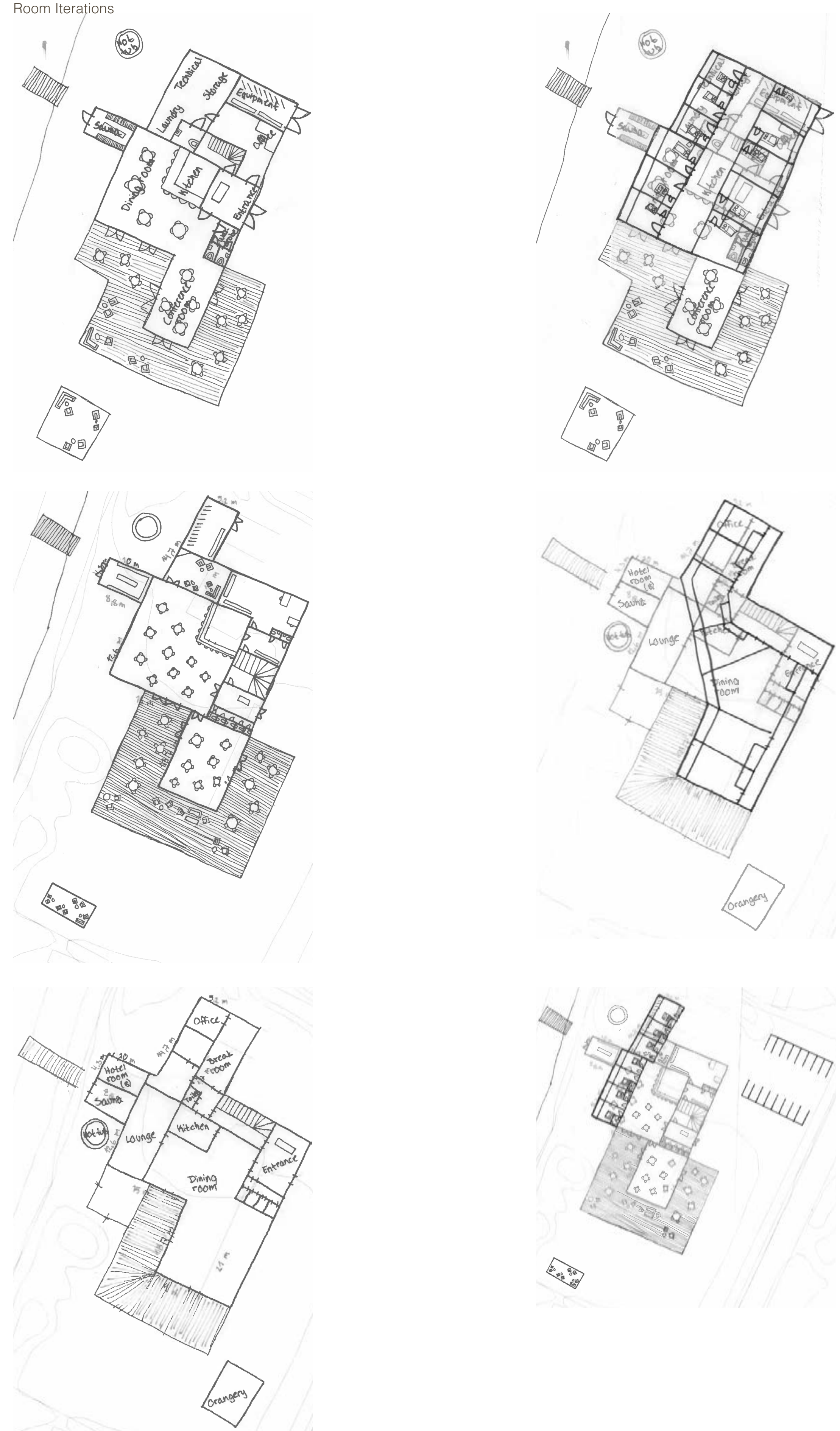


Seperated, Same Typology



Ill. 90 *Sketch Exercise 2*

Room Iterations



Transformation Options

To assess the renovation of the cement factory, a comparison of the existing building and a completely new building will be made to put emphasis on the benefits of renovating the existing buildings and its potential to change its original factory-function to a habitable and usable beach hotel. This comparison will focus on the building's environmental impact through LCA.

It is not possible to reach a substantial U-value of the floor by renovation that comply with the building regulations, due to a high demand of needed insulation and to accommodate moisture it is only possible to add 50-70 mm of insulation on top of the concrete (Brandt, 2012). A new floor with a U-value of 0,1 W/m² K will be built to make the building habitable though it has a negative impact on the LCA.

> *"The floor and roof usually stand out. This means that if you are considering breaking up the concrete floor slab as part of the restoration of a building, the retrospective assessment shows that this would be very carbon-intensive..."*
> *Anne Mette Rahbæk (Realdania, 2022)*

The new building for comparison will be constructed with a light construction built from construction wood with both an exterior and interior wood cladding. The new building is insulated throughout the construction with mineral wool whereas the renovated version of the existing building is insulated with wood fibre insulation. The roof of the new building is insulated to fit the building regulations for new buildings with a roofing felt cladding.

The new building has the following U-values

Building Element	U-value W/m² K
Roof	0,10
Walls	0,12
Floor	0,10

Using the LCAbyg software to calculate the climatic impact of the three instances

	Global Warming Potential (GWP) kg CO_2-eq/m²/year
Existing Building Before	1,45
Existing Building After	3,80
New Building	4,59

The climatic impact of the existing building is low due to the amount of material use for its construction, but with no insulation and roof construction the energy consumption needed to make the building habitable will inevitably be too high, which means the climatic impact from an energy perspective is assumed to be excessively high and renovation is needed to make the building habitable and more climate friendly. Demolishing and building a new building will ultimately have the largest environmental impact due to the amount of materials needed for the construction.

Energy Performance

BE18 is used as a tool to do calculations of the existing building's envelope performance to analyse and visualise what the required changes are to reach an optimised energy performance in comparison with the listed Danish energy frame classes. As this is a rough calculation, it is only in regard to the changes required for the building envelope such as the walls, roofs, floor, and windows. There are two options to consider for a better envelope performance; the first option is through preserving the existing building and do a total renovation and reinsulating the whole building envelope, and the second option is to demolish the existing building, and build a brand new, similar building.

Observing the analyses, the two different options of either the total renovation or constructing of a new building achieve similar results having the second option slightly better as it reaches the energy requirements for the Energy Frame for BR18 but the first option greatly comply with the renovation class regulations with no significant difference to new building regulations.

Energy Frame Class Key Numbers

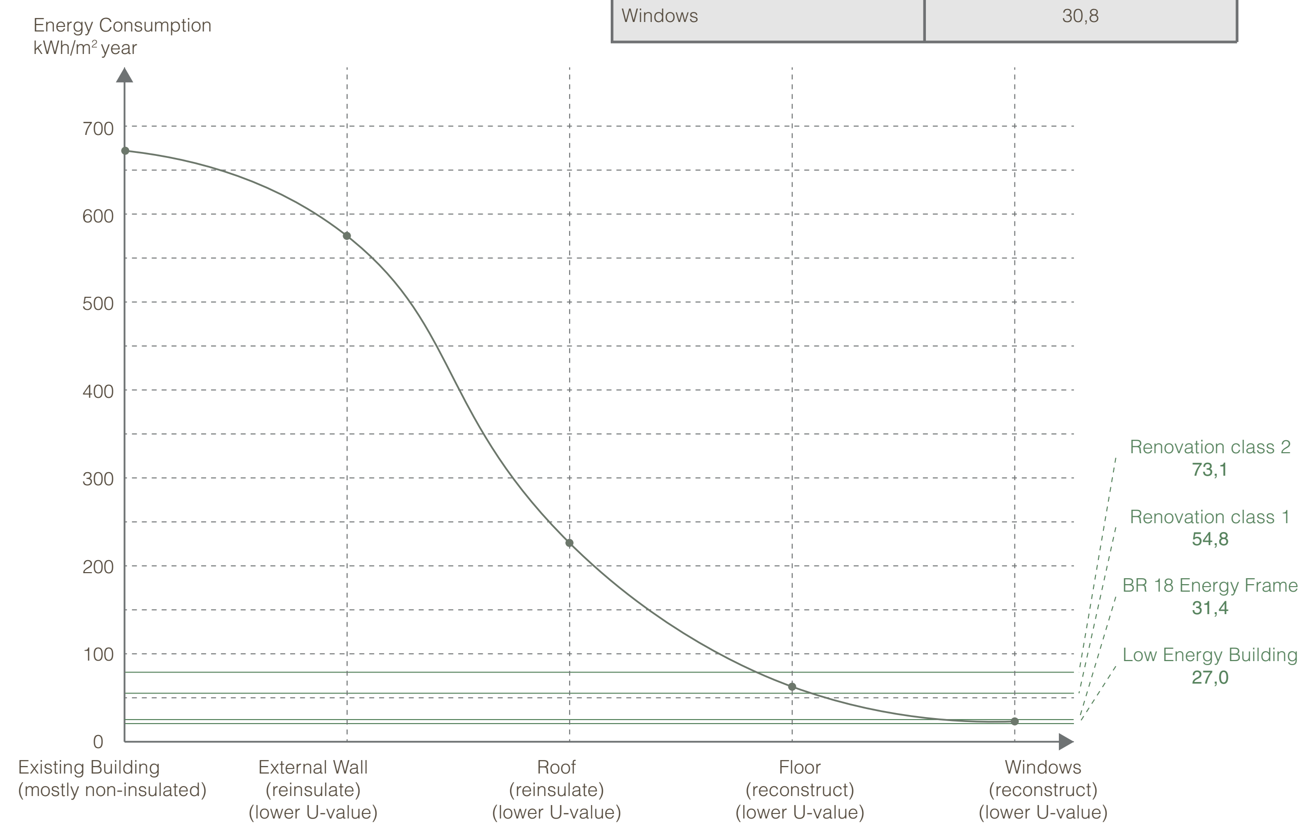
Energy Frame Class	Key Numbers kWh/m²
Renovation Class 2	73,5
Renovation Class 1	55,1
Energy Frame BR18	31,6
Energy Frame Low Energy	27

Total Renovation
Envelope Performance Rough Calculation

Total Renovation	Energy Requirement kWh/m²
Existing Building	663,8
Walls	579,2
Roof	246,2
Floor	72
Windows	35

New Building
Energy performance Rough Calculation

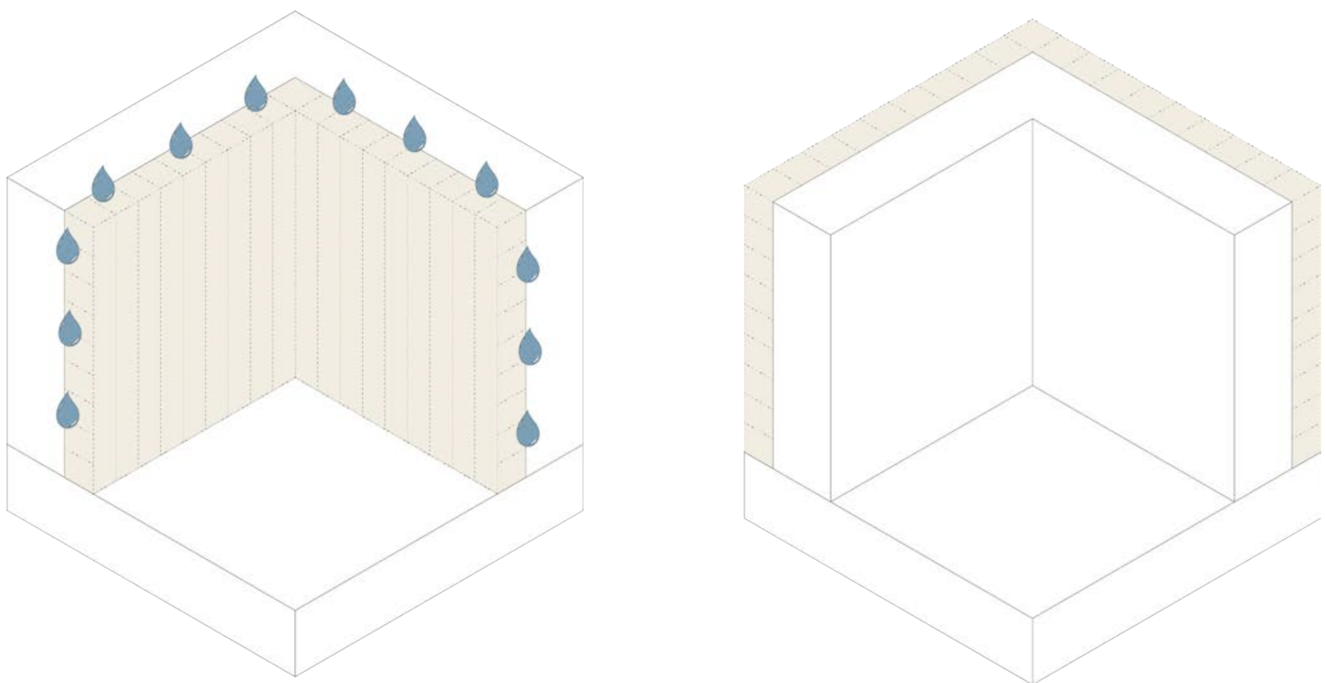
New Building	Energy Requirement kWh/m²
Existing Building	663,8
Walls	576,8
Roof	242,1
Floor	67,8
Windows	30,8



Ill. 91 *Energy Performance*

Insulation Options

When choosing how to optimise the existing building many considerations must be made regarding the buildings hygrothermal conditions. There are two options for reinsulating the building; outside and inside.
Internal insulation is preferred to preserve the cement factory's exterior expression but the result of reduced heat flow to the existing walls makes the walls become colder which increases the risk of condensation between wall and the new layer of insulation. Condensation may in course of time result in moisture-induced damage, fungal growth, wood decay, frost damage (Jensen, et al., 2021).
External insulation is chosen for the renovation because the existing walls will be kept warm and protected from the outside climate and it will be possible to solve issues regarding thermal bridges in critical areas like intersections between the external walls and adjoining building elements (Jensen, et al., 2021).

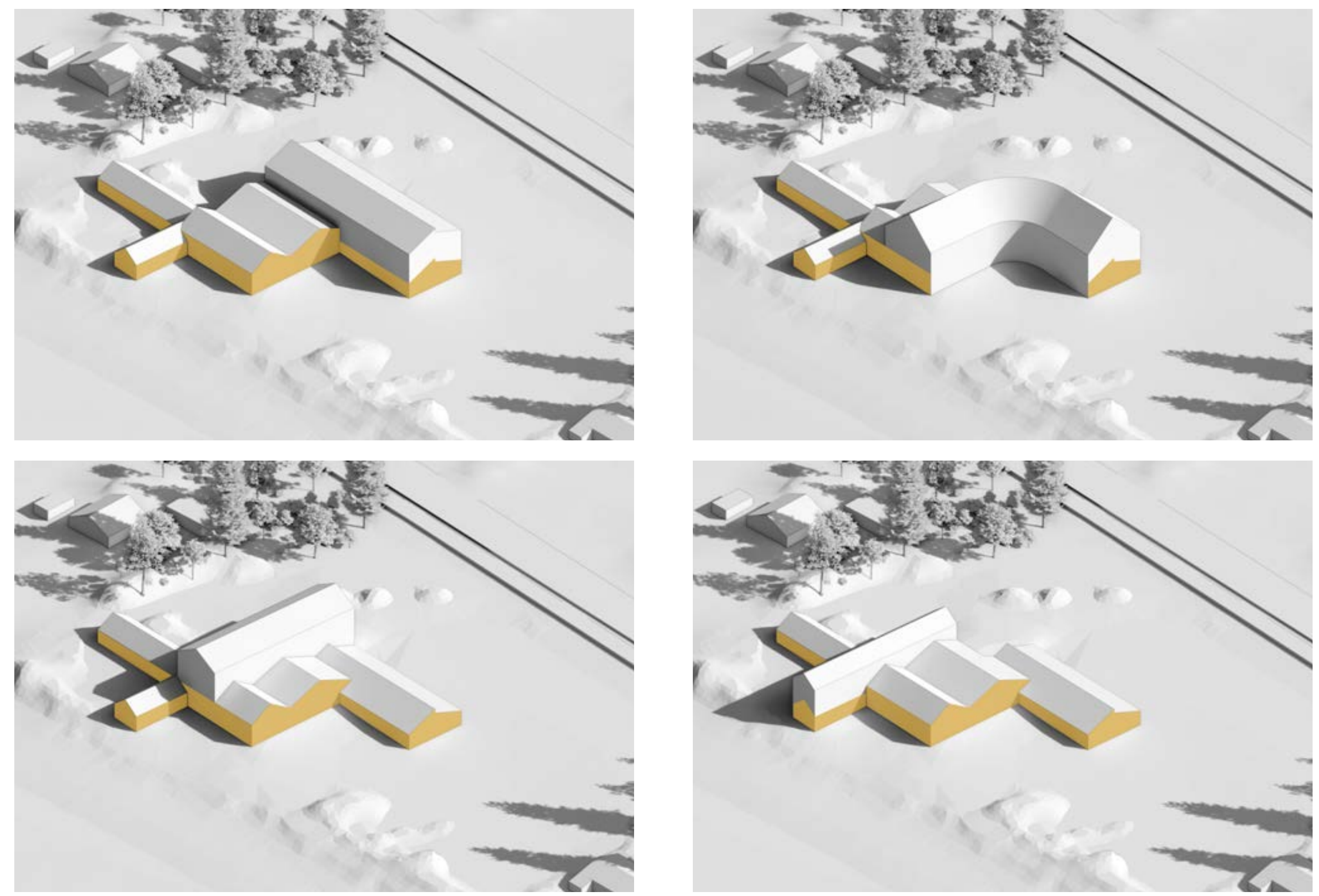


Ill. 92 *Insulation Options*

Volume Study

Floor Addition

A possible solution to increase the number of square meters is to add an extra floor to the existing building. Doing so will also maximize users' view of the ocean, which is one of the key factors of a beach hotel.
Different proposals of the floor-addition are drawn with the 3D-software Rhino to illustrate designs of the building's exterior expression. A further study of the structural components in the existing construction made the idea of a floor addition not possible because it would require the exiting construction to be reinforced by either an interior or exterior steel, wood, or concrete skeleton to be able to carry the load of the floor. Ultimately this would compromise the desired expression of the beach hotel and this solution is discarded. See appendix 1 for more studies.

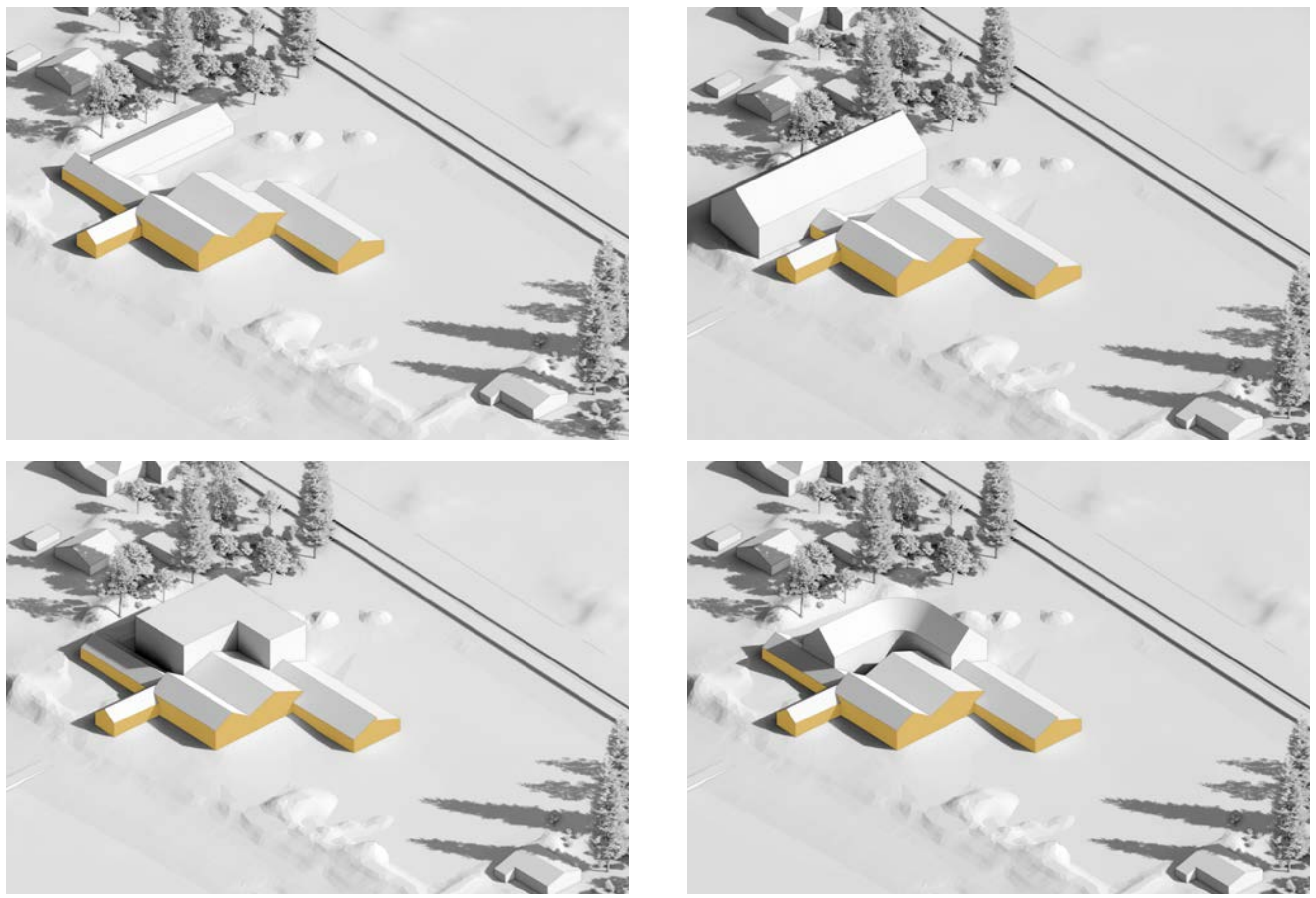


Ill. 93 *Floor Addition*

Volume Study

Building Extension

After discarding the design solution of a floor addition, the possibility of a building extension is explored. See appendix 1 for more studies.
The major challenge in this study is to design a building extension that fits and respects the existing building, which already has a very complex shape. Additionally, the ocean-view from the users will also be a challenge in regard to the placements of a new building extension.
The conclusion of this study is to try out a new volume instead of an extension in order to respect the existing building and to strive for a building addition that does not further compromise the complexness of the building.

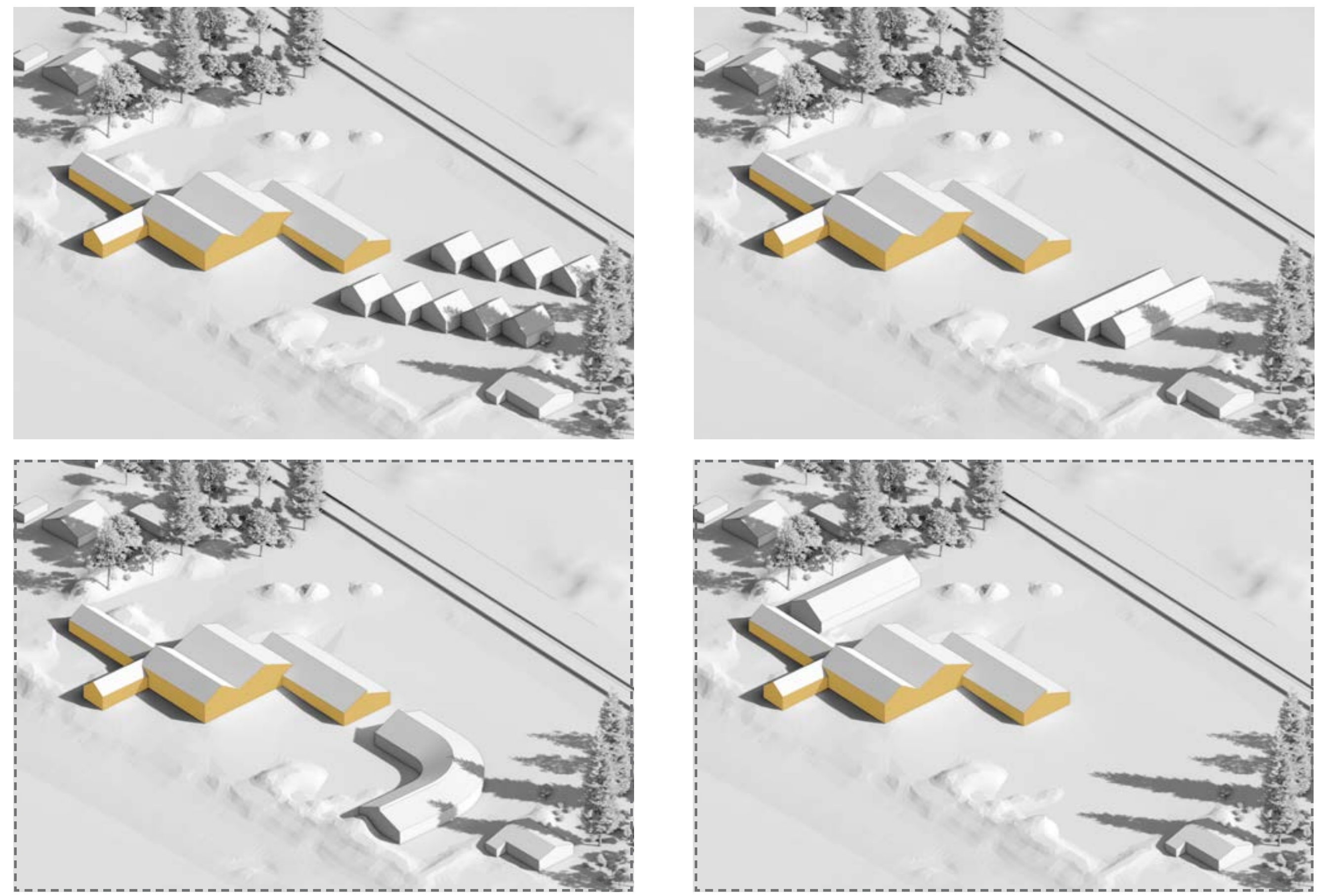


Ill. 94 *Building Extension*

Volume Study

Additional Building Volume

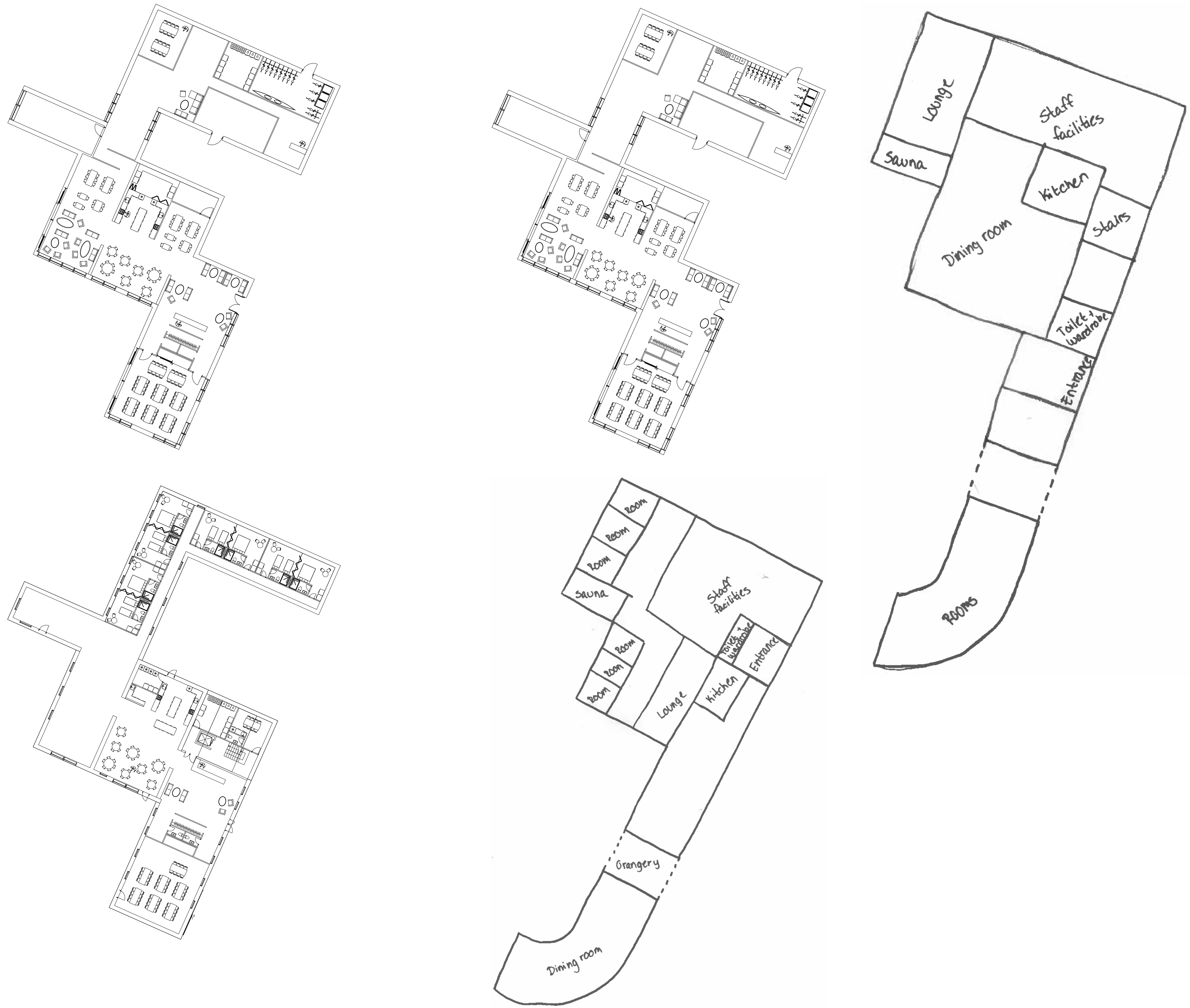
Different solutions of the added building volume are made to showcase a clear separation from the existing building and in that way respect the existing building. See appendix 1 for more studies.
This study resulted in two proposals showing potential for further investigation, one proposal of an additional building completed in an organic form to differentiate from the existing building and a proposal of an additional building to the north of the site to comply with the microclimatic analyses.



Ill. 95 *Additional Building Volume*

Floor Planning

Numerous floor plan iterations have been made for the two distinct building volumes. These attempts have been conducted to arrange the rooms in different locations in the building, however it is clear that rooms with longer durations of use such as the restaurant, lounge, and multi-room are best suited to be placed towards south. The main challenge lies in the placements of the hotel rooms and the staff facilities, and as the southern part will be used for the bigger rooms, it is then focused on placing rooms and the staff facilities towards north, introducing a new building volume.



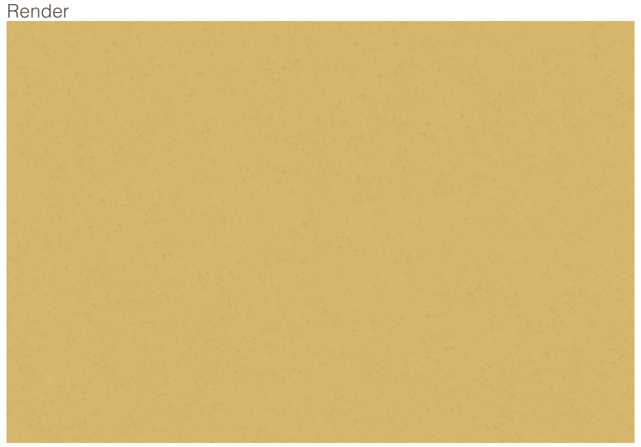
Ill. 96 *Floor Planning*

Facade Claddings

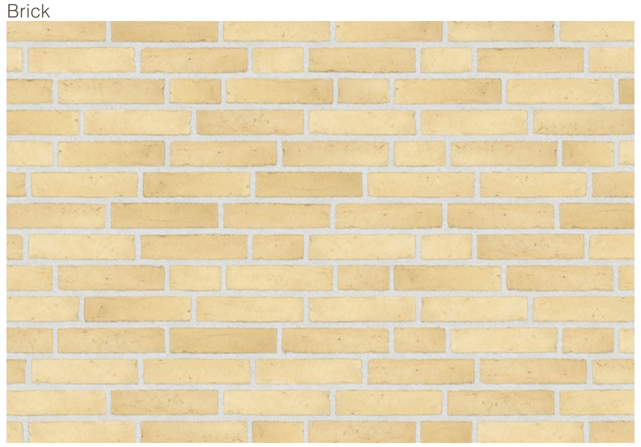
A clear transition between the existing building and the new building is desired to respect the existing building through a clear separation between the existing- and new building. It is desired to preserve the identity of the existing building by using facade cladding inspired by the existing yellow render.

According to the district plan the facade cladding of the summer houses around the cement factory must be made in bricks, render, or wood. To respect the district plan different combinations of these materials are tried out to gain insight in the desired material choice. The wood cladding and roof on the shed and the existing red roof tiles will be reused on the new beach hotel.

Render



Brick



Pine Wood

Ill. 97 *Materials*

Ill. 98 *Facade Claddings*

LCA Facade Cladding

LCA will be used to give an insight on the materials' affect on the overall LCA result that further on can help choose the facade cladding for the beach hotel (Appendix 2). The results of the materials are compared in three different scenarios; Comparison of Phases, Recycle Potential, and Transport.

Comparisons of Phases

During the design process the usage phase (B) is not accounted for since the study is needed to predict the energy consumption of the beach hotel. Therefore, the production phase (A) and end of life phase (C) are divided and compared to get a total idea of the LCA results.

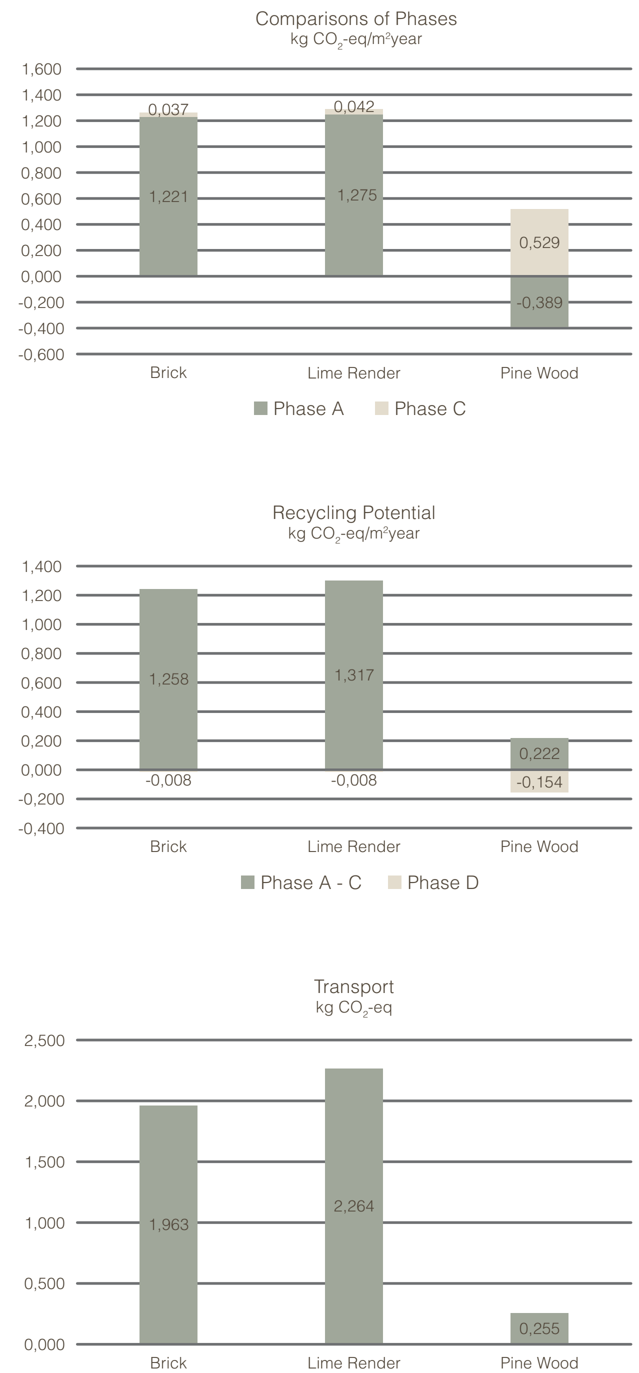
Recycle Potential

Phase A and phase C are compared with phase D to see the potential of reuse, recovery, or recycling of the material after its end of life at the beach hotel. Since the D phase is uncertain the result must be considered carefully.

Transport

Since the materials used in the study are of different types the manufacturing of these materials varies and may be extracted from different places around the world. Therefore, is transportation of the materials a determining factor in the material choice. An extended calculation of transport is made to showcase the environmental impact of which transportation can have. The calculations are made with the standard truck with a maximum load of 26 tonnes and the weight and thickness of the materials are involved plus the distance from where the material is produced.

Further calculations for transport can be found in the appendix 3. The result of the study showed pine wood emits the least amount of CO_2 and is the most optimal material to use for facade cladding in terms of LCA. The next step is to make a study of different wood cladding combinations to preserve the separation between the existing building and the new building.



Ill. 99 *Graphs*

Facade Expression

Based on the LCA calculations on page 84, wood is the most optimal material to use. Additionally, the initial façade study on page 83 suggest that bricks and render do not align architecturally. It is therefore chosen to use wood as the most prominent façade cladding. Afterwards, various combinations and types of wood cladding are explored to establish an architectural idea of which combinations of façade expressions highly relates to the identity of the existing building as well as having a clear transition between old and new. To achieve this, it is chosen to use wood shingles on the new building to ensure a noticeable separation between new and old building.

Ill. 100 *Materials*

Ill. 101 *Facade Expression*

LCA Insulation

To choose the most sustainable insulation material for the renovation of the cement factory, four materials have been compared in climatic impact and amount of material needed based on the material's thermal conductivity. The materials are wood fibre insulation, mineral wool, straw, and expanded polystyrene (EPS) which each has a low thermal conductivity (Appendix 4).

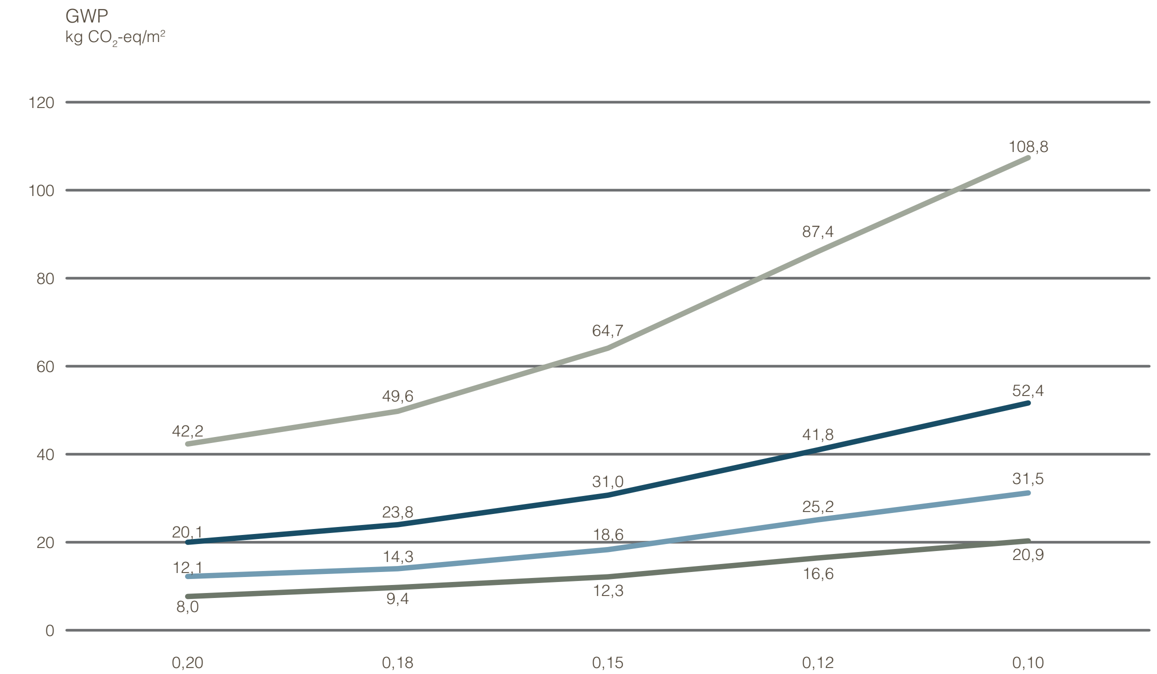
Wood fibre- and straw insulation are both made from organic materials and are highly sustainable as they require little processing and straw can be found on-site which limits the transportation of the material. Mineral wool and EPS are included in the comparison due to mineral wool being the most common insulation material in Europe and EPS is already used as insulation material in the existing warehouse building.

A quantitative study of twelve scenarios has been made comparing the different insulation materials in the three existing wall constructions. Each scenario investigates how thick of a layer of applied insulation is needed to reach certain U-value respectively, 0,2 W/m²K, 0,18 W/m²K, 0,15 W/m²K, 0,12 W/m²K, and 0,1 W/m²K.

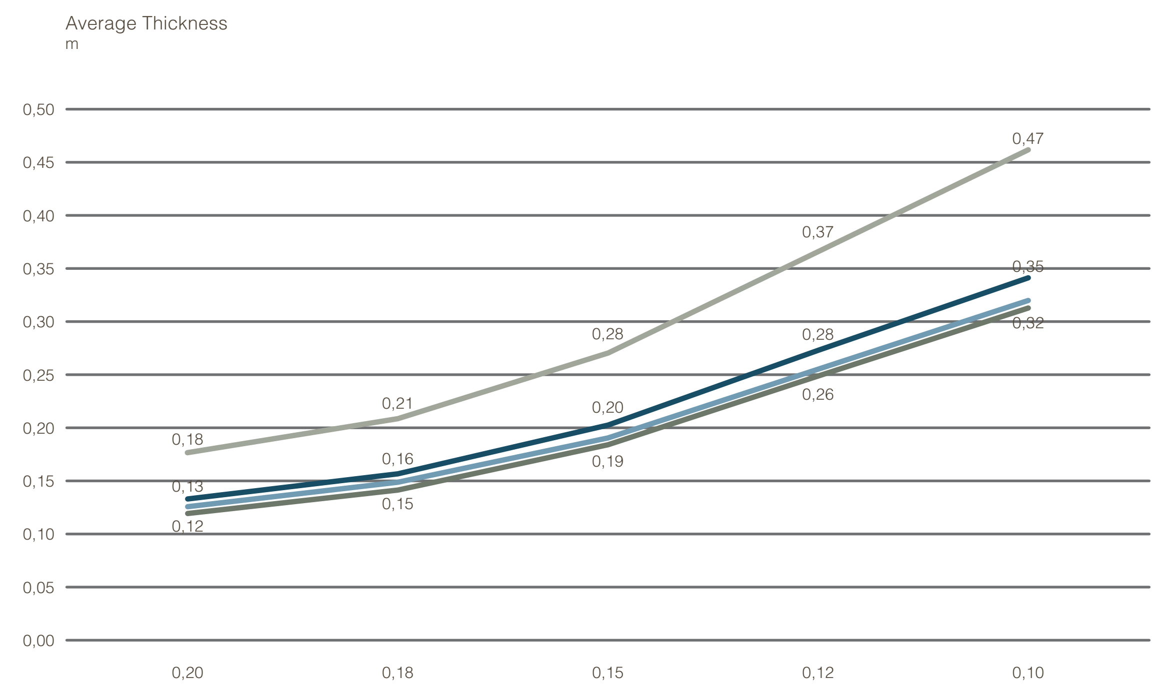
The result of the study shows Straw has the lowest climatic impact followed by wood fibre (ill. 102) but the amount of material needed to reach the respected thermal performance is much higher due to the high density of the material (ill. 103) and may compromise the architectural expression of the exterior facades.

The chosen insulation material for the renovation will be wood fibre insulation due to it having the lowest thermal conductivity of the two natural materials though mineral wool has a lower thermal conductivity but has a higher climatic impact than wood fibre.

	Thermal Conductivity W/mK	Density kg/m³
Wood Fibre Insulation	0,036	55
Mineral Wool	0,032	39
Straw	0,056	100
Expanded Polystyrene (EPS)	0,040	18



Ill. 102 *GWP*

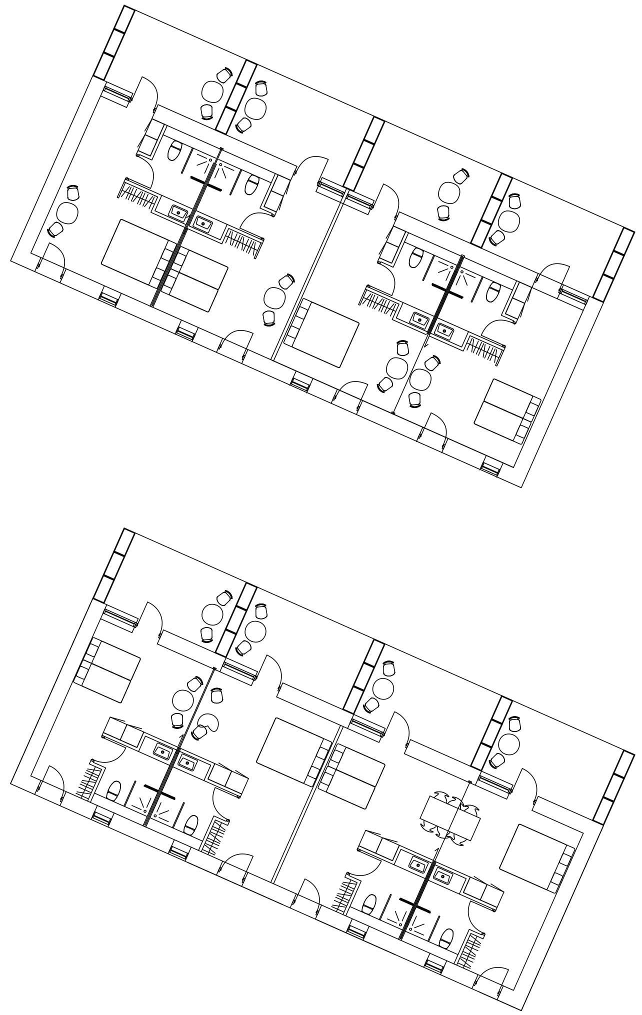


Ill. 103 *Average Thickness*

Wood Fibre Mineral Wool Straw Polystyrene

Floor Planning Optimisation

The main challenge on optimising the floor plan is how different rooms such as the entrance area, restaurant, lounge etc. transitions with each other while having each their own qualities. Additionally, a challenge also arises regarding if the multi-room should be positioned either in close connection with the restaurant or towards south having a more indirect connection with the other larger rooms and since prioritising a clear view of the ocean, it is decided to place the multi-room towards south.
This phase also introduces the importance of the line of sight in different situations in rooms, e.g., having a clear view of the ocean as soon as stepping inside the main entrance of the building as well as inside the lounge area. Additionally, the sauna placed to the west closest to the ocean also provided with a panoramic view to highly creates a close connection to the ocean.
Overall, the aim is to create an inviting and captivating atmosphere at the beach hotel that differs from room to room, and these design decisions contributes to that objective.



Ill. 104 *Floor Planning Optimisation*

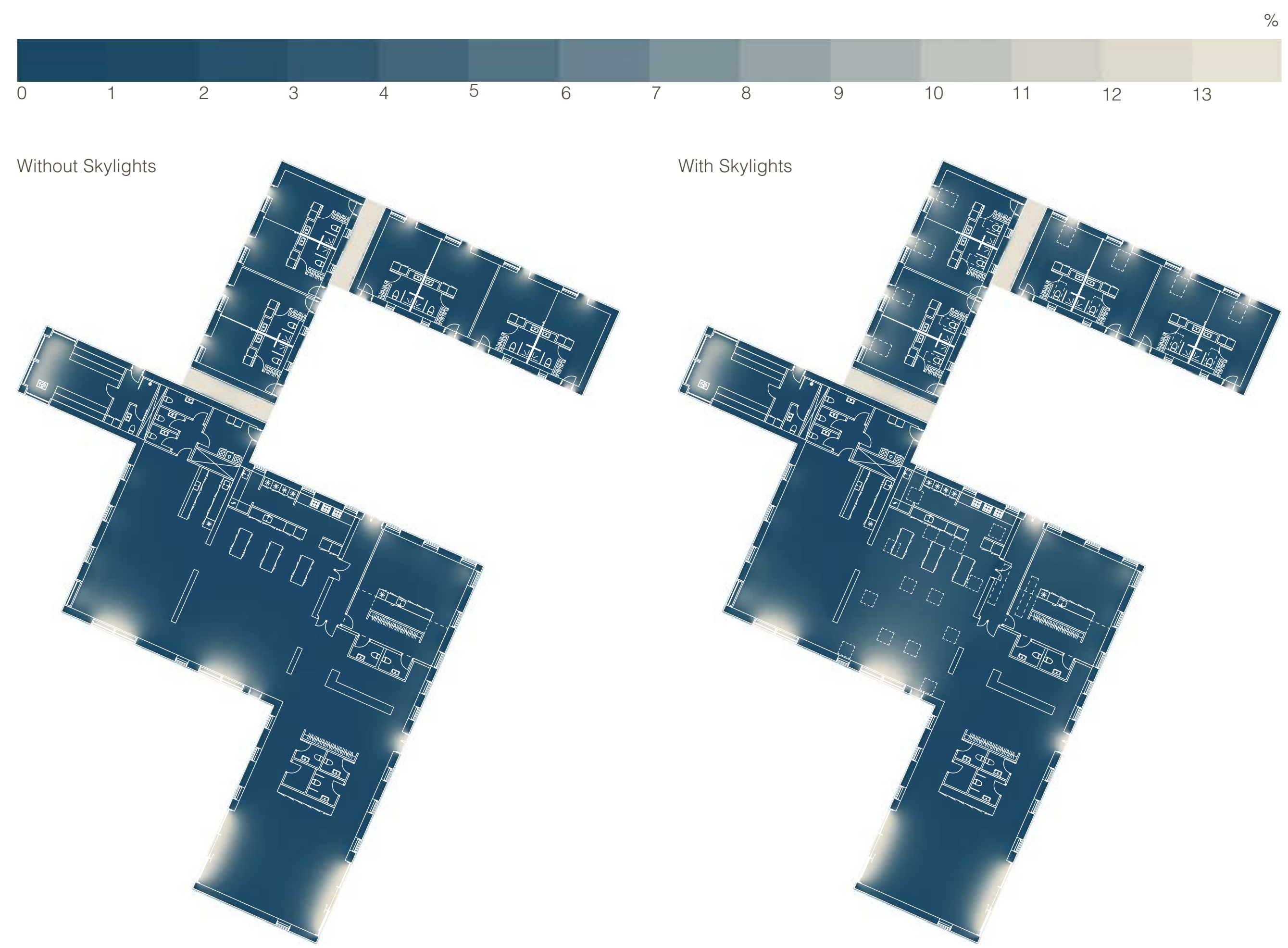
Daylight Analysis

Daylight analysis is a tool to provide a valuable insight into how natural light interacts with the building's design and can further ensure that the building provides a comfortable natural environment for users. The first iterations are made without the implementation of skylights and results in an average daylight factor of 1,8% for the whole building with the most critical area in the hotel rooms with a daylight factor of under 1,7% which is suboptimal.

The second iteration is made by including the existing skylights into the main building and adding skylights for both the bedroom and bathroom in each of the hotel rooms. This results in a more optimal daylight factor of all buildings, especially increasing the daylight factor in the hotel rooms up to almost 3%. Therefore, skylights will be implemented in the design to increase the amount of natural daylight into the interior.

Building	Daylight Factor %
Building 1 (Main Building)	1,8
Building 2 (Hotel Rooms)	1,8
Building 3 (Hotel Rooms)	1,7
Whole Building	1,8

Building	Daylight Factor %
Building 1 (Main Building)	2,4
Building 2 (Hotel Rooms)	2,9
Building 3 (Hotel Rooms)	2,8
Whole Building	2,7



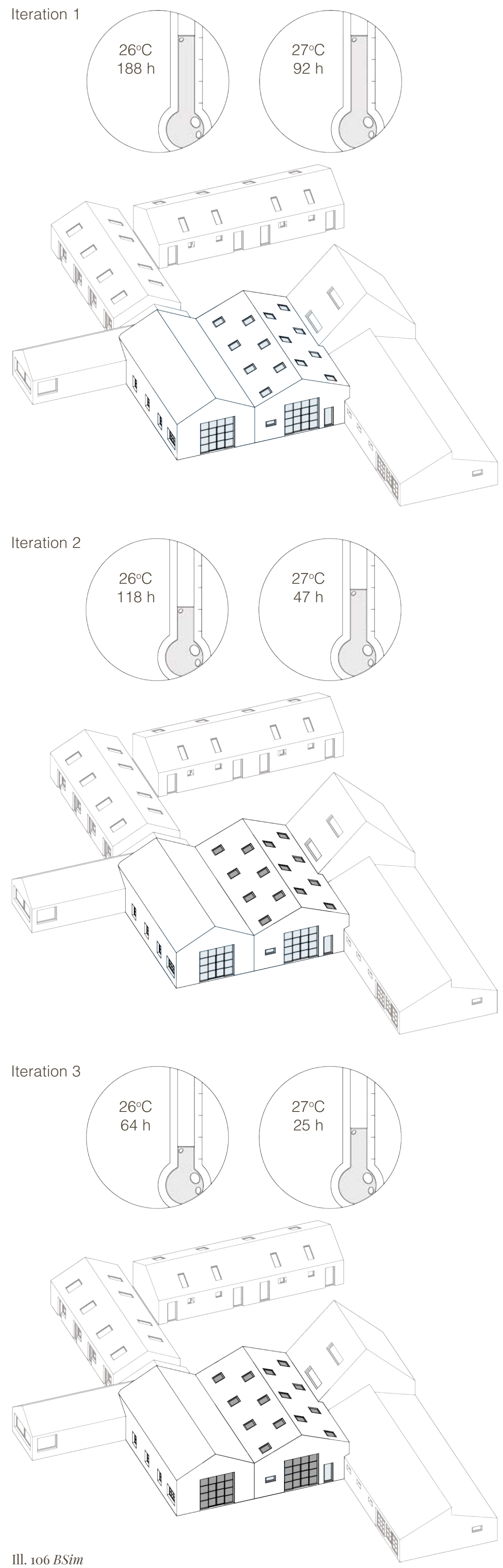
Ill. 105 *Daylight Analysis*

BSim

The most occupied facility in the beach hotel is the restaurant where guests gather to enjoy their breakfast and dinner. Securing an optimal indoor climate is necessary for the guests to feel comfortable especially in the summer where the capacity of habitants is greatest.

A simulation of the restaurant has been made through the indoor climate analysis software, BSim, to secure the amount of overheating doesn't exceed the limits of the Danish Building Regulations, due to the large garage ports being substituted with glazing. The Danish building Regulations states that the indoor temperature can't exceed 26°C for more than 100 hours a year and 27°C for than 25 hours a year (Bygningsregelement, 2018).

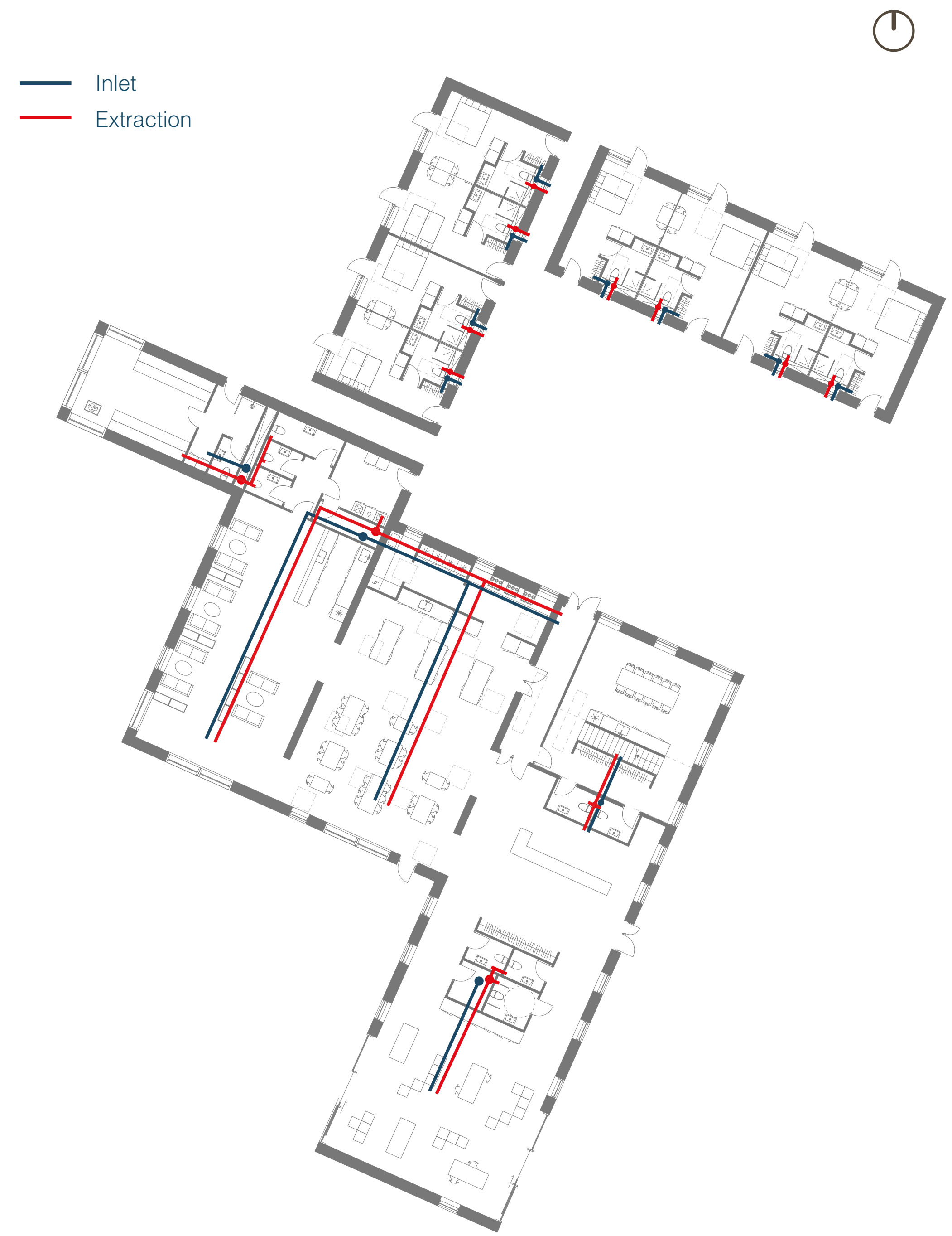
The first iterations were made without any solar shading and accumulated 188 hours above 26°C and 92 hours above 27°C. Making the windows operable and implanting shutters for the skylights reduced the number of overheating hours to 118 hours above 26°C and 47 hours above 27°C. Further implementation of natural ventilation and applying solar shading that can cover 50% of the large garage ports gave the result of 64 hours above 26°C and 25 hours above 27°C (Appendix 6).



Ill. 106 *BSim*

Ventilation

The building has been separated into multiple ventilation zones, each with their own aggregate, to decrease the amount of piping needed to be distributed throughout the building.
Ventilation zone A consists of the entrance and staff room and bathroom, a rough calculation of the needed air supply shows a needed flow rate of 55,3 l/s. With the ventilation strategy chosen to be mixing ventilation, a CX3010 ceiling aggregate, which can supply 16-144 l/s, has been chosen to supply air due to its compactness (EXHAUSTO, n.d.).
Ventilation zone B consists of the multi-room and requires the largest amount of air supply if the room would be used for activity which requires an air supply of 2 l/s pr. m^2. The calculated needed flow rate is 257,4 and a CX3030 aggregate which can supply 43-467 l/s is chosen for this zone (EXHAUSTO, n.d.).
Zone C and D consists of the main area of the beach hotel, the restaurant, the kitchen, and the sauna. Zone C requires a flow rate of 96,8 l/s and zone D requires a flow rate of 48 l/s. Both zones are installed with CX3010 aggregates (EXHAUSTO, n.d.).
Ventilation zone E represents all the bedrooms, and each room doesn't require a large amount of air supply due to the assumption of the rooms only being active during the night. Each room is installed with their own ventilator to primarily extract air from the bathrooms.



Ill. 107 *Ventilation*

Energy Performance

The overall transformation optimisation regarding the building envelope and window sizes creates an energy performance that is simulated through Be18, this time adding further external factors such as ventilation and internal heat supply that highly affects the overall energy demand of the building. This results in an energy frame of 52,2 kWh/m^2/year and makes it possible to reach the standard for Renovation Class 1 at 54,8 kWh/m^2/year. Implementing solar cells as an active strategy could further enhance the energy frame to reach at least the Energy Frame BR18 at 31,4 kWh/m^2/year, which is the main goal for the project (Appendix 5).

Energy Frame Class Key Numbers

Energy Frame Class	Key Numbers kWh/m^2
Renovation Class 2	73,1
Renovation Class 1	54,8
Energy Frame BR18	31,4
Energy Frame Low Energy	27

(Bygningsregelement, 2018)

Thin-film and Building Integrated Photovoltaics, BIPV

The type of solar cells implemented are either thin-film or built-in photovoltaics (BIPV) as both have a large architectural advantage to easily integrate with a roof, while BIPV has the possibility to have the same visual appearance as the existing roof materials with its mat coating. On the other hand, choosing BIPV's also has a disadvantage as the extra coating on the surface lowers the efficiency of the energy converted; a typical black thin-film photovoltaic panel has an efficiency of 7-18% with a peak power of 0,134 - 0,174 kWh/m^2, which is one of the values needed for Be18 (Marszal-Pomianowska, 2021).

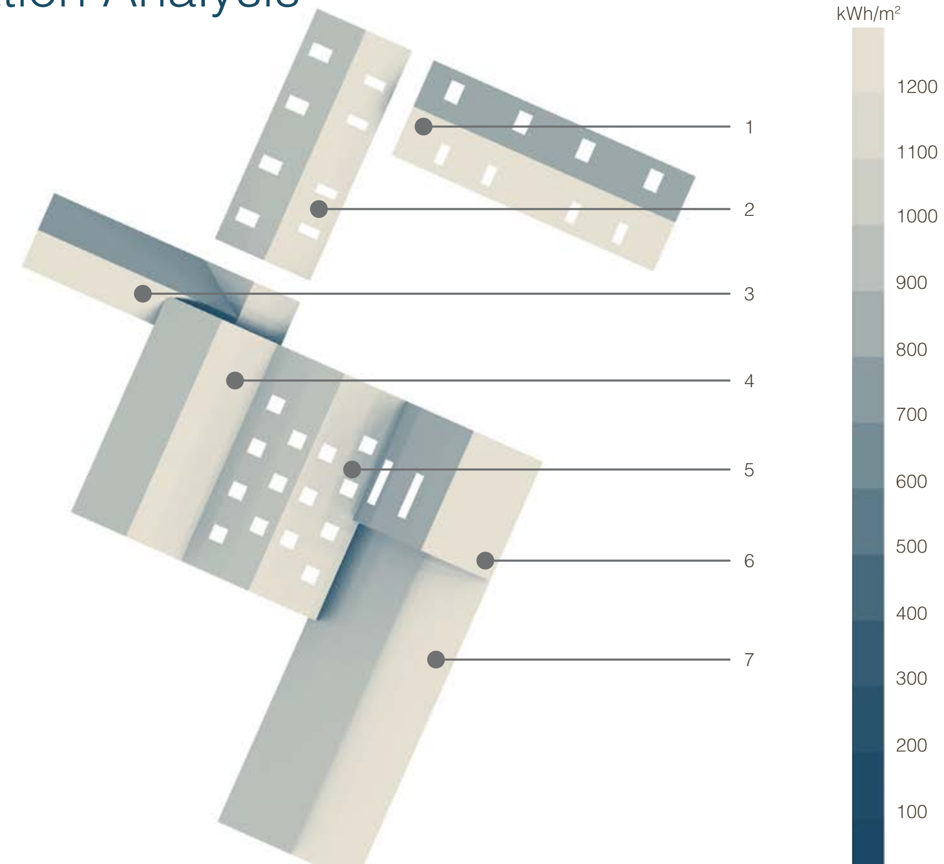
For the BIPV solution, however, it is not possible to calculate the precise efficiency and its peak power as the manufacturer, Mitrex, cannot provide these values for the project's exact case. Therefore, the value used for the peak power is at 0,13 kWh/m^2 to ensure that the effect fits BIPV's with the aforementioned disadvantage (MITREX, 2023).

Including the value for the solar cells in Be18 can help define the minimum area required to reach the energy class for BR18 resulting with an area of 65 m^2 of BIPV on the roof to reach an energy frame of 31,3 kWh/m^2/year which is right beneath the BR18 class of 31,4 kWh/m^2/year. Determining which type of solar cells depends on which roof areas are the most suitable considering the roof size, radiation value, and its visibility to users.

Energy Frame Class	Target Key Numbers kWh/m^2
Renovation Class 1	54,8
Energy Frame BR18	31,4

Energy Frame Class	Acquired Key Numbers kWh/m^2
Without Photovoltaic	52,2
With Photovoltaic	31,3

Radiation Analysis



Ill. 108 *Radiation Analysis*

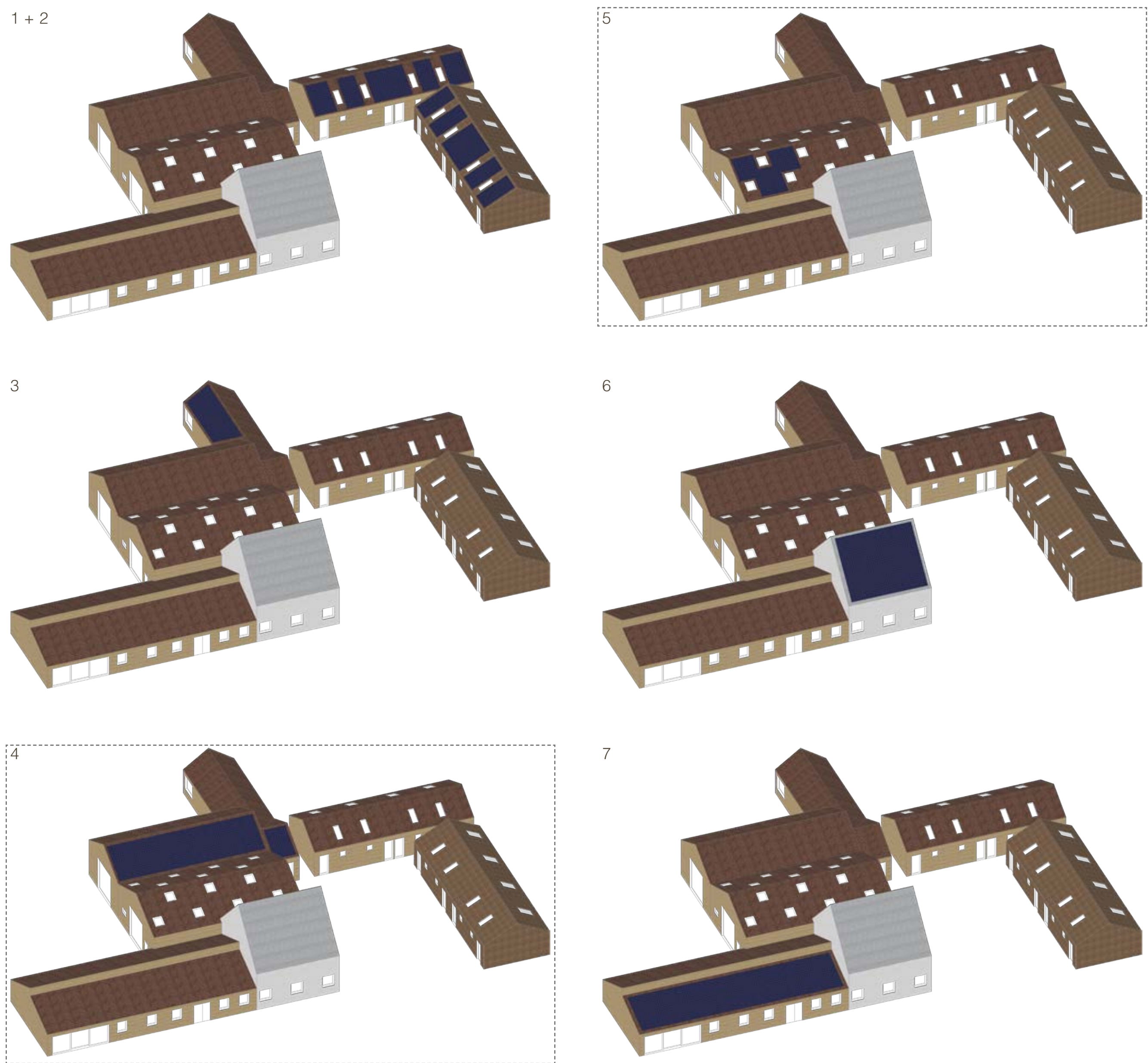
Roof	Area m^2	Solar Radiation kWh/m^2	Visibility to Users
1	66	1285	Yes
2	54	1173	Yes
3	31	1179	Yes
4	65	1147	No
5	66	1047	No
6	56	1230	Yes
7	100	1144	Yes

By conducting a radiation analysis for a year, it is possible to optimise the placements and configurations for the solar photovoltaics on a roof to maximise energy production and its architectural effect of the facade. Analysing all roofs will give an insight on which parts of the roofs that is most optimal to use through a comparative analysis.

The roofs are evaluated based on their size, solar radiation exposure, and visibility to users to determine which ones are more suitable for the installation of photovoltaics. After considering these factors it was decided that the optimal areas for the solar cells are on the entirety of roof 4, which has one of the largest areas, and half of roof 5 which result in a combined area of 100 m^2. Additionally, these are the least visible areas to users and therefore allow for greater flexibility in determining the amount of solar cells without a significant impact on the overall appearance of the building's façades. It is also to be concluded to use normal thin-film solar cells as it has a higher efficiency value compared to BIPV, and as it is to be installed on the areas less visible to users, there will be no need to implement BIPV.

Photovoltaic Placement

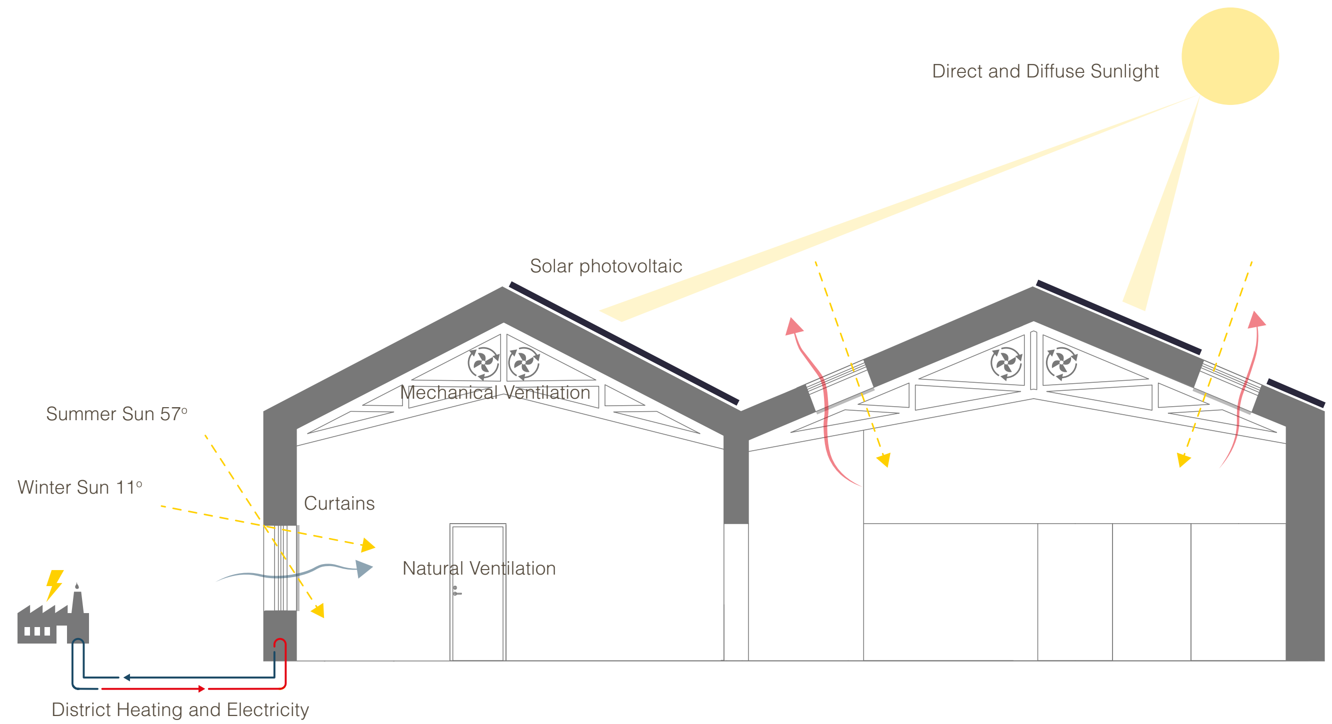
Aesthetic considerations have been made to decide the most optimal location for the solar photovoltaics. The goal is to create a solution for the solar panels to seamlessly integrate into the roof and upon evaluating the options, it is observed that solar panels on roofs 1 and 2 creates a cluttered expression due to the existing chosen claddings that differs from each other. Similarly, on roof 6, the solar panels could stand out too prominently. Having chosen to reuse the existing roofing tiles on most of the roofs, it is therefore not feasible to integrate solar panels into them, instead it is chosen to use the roofs that has the least visibility from guests and concludes roof 4 and 5 to be the most optimal to install the solar photovoltaics.



Ill. 109 *Photovoltaic Placement*

Passive and Active Strategies

To meet the requirements from the Danish Building Regulations, different passive and active strategies have been integrated in the design.
To reach the Energy Frame BR18 65 m² of photovoltaics are implemented in two roofs towards southeast. The beach hotel consist of natural ventilation such as, stack, cross, and single sided, as well as mechanical ventilation. To avoid overheating solar shading for the skylights and the large garage ports are implemented. The beach house is connected to the local district heating system which provides the building with hot water, and are supplied with electricity from the grid.



Ill. 110 *Passive and Active Strategies*

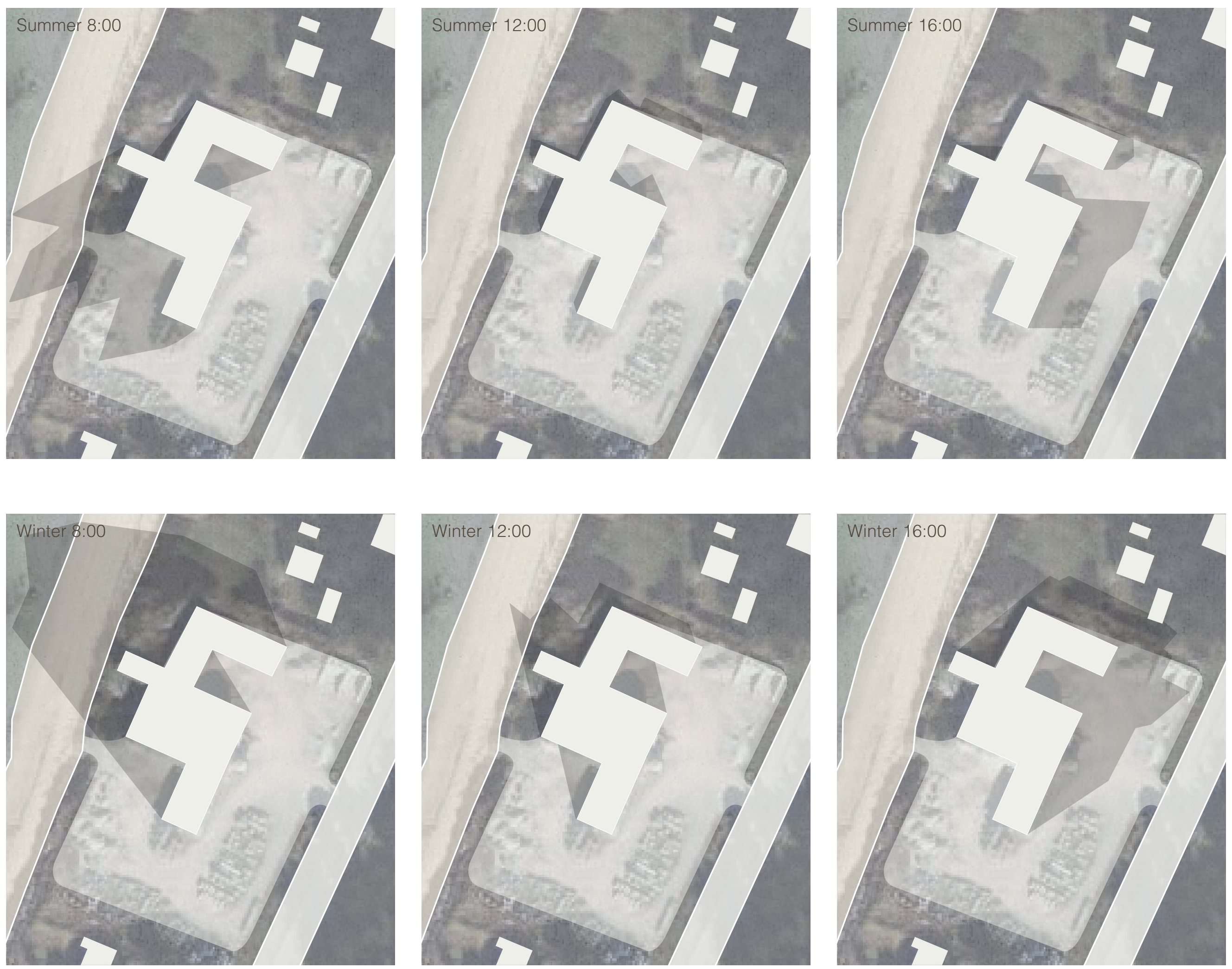
Urban Planning

The overall main challenge for the urban planning is the layout and positioning of terraces, pavilion, hot tubs, courtyards etc, therefore a more detailed shadow analysis is used as a tool and visualised in specific times of the day during the winter and summer. The goal is to gain a more precise understanding of how shadows are cast on the site that will further help placing different urban areas around the building.

The outdoor space adjacent to the restaurant and multi-room is intended as a summer terrace that receives direct sunlight between the hours of 8:00 and 16:00. A pavilion is also added as an outdoor space for autumn and spring with a cooler outside temperature, while the pavilion is placed towards south and allows to be heated up and be able to be used for the cooler seasons. Furthermore, the analysis also reveals that the semi-private courtyard for hotel guests mostly receives direct sunlight in the mornings and therefore a small sitting area is placed for the mornings that guests and the restaurant can use, as the southern terrace only receives direct sunlight from noon and throughout the evening.

The private terraces for each hotel room are placed on the opposite sides of the building compared to the courtyard for the oceanic view. Direct sunlight on the private terraces varies a lot depending on the season; in the summer the private terraces receive more direct sunlight both in the summer mornings and evenings while being completely shadowed in the winter.

The main challenges for the placement of the hot tubs are not only to receive direct sunlight at least in the winter, close to the water, but also being placed in a more private area with less visibility from guests in the large outside terrace. The hot tubs are placed in front of the sauna towards west to obtain a close connection to the sauna and the oceanic view of the beach, while also receiving direct sunlight during winter evenings.



Ill. 111 *Urban Shadow Analysis*

Ill. 112 *Urban Planning*

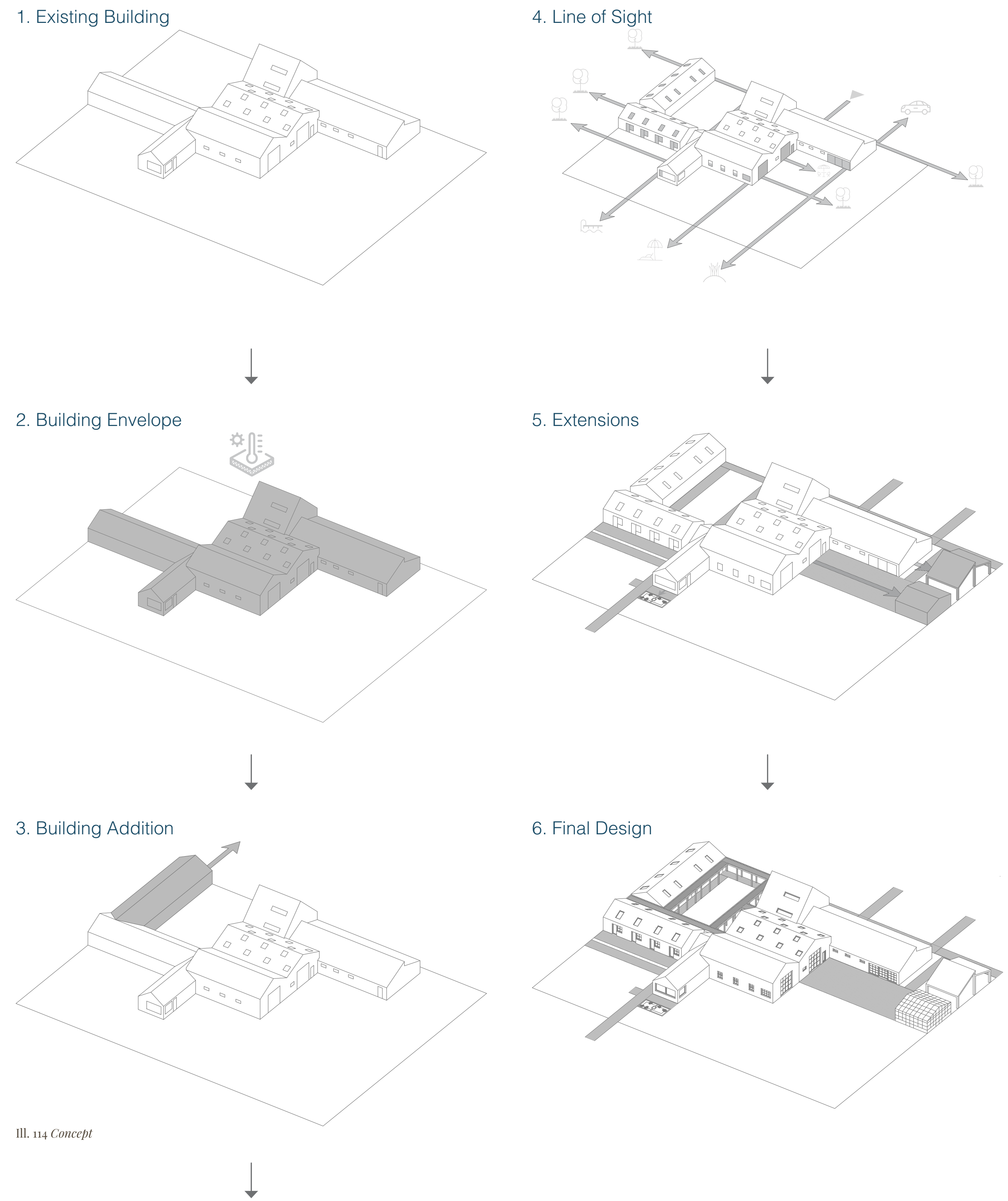
Ill. 113 *Coast*

Presentation

Badehotel Havvejen

Every step of this transformative journey is guided by an unwavering commitment to preserve the building's character and its harmonious relationship with its highly natural context, experiencing Samsø's identities in an adhering way. While embracing the modern focus of environmental sustainability, emphasising Life Cycle Assessment through thoroughly choosing materials that align with our vision. The past is honoured, the present is commemorated, and the future is shaped by our commitment to sustainability.

Concept

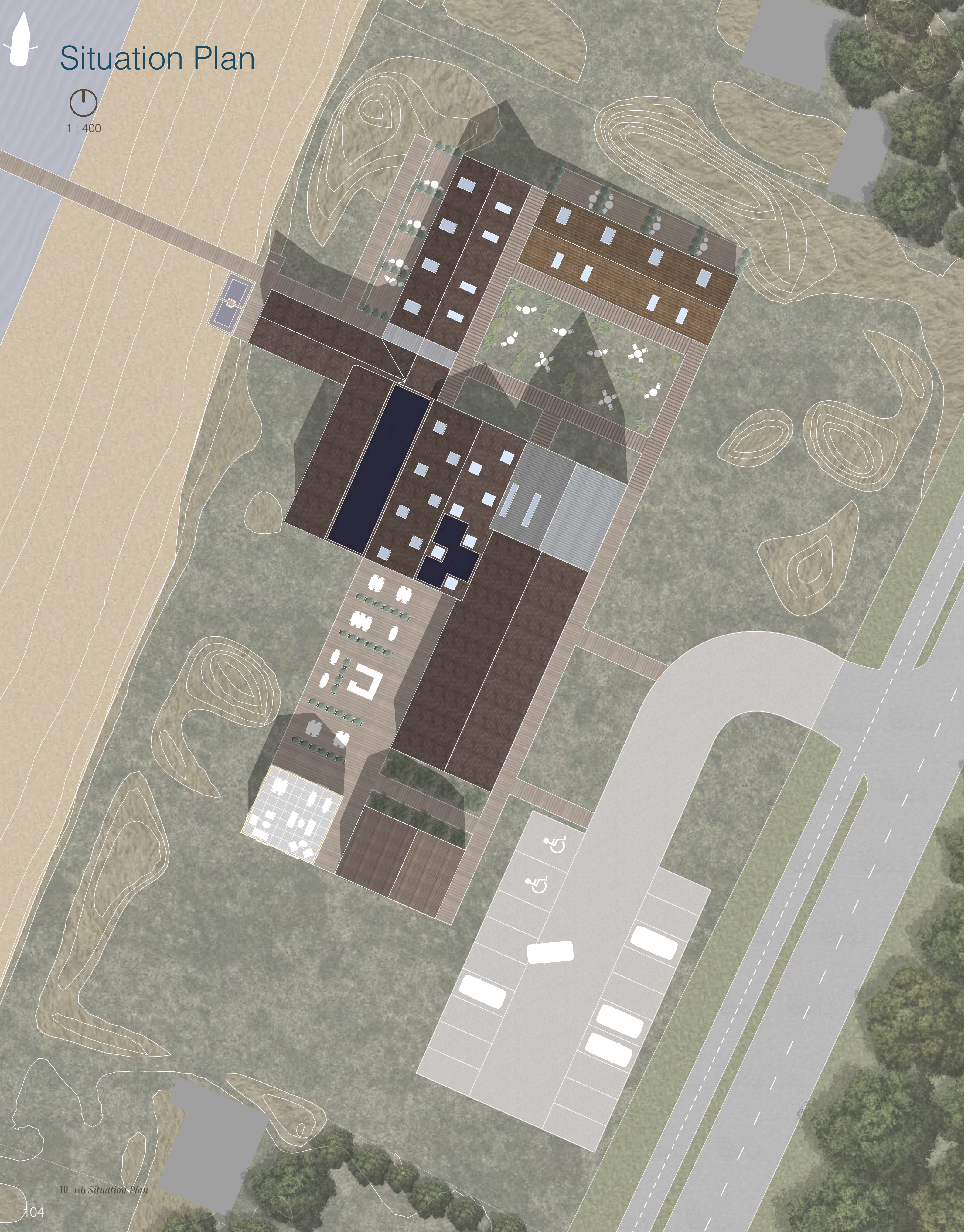


Ill. 114 *Concept*


Ill. 115 *From the Beach*

Situation Plan

1 : 400



Ill. 116 Situation Plan

1 : 350

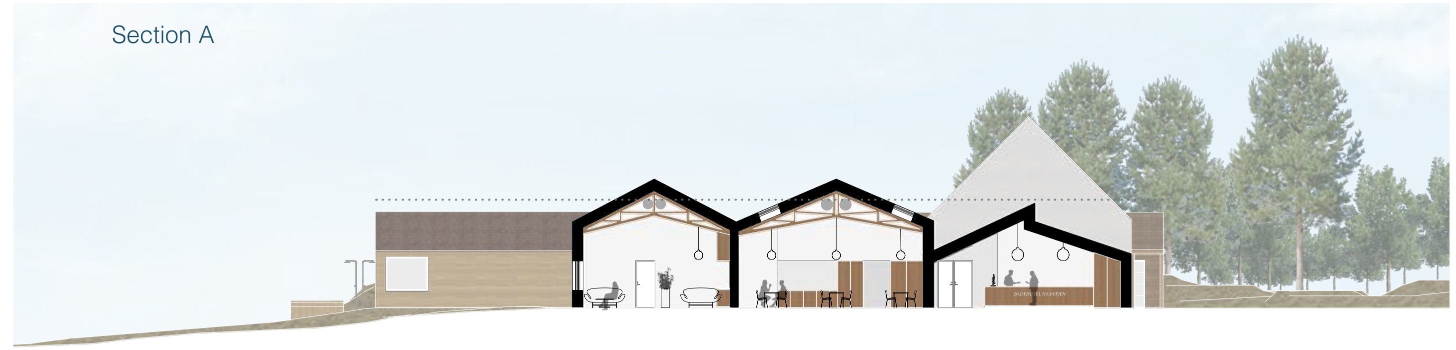
Ill. 117 Facades

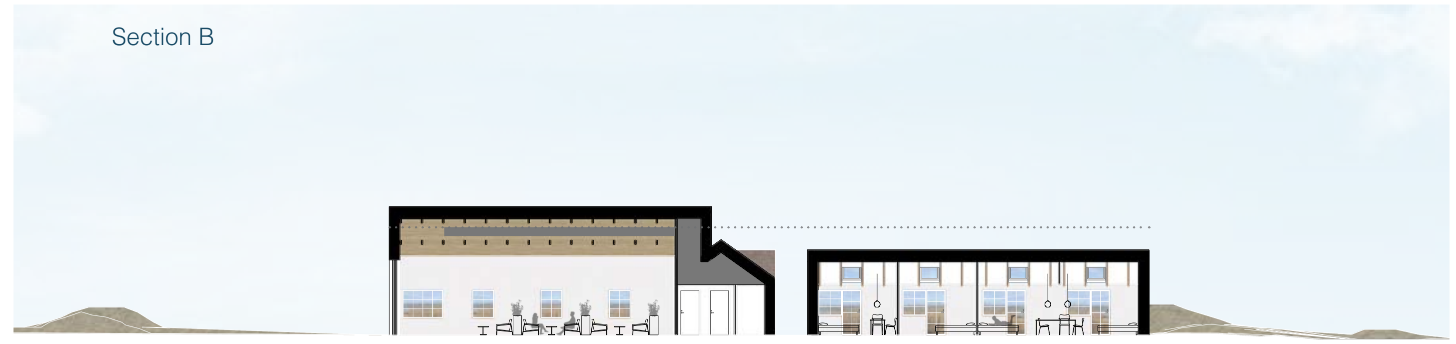
Floor Planning

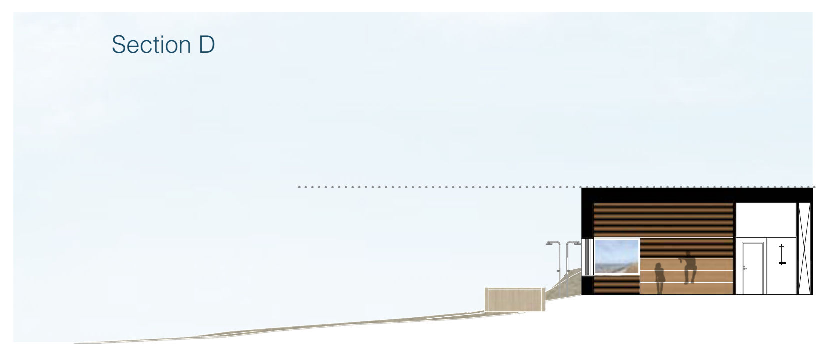
Ill. 118 *Floor Planning*

1 : 350

5 m height







Ill. 119 *Sections*

Ill. 120 *Arrival*

When guests arrive to Badehotel Havvejen they are instantly met by the rural terrain where the beach hotel is centred between the dunes and the beach. Walking from the parking lot towards the main entrance the guests will have a clear sight line the ocean between the outdoor pavilion and terrace restaurant where they can hear the wind rushing through the reeds coming from the west.

Entrance

Upon entering Badehotel Havvejen, guests are immediately greeted and provided with a calming atmosphere through use of natural materials, and additionally introducing different lines of sight, presenting the restaurant, lounge and all the way to the direct view of the ocean.

Ill. 121 *Entrance*

Restaurant

Restaurant Havvejen, the very heart of the beach hotel, represents a harmonious blend of natural and industrial elements along with several skylights that allow for natural lighting. This combination creates a comforting, and visually appealing environment, making it an ideal place to enjoy a delicious meal from Samsø's local culinary culture. Connected with the main dining room is a service kitchen, where chefs are able to combine, garnish, and serve food directly from Samsø to guests, creating an even deeper connection, not only between chefs and guests, but from Samsø to guests.

Ill. 123 *Preparing Kitchen*

As the evening falls into the beach hotel, fading sunlight casts a soft natural light, creating a slightly dark, intimate, and enchanting atmosphere. With a fireplace that highlights coziness with an evening cup of coffee.

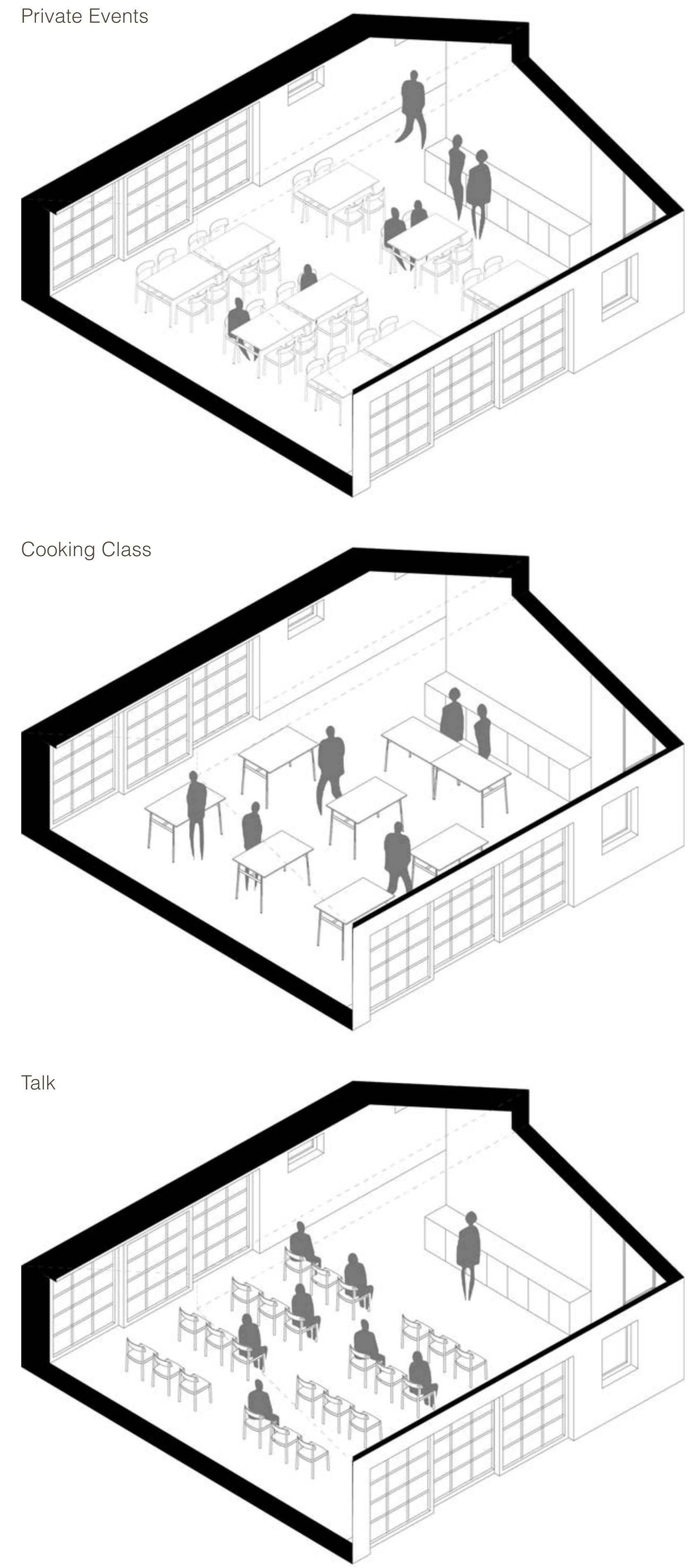
Ill. 124 *Lounge*

A combination of a warm and natural colours, fireplace and a breath-taking view of the ocean will create a unique atmosphere, thus being in a space with an industrial character. Enjoyed with a glass of drink with a direct view of the ocean.

Ill. 125 *Lounge*

Multi-Room

The multi-room is a continuation of the restaurant but in a separate section. The purpose of the multi-room is that it can be used for several different set-ups depending on the occasion within Badehotel Havvejen's identity. It could be private events, cooking classes, and talks about the culinary world.



Ill. 126 *Multi-Room*

Terrace

Ill. 127 *Terrace*

Between the beach hotel and the ocean is placed the outdoor restaurant terrace, perfect for enjoying meals in the sunny weather with a direct view to beach and ocean. The sound of birds singing and the wind in the trees enhances the natural feeling of being close to the nature. The outdoor kitchen situated in the middle of the terrace bring the guests closer to the process of the food they are consuming.

The terrace is usable at any time of the day, especially when the sun is present, and in the evening or after dinner where guests can enjoy each other's company with a cold drink in their hand while watching the sun setting in the horizon.

Pavilion

Ill. 128 *Pavilion*

Outside of the summer season when the outside temperature is decreased, then the pavilion, heated up throughout the day, is the perfect place for guests to enjoy their meals or just a cup of coffee to have relaxed conversation with each other. The pavilion with its full panoramic view to the surroundings gives the opportunity to experience the nature when the number of tourists is limited, and the animals are emerging from their hideouts. The base of the pavilion is built from old wall components previously used in the cement factory giving the guests an atmospheric sense of the identity of the old factory.

Hotel Rooms

Single Room

The single, private room of Badehotel Havvejen with a double-sized bed highly showcases the industrial character of the existing building, filling the space with natural daylight, and offers a close and deeper connection with nature.

Ill. 129 *Single Room*

Ill. 130 *Double Room*

Double Room

The hotel rooms provide various room configurations with a large sliding door implemented into the hotel rooms. Allowing for flexibility in accommodating guests to cater a wider target audience such as friends, couples, and other relations that wishes to spend a quality time together in a unique way.

Private Terrace

The guests can retract to their own private terraces and still enjoy the outdoor environment if they need a break from the more populated areas of the beach hotel. Like the restaurant terrace the guests can relax and catch a breath while enjoying the setting sun with some cold to drink. Not only can guests enjoy the terrace in the evening they can also have their morning coffee while experiencing the surrounding nature.

Ill. 131 *Private Terrace*

Ill. 132 *Courtyard*

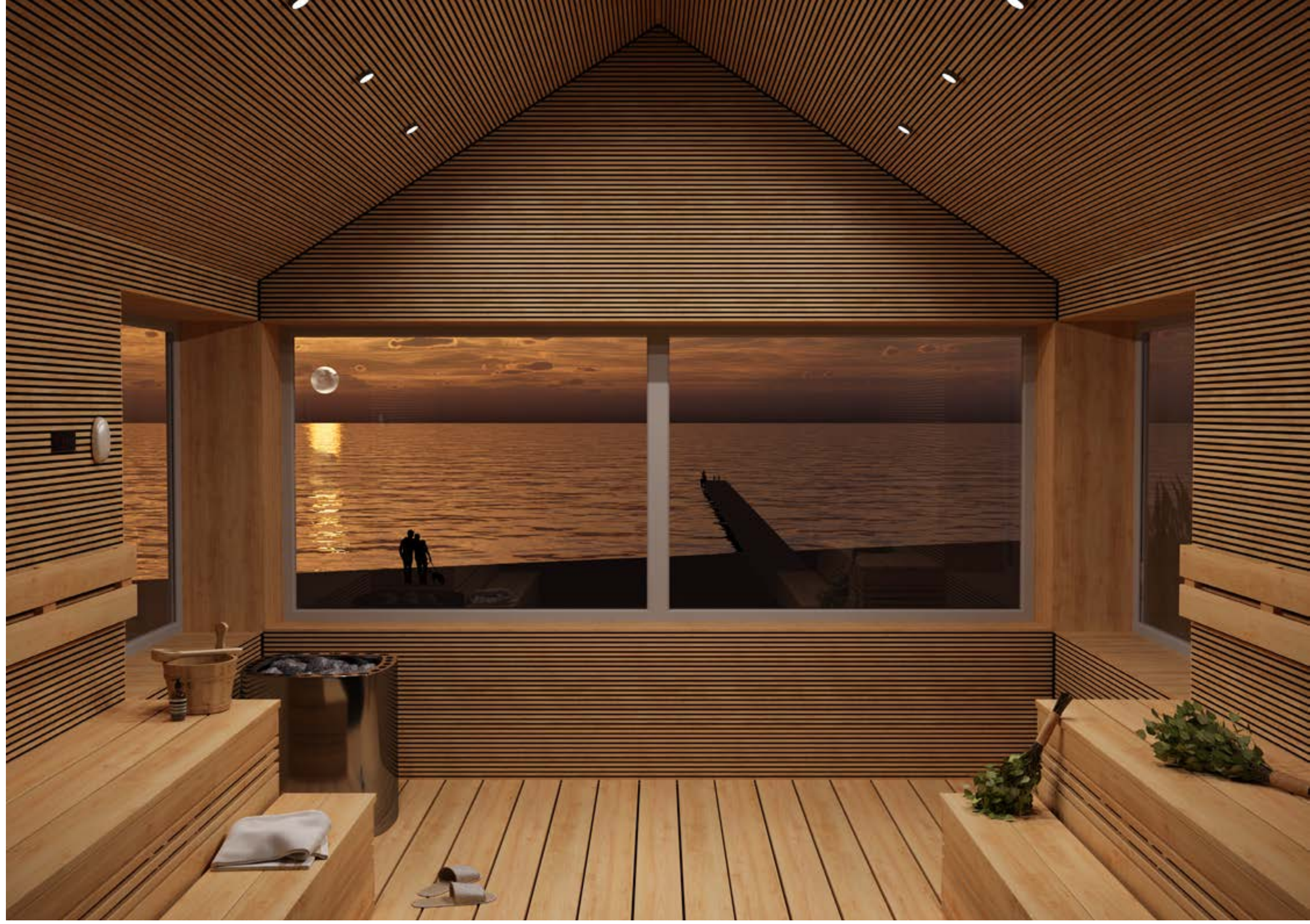
Courtyard

The courtyard is surrounded by all the guest rooms making it the ideal place for the guests to step outside to feel the warmth of the morning sun rising in the east. The location of the courtyard is perfect to enjoy breakfast and a cup of coffee in the early morning hours.

The overhang encloses the courtyard creating a private and intimate space for the guests with a passage leading directly to the ocean through the bathing jetty.

Ill. 133 *Courtyard*

Ill. 134 *Bathing Facilities*



Ill. 135 *Sauna*

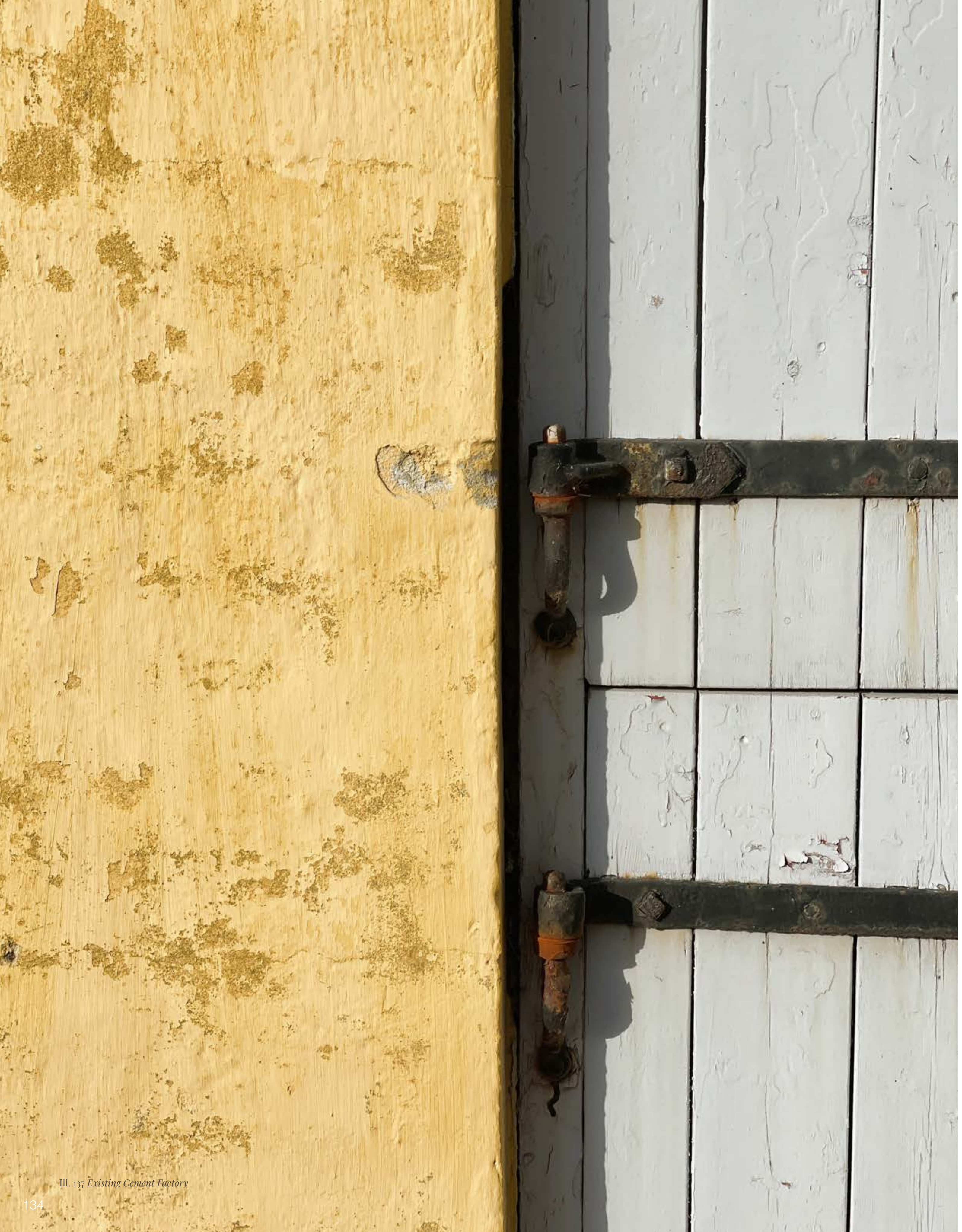
Bathing Facilities

The sauna is a tranquil and therapeutic space designed to encourage relaxation and cosiness, being greeted by a warm soft light, wooden interior. Being located closest to the ocean highlights the connection even more, both visually, emotionally, and physically. Right in front of the sauna is the outdoor hot tubs, connected and extending towards the beach and the ocean, emphasizing relaxation between oneself and the weather.

Staff

The break room and office space are designed to encourage a sense of community and connectivity between staff of the beach hotel, complementing each other to balance the need for relaxation and socialisation. The office space is placed on a mezzanine, where ambient soft light will be present during work hours.

Ill. 136 *Staff Facilities*



Ill. 137 *Existing Cement Factory*

Technical Plan Drawing

Ill. 138 *Floor Plan with Measures*

Materials

Ill. 139 *Materials*

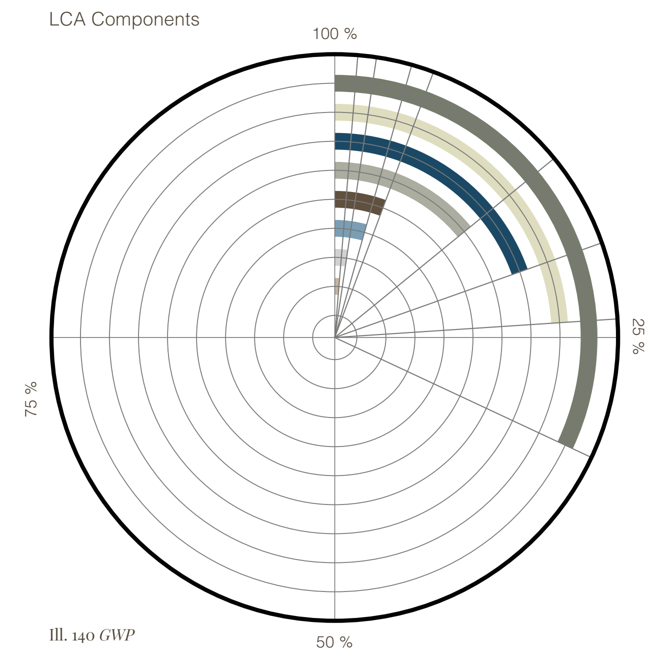
Life Cycle Assessment

The final Life Cycle Assessment provides a holistic evaluation of the environmental impact of the renovation and transformation of the Sælvig Cement Factory into Badehotel Havvejen. In the assessment is included the impact from the different building components and the operational needs of the building collected from Be18 (Appendix 7).

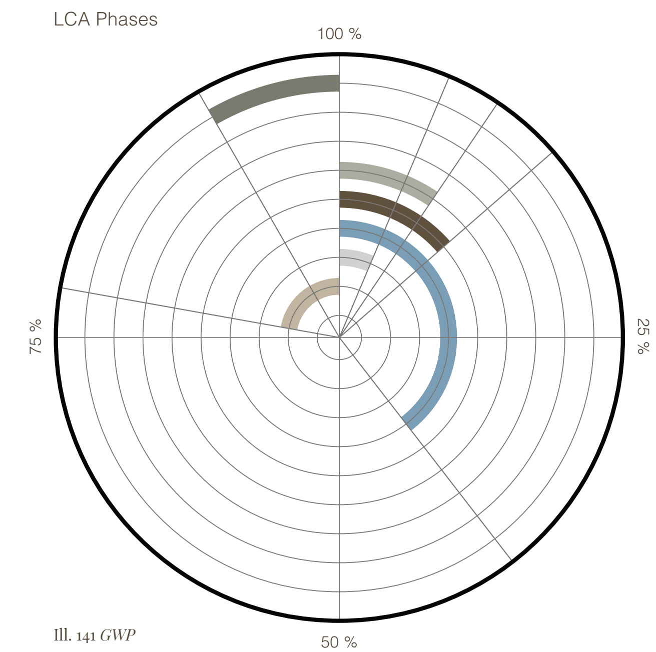
The total environmental impact of the building, looking only on its global warming potential (GWP), results in 6,9 kg CO_2-eq./m²/year. Looking at which building components emits the highest amount of carbon dioxide (ill. 140) is the new floor deck emitting about a third of the total environmental impact due to the high amount of concrete used. Other contenders are the solar panels emitting 19% of the impact and the operation of the building emits an impact of 23%. The exterior walls emit only 5% of the CO_2 which highlights the benefit of renovating the existing walls in comparison to the new roof emitting 14% CO_2.

Looking at the phases of the LCA (ill. 141) the largest amount of CO_2 emissions happens in the Waste Processing phase (C3) of the end of life (C). This is mostly due to the large amount of wood used in the building not being calculated for reuse or recycling.

Since the cement factory has been transformed and put into new use, the results of the LCA can't be compared to the regulations of a new building, though with a result of 6,9 kg CO_2-eq./m²/year, the building complies with the 2025 Voluntary CO_2 standard demand of 7 kg CO_2-eq./m²/year. The Voluntary CO_2 standard demand will be restricted by 1 kg CO_2-eq./m²/year every other year (Lcabyg, n.d.).



Ill. 140 *GWP*



Ill. 141 *GWP*

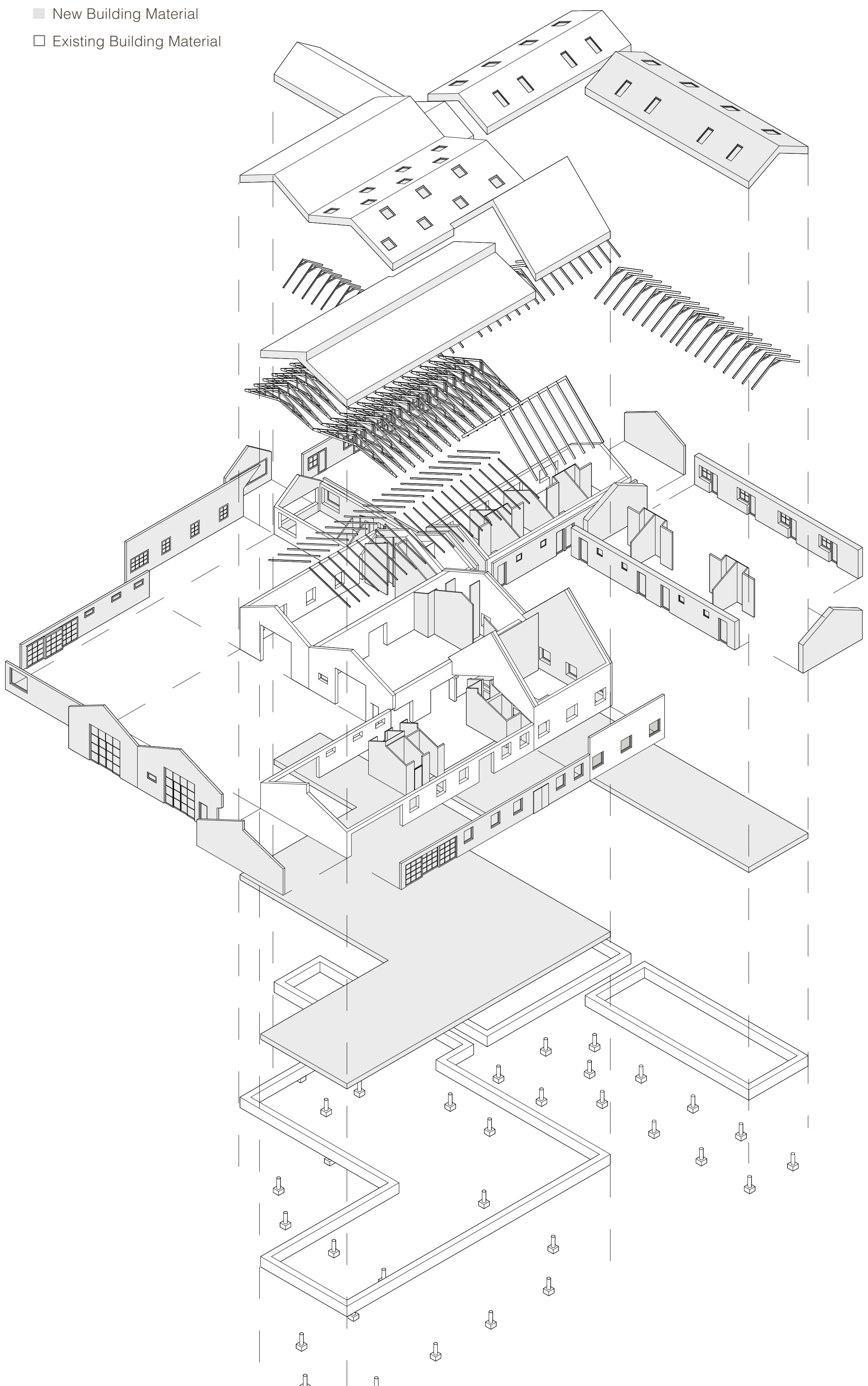
■ Total Global Warming Potential

Floor Deck	32 %	Exterior Walls	5 %
Operation	23 %	Windows and Doors	4 %
Solar Panels	19 %	Foundation	2%
Roof	14 %	Inner Walls	1%

■ Total Global Warming Potential

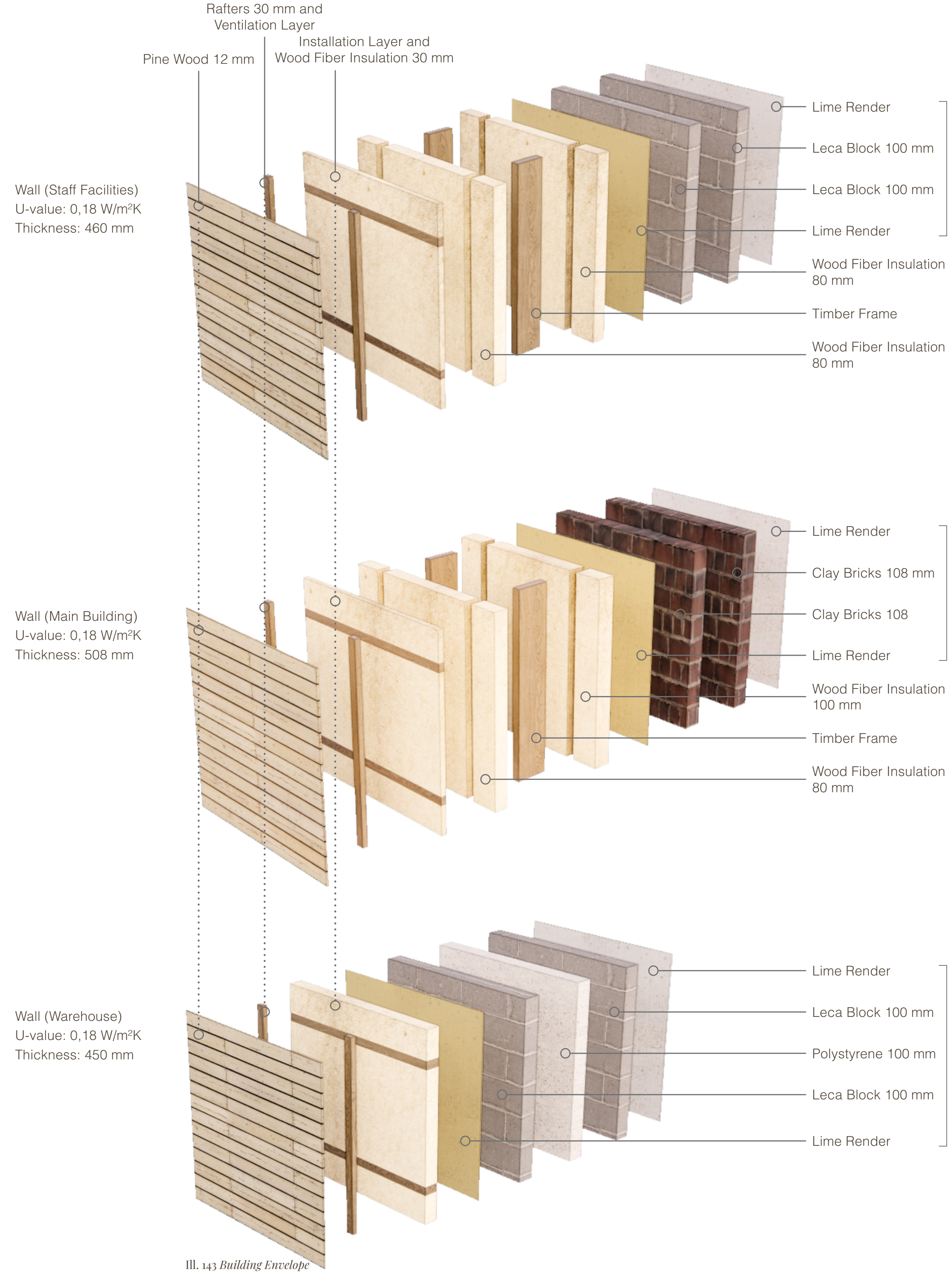
A1-3	-8 %	B6	14 %
A4	0 %	C3	41 %
A5	0 %	C4	4 %
B4	9 %	D	-22 %

Structural System



Ill. 142 *Structural System*

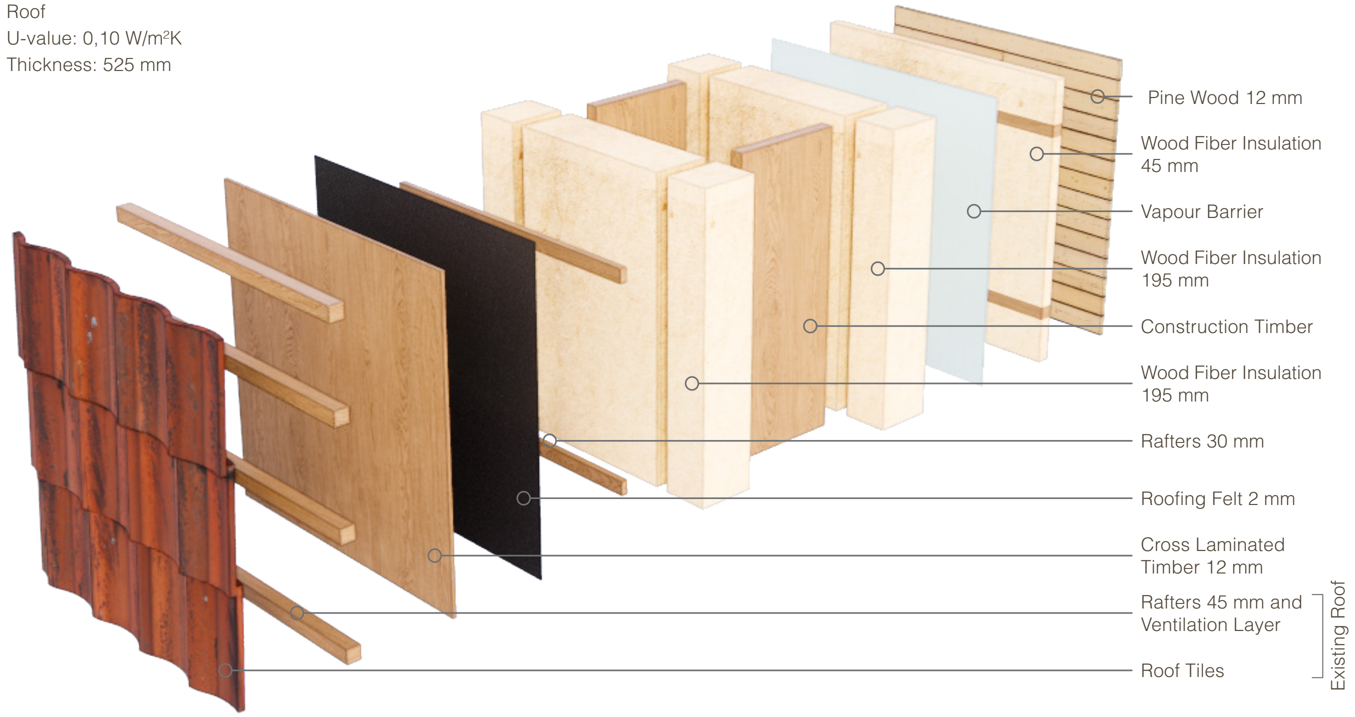
Building Envelope



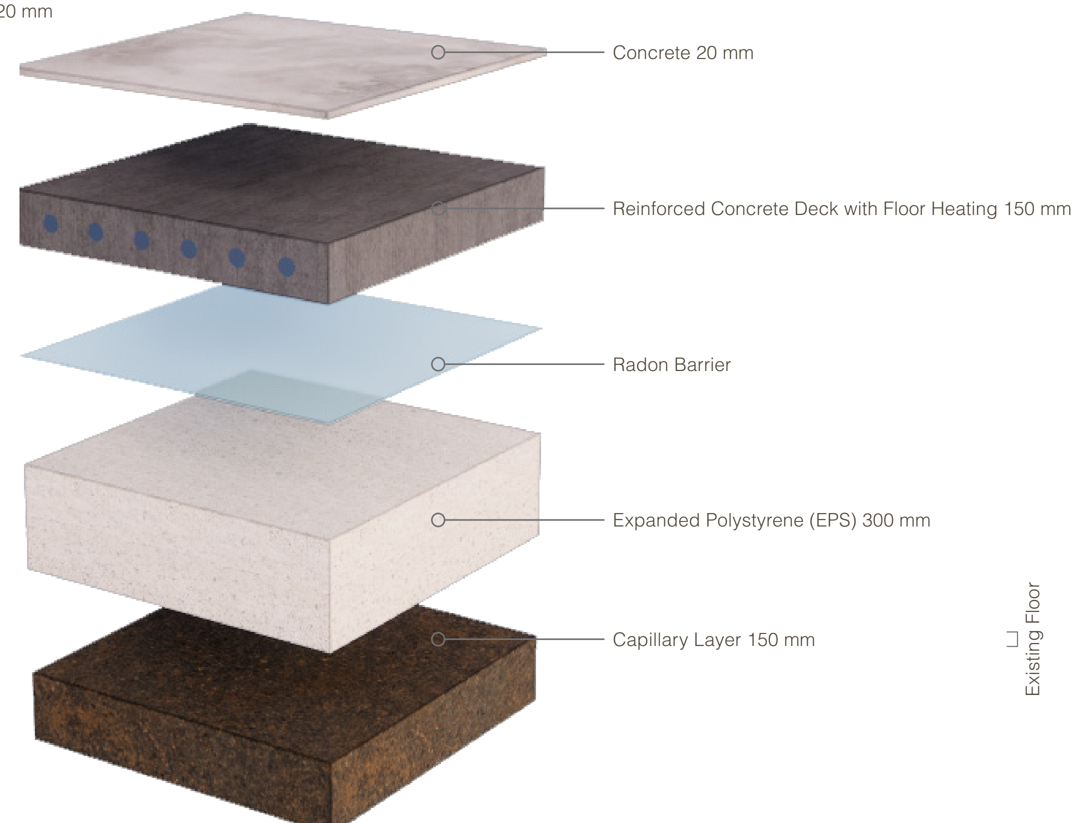
Ill. 143 *Building Envelope*

Building Envelope

Roof
U-value: 0,10 W/m²K
Thickness: 525 mm



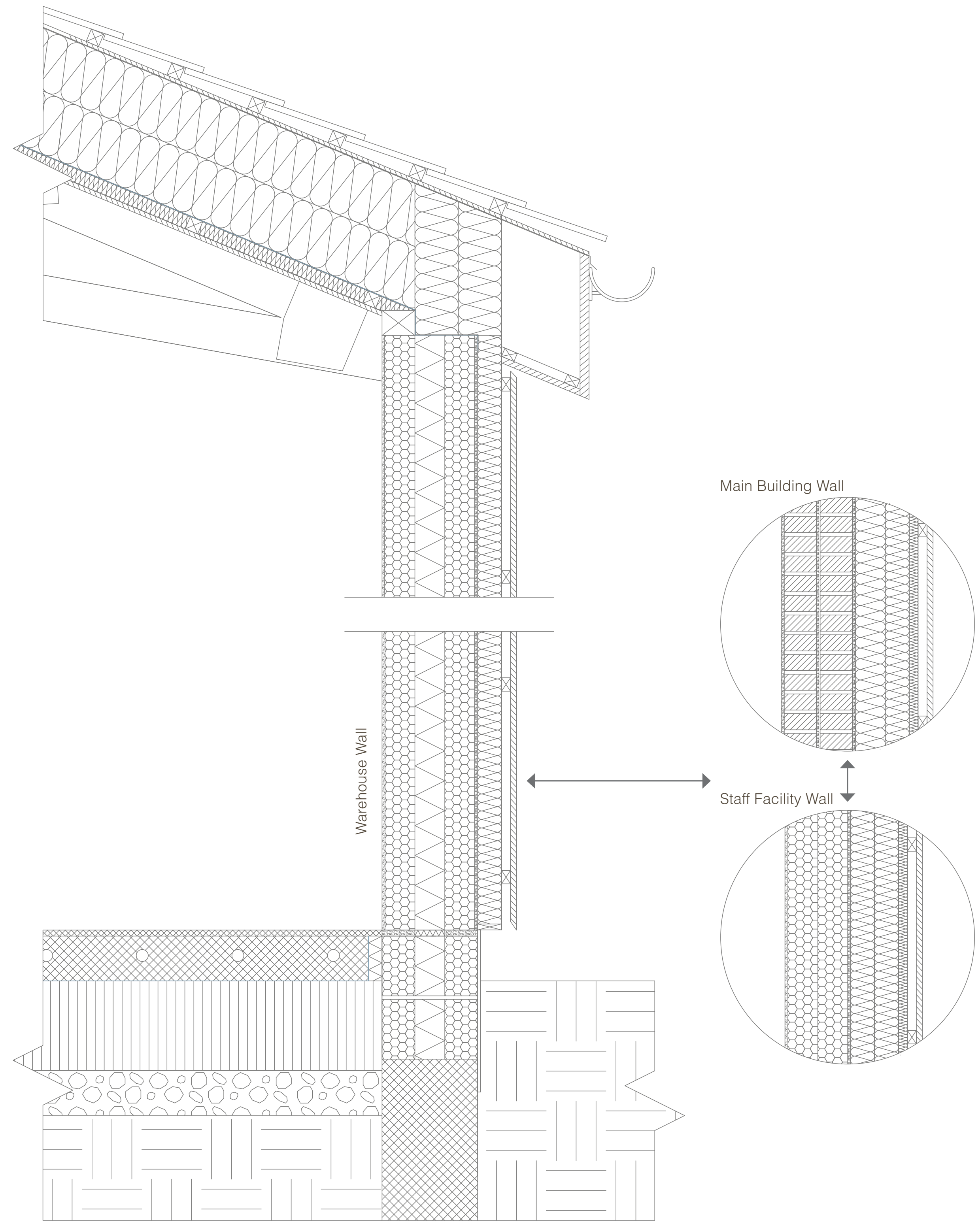
Floor
U-value: 0,1 W/m²K
Thickness: 620 mm



Ill. 144 *Building Envelope*

Detail Drawing

Roof, Wall and Floor
1 : 20



Ill. 145 *Detail Drawing*

Ill. 146 *Ballen Harbour*

Epilogue

Conclusion
Reflection

Conclusion

As a conclusion, this master's thesis presents a visionary concept for the development of a sustainable beach hotel through the transformation of an old cement factory, with a highly industrial character. The proposal prioritises environmental sustainability by favouring renovation over constructing a new building and seeks to highly preserve the historical identity of the cement factory. The transformation approach of the building highly follows the restoration practices in the 20th century, addressing the Venice Charter transformation principle of Transform with Respect, preserving the external volume, and preserving the industrial interior atmosphere.
This awareness of preserving the building's character, and how it relates to its natural context and Samsø, has been a general theme throughout the thesis, including Life Cycle Assessment as a modern focus of environmental sustainability with the choice of materials that follows throughout the whole process and clarifies the benefits of preserving the existing building, optimising it with exclusively natural materials. The beach hotel's common and private facilities are intended to create a unique experience for guests that encourages a year-round establishment, allowing guests to fully embrace the essence of an authentic traditional beach hotel, as well as align with Samsø's culinary identity.
The proposal of this transformation thesis aims to inspire a sustainable transformation approach of an existing building with a highly industrial character and repurposing it with a hospitality function and highlights the potential of preserving and reusing historical structures. The vision presented in this thesis will serve as a stepping-stone towards a highly sustainable and authentic beach hotel, blending history, identities, functionality, and environmental consciousness in a harmonious way.

Reflection

Performing Life Cycle Assessment on a renovation and transformation project is a rather new topic and especially transforming an industrial building into a habitable building are only shown in limited cases.

Life Cycle Assessment has throughout the process been the main technical aspect of this thesis and should act as the deciding factor for material compositions. This means that other technical aspects of the thesis have not had an in-depth analysis detailing every aspect of the subjects other than through a conceptual basis and through standard calculations. Further investigations of indoor climate will help emphasise the well-being of hotel guests and staff securing the comfortability of the facilities. Also, further investigations of the structural system would highlight the possibility of adding additional building stories instead of assuming the construction wouldn't be strong enough.

Although that the new beach hotel complies with the 2025 Voluntary CO_2 standard demands, if it were to be built in in 2027 or in further years where the demands would be further restricted, such renovation project would not be possible. Therefore, in the future the most sustainable solution would be to demolish and rebuild a completely new building and upcycle the old materials for furniture and other purposes, that would incorporate the principle of "cradle to cradle" and eliminate a lot of materials from waste processing.
This could potentially result in a lower environmental impact due to the possibility of reaching the zero-energy building class, which would also contribute to Samsø's identity of being self-suppliant of energy, due to historic building built in a time with lesser restricted energy demands often has a higher climatic impact.

Transforming a building with material impacts in mind has potentially been a barrier for different comfort factors in the design with only using minimal amount of materials. Acoustic comfort has only been showcased in renders with acoustic lamella panels in the ceiling, but further research of the acoustic properties in e.g., the restaurant would show the reverberation time would likely be too high due to the amount of concrete used for the flooring. As for the wooden flooring, either floating or on joists, would lower the reverberation time due to wood being more sound absorbing than concrete, but would require a higher amount of material use.

The focal point in the design has throughout the entire thesis been to transform the existing cement factory and renovate it to be habitable by guests and visitors, which means the newly built building with guest rooms has not been a priority other than giving more space for guest rooms. Though a new building has the potential to be fully optimised in terms of indoor comfort and spatial qualities to secure the wellbeing of guests, which could also be translated to the rest of the beach hotel to cultivate the relaxation aspect that follows and is expected when going on a holiday.

The agricultural heritage aspect of the project has been communicated and implemented through multiple iterations of plan drawings but could be further elaborated through interviews with chefs from Samsø to elaborate on a chef's needs for kitchen facilities.
Additionally, other staff facilities could have been further investigated looking into the fact that receptionists might need to be available during the night, which would perhaps require facilities with a bed for the staff.

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Appendix

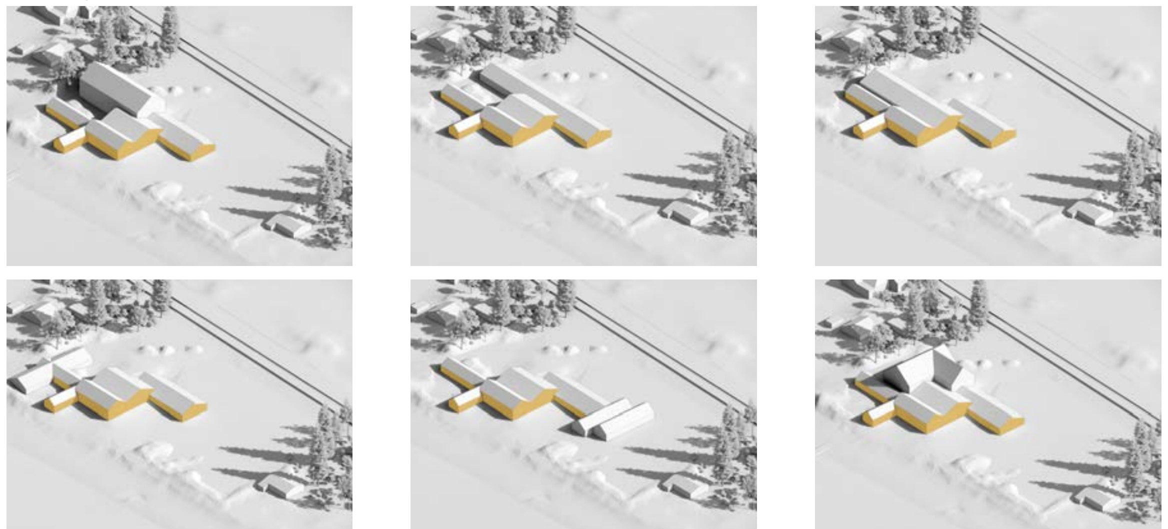
1: Volume Study
2: LCA Facade Cladding
3: Transportation Facade Cladding
4: LCA Insulation Study
5: Final Key Numbers BE18
6: BSim
7: Final LCA

Appendix 1

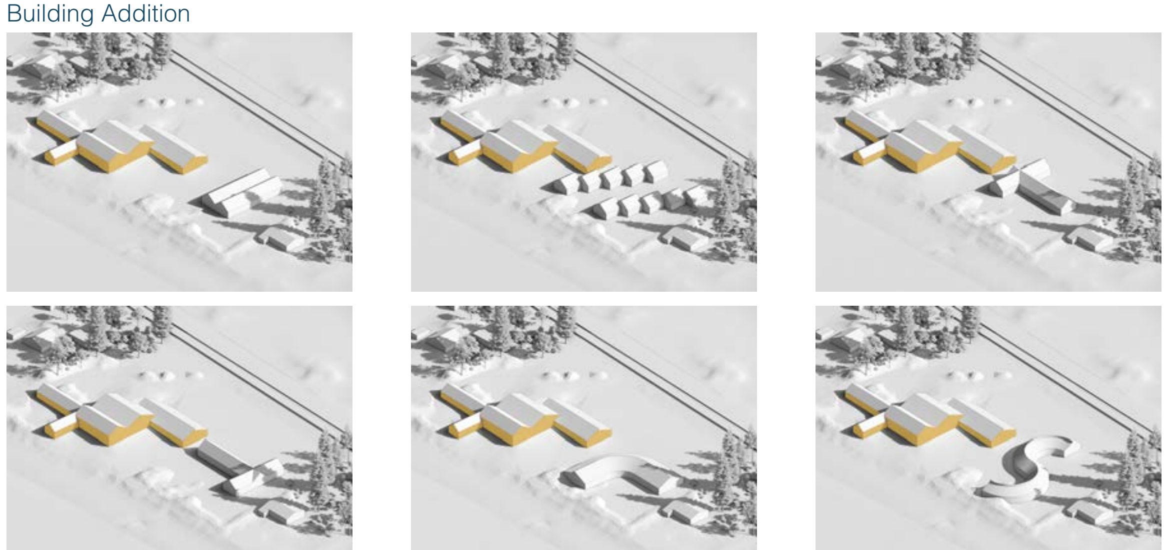
Volume Study

Floor Addition

Building Extension



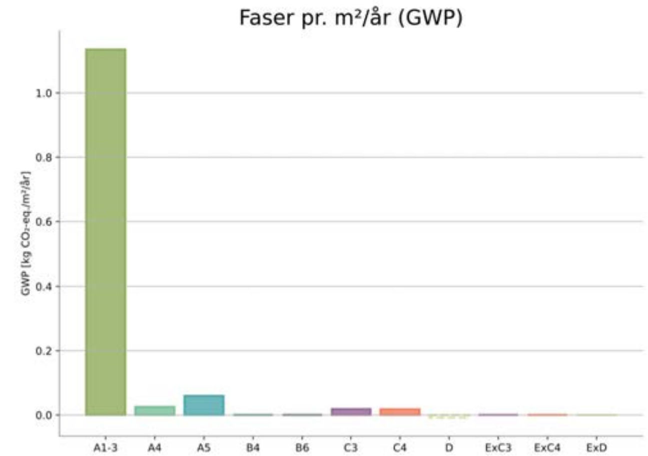
Building Addition



Appendix 2

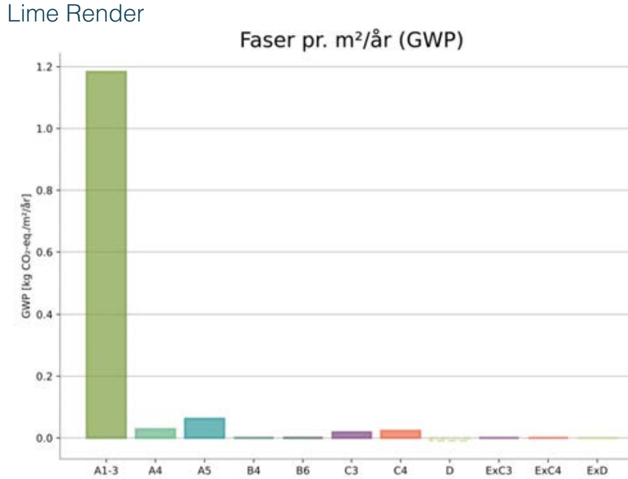
LCA of Facade Cladding

Brick



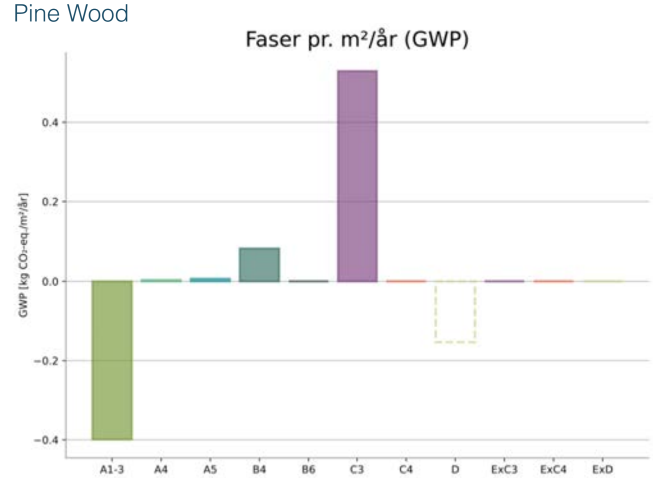
Navn	Værdi
A1-3	1,136e+00
A4	2,575e-02
A5	5,992e-02
B4	0,000e+00
B6	0,000e+00
C3	1,875e-02
C4	1,817e-02
D	-8,419e-03
ExC3	0,000e+00
ExC4	0,000e+00
ExD	0,000e+00

Lime Render



Navn	Værdi
A1-3	1,183e+00
A4	2,885e-02
A5	6,273e-02
B4	0,000e+00
B6	0,000e+00
C3	1,875e-02
C4	2,357e-02
D	-8,419e-03
ExC3	0,000e+00
ExC4	0,000e+00
ExD	0,000e+00

Pine Wood



Navn	Værdi
A1-3	-3,991e-01
A4	3,533e-03
A5	6,683e-03
B4	8,147e-02
B6	0,000e+00
C3	5,292e-01
C4	0,000e+00
D	-1,536e-01
ExC3	0,000e+00
ExC4	0,000e+00
ExD	0,000e+00

Appendix 3

Transportation Facade Cladding

Material	Density kg/m³	Thickness m³ *	Result kg
Mortar	1900	0,108	205,2
Bricks	1700	0,108	183,6
Mortar	1900	0,108	205,2
Bricks	1700	0,108	183,6
Render	1750	0,020	35,0
Timber Pine Wood and Spruce	420	0,019	7,98
Surface Coating	0,8	0,002	0,0016
Pine Wood	550	0,024	13,2

Material	km	kg	Truck $kgCO_2e$/kg km	Result $kgCO_2$	Total Result $kgCO_2$
Mortar	10	205,2	8,97E-05	1,84E-01	
Bricks	108	183,6	8,97E-05	1,78E+00	1,96
Mortar	10	205,2	8,97E-05	1,84E-01	
Bricks	108	183,6	8,97E-05	1,78E+00	
Render	96	35	8,97E-05	3,01E-01	2,26
Timber Pine Wood and Spruce	134	7,98	8,97E-05	9,59E-02	
Surface Coating	10	0,0016	8,97E-05	1,44E-06	
Pine Wood	134	13,2	8,97E-05	1,59E-01	0,25

* The study regards 1 m² wall

Appendix 4

LCA Insulation Study

Insulation materi	Wood fil	Lambda	Thickne	GWP u.	GWP m. D	Total Vo	kg	Transport
	Warehouse Building							
	0,20	0,0431	0,04	1,2113	-0,09668	5,64	310,2	13,912
	0,18		0,06	1,923	-0,1534795	8,9535	492,44	22,086
	0,15		0,11	3,3311	-0,26587	15,51	853,05	38,259
	0,12		0,18	5,5418	-0,442311	25,803	1419,2	63,65
	0,10		0,25	7,5708	-0,60425	35,25	1938,8	86,953
	Masonry Building							
	0,20	0,0431	0,19	5,7538	-0,45923	35,34	1943,7	87,175
	0,18		0,214	6,4806	-0,517238	39,804	2189,2	98,187
	0,15		0,262	7,9341	-0,633254	48,732	2680,3	120,21
	0,12		0,334	10,115	-0,807278	62,124	3416,8	153,24
	0,10		0,405	12,265	-0,978885	75,33	4143,2	185,82
	Staff facility							
	0,20	0,0431	0,17	5,1481	-0,41089	8,84	486,2	21,806
	0,18		0,194	5,8749	-0,468898	10,088	554,84	24,885
	0,15		0,242	7,3285	-0,584914	12,584	692,12	31,042
	0,12		0,3139	9,5058	-0,7586963	16,323	897,75	40,264
	0,10		0,385	11,659	-0,930545	20,02	1101,1	49,384
	Total		Avg. Th	GWP u.	GWP m. D	(m2)	kg	
	0,2		0,1333	12,113	-0,9668		2740,1	122,89
	0,18		0,1572	14,278	-1,1396155		3236,5	145,16
	0,15		0,2047	18,594	-1,484038		4225,4	189,51
Density	0,12		0,277	25,162	-2,0082853		5733,7	257,16
	0,1		0,3467	31,494	-2,51368		7183	322,16

Mineral	Lambda	Thickne	GWP u. D (	GWP m	Total Vo	kg	Transport
0,20	0,0394	0,035	1,9313	1,8837	4,935	192,47	8,6321
0,18		0,058	3,20044	3,1216	8,178	318,94	14,305
0,15		0,101	5,57318	5,4358	14,241	555,4	24,91
0,12		0,167	9,21506	8,9879	23,547	918,33	41,187
0,10		0,23	12,6914	12,379	32,43	1264,8	56,725
0,20	0,0394	0,174	9,60132	9,3647	32,364	1262,2	56,609
0,18		0,196	10,81528	10,549	36,456	1421,8	63,767
0,15		0,24	13,2432	12,917	44,64	1741	78,082
0,12		0,305	16,8299	16,415	56,73	2212,5	99,229
0,10		0,37	20,4166	19,913	68,82	2684	120,38
0,20	0,0394	0,155	8,5529	8,3421	8,06	314,34	14,098
0,18		0,177	9,76686	9,5261	9,204	358,96	16,099
0,15		0,22	12,1396	11,84	11,44	446,16	20,01
0,12		0,285	15,7263	15,339	14,82	577,98	25,922
0,10		0,35	19,313	18,837	18,2	709,8	31,835
		Avg. Th	GWP u. D (	GWP m.	D (m2)	kg	
		0,1213	20,08552	19,59		1769	79,34
		0,1437	23,78258	23,196		2099,7	94,171
		0,187	30,95598	30,193		2742,5	123
		0,2523	41,77126	40,742		3708,8	166,34
		0,3167	52,421	51,129		4658,6	208,94

Straw	Lambda	Thickne	GWP u.	GWP m	Total Vo	kg	Transport
0,20	0,058	0,05	0,7455	0,421	7,05	705	31,619
0,18		0,085	1,2674	0,7157	11,985	1198,5	53,753
0,15		0,15	2,2365	1,263	21,15	2115	94,858
0,12		0,245	3,653	2,0629	34,545	3454,5	154,93
0,10		0,34	5,0694	2,8628	47,94	4794	215,01
0,20	0,058	0,256	3,817	2,1555	47,616	4761,6	213,56
0,18		0,288	4,2941	2,425	53,568	5356,8	240,25
0,15		0,353	5,2632	2,9723	65,658	6565,8	294,48
0,12		0,45	6,7095	3,789	83,7	8370	375,39
0,10		0,545	8,1259	4,5889	101,37	10137	454,64
0,20	0,058	0,229	3,4144	1,9282	11,908	1190,8	53,407
0,18		0,26	3,8766	2,1892	13,52	1352	60,637
0,15		0,325	4,8458	2,7365	16,9	1690	75,797
0,12		0,42	6,2622	3,5364	21,84	2184	97,952
0,10		0,515	7,6786	4,3363	26,78	2678	120,11
		Avg. Th	GWP u.	GWP m	D (m2)	kg	
		0,1783	7,9769	4,5047		6657,4	298,58
		0,211	9,438	5,3299		7907,3	354,64
		0,276	12,345	6,9718		10371	465,13
		0,3717	16,625	9,3883		14009	628,28
		0,4667	20,874	11,788		17609	789,76

Expand	Lambda	Thickne	GWP u.	GWP m	Total Vo	kg	Transport
0,21	0,0468	0,037	4,1714	3,0133	5,217	93,906	4,2117
0,19		0,059	6,6517	4,805	8,319	149,74	6,7159
0,16		0,104	11,725	8,4698	14,664	263,95	11,838
0,13		0,17	19,166	13,845	23,97	431,46	19,351
0,11		0,235	26,494	19,138	33,135	596,43	26,75
0,23	0,0468	0,178	20,068	14,496	33,108	595,94	26,728
0,21		0,2	22,548	16,288	37,2	669,6	30,032
0,17		0,245	27,621	19,953	45,57	820,26	36,789
0,14		0,312	35,175	25,409	58,032	1044,6	46,849
0,12		0,37	41,714	30,133	68,82	1238,8	55,558
0,23	0,0468	0,159	17,926	12,949	8,268	148,82	6,6748
0,20		0,181	20,406	14,741	9,412	169,42	7,5983
0,17		0,225	25,367	18,324	11,7	210,6	9,4454
0,14		0,293	33,033	23,862	15,236	274,25	12,3
0,11		0,36	40,586	29,318	18,72	336,96	15,113
		Avg. Th	GWP u.	GWP m	D (m2)	kg	
		0,1247	42,165	30,459		838,67	10,886
		0,1467	49,606	35,834		988,76	14,314
		0,1913	64,713	46,747		1294,8	21,284
		0,2583	87,374	63,116		1750,3	31,651
		0,3217	108,79	78,59		2172,2	41,863

Appendix 5

Final Key Numbers BE18

Nøgletal, kWh/m² år

Renoveringsklasse 2

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
73,1	0,0	73,1
Samlet energibehov		31,3

Renoveringsklasse 1

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
54,8	0,0	54,8
Samlet energibehov		31,3

Energiramme BR 2018

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
31,4	0,0	31,4
Samlet energibehov		31,3

Energiramme lavenergi

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
27,0	0,0	27,0
Samlet energibehov		31,3

Bidrag til energibehovet

Varme	61,4
El til bygningsdrift	-11,0
Overtemp. i rum	0,0

Netto behov

Rumopvarmning	41,1
Varmt brugsvand	5,3
Køling	0,0

Udvalgte elbehov

Belysning	74,5
Opvarmning af rum	0,0
Opvarmning af vbv	0,0
Varmepumpe	0,0
Ventilatorer	0,0
Pumper	0,0
Køling	0,0
Totalt elforbrug	28,9

Varmetab fra installationer

Rumopvarmning	20,3
Varmt brugsvand	0,0

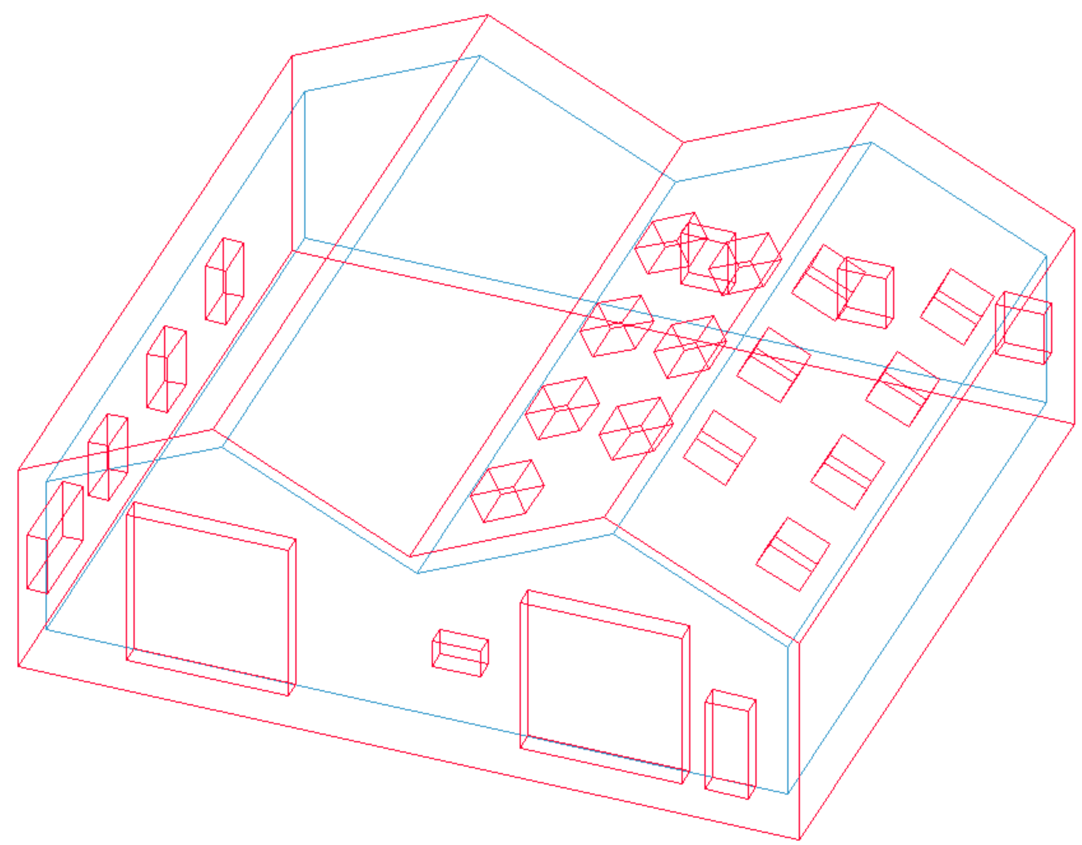
Ydelse fra særlige kilder

Solvarme	0,0
Varmepumpe	0,0
Solceller	11,0
Vindmøller	0,0

Appendix 6

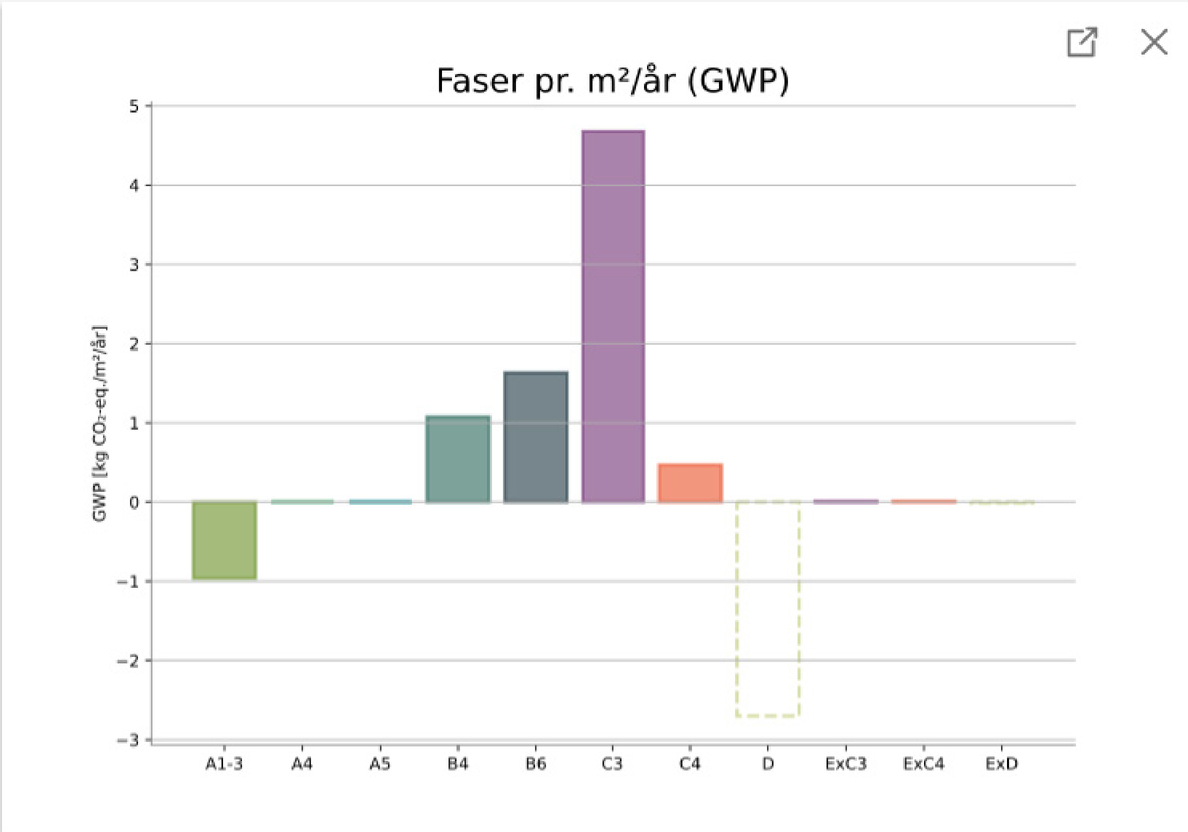
BSim

Warehouse	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	11578,92	2231,29	1874,69	1846,30	598,75	169,32	0,00	0,00	0,00	48,73	786,54	1740,82	2282,48
qCooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qInfiltration	-2809,35	-365,66	-333,87	-385,97	-236,37	-172,92	-121,91	-95,11	-98,48	-125,70	-202,45	-305,58	-365,33
qVenting	-2853,74	-185,17	-164,64	-190,74	-132,19	-202,29	-466,38	-512,29	-465,48	-80,59	-123,02	-155,08	-175,86
qSunRad	6859,60	115,43	253,38	596,98	847,61	1076,12	944,71	907,67	788,17	688,34	407,92	151,33	81,91
qPeople	4684,25	317,75	287,00	317,75	307,50	317,75	615,00	635,50	635,50	307,50	317,75	307,50	317,75
qEquipmen	328,50	27,90	25,20	27,90	27,00	27,90	27,00	27,90	27,90	27,00	27,90	27,00	27,90
qLighting	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qTransmiss	-15203,37	-2050,50	-1869,93	-2131,84	-1217,76	-904,18	-740,70	-503,58	-470,16	-599,74	-1012,43	-1641,74	-2060,80
qMixing	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qVentilation	-2584,80	-91,05	-71,82	-80,38	-194,54	-311,70	-257,71	-460,10	-417,45	-265,55	-202,21	-124,24	-108,04
Sum	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,00	-0,00	0,00	0,00	0,00	0,00
tOutdoor me	8,1	0,7	0,4	-0,7	7,1	11,5	14,2	17,8	17,9	14,5	9,8	3,4	0,7
tOp mean(°(	22,0	21,2	21,3	21,2	21,4	22,2	22,5	24,3	24,2	22,2	21,2	21,2	21,2
AirChange(/	0,5	0,3	0,3	0,3	0,3	0,5	0,9	1,2	1,2	0,4	0,3	0,3	0,3
Rel. Moistur	41,0	29,5	29,6	27,5	36,5	42,7	52,7	53,6	52,2	52,8	48,7	35,7	30,9
Co2(ppm)	645,8	657,6	659,1	660,8	666,3	635,4	662,7	572,0	594,6	655,2	668,3	660,8	657,0
PAQ(-)	0,4	0,6	0,6	0,6	0,5	0,3	0,2	-0,0	0,0	0,2	0,3	0,5	0,5
Hours > 21	5943	348	345	409	469	585	538	744	744	637	410	356	358
Hours > 26	64	0	0	0	0	0	2	34	25	3	0	0	0
Hours > 27	25	0	0	0	0	0	0	13	10	2	0	0	0
Hours < 20	1068	169	155	170	88	25	83	0	0	1	75	142	160
FanPow	1209,55	88,09	79,24	86,75	79,95	97,73	109,86	170,69	160,47	86,65	79,23	82,55	88,33
HtRec	4148,52	644,88	586,85	679,24	368,76	208,90	110,53	31,12	23,93	76,75	260,12	513,51	643,94
ClRec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HtCoil	1840,45	351,31	326,43	375,58	96,38	10,01	60,38	0,00	0,00	0,57	48,25	236,13	335,41
ClCoil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Humidif	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FloorHeat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FloorCool	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CentHeatPu	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CentCooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CentHeatPu	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CentCooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00



Appendix 7

Final LCA



Navn	Værdi
A1-3	-9,660e-01
A4	0,000e+00
A5	0,000e+00
B4	1,075e+00
B6	1,631e+00
C3	4,677e+00
C4	4,689e-01
D	-2,700e+00
ExC3	8,405e-03
ExC4	1,007e-02
ExD	-1,411e-02