Chikorievænget

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Title Page

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Abstract

The following paper present a design proposal for a sustainable building community with the focus on environmentally sustainable materials, that can be incorporated into a circular process, furthermore a strong architectural quality, that take its fundamentals from the Nordic context. This student project is meant to serve as an inspiration and investigation within the chosen focus areas and the design proposal created through an integrated design process, with the result in a cluster of sustainable single-family houses with developed and evaluated parameters in relation to functional, technical and aesthetical aspects to reach the desired vision of the project. The project site is located in Sorø, Sjælland in a newly build area.

Motivation

Ill. 01. NIklas & Emil

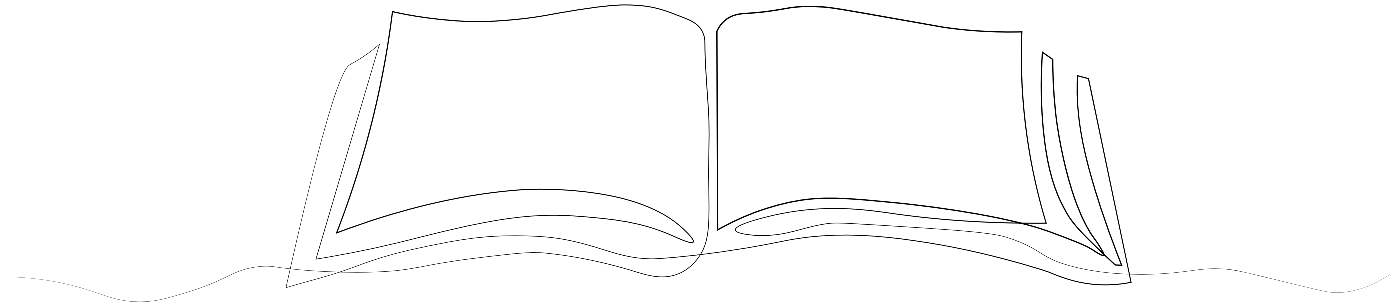
Who are we?

Niklas Dahl Petersen and Emil Pøckel Hemmingsen, the authors of this report, are students at Aalborg University, Architecture, MSc in engineering. Along with two different backgrounds but a shared passion for architecture and all its facets. With a diverse set of skills acquired through BSc and MSc, collaborated in skill and interest to write this master's report on materiality and Danish architecture. Introductions are made in the first chapters of this report, specifically what the report is about and how the report proceeds to present the accumulated knowledge and work process towards the final design proposal of this master thesis.

This thesis is driven by learning objective of the last semester of the education, Architecture & Design with focus on sustainability, working with integrated design to make high quality architecture, but also the personal interest of the group. Knowledge, skills, and competences of the semester within the field of architectural design-engineering on a international standard. The personal interest of this thesis is the study of Danish architecture and the focus on materials. The objective is to design a theoretical sustainable street with buildings which provides not only shelter and protection but also quality and comfort to make it a home.

The group have diagnosed a problem with the way Danish tract houses are build, there lack of conscious for sustainable materials and compromised indoor quality. Looking back at building traditions, the Danish functional mindset had created a connection with nature, which in the last decade has been lost due to general building regulations and standardized architecture, replicated in different projects with little interest in the microclimate. (Poulsen and Lauring, 2019). To design an environmental and social sustainable building it is important that the inhabitants want to live sustainably, people who want to change their habits and take alternative choices to save electricity, water, and heat. The sustainable lifestyle combined with sustainable buildings, not only looking into passive and active strategies that reduce the operation emission but also looking into the choice of building materials.

Reading guide



Ill. 02. Development

The report is divided into 6 chapters.

1.0: The preliminary chapter sets the premise of this report and creates the initial statements about the problem, its context, and the methodology that is used throughout the report to achieve an integrated process that incorporates all the relevant parameters to fulfil and gather the fundamental knowledge to reach a satisfactory result and reflect upon the learning objectives of this master semester.

2.0: The theory chapter focuses on and embraces the two main topics that investigate the extent of the thesis problem and conclude on the collected theoretical knowledge, to create a basis for design criteria.

3.0: The analysis chapter includes all relevant contextual analytical knowledge that is needed in relation to the focus areas and encloses the contextual conditions related to microclimatic parameters, urban scale and the user group.

4.0: The Recapitulation conclude based on previous chapters and summarizes the problem, which leads to the vision of this project. The design criteria are formulated to start and steer the design process, and with these steppingstones shape the framework and foundation of the thesis design.

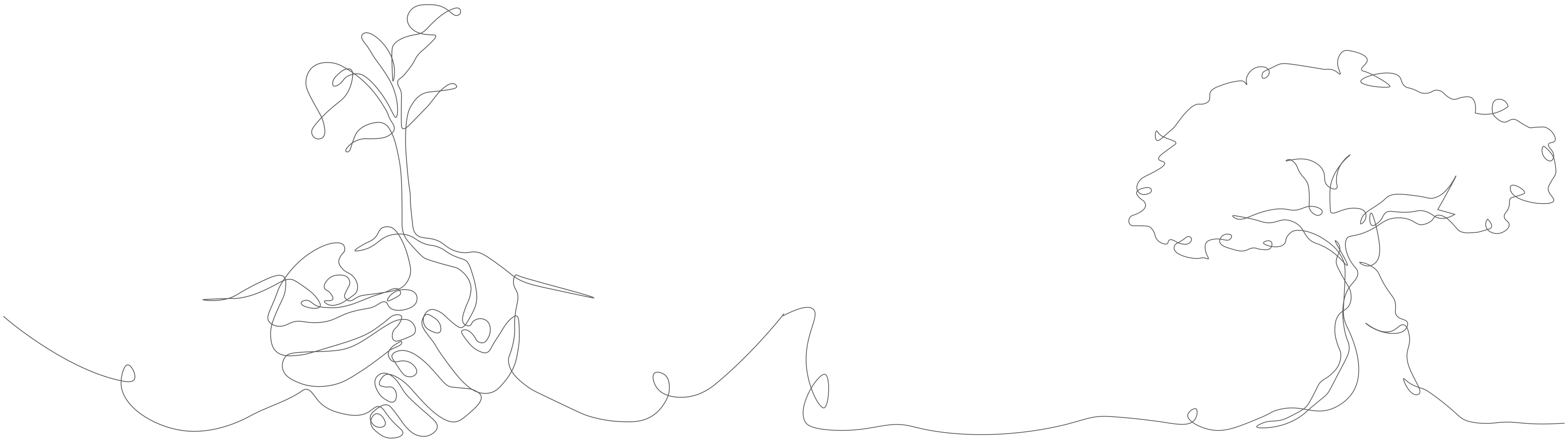
These chapters together create the program of the report and provides the full understanding to start the further work into the design process and synthesis which produces the finished thesis design.

5.0: The presentation chapter consist of the final design proposal and is displayed throughout drawings, visualizations, text and supplementing diagrams to give the full insight of the project's extent.

6.0: The design process chapter describe and highlight the process towards the final design proposal with its different phases of integrated aspects. Finally, a conclusion and reflection on the thesis and its process.

1.0 Introduction

1.1 Confrontation



Ill. 03. Preserve nature

Ill. 04. Environmental pillar

1.1.1 Our common future

The Brundtland report, also known as Our Common Future, was published in 1987 and describes how sustainability can be divided into three pillars: environmental, social, and economic. It is implied that there must be a balance between these three in order to achieve true sustainability. With the implication of balance among the three pillars, the aspects of each pillar are interchangeable and thus equally important. However, one could argue that without the environment, there would be no society, and without society, there would be no economy. The environmental pillar is therefore the load bearing one.

When comparing sustainable approaches to other, the cost is often higher, this makes the client reconsider to environmentally friendly solution. The concern for the price Is valid however it is also a short-term ideology.

The cost of inaction is incredibly high, if countries fail to meet their desired Nationally Determined Contribution (NDCs), the price would be trillions of dollars. Simply put, an NDC, is a plan for reducing emissions and adapting to climate change. Each Party from the Paris Agreement is required to develop and update their NDC every five years. In fact, the potential for saving 126-616 trillion dollars before 2100 is currently available if the human population follow the current emission reduction effort. On the contrary, if countries are unsuccessful in implementing their current NDCs, the whole world would lose between 149-791 trillion dollars before 2100 (Wei et al., 2020).

Looking at the relation between economy and sustainable approaches it is important to understand that economy is not only relying on nature but depends on it. Professor of Economics, Sir Partha Dasgupta, has in an independent review on Economics of Biodiversity underlined the importance of including natural capital to secure sustainable economic development.

"The solution starts with understanding and accepting a simple truth: our economies are embedded within Nature, not external to it." (Dasgupta, P. 2021, p. 2).

Sir Partha Dasgupta states that nature is an asset to our life just as important as roads, healthcare, or education. He believes that biodiversity makes nature resilient and adaptable.

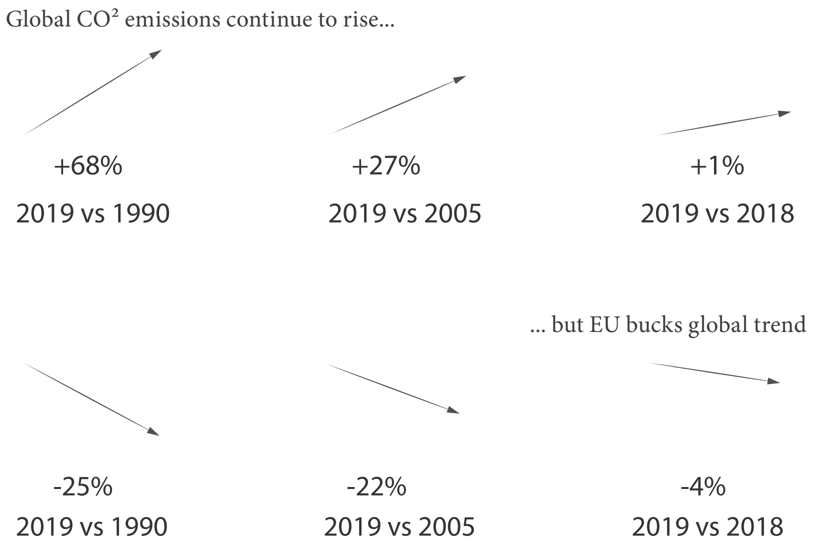
As humans use the earth as a sink for all our waste products, carbon dioxide and other forms of pollution, the biodiversity decreases. By reducing biodiversity, nature and humanity suffers.

“Our economies, livelihoods and well-being all depend on our most precious asset: Nature. “(ibid).

Either we need to get better at demanding a broader and more comprehensive economic analysis that does not limit the aspect of economic sustainability to a single project at a single point in time, or we need to move toward a new understanding of sustainability as an acceptance of the systems on which we rely. Insisting that nothing that is harmful to our planet, or our society can never be called sustainable, no matter how ‘economically sustainable’ it may appear. Using economy as a tool to promote sustainability, but not to define it.

"We have collectively failed to engage with Nature sus¬tainably, to the extent that our demands far exceed its capacity to supply us with the goods and services we all rely on."

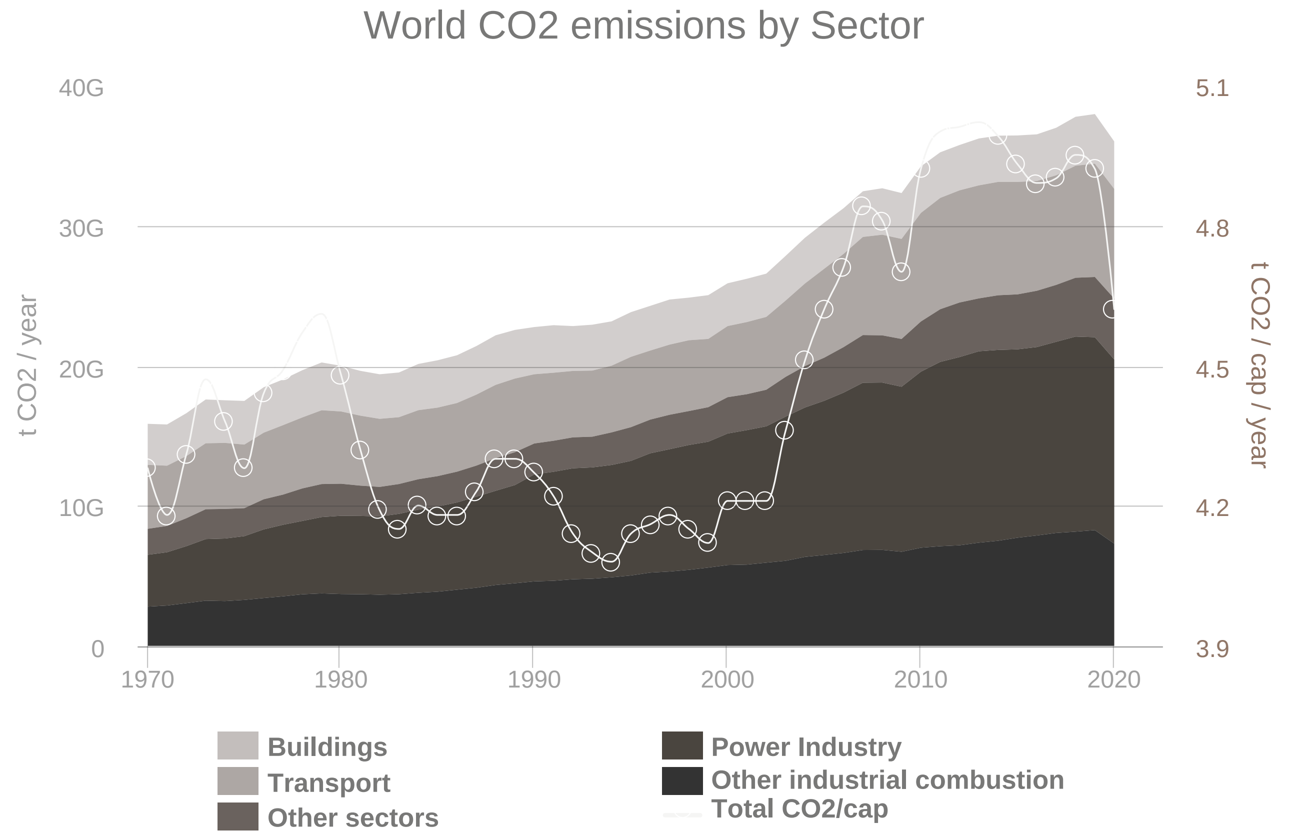
(Dasgupta, P. 2021 p. 1).



"Scientific evidence for warming of the climate system is unequivocal."

Intergovernmental Panel on Climate Change, 2020.

Ill. 05. EU dedication & rising CO2



Ill. 06. Sector CO² emissions (EDGAR, DK, 2022)

1.1.2 EU data

In 2020, the world had an emission of total 35,962.84 Mt CO_2 with the data collected from 220 countries in absolute value by country. In this large number Denmark, stand for 25.71 Mt, which result in 0.07% of the total emission of CO_2 globally. However, it can be ambiguous to understand the magnitude and what is incorporated in the absolute value by country, because seen per capita it gives a different perspective on the numbers and understanding of it (EDGAR, 2022).

Without the numbers and not diving too much into this topic, take a simple assessment looking at export consequences, consumption and where things are produced. Some countries are under a huge manufacturing market with greenhouse gas intensive production that supplies and maintains certain standard of living in other countries (Cepos.dk. 2020).

As a result, the argument progresses toward us having to solve global warming entirely and contribute whatever we can as a country. This is the starting point for this thesis, because how big of a change can Denmark with its 0,07% really contribute with?

To start with, what does Denmark contribute regarding to emissions. The number 25.71 Mt CO_2 in 2020 comes from five main sectors shown in ill 06, which also include the total emission per capita over the centuries.

1.1.3 Global emission

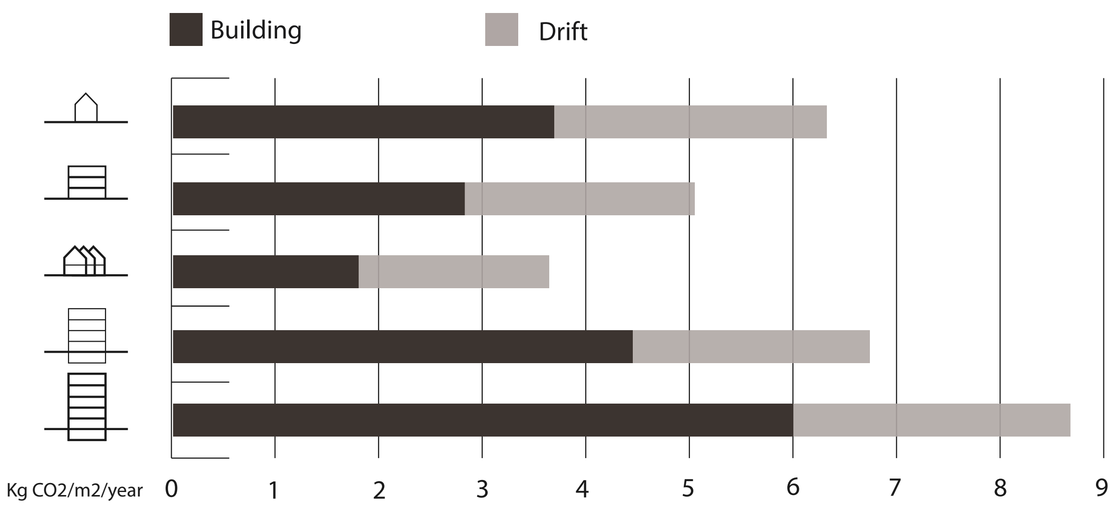
However, with a closer look into the Emissions Database for Global Atmospheric Research and the Global reporting 2021 from the Danish Energy Agency, it gives different numbers at crucial topics, which helps to provide the overall understanding of the total emissions. The two numbers in questing is the per capita that with EDGAR calculations is 4.43 t CO_2/cap and for the Global reporting 2021 is 11 t CO_2/cap. The reason for the different output is on the base of what that threshold is for the calculations of the emissions or the whole climate footprint (per capita) such as production, transport, use and waste/recycling. In total Denmark still have a small contribution to the global warming. Nevertheless, to understand, it is not so explicit, but knowing that we are common in the fight against global warming when it comes to our production and consumption (EDGAR, DK, 2022).

Contributing to CO_2 emissions has an impact regardless of scale and should be minimized to the greatest extent possible for the country, returning to the original question. What can Denmark contribute with regarding lowering the emission of CO_2?

With such a small impact on the global output of CO_2 emission, it is limited in what effect Denmark can have by just focusing solely on reducing its CO_2 footprint, therefore it is important that Denmark needs to provide and invest in knowledge for more sustainable solutions to lead in a sustainable path for other countries to tail (KEFM, 2021).

"Denmark contributes to significant reductions around the world. Our companies sell energy technology, and as a country, we provide a great deal of climate assistance as well as advice and cooperation, which has been shown to lead to very large reductions."

Minister of Climate Dan Jørgensen, 2021.



The National Building Research Institute calculated the environmental impact and energy consumption for the operational phase as well as the other phases (building material production, construction, demolition, and material treatment) in six different building types. All the examples demonstrated that the materials weighed as much as, if not more than, the operating consumption seen over building lifetime.

Ill. 07. Material load

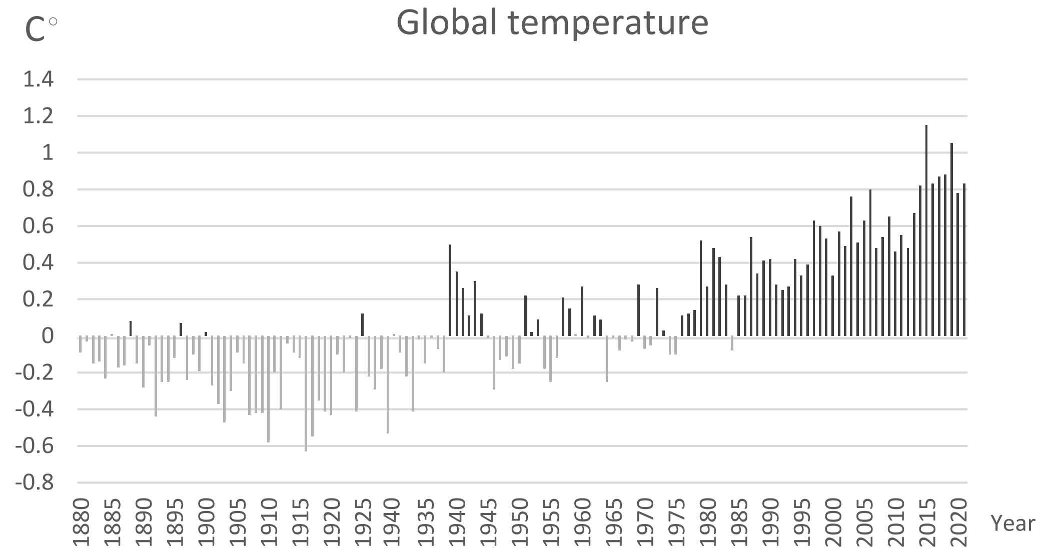
(BUILD, 2022)

1.1.4 Construction emission

With the government, taking some steps towards the transition over to a more sustainable context. Private companies such as Innovationsfonden and Realdania have come together to support research and development projects within the promotion of circular adaptation in the construction industry, with 40 million DDK.

The focus within this segment is that the construction sector accounts for 40% of the total CO_2 emissions globally and out of the 40%, 11% makes up for the building materials. Looking at Denmark, its construction industry stands for 20% of Denmark's total CO_2 emissions. Yet, that figure only covers the energy consumption for heating and operation of the buildings. Here the value becomes unclear, because to this must be added embedded energy to produce materials, transport to the construction site and the construction on site to get the full outline of what the construction industry is contributing to regarding CO_2 emissions. Here, the development of circular solutions based on reuse and recycling are central (Innovationsfonden, 2020).

On these vaguely numbers the State Building Institute (SBi) in 2017, also known as the Institute for buildings, city, and environment (BUILD) today, investigated the actual environmental impact of construction and operation of buildings. They concluded that the energy use of operation in newly constructed buildings after the building regulations 2015 (BR15) was similar or lower than the construction part when included production, assembly, demolition, and waste management as seen Ill. 07.



Ill. 08. Yearly surface temperature

Yearly surface temperature compared to the 20th-century average from 1880–2020. Grey bars indicate cooler-than-average years; black bars show warmer-than-average years. NOAA Climate.gov graph, based on da ta from the National Centers for Environmental Information.

(Climate Change: Global Temperature | NOAA Climate.gov, 2022)

1.1.5 Rising temperatures

There has been, in the the last decade, a focus on lowering operating energy consumption, which has been accomplished in party through material performance by reducing transmission loss trough added insulation and improved windows. This resulting to increase embedded CO_2 in building construction.

Hereby the problem changes direction and with emerging environmental issues that require a strong focus, the embedded energy consumption must be a visible and understandable part of the total CO_2 emission. However, a part of the building process, many experts recommend using life cycle assessment (LCA) as a tool to assess the entire environmental impact of the materials. (Andersen, U., 2017)

One of the reasons major factors of climate change is built-up of greenhouse gasses. Damage has undergone and it is now not possible to avoid temperature changes, but if the earth is a planet the human population want to continue inhabiting, the need for change is now (United Nations Environment Programme 2020). Look Ill. 08 for yearly surface temperatures.

1.2 Project direction

The main, focus set on building materials concerning the environmental impact and the related emissions undertaking the building lifespan. Parallel to this a second topic will be added as another important focus area that will be explored; the second focus area originates in the interest and motivation of the group. The architectural aspect and the overall quality of Danish architecture and its history, and more in depth the important coherence in the detail of the materials and the architectural quality.

Birthe Iuel, chairperson of Building Culture Denmark, have a critical view upon the state of Danish tract housing today and explains why it is needed to reclaim respect and understanding for the average family home. Birthe Iuel states:

“Our Danish building tradition, where simplicity, harmony and solid materials were paramount, no longer exists, and I therefore believe it is time that we focus on the inferior quality in much of the tract house construction. This applies to both the aesthetics of the houses and the choice of materials.”

As the interview goes on the journalist, inquire into the critical opinion with a series of questions. The reason for this critical stand is due mainly to the development of this housing typology since the 1960´s where there has been a decline in quality. The lack in quality shows in replicated designs and poor material choices, what should be focused on is durable and long-lasting materials and the importance of architectural policy from the municipality. Better Building Practices movement was a tool to guide the architectural quality and Birthe Iuel believes Denmark should not build on the principles established in 1915 but construct out from new interpretations of these principles to today's Denmark” (Henriksen, 2015).

“Approximately 50,000 houses were built according to the principles of the movement, as well as 75,000 master mason villas that were directly inspired by the principles. Today, there are more than 50 type house companies, which together sell approximately 2,700 type houses a year". - (Henriksen 2015)

It is within this scale and housing typology the thesis will address the architectural issues in the popular tract houses being built in Denmark. To set the context and address the state of the architectural quality in the ordinary family houses, a fictive client will be established consisting of a building community that will build houses for each family.

1.2.1 Pre vision

With this focus on sustainable materials, circularity and traditional Nordic architecture based on a context with a building community that will build several houses with a strong focus on sustainability around environmental and social aspects. The expectations of the design in this thesis will be a sustainable construction that has an awareness of its context and time, while at the same time also having a focus on the contemporary climate issues. To achieve the desired result, the process will be guided by a methodology that works with tools and helps to strengthen an integrated design that incorporates aspects of the design and its focus areas, as described in the introduction.

1.3 Approach

1.3.1 Methodology

A methodology is a systematic of methods used in a specific area, these methods can be a way of explaining and present the thesis thoughts and ideas. Models and particular perceptions of 'reality' based on a set of theoretical exemplifications are reflected in methodologies. A methodology should inform not only what actions to take, in what sequence, and how to perform those steps, but also why those steps should be completed in that order (Architecture Methodologies and Frameworks – IasaGlobal, 2022).

Architecture design is a delicate process, and having a systematic set of methods, procedures, and techniques aids in making justified judgments, reflecting on, and discussing constructed design decisions that address sustainable, social, or contextual factors.

The Integrated Design Process (IDP) has been favored above other techniques at Aalborg University because of its adaptability to combine diverse segments of architecture such as engineering and sustainability from the start of the design process, guiding a holistic design.

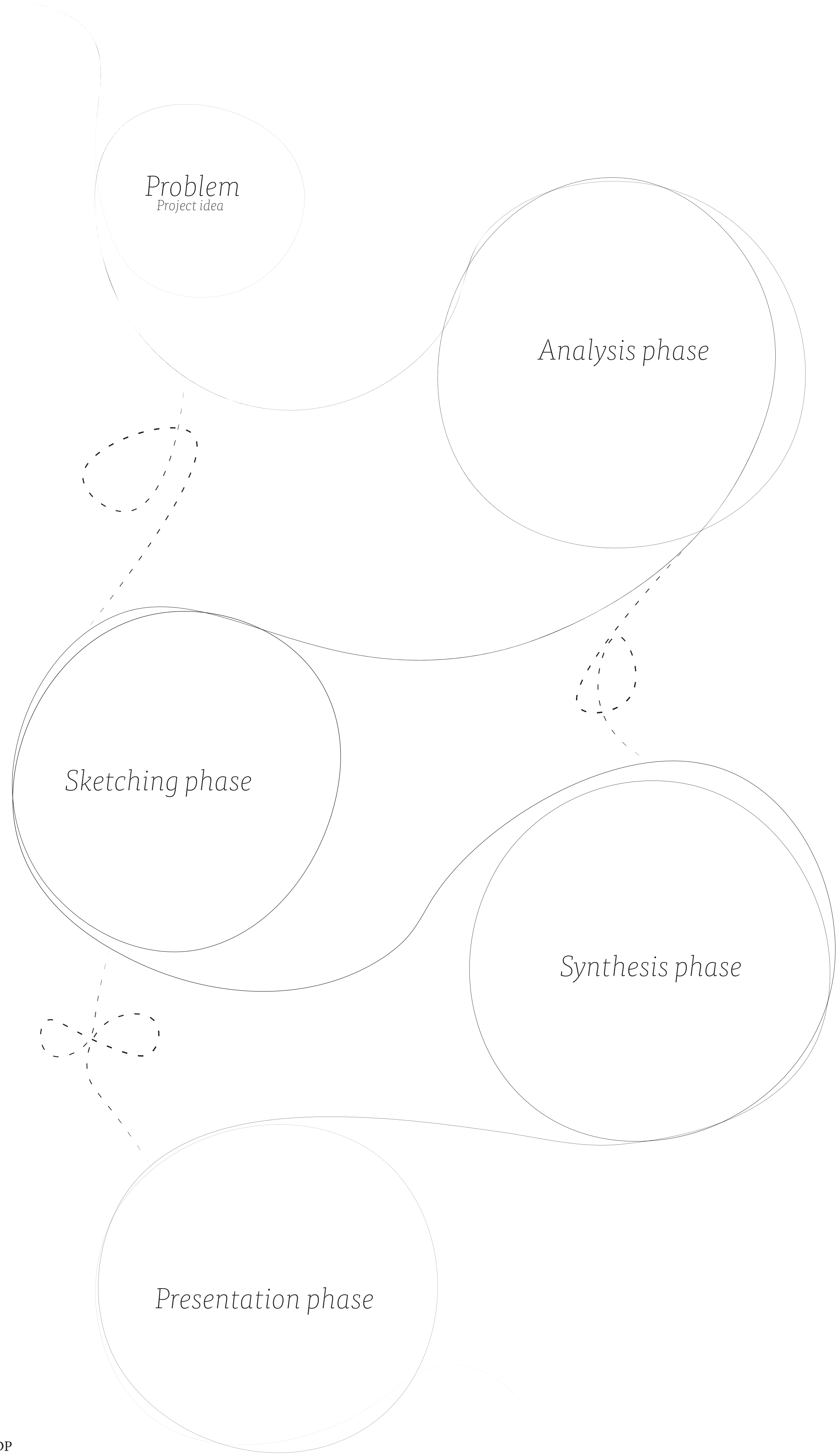
Through five phases: problem, analysis, sketching, synthesis, and presentation, it promotes a focus on design, construction, building operations, and occupancy.

The IDP is described as an iterative process in which different tools are used at different stages to gain a better understanding of the thesis (Knudstrup, M. 2004).

To achieve a balanced depth in the design, a comprehensive awareness of the value of all components, including social, cultural, functional, and technical are required. As a result, a basic grasp of the value and role of each instrument, as well as their connection, is beneficial and is described on the following pages. Research articles, photography, and mapping are utilized to obtain relevant knowledge, particularly in the early stages of the thesis, but not exclusively.

They can include architectural and technical information, as well as serve as a foundation for the thesis. Simulation tools can be used for in-depth evaluations to confirm choices made during the design process. The tools for such investigations are widely available, and any area of the thesis can be examined. The tools' limitations are their inability to stay up with the latest research and trends, as well as the fact that there is only one tool for each analysis.

In addition, numerous sketching and presentation tools can be utilized to communicate the thesis, however this adds another layer of tools to be employed.



Ill. 09. IDP

1.3.2 Methodologies

Gathering knowledge

Aims to develop theory from methodical application of research

Litterature studies

Literature studies are used in the early stages of the integrated design process to better achieve an In-depth understanding of a specific topic. This method is used to create an architectural platform for the generation of ideas and decision-making. The study of literature is done primarily in the early stages, but it is used throughout the IDP to gather inspiration, relevant knowledge, and critical perspectives on a topic.

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

Case study

Studies of built or unbuilt projects with the goal of learning about effective and ineffective solutions in order to put the groundwork for the sketching and synthesis phase.

This strategy relies heavily on the careful framing of the study and the omission of extraneous data. This method is frequently combined with literature reviews. Tools: Literature, general knowledge, contacts, field trips, architectural magazines, databases

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

On and of site studies

Intends to gather usefull information of the site context

Mapping

Mapping provides critical information about the site and its surroundings at various dimensions of the design, addressing features and obstacles and providing strategies for future blockage or usage. During the analysis phase, data such as infrastructure, geography, topography, functions, and so on are provided through mapping, providing insight into the context's environment.

Tools: digital programs (QGis, klimatilpasning. dk), Google maps

Site visit

Visiting the site is very important in order to get an understanding of the site and its sorroundings. Information and impression of a site is lost through a computer screen. Visiting the site gives local down to earth understanding of scale, distances, neighbours, views, potential risk etc.

Tools: photographs, note taking, observations

Methodology for technical aspects

Generates results by means of technical data

Calculations

Calculations must be used from the start of the design process to reinforce the IDP. It is critical to include quick calculations in the early stages of the design process to determine whether the layout can meet a variety of critical requirements in terms of energy use, indoor comfort, and power demand. The calculation tools available can handle everything from simple hand calculations to complex validating calculations.

Tools: BE18, Microsoft excel, calculations by hand , LCA byg.

Simulations

Simulations are typically used during the analysis, sketching, and synthesis phases. This provides detailed information about the microclimate and structure, as well as an understanding of overall building performance. The simulation method is divided into two parts: single-parameter and multiple parameter simulations.

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

Methodology for generating ideas

Creates a structured approach towards a mostly intuitive process

Inspiration boards

The design boosting feature is used throughout the process, but especially during the analysis and sketching phases, where it initiates design flow, inspiration, architectural position, and defines the design direction. To generate ideas for the process, moods, perceptions, feelings, expectations, cases, and materials are all used. The goal of this strategy is to determine the style and direction of the project; inspiration is essential.

Tools: sketching, photographs, Pinterest

Sketching

Sketches are created by generating ideas based on prior analysis, which is done in collaboration with other methods such as brainstorming, mood boarding, and mind mapping. The sketches are vision-based and consider a variety of constraints and criteria. This method is an iterative process that is an essential component of integrated design.

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

Volumetric studies

The process of converting a 2D drawing into a 3D model reveals potentials and challenges with a proposed design. Creating this constant shift between 2D and 3D is beneficial because it allows one to grasp various unresolved issues. A digital model is a useful tool throughout the entire process because it allows for the consideration of details separately and in relation to one another, resulting in a more comprehensive perception of the proposed spaces.

Tools: analogue model making, CAD tools, Revit, Sketch-up

Presentation methodology

Summarizes and advertises the final design to a third party

Infographics

Infographics can graphically convey a set of data to quickly and precisely present information. Graphs can help find patterns and trends, which can improve data insight.

Tools: Illustrator, Excel, Photoshop, analogue hand drawings

Renders

Renders are used to create photorealistic illustrations from 2D or 3D models using digital tools. Renders enable the project to be visualized by presenting both interior and exterior spaces, communicating intended atmospheres and functions, and establishing relations with other spaces.

Tools: Twinmotion, Enscape

Illustrations

Illustrations are intended to visualize a concept, process, or explanation, and are frequently communicated in a specific style in conjunction with composition. It aims to communicate what cannot be expressed in words and can be carried out at all stages of the process.

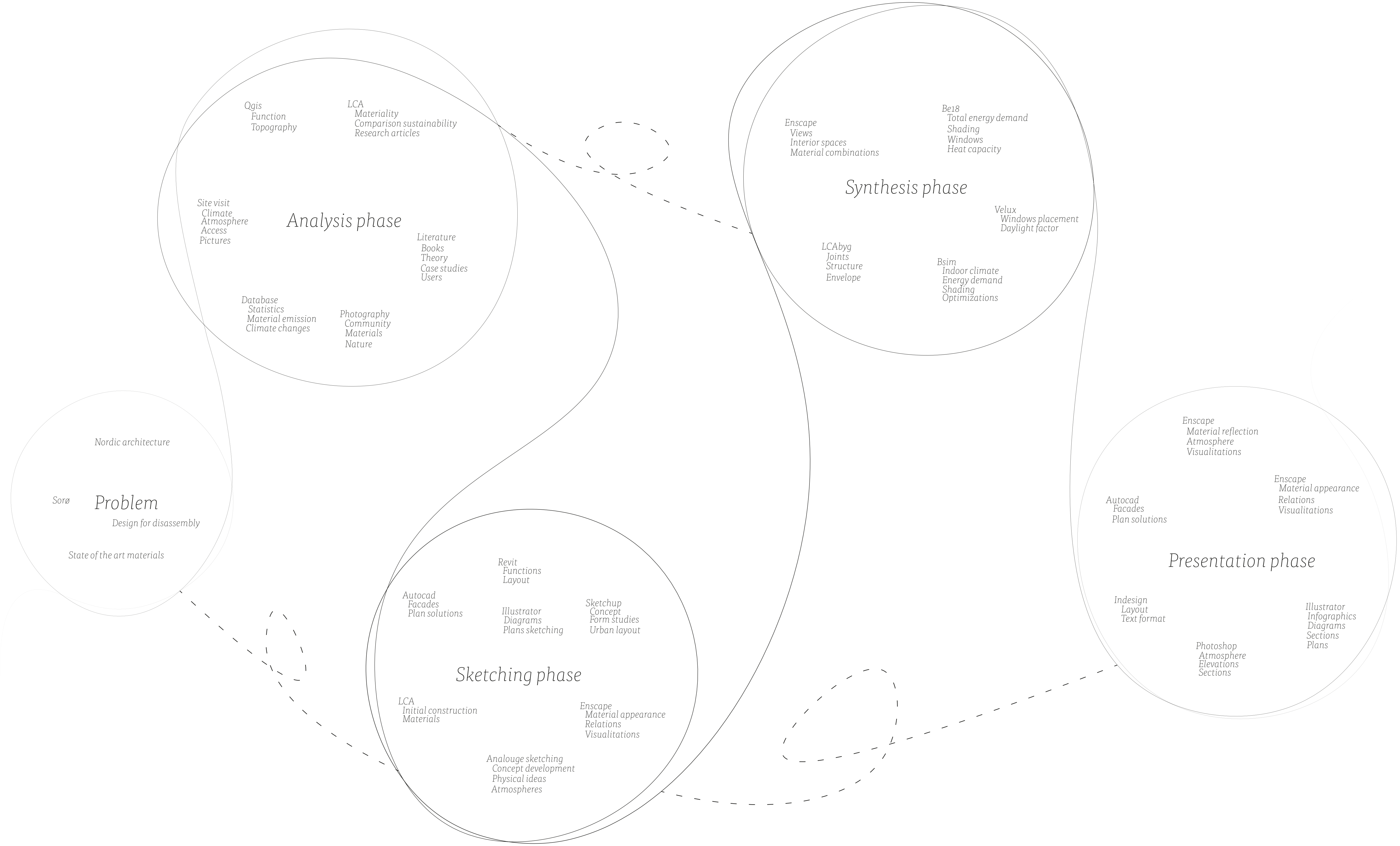
Tools: Illustrator, Revit, Photoshop, CAD tools

Report

Creating a systematic report that covers all aspects of the IDP provides a good synthesis of the design process, from the initial problem to the analysis, sketching, and synthesis phase, to the project's final presentation. The report provides insight into the various thoughts and challenges encountered along the way, as well as a deeper empathy for the final design.

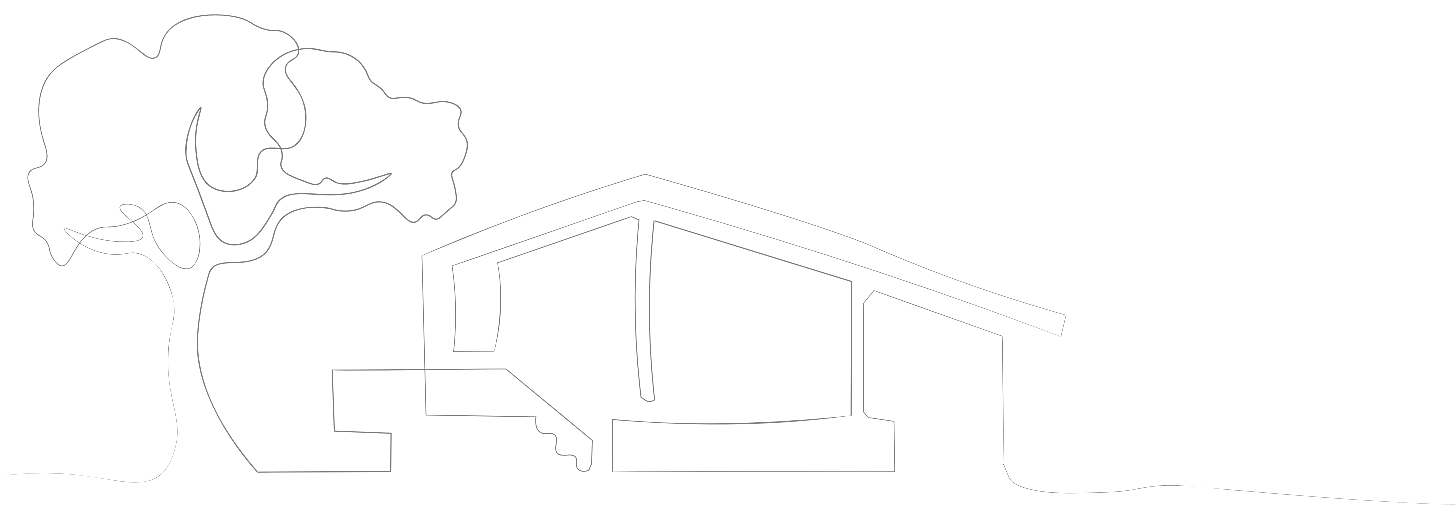
Tools: InDesign, Word

1.3.3 The integrated design process



Ill. 10. IDP

2.0 Theory


Ill. 11. Architecture is many things

2.1 Architecture theory

This topic will begin with an examination of the Nordic style in architecture before moving on to a Danish context. Danish architecture history, detailing, material use, and Danish building customs will be covered. As architecture has become a global profession, working across borders in interdisciplinary teams, local traditions and materials do not dictate the agenda. The question is, how is it possible to maintain the unique tendencies and values that define Nordic architecture and contribute to our international leadership in architecture? Furthermore, what are the distinct place-specific traditions on which we build in the Nordic region?

For many years, Scandinavian buildings have been designed in their simplicity to meet the necessary climatic demands. Where most of the population had to survive, possessions were simple, few, and functional. Scandinavian nations have historically been poor in comparison to other countries in Europe, where countries such as England, Germany, and France have been central to prosperity, development, and culture. Where the Scandinavian countries borrowed and took inspiration from major style periods up to 1900s, the industrialisation of Europe created prosperity for the citizens and nations in Scandinavia (Englund, 2005).

But what is it that creates the distinctive Nordic style, which has become a symbol of high quality architecture throughout the twentieth century, having focus on context, materiality and detail for building technique. The Nordic countries have vast distances of coastline, lakes scattered inland, and forested areas, where winters are cold and dark, but summers are warm and bright. If the proximity of nature is emphasized in the architecture's design and materials, the buildings frequently use the surrounding context in a parallel extension of the building that forms a natural symposium between the two elements, it is also seen that the building can be used as a contrast to create a different expression. What all the buildings have in common, both calm and dramatic, is that they use the same basic principles; respecting traditions, updated building technology, materials and trends (Ibler, 2017).

Where the means may include the design of rooms, surfaces, and construction, as well as how cut-outs in these elements form the frame of the window, the importance of the window was placement in the room and the function of the room must be included to get full use of daylight. These elements together consist of materials that are an essential part of the Nordic building tradition, where the materials address the context and can be used in a multitude of contexts and variants within housing construction. What can be described as the classic building materials are bricks, wood and glass which are used differently according to the material's properties. The distinction is ultimately found in the composition and design of the tools and materials, which results in what is recognized as good Nordic architecture. With this as a starting point, history will be unfolded and investigated to a greater extent in order to summarize the current quality of the detached house.

In Denmark there was a renewal of house construction at the end of the nineteenth century, and with "Better building practice" beginning in 1915, an association formed by professionals, architects, and other relevant people in construction and culture who would map principles and methods to increase and manage the architectural quality of single-family homes. The book described the building's design, having equal and classic proportions, some details, and an honesty in the material choice to help create a homely environment with practical and up-to-date decor. (Bedre Byggeskik - Historiske Huse, 2022).

The individual house building can be described as a detached house, a house with an associated garden on a plot which is dedicated to the residence of one family. Within this category of detached houses, there are many examples of design and quality that through the 20th century represent a development of construction method, construction, choice of materials and craftsmanship. Influenced by war, industrial development in materials and technology, in addition style periods and other trends within the current time. With the start-up in the “Statslånshuse” in the 1930s, which made the detached house accessible to a broader number of the Danish population and thus changed geographical and social aspects for most of the citizens within the social class. In the early 1950s and therefore after the war, there were completely new and untraditional house types that appeared in Denmark. Namely the "modernist house" with a completely flat roof, large glass sections and open floorplans. This was primarily due to a favourable period for the detached house in Denmark and the fact that architects sought inspiration abroad, which provided opportunities for new building materials and techniques for the country. In the 1960s, there was economic recovery and prosperity among the population, ushering in a new era for Danish detached house construction. The detached house is becoming more standardized and a "shelf item," with type house buildings and new detached house neighbourhoods springing up all over the place, radically altering the Danish cultural landscape and thus becoming a tract house. ▶

With the start-up and through the 1970s, the progress did not stop for the tract house concept, although there was criticism of the life in the detached house. The criticism was towards the need for better urban planning, as the areas and houses were perceived without identity and alienating. After a long period of progress, new construction numbers decreased; however, this did not halt development, and the postmodern detached house has its origins in the 1980s, wherein the 1970s socialism was replaced by individualism. Postmodernism created confusion about the concept of architectural quality in Denmark, as many thought it was dishonest, superficial and did not demand real quality of the materials and visible constructions. Instead, masonry walls and plaster walls were treated to look the same, and constructions were hidden behind layers of cheap plaster.

With many of the same materials and techniques that were used in the 1990s, where the main features were a roof that connected the entire house with a built-in carport, this is still one of the primary main features seen in what is built in Denmark today. (Andersen and Jensen, 2019).

An otherwise proud nation around its building tradition with a focus on simple, aesthetics, practical and contemporary housing has turned into a mass production that mostly deals with economic and time parameters for customers and the tract house companies. However, the newly built houses consider the emerging problems that are seen in the older tract houses concerning too little daylight, poorly insulated envelope and a plan layout that don't benefits modern functionality (Kiersgaard Espersen, 2021).

But in most of the newly built type houses, there has not been much development when it comes to the choice of material and design, which primarily consists of brick, aerated concrete, gypsum interior walls and individual wooden elements throughout the building. The lack of focus on material selection and design provides a look back at the start-up of the uniform tract house in the 60s and the critical outcomes of this catalogue item.

With a great tradition in the design of the right proportions and quality in the materials, glass, wood and brick are explored through three case studies, which thereby analyse where tradition, context, design and materials work in a way not seen in the general tract house.

2.1.1 Nordic architecture - Glass

Since 20th century modernism, glass has been used more, where modernism referred to individual houses with large glass sections, which with the free space plan using constructive columns created an overview through the house, which many found attractive. However, the glass as a material can be more than just a window. It creates a framework, a connection between interior and exterior which gives and smooth transition from inside to outside opening the room and invites nature. Inside and outside becomes completely transparent using consistent materials that also help to give a building a coherent holistic understanding that lays a foundation for good and understandable architecture.

With today's construction dimensions, it allows for different locations of the window that create different potentials in the architectural expression and function, which can be assessed based on what one would like to achieve. Using the thickness of the wall and placement of the window on the outside, therefore having a smooth exterior façade, the window frame is then able to be inhabited and used for contemplation. Oppose to this a placement further in the wall, which create a different expression and screens for the direct sunlight hitting the glass surface, which can help to influence the indoor climate. The glass in its simplicity is timeless and helps to give the architecture character and the location in its context (Glass - Ibler, 2017).

Villa Överby

Architect: John Robert Nilsson Architects

Size: 250 m²

Location: Stockholm, Sweden

Built year: 2009

Ill. 12. Villa Överby front

Ill. 13. Villa Överby side

Villa Överby has very clear connections to modernism and the international design elements. Simplicity and light weight are consistent throughout the construction and with a degree of detail that create great architectural quality.

A location consisting of a varied nature with water, rock, and forest, where the building arises from a plateau as a quiet monument in its natural surroundings. What is concluded on this project is that through the villa is a clean processing of material choice, how it proven creates a connection of the home's interior space and its exterior surroundings. The facades relate to the surroundings by clarifying the function through the transparency of glass and its solid wood. On arrival at the home, one is greeted by a sharp design and with its minimalist and simple, large facade, gives an understanding of the entrance.

The entrance façade wall is kept dense and closed, which creates a mystique atmosphere, which is hidden behind the wall. The rest of the house elevations consist of floor to ceiling windows which invites all the rrounding nature into the living spaces (Villa Överby, 2009).

2.1.2 Nordic architecture- Wood

Wood, a natural resource that has always been used over time, from very small objects, to ships and buildings. With wood, characteristic architecture can be created and the possibilities can be unimaginable, wood can be used for most parts of the house from the construction and the facade to the ceiling, floor, and window frames. Whether a sharp geometry is created or softer designs, wood can be used, but it requires a knowledge of the individual wood species' properties, advantages, and limitations to get the most out of the material. With old and new techniques, wood can be cut, reshaped, and processed to an extent that it can adapt to most useful possibilities. Wood is a versatile material, which parameters or properties must be considered to choose the right type of wood and achieve an optimal result. The placement of the wood is vital knowledge, is it located inside or outside, it is protecting or to be protected.

In addition, all relevant aspects can be considered, where the type of wood is probably the most basic and affects the rest of the aspects. A piece of wood is unique and can give different expressions, but to keep it natural or treat it with oil, the amount of expression the wood can give is many. It also comes down to how to assemble the selected piece of wood with scrubs or nails that can help create a pattern or have some technical advantages. Finally, wood provides warmth and softness to the design and can be combined with other materials that may be better to use in certain elements to achieve optimal material utilization (Wood - Ibler, 2017).

Holiday home

Architect: Mette Lange Architects

Size: 120 m²

Location: Lysingur, iceland

Built year: 2015

Ill. 14. Vacation house hearth

Ill. 15. Vacation house entrance

This cottage is in southern Iceland with a view of a large natural grass landscape, in addition, the house is located on a small hill in a cluster of trees that creates a bit of shelter and hides the house in the otherwise open context. The design shows a clear respect for the area and produces a traditional Nordic design with a focus on nature and building materials. The open floor plan and the space organization provide minimal corridor areas and an optimal utilization of space in each individual room; surfaces are processed through an understanding of the material in question and its technical and aesthetic properties. With a combination of cold and warm materials and a central fireplace, where the ceiling, doors and some of the walls are made of wood, while the floors and the other walls are in-situ cast concrete marked with wood grains. The fireplace is the heart of the home and have a large window area that spectacular views and indoor light, while the outside wood façade panelling and the green roof blend together with the surroundings and its nature (Vacation house, 2015).

2.1.3 Nordic architecture - Brick

Brick, like wood has a long history of use through time and in Denmark it is a popular facade material that is also tied up in a long Danish building tradition within technology and aesthetics, which is behind good craftsmanship. Most of the single-family houses are built in brick and the material does not stand out in the landscape or on the residential road. With a brick house, you have a timeless material in good quality that patinates a bit through the long life of the material, it can withstand the Danish climate and does not require much maintenance. The use of brick contribute with many architectural possibilities of use both inside and out.

Compared to the brick use, it can provide many different qualities to the home. Whether it is used constructively outdoors to be resistant to climatic conditions, there can still be aesthetic considerations by considering the colour, shades and which joint one is laying the brick in. On the other hand, it can be used indoors to provide warmth, texture and in interplay with other materials create an exciting space (Brick - Ibler, 2017).

Villa Juniskær

Architect: Hermansson Hiller Lundberg

Size: 210 m²

Location: Sundsvall, Sweden,

Built year: 2015

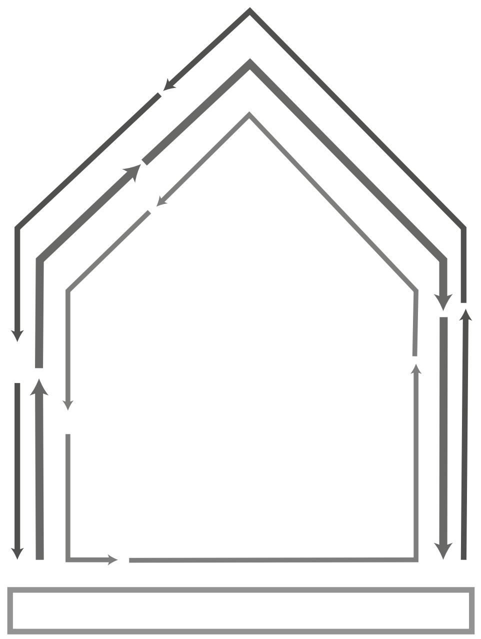
Ill. 16. Villa Juniskær entrance

Ill. 17. Villa Juniskær backside

This brick villa is in a natural area on a sloping plot, the residence stands out clearly with two building volumes with balanced proportions and heights. The two building volumes are parallel to the plot and open to nature. A simple saddle roof and masonry in cross-connection with a brick sole bench that emphasizes the location of the windows and the connection to the surroundings together give the house character that can seem completely monumental and like a detached monolith from a nearby mountain. What is interesting in this construction is the processing of the brick detailing the placement of the window, and the sharp contrast between the heavy masonry wall and the big see-through glass area, that corresponds to the internal functions.

With a screened and otherwise closed meeting with the entrance facade, a balance is created using three proportional functions; garage, entrance area and the window where with the design, shades and material begins to create a detail in the solid brick wall. By this minimalist processing of the meeting with the house one gets an understanding of the building and its architectural quality. At the back one is welcomed by an open facade with large windows that relate to the natural area and provide light, views and joy to the interior features (LUNDBERG, 2015).

2.2 Material potential



Ill. 18. The skin of of a building

(Brand, 1994)

2.2.1 Design for disassembly

The building sector in Denmark knows the cradle to cradle very well and is one of the frontrunners in the world in terms of circular economy and garbage reuse disposal. However, there is still a lot of potential in the building industry in terms of circular economy.

As part of the circular economy the building materials used in the construction needs to be extracted without much loss or damage to the material. For this to happen the future buildings need to be designed as material banks, one way to do this is by design for disassembly.

Design for disassembly is a holistic approach to design, where the goal is to make it easy to disassemble the different layers of the building. This strategy might be the foundation for future sustainable buildings, since it establishes a way for the various components in which they can be reused, reassembled, and recycled.

According to Stewart Brand in his book "How buildings learn", we can capture the essence of a building construction by understanding its different layers. For him, a building is composed of different layers that are described as the "6S": Site, structure, skin, service, space, plan and stuff (Brand, 1994). The structural layer can have a lifespan of 60-200 years depending on the quality and protection. The skin can last between 30-60 years, it is important to choose the right material to have the optimal lifespan for the specific project.

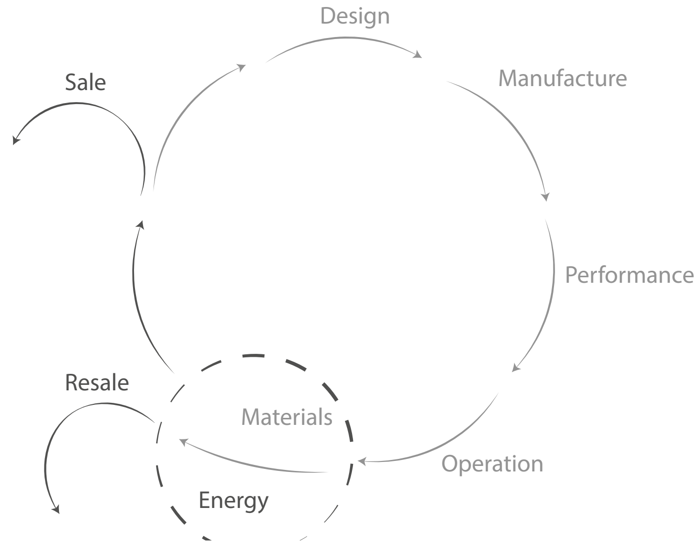
The individual components should be assembled according to lifetime of the specific material in the specific layer of the building. This should be done in a way so reparations and replacement can happen without damaging the surrounding materials (Gaisset, 2011).

2.2.2 Material thoughts

You are sustainable right? But wait a minute - you care about the environment. In fact, when you went shopping for a carpet recently, you deliberately chose one made from recycled polyester soda bottles. Recycled? Perhaps it would be more accurate to say downcycled. Good intentions aside, your rug is made of things that were never designed with this further use in mind, and wrestling them into this form has required as much energy - and generated as much waste - as producing a new carpet. And all that effort has only succeeded in postponing the usual fate of products by a life cycle or two. The rug is still on its way to a landfill: it's just stopping off in your house en route.

- (McDonough and Braungart, 2010)

The building industry is responsible for up to 40% of the materials being used and about 35% of the world's waste. In 2018 the US had fifty million metric tons of material debris generated by construction and demolition, 67,5% of this comes from the use of concrete (Share of U.S. C&D waste by material | Statista, 2022). Switching from a linear economy to a circular economy is one solution with huge potential to this environmental challenge. Today the building industry stick to a model based on cradle to grave, which means that the products generated during extraction and production is lost at the end of a buildings lifecycle.



Ill. 19. Circular economy

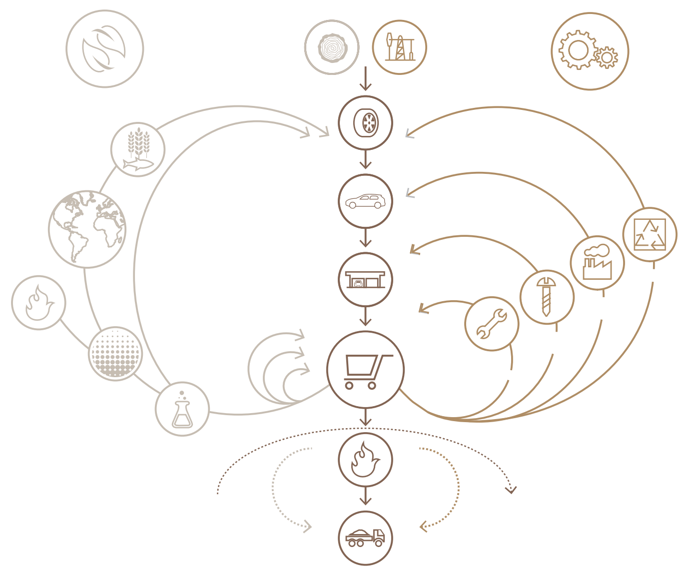
(Guldager Jensen, K. & Sommer, J. 2019, p. 25).

2.2.3 Circular materials

An alternative model based on cradle to cradle, challenges the linear approach, where products must be produced so a specific material can be isolated and repurposed. This approach can be divided into a technical and biological model (Guldager Jensen and Sommer, 2019).

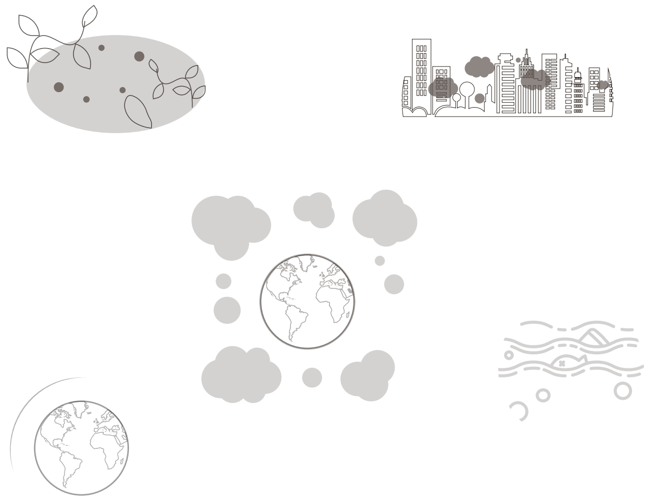
The technical aspect consists of materials that after end-use can be isolated and reused in new buildings and structures without losing value and quality. Materials like steel, concrete, and brick are often in this category.

The biological consists of materials that can be considered a part of the ecosystem and thereby function as potential nutrients for natures production of organic resources. Timber is an example of a material that is biodegradable, where the material can reinter nature and thereby return borrowed nutrients for the ecosystem. Wood products are frequently treated or mixed with non-biodegradable elements, exposing the material to toxicity and chemicals which prevents the wood from returning the borrowed nutrients back to nature (Ibid).



Ill. 20. The biological and technical material cycles.
It is the goal, to keep materials within the clossest loops possible.

(Guldager Jensen, K. & Sommer, J. 2019, p. 179).



Ill. 21. LCA parameters

2.2.4 Material selection

This chapter investigates the material potential, to utilize the properties of state-of-the-art materials. To understand these materials, it is critical to investigate the environmental impact of using life cycle assessment.

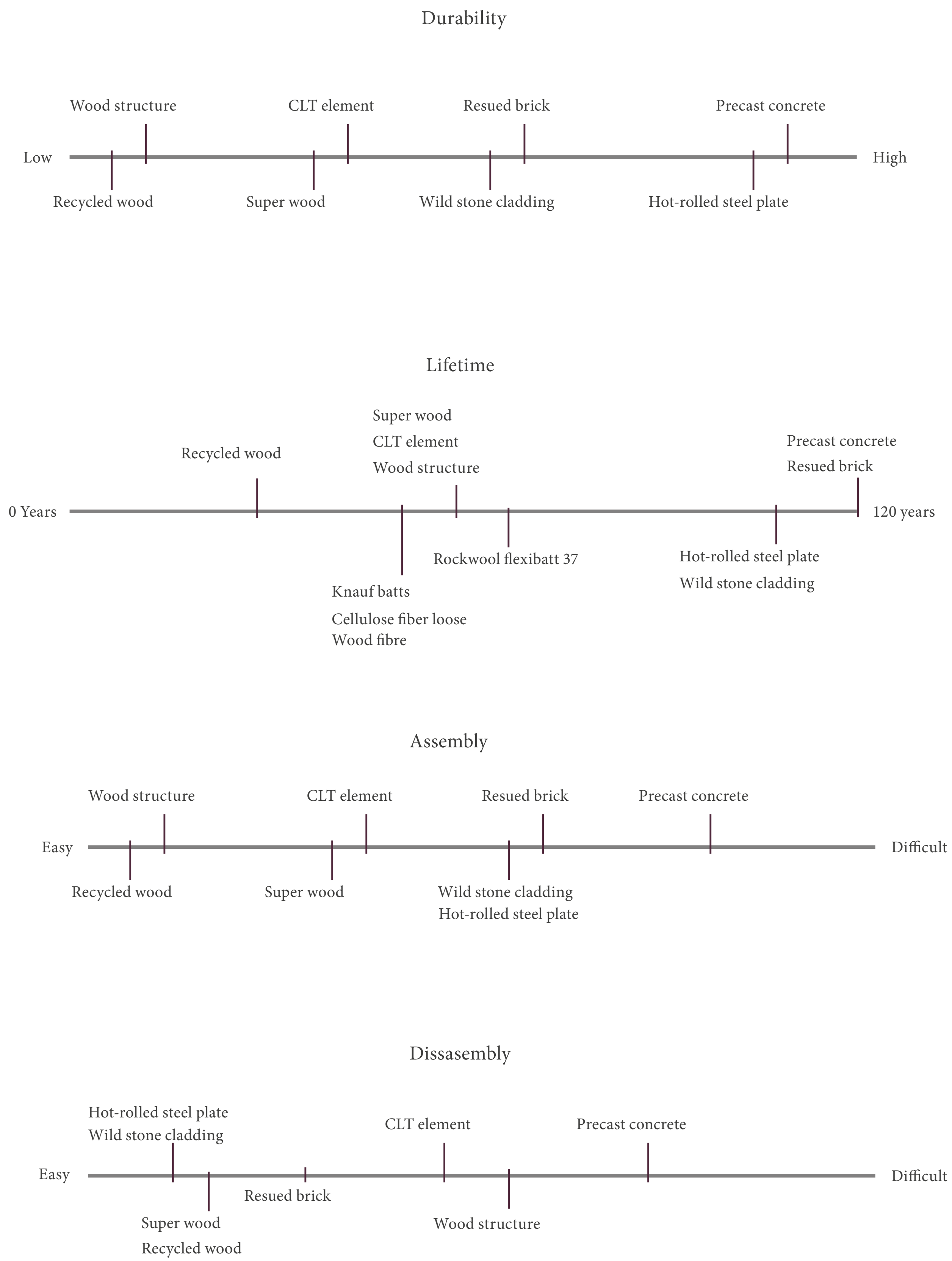
The use of Lcabyg leads to an understanding of material emissions, having the thesis focus on lowering the embedded CO_2, a material investigation should be made.

As the actual amount of each construction material is not yet known, equal amounts of each material category are analyzed. The results (appendix 01) show that the reused bricks have a high global warming potential even though they are reused, this is caused by the high energy process the brick must go through to be cleaned before use. The wood products have a negative GWP because they are recycled and not incinerated, wood stores CO_2 by growing and releases it again incinerated or laid out to decay (Cesprini et al. 2019).

The analysis shows that rockwool performs well considering the alternatives, sheep wool also performs well in the GWP category but are the worst or medium in the rest. The analysis shows that not all traditional building materials performs bad in term of emissions. It is taken into consideration that not all these materials perform equally insulation wise.

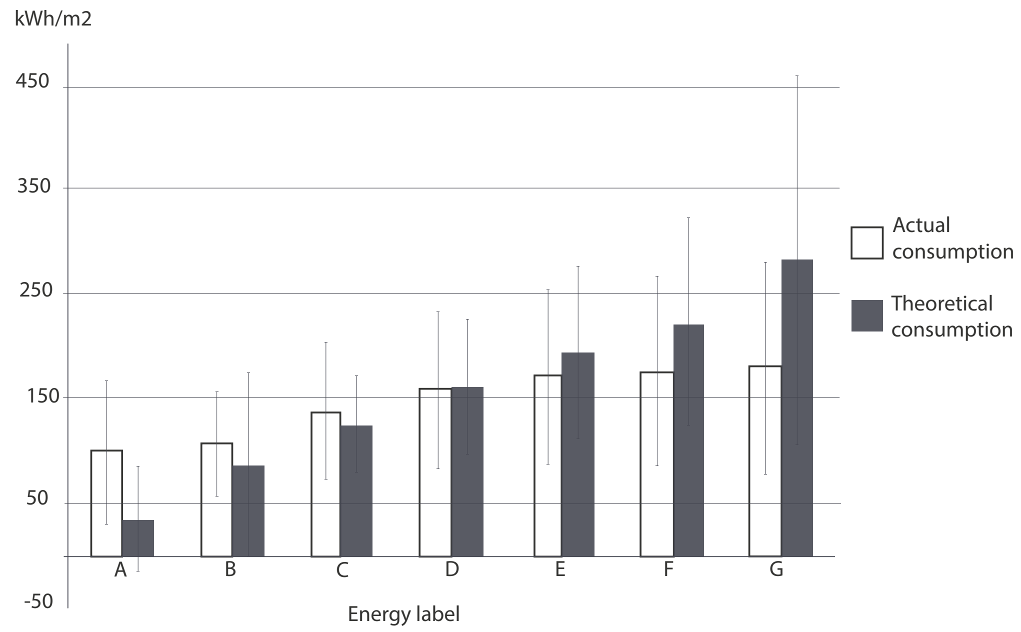
The exterior cladding analysis scores wild stone and steel material as the worst performers, which is not surprising because of the high energy needed for the extraction. It is however important to consider the lifespan of the materials, wood is not always able to endure 50-60 years of service, and still be used directly in another building afterwards. The stone and steel need little processing before being able to be reused without much quality loss, because of its durability, once manufactured these materials last long

The next pages show an illustration of four criteria that will help pick materials for later use. The analysis is a start for a bigger In-depth library that investigates available materials and compares them to each other.



Ill. 22. Material properties

2.3 Sustainable house design



Ill. 23. Actual & theoretical consumption of energy rated houses

(van den Brom, Meijer and Visscher, 2017)

2.3.1 Performance gap

Our everyday life is connected to energy use which is primary used in and around the house. All the task that requires energy like cooking, heating of the house, turn on the light, taking baths, watch TV, wash cloths and so on Is done within the household. The energy, water and heating demand are derived effect of these practices which basically involves the interaction between the occupant and the material dimensions in this case the architecture, design of the dwelling and technologies.

This means that our interaction with the physical framework is the basis of resource use and the understanding of the inhabitants behavior in relation to the building is primary when talking about sustainable building.

There is an indication of a gap between the energy certification of the house and the actual energy use. The difference between G and A energy certified houses is in the theory large, but when people use the house, the actual difference is not that big. People who live in an A certified houses tend to have less sustainable behavior, they walk barefoot and when they get too hot, they open windows, where often the house responds with more heating. Whereas people who live in G houses, is familiar to the cold surfaces and put on more clothing, they often use blankets rather than turning up the heat. A study from neatherland shows the theoretical and actual heat demand for building rated from A to G (van den Brom, Meijer and Visscher, 2017).

Kvotehuset/MiniCO² husene - Realdania By & Byg

Architect: Pluskontoret arkitekter

Buildyear: 2013

Building type: One family house

Area: 138 m²

Ill. 24. Kvotehus plan (Kleis, 2014)

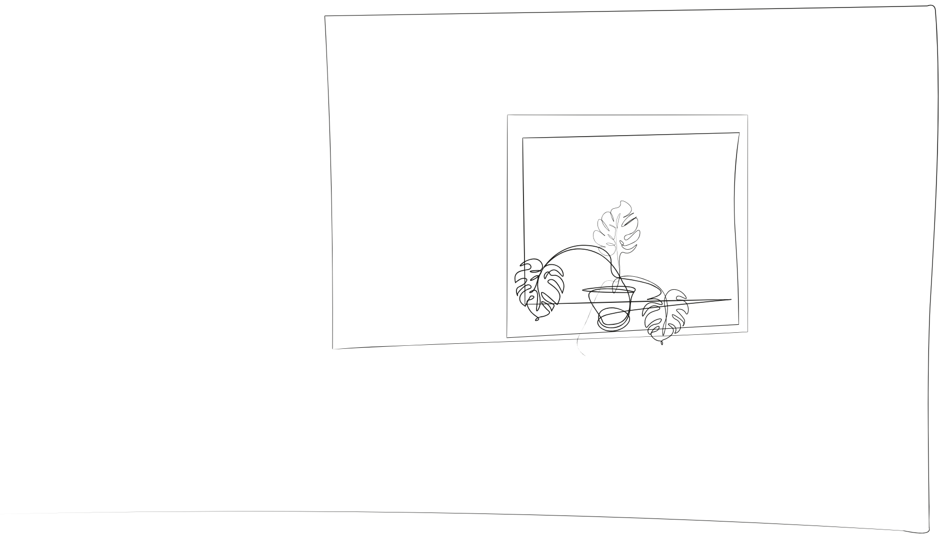
2.3.2 Case study: kvotehuset

The Kvotehus focus on inhabitant behaviour and consumption pattern to investigate much CO_2 emission can be reduced by supporting the resident in a sustainable behaviour. The kvotehus is one house of 12 in a larger project called Mini-CO_2 husene (Mini-CO_2 husene, 2022).

The house works with three tools to reduce the carbon emission. One is to use the way architecture is formed, where functions are located correct in terms of daylight and sun orientation, also in correct in terms of room privacy and social level. Two is inbuilt technology which monitors and give feedback on the electricity, heat, hot and cold-water use. Third is that the inhabitant voluntarily puts a quota on the max amount of carbon emission allowed per month.

The house covers a variety of active and passive systems to reduce it to a low energy house, passive and active shading, mechanical ventilation, high insulation rate, low energy windows etc. In the plan design is also incorporated sheltered exterior drying rack, a pantry and a screen situated in the middle of the house. This screen is essential for the house quota system, it works as a supervisor of the house but also as a control system, an emergency button is on the screen. Pressing this button deactivates all systems, so if the family has reached there CO_2 limit the house shuts down. This is to give the house and the inhabitants an understanding of how important their mission is, they need to safe electricity so it will be available next month.

The house is a longhouse placed diagonally on the plot, with a single tilted roof towards west. The house has the placements of the house according to sun and privacy. In the southern part of the house is the public and "warm" areas like living room and kitchen. The northern part of the house is where the "cool" rooms are placed, private rooms like bedrooms and a bathroom.



Ill. 25. Biophillic interior

2.3.3 Biophillic design

The project has a strong emphasis on nature, which relates to the Sorø context, the use of materials, and the nature-inspired Nordic architecture. Contact with nature benefits human health by reducing stress and improving overall well-being, but Danish people spend most of their time indoors. The principles of biophilic design aid in bringing nature and outdoor feelings into the built environment.

Recognizing the importance of human well-being in sustainability discussions is the key to creating properly designed interior and exterior spaces in architecture. The term biophilic design refers to the use of natural patterns used in the shaping of the architecture. It is a field of study that seeks to investigate the interactions between human behaviour and the environment to transform them into sustainable practices. Biophilic design can be used as one of the tools to make architecture socially sustainable (DeGroff, McCall s. d.).

The impact that nature has on human physiological and psychological responses can be transferred to architecture to provide similar benefits from the environment and to promote positive effects. The incorporation of essential natural properties into architecture improves the quality of human life. Simple pragmatic architecture is incapable of bringing this into the living environment.

The phenomenon "home", relating to the place one lives covers a space which is not interior, but can be extended to a private garden or the whole plot. Biophilic design emphasizes the importance of the primary goal of architecture by questioning the reason and method of building a house, thereby contributing to improve the quality of the life of people as well as being durable. Ensuring the sustainability of a society that directly affects the construction of a building.

The architect Juhani Pallasma discusses the phenomenon of "home" and how architects can create one, or at least set the framework for something that residents can move into and make their own.

"(...)home cannot be produced at once; it has its time dimension and continuum, and it is a gradual product of the dweller's adaption to the world." (Pallasmaa 1995 p. 133)

The role of the architect is mainly to create the building in which the occupants manipulate into their home. As described by Peter Zumthor in "Atmospheres":

"it is not always possible to put your finger on what creates good architecture: "Quality in architecture to me is when a building manages to move me. What on earth is it that moves me? How can I get it into my own work? … One word for it is atmosphere" (Zumthor 2006 p. 11).

As a result, the architect relies on their ability to create atmospheres in the homes. There is a link between what Zumthor describes in his book "Atmospheres" and what the 14 biophilic design principles describe. Biophilic design can be used to create environments that are both architecturally pleasing and comfortable for residents. By implementing biophilic design principles, it is possible to create architecture that is socially sustainable by increasing human comfort and well-being in the home.

2.3.4 What makes a home

Discussing the topic "what makes a home", the definition of the term is vital. The house is frequently associated with something that can be purchased and owned, something replaceable that does not have emotional or special feelings attached to it. The home is what a house isn't: irreplaceable, filled with memories, and a place steeped in family history. A home is a psychological element that is unique to everyone (Vacher 2010). It is impossible to define a house as a home if it does not have residents. Transitioning from one house to another necessitates the transport of personal belongings and memories.

Even though the terms house and home are frequently used interchangeably, it is not necessary to own a home; the definition extends beyond material possessions. A home is associated with feelings and emotions, which take time to develop and attach. The house is also connected to its surroundings, community, and neighbourhood, all of which have an impact. Residents redecorate their homes over time to reflect their personalities, and the house becomes an extension of their identity. The personal touches and the sense of belonging have an impact on the residents. When elements are disrupted or lost, it can appear as if parts of oneself are missing (Lawrence, 1987).

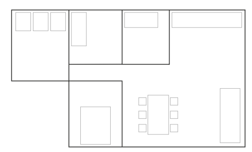
It can be difficult to pinpoint the specific features that make a house a home. People have different personalities, and their priorities, as well as their daily routines, differ. Some characteristics, on the other hand, can be used broadly to get a sense of direction in designing the best possible homes. This includes considering the worth of one's neighbours or community. It is natural for people to want to feel included and a part of a particular group of people. Because a sense of belonging is inextricably linked to comfort, finding a sense of belonging at home is critical. People are drawn to similarities, to things they share.

Factors such as income, education, and personal interests all play a role in determining this. While some believe that their neighbours and society, are what binds them to the house, others believe that personal improvements or changes to the house transform it into a home. This sensation is the result of putting in long hours to make the house special and unique for the residents. Some people spend a long time handcrafting each detail. Others simply decorate their homes with mementos of themselves (Gram-Hanssen & Bech-Danielsen 2004).

2.3.5 Flexibility over time

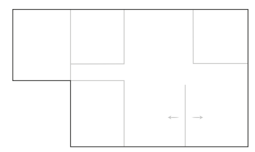
For a house to be sustainable it must be used its entire lifespan, one way of doing this is by introducing flexibility into the design. Architecture is designed by and generally for people, it is therefore important that the design fit the users and their needs. Designing a house for a specific family and then expecting that family stays there during the lifespan of the house or an identic family takes over, is naive. Users of a house will change overtime, either in size or by a different family moving in. The term family is no longer a short description and comes in a various constellation. Therefore, to be sustainable its entire lifespan, the home needs to be flexible or adaptive to the family (Lauring 2019).

As a way of working with variable homes, three terms are presented by Kresten Bloch and Per Rasmussen in 1983 in Fleksibilitetsformer i boligbyggeriet. Principles: utility, changeability and extensibility, see ill. 26-28 (Bloch, Rasmussen 1983).



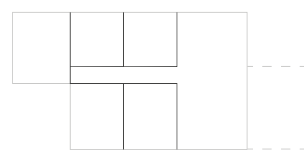
Ill. 26. Utility

The exterior and interior boundaries are static so the flexibility lies within the association and dimension of the spaces, as they are made usable for different functions and purposes and furniture can be re-arranged as needed.



Ill. 27. Changeability.

The exterior boundaries are static, and the interior boundaries are rearrangeable, so the flexibility lies within the possibility of changing the interior to allow for more or fewer rooms or for bigger or smaller rooms.



Ill. 28. Extensability.

The exterior boundaries are extendable, so the flexibility lies within either extending or reducing the area of the unit at a pre-defined area without it having influence on other units.

2.4 Theory conclusion

Summarizing and concluding, what essential factors is it that embraces the quality of Nordic architecture and the importance about materials, detailing and designing space according to multiple factors.

First of all, the architecture should be a convincing response to the current task, its place and time. Have an understanding with its context and surroundings, to properly place and blend in with the exciting context to make overall improvements to its environment. Then make use of existing knowledge and technology that is relevant and process the accumulated knowledge properly towards a finished design, but the good house respect tradition while also challenging it and thus contributing to the architectural development.

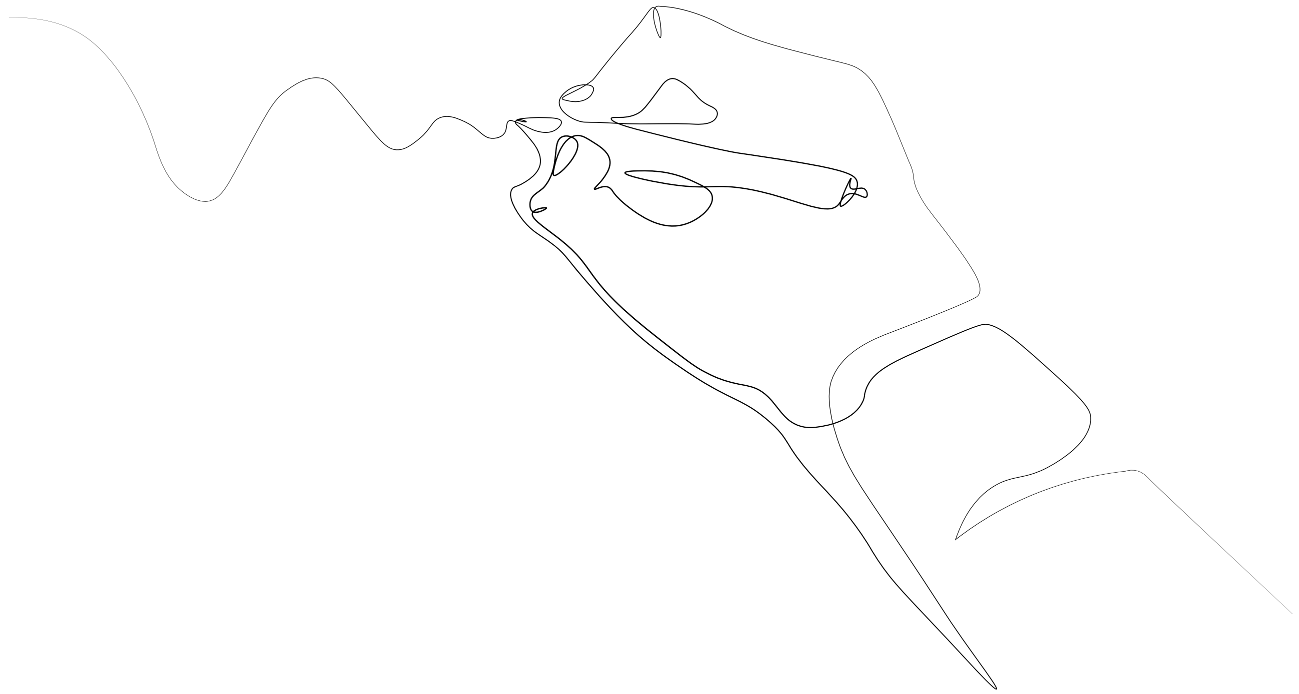
The evaluating whether a material is sustainable, multiple factors need to be looked at. How many substances does it emit under production, the lifetime of the material, frequency of maintenance, aesthetics timeless? Material selection is a vivacious part of the architecture, it is used as a tool to create atmospheres. People are dissimilar but they often share ways of understanding and interpretation if they derived from the same culture. Material choice can create impressions of density, depth, temperature and other. Regularly if a human recognizes a shape or feeling they tend to be satisfied and this leads to architecture having traditions. Recognizing a building style, form, shape and even material detail allow us humans to arrange everything in relation to ourselves. Our surroundings influence us through scale, light, shade, colour, etc. By exercising our ability to comprehend these emotions and their impacts on us, by staying in touch with our surroundings, we get to the nature of architecture.

The essence must lie in the architecture, the relation between the houses and the surroundings. Design for the human scale, rooms, open or closed, safe or interesting, darkness or well-lit and other contrasts. Employ the local society, the surrounding history, and the Danish culture.

The material analysis shows that not all alternative materials are the better option, even when stamped with sustainable labels. The manufacturing of the traditional building materials has been optimized a lot more than the new alternatives available on the market. Rockwool is a material which performs well in both environmental stats and heat insulation properties. The reused brick even when upcycled requires a lot of energy compared to wooden construction. The brick has other benefits like high heat capacity, structure and cladding all in one, reasons for it to still make it a material able to compete. This analysis does not cover the entire building material market which means there could be other useful materials hidden out there. The requirement for the chosen materials was to be as close to a cradle-to-cradle process as possible, which is far from what all EPD have. To make materials Cradle to cradle they need to be assembled with losing quality. Ways doing this is by implementing guidelines from the design for disassembly. Using standard and limited palettes of connectors will decrease tool needs, and the time and effort to switch between them.m. Use bolted and screwed connections. This allows for easy disassembly and easy sorting in the process. Glue and other chemically produced adhesives damage the materials. By using clay and lime mortar, the materials can be easily disassembled again.

The Kvotehus uses a logical placement of the room and utilities, having south-oriented public spaces and north oriented private rooms. The relation in-between house areas and exterior zones like streets and gardens all feed into the logic of the plan solution. The architectural features like an outside covered drying rack and a cool pantry used for food storage help to reduce the use of electrical utilities and virgin material for a bigger fridge and dryer.

Furthermore, looking at biophilic design, simple design tools can be withdrawn from theory and be used in the project design criteria. As the tools focus on interior atmosphere and the connection with nature there is a direct link to home design and Nordic architecture. Designing a home, two parameters were discovered to be important in ensuring that the houses designed can become homes. First, a space that can be personalized through styling and interior design. Second, creating a community of people who share interests strengthens the sense of community and belonging.



Ill. 29. Theory conclusion

3.0 Analysis

3.1 Site & Sorø

3.1.1 Project location

Why Sorø?

Sorø has in the recent years had an increasing number of newcomers moving from bigger cities to enjoy the suburban lifestyle. The municipality have a big focus on nature and healthy wellbeing as well as local community. Sorø shares some key words as this thesis wants to focus on and because of this Sorø is a great location to do this project in.

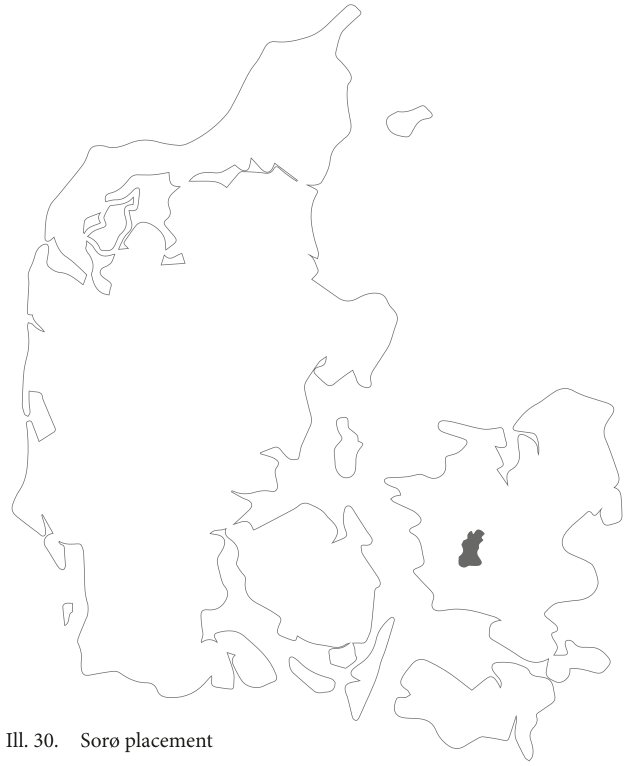
> "The good everyday life for everyone, in a sustainable municipality with nature, culture and history"
>
> - Sorø municipality

3.1.2 Sorø as host

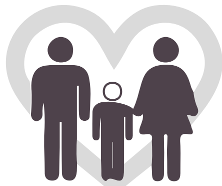
Sorø Municipality, are aware of the importance of seeking out sustainable long-term solutions to the current challenges in our time concerning social and environmental aspect. They emphasise that when as a part of this world and as a municipality, they have the responsibility to help and create the offers and solutions that shape the citizens' future.

The main structure of the municipality plan 2019-2030 contains ten sections. The ten sections stems from the themes from their Vision and Planning Strategy 2022. Through these four categories, they work parallel with nine of the UN's World Goals to guide and form a framework to have an ambitious plan, which by 2030 will pave the way for a more sustainable context - both within economic, social and environmental aspects.

The selected UN World Goals also help to describe and produce the municipality's visions and initiatives to support these four themes' purposes. The main structure also includes a descriptive future plan that includes concrete guidelines for area functions and use, focusing on ensuring that new initiatives in the best possible way take place in respect of conservation values and protection considerations on the areas of e.g. natural, landscape and cultural-historical character.



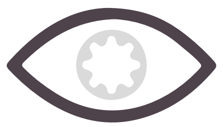
Ill. 30. Sorø placement



Theme 1. The good everyday life with health and well-being for everyone

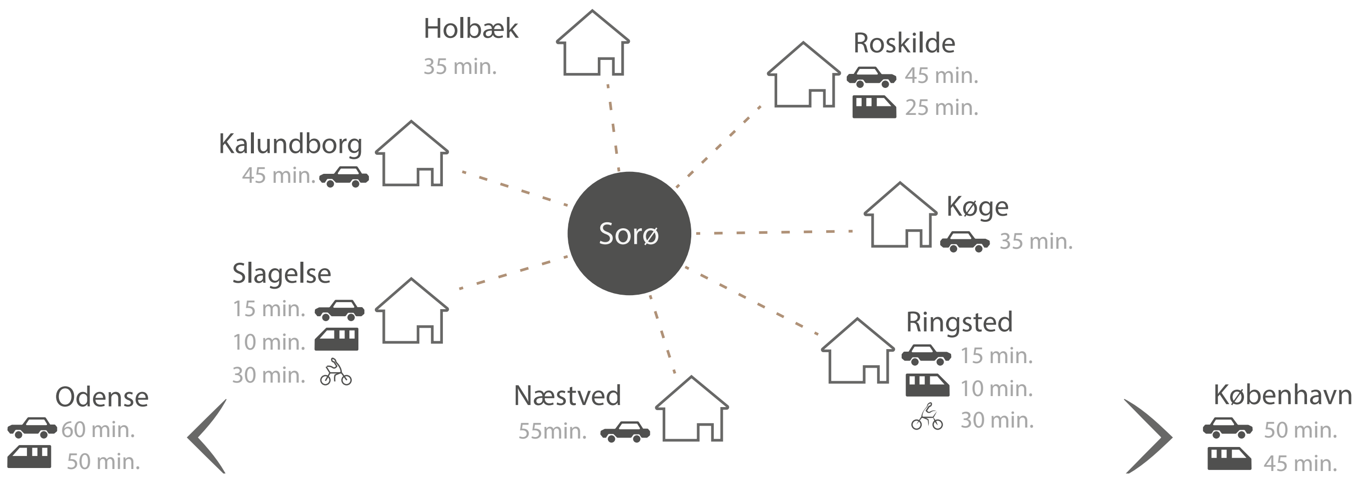
Theme 2. Living cities and communities with nature, culture and history

Theme 3. Knowledge and growth - work and education for all



Theme 4. Business, infrastructure, innovation and technology

Ill. 31. Sorø themes



Ill. 32. sorrounding cities distances

3.1.3 Sorø connections

The municipality places great emphasis on having a collaboration with its citizens and stakeholders on the development of a vibrant and sustainable city and community with nature, culture and history - and with a focus on responsible consumption and efficient resource utilization. Whether it is about developing a local area through a comprehensive plan, or it is about promoting responsible energy consumption or waste management, the good solutions must be found together, as a community.

Sorø Municipality strives to be a good place to live for its citizens. A diverse and vibrant municipality with a rich nature, culture and history, and with security and proximity. A municipality that is easy and accessible to move around in, and with a central geographical location on Sjælland with only 45 minutes transport time to Copenhagen and Odense.

To emphasize their values and briefly summarize, it is very much based on a sustainable approach to all every day and future issues with a strong focus on the city's nature, cultural history and the social involvement with its community and locals. In addition, an important factor for continuing to have a positive municipality is to be able to offer attractive building plots and a diverse housing market that corresponds to the wishes and needs of citizens and newcomers. (Municipal plan, 2019)

> The goal for Sorø is to attract new inhabitants and keep the ones already living there, they believe this is possible because of the nature surrounding Sorø, the culture, history, and growth. The ambition for the city to grow is present in Sorø municipality. (Sorø, 2022)

Ill. 33. Potential site locations

Sorø 1:5000

3.1.5 Potential sites

The project team went on a field trip to Sorø to investigate potential sites. Prior to the trip, four potential sites in Sorø and its surrounding areas were marked. The candidates differed in terms of their qualities, context, and size, which was assessed on-site. The field trip's interesting topics were the context and the microclimate; with low energy housing in mind, the group walked through the sites and discussed the pros and cons of each individual visit. The four locations differed in atmosphere and other factors that could influence the choice of project location.

Ill. 34. Pictures of site 1, compact site with green sorroundngs

Site 1 was on the edge of a forest, an open field used for recreation. Context were trees, a road, and some garage storage.

The site was not chosen because the field was daylily used by a nearby kindergarten. The open area was the only nearby grass area in a small radius, the context is more of a natural setting and gave more quality to Sorø municipality and the area. The site visit gave insight in the use of the field, having people cross over it, potential project had to integrate this need of passage.

Ill. 35. Pictures of site 2, Open field with trees to the north

Site 2 was part of a big residential area which had an open site in the end of the road.

The site was chosen because the context related to the project interest, the microclimate had great potential for good use of wind induced natural ventilation, passive solar gain, and minimum shading on site. The site had an old oak tree which was saved during a demolishing of an old farmhouse, the tree had history which contributed to site quality. The grid structure of the area gave interesting ideas for the reduction of the car use.

Ill. 36. Pictures of site 3, encircled site with distinctive type of wheat

Site 3 was a small new residential area which had fields filled with vegetation and big surrounding hills.

The site had a charming atmosphere, the field with tall brown vegetation and the hills gave play-full urge to run and play as a child. The site was not chosen because the hills created a shadowing effect on the site which gave the site area a problem with shadings. The highway was visible from this site and created noise both visually and sound wise.

Ill. 37. Pictures of site 2, hilled site with sorrounding agriculture and industry

Site 4 was on a field close to industry and nearby the highway. Green location with good views but potential traffic noise

The site had great potential with great views over a nearby forest and lake, however the noise from the highway and the smell from surrounding fertilized fields made it clear that there would be obstacles for successful housing in the area.

3.1.6 The project site

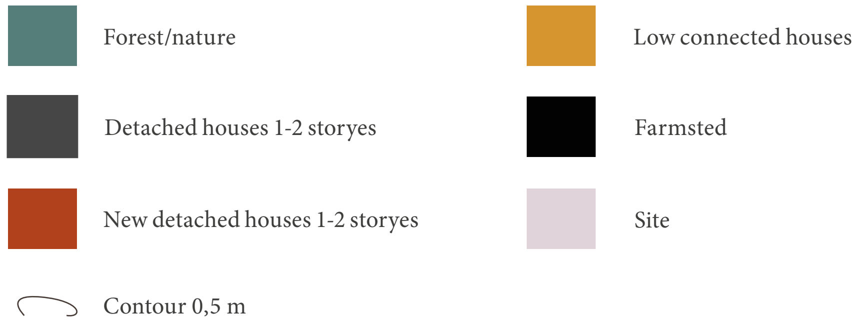
The chosen project site where site location 2. The site is in a new residential area in the southwestern part of Sorø, Frederiksberg. Surrounding the site is new houses of mainly one typology, single story houses, but many different colors, expression, and heights. Nearby is water and nature all in walking distance, great combination with the suburban living.

In the next couple of pages, the site will be analyzed, with a focus on microclimate and mapping the qualities of the site and potential problems will be found.

3.2 Site analysis

3.2.1 Mapping

Ill. 38. Mapping 1:1250



3.2.2 Functions

To have a deeper understanding of the site and the area it lies in, mappings is done. The city of Frederiksberg covers the basic facilities for small town living. North of Frederiksberg, there is shopping options in the pedestrian street and the academic grounds provide education above grounds school level.

3.2.3 Topography

With an empty building site, it is critical to gain an understanding of the topography in order to understand the movement and natural flow. Topography can be difficult to understand and show in complete detail, as it is rather complex and may change over time. The site visit gave an insight as to how the site was very different, from what is seen on the map. When arriving at the site, forest to the right and open fields to the left. In the horizon, one could see a small hill. As seen on ill. 38 the area has deep valleys North east of the site, giving an interesting natural depth. Apart from the fields and trees, the nature of this area also consists of lakes, forests and even a chalk pit.

Everyday destinations	Distance	Time by foot	Time by bike
	[km]	[min]	[min]
Frederiksberg skole	0,8	9	2
Groceries	1,4	17	4
Daycare	1,5	19	5
Trainstation	2,1	25	7
Forest	0,8	9	2

Ill. 39. Distances chart

3.2.3 Access

Despite being close to a major road, the site location is relatively free of traffic. It is possible to drive past the site, but it is not possible to access by car from the north unless a connection is made. The site is linked to a network of roads and bicycle paths, allowing for quick and direct access to the train station. In general, this part of Frederiksberg has a lot of foot and bicycle paths.

3.2.4 House typology

The sites' location is in a very new area, where the houses are either being build or less than five years old. These houses are mostly single level, facades consisting of bricks, plaster or wood and roofs that are flat, tilted pitch roof or single side tilt. The houses have a large variety in color, size and materials. Some of the streets follow a specific typology and others have multiple ones.

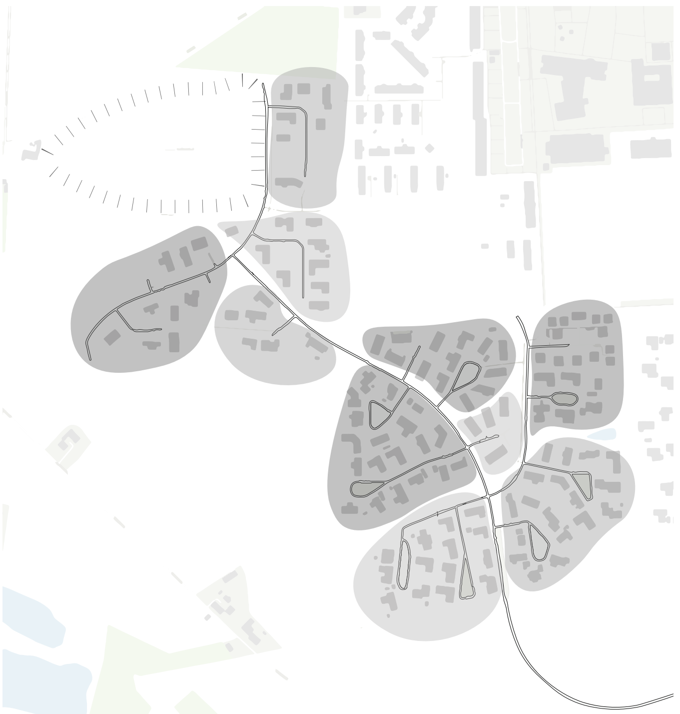
In the older part of Frederiksberg, a more classic masonry type of houses is found. Dominating red bricks but also yellow and painted brick houses with tilted pitch roof. The houses in this part of the city have large gardens and bushes in-between each other.

East from the school there is a new strictly designed housing area consisting of single-story long houses and yellow bricks. To the west of the site the house typology is farming houses, big and small sizes with large driveways, a lot of privacy with a distance from the road.


Ill. 40. Nearby typology 1


Ill. 41. Frederiksberg house


Ill. 43. Nearby typology 3

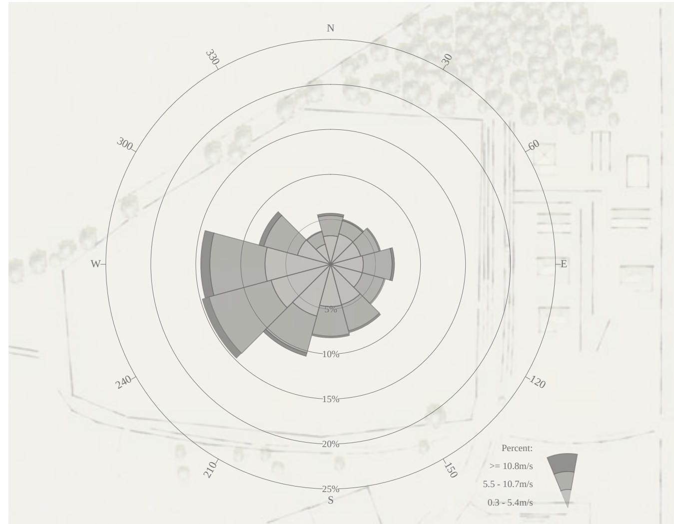

Ill. 44. Cul-de-sac branches


Ill. 42. Nearby typology 2

3.2.5 Wind

The site's microclimate must be considered to have good conditions for, the backyard, the spaces between the houses, effective natural ventilation, access to daylight, and passive solar heating. Wind direction, as well as the path of the sun and shadow from the context, must be examined to identify challenges and opportunities in the microclimate.

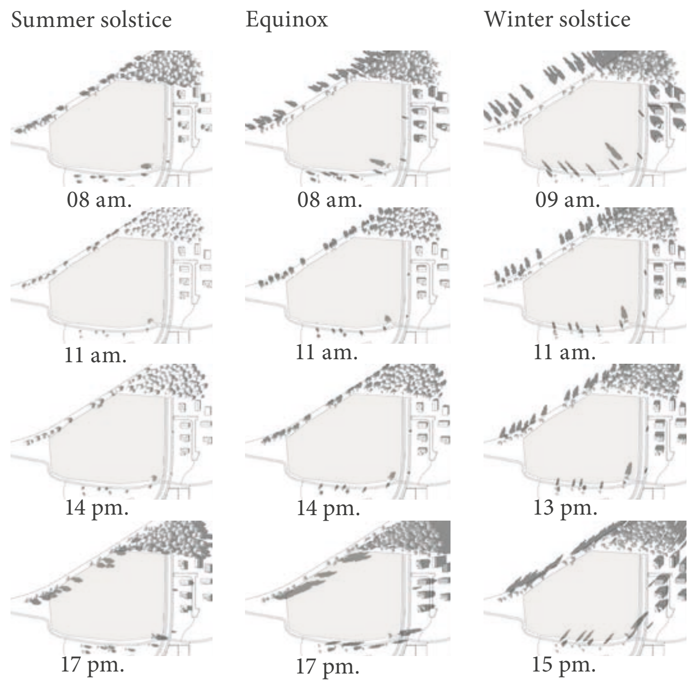
The wind analysis is based on the wind rose from Copenhagen air, which is not the closest but the most similar to the site. The year 2021 wind data from Sorø municipality were used to compare data (Lokationarkiv, 2022). Sorø has low medium wind velocities, but high-speed winds do happen. The site is in a semi open field, with a few trees surrounding the location, an evaluation would be that there is a few windbreaking elements. The wind is however dominantly from west and southwest where the windbreaking elements, the trees, is to the north.


Ill. 45. Wind rose Copenhagen (DMI.dk)

3.2.6 Sun study

According to the site's shadow analysis, the site only has shadowing issues along the edges, and only for short periods of the day. The trees along the site and to the north-east are deciduous which will shadow less during winter. A saved tree on the site has a big crown and could be utilized for its shadowing properties during summer.

The site has a big potential for providing sunny outdoor areas and passive solar heating in the winter. More trees are planned to be planted north of the site to improve sound barrier from the road. The site has a big potential for providing sunny outdoor areas and passive solar heating in the winter. More trees are planned to be planted north of the site to improve sound barrier from the road.



Ill. 46. Sun study

3.3 Considerations

3.3.1 District plan

An investigation of the district plan was made to generate ideas and not to limit the design. The district plan encompasses an area west of Frederiksberg that was previously used for farming; the old farm has since been demolished. The district plan covers the area of 117.668 m2, of which the site occupies an area of 26.300 m2.

The district plan encourages large plots of the size of 400-600 m2 with low buildings with a maximum of two stories. The municipality wishes to create an area with diversity in building types, all with easy access to green and recreational areas. The municipal h divided the designated site into four lessor areas and one of them decided to be used for a social purpose, complementing the area. The area was previously used for organic farming, and no toxic materials have been found in the soil. Although a wastewater system will be required, rainwater must be handled on-site.

The district is close enough to the city to be connected to the city's heating, water, and electricity grids. Heat will be provided by Affald Plus, which generates sustainable energy from bio waste, primarily garden waste. In January 2022, Affald Plus opened their new local district heating plant in Sorø, supplying the area with efficient use of water temperatures up to 85%.

The district has a road to the north that can cause noise; a building line is set up 10 meters from the road to reduce traffic noise. The district is in an area with limestone extraction to the northwest, which will not disrupt the area in any way but will add to exciting nature exploring and viewpoints.

In terms of appearance and materials the district plan provides with multiple options rather than restrictions. Facades can consist of blank wall, water washed brick, plastered, coloured concrete or organic material like wood. Smaller parts of the façade which extrudes can consist of metal, glass, or stone composition material. It is however not allowed to build log house.

Roof can be of flat roof, single sided tilt with 20-degree angle or double tilted pitch roof with up to 45-degree angle. Roofs can be done with hip roof or half hip roof. Material roof can made of slate, clay tile, felt, or green roof like sedum. The district plan dictates a use of solar power on the roof or the walls of the house, it must be integrated in the design and must follow a similar principal. (Sorø-kortet, 2022)

3.3.2 PV a discussion

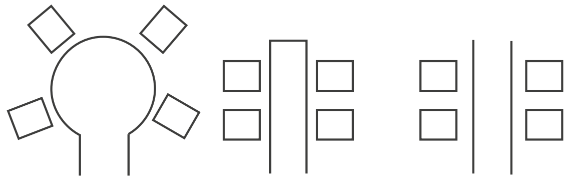
The question of the integration of renewable energy sources needs to be asked. Knowing the area and the disadvantages of the different types of renewable energy sources, the only logical candidate seems to be PV solar panels. But is it logical?

As this project pursues a material choice where the majority is part of a circular economy, does it then make sense to incorporate a Photovoltaic solar panel to design? The renewable energy is off course much needed in the future. However, the project wonders if PV's is the right choice.

The district plan, states that every house should incorporate solar panels integrated into the roof, it needs to be done so it doesn't ruin the architecture. Ruining the architecture can mean many things but ruining the concept is another. The world is facing the problem of using too much virgin materials, also the next couple of years there will be a lot of photovoltaic panels waste. The main photovoltaic panels used are either thin film or silicone, depending on the type over 85% of the panel is made of glass. Glass is easy to recycle but requires a lot of energy to do. Also, the world Is facing a glass shortage which makes the price of glass rise.

Photovoltaics loses 25% of their efficiency after 30 years. Depending on the country and the popularity of this renewable energy source, the time of replacement is soon. The demand for new panels will be sky high in the incoming years and the recycling of these are crucial to follow up with new demand.

The project discusses the use of PV panels and are skeptical towards the real potential of them in current context. Denmark is a country which in average has less than 4 hours of sunshine everyday half of the year, other countries like Egypt has in average more than 7 hours of sunshine every day the entire year. Considering the use of virgin materials, transport from production and wasted potential energy comparing Egypt and Denmark, then it doesn't make sense to add or integrate such panels in this project.



Ill. 47. 1. Bulb cul -de-sac 2. Dead-end cul-de-sac 3. Through street

3.3.3 Cul-de-sac a discussion

The cul-de-sac is a very popular way of living and has been for a long time, the street typology originated in 1920. Developers discovered that fitting odd shapes roads with houses, they could increase profit, utilizing areas near rivers and property lines (Hochschild, 2015). Homeowners also loved the fact that these streets had less traffic, less noise and were save for children. Despite the affection from the people, urban architects criticized the cul-de-sac, it forced them into using cars more, negating the walkable neighbourhoods.

Three major cities in USA banned the use of cul-de-sac in urban planning, Austin, Texas being one of them (Hochschild, 2015).

However, it is proved that living in a cul-de-sac one would have a closer connection with neighbours and a higher degree of cohesive living compared to a through street. A study of the people living on the three different types of streets show that the residents on the bulb cul-de-sac have the most positive results of the three. The cul-de-sac with its shared social space, lack of "outsiders" and the sense of territoriality promotes a stronger neighbourhood.

Neighbours living on bulb cul-de-sacs experience greater attitudinal and behavioural social cohesion than neighbours living on dead-end cul-de-sac and through streets.

The data shows that the bulb cul-de-sac have the most social coherent residents, using the bulb as a safe place for gatherings and activities. The bulb residents do tend to move out when the children reach a certain age, and the safe street is no longer a necessity. The study shows that the level of social activity among the resident relies on the children (Hochschild, 2015).

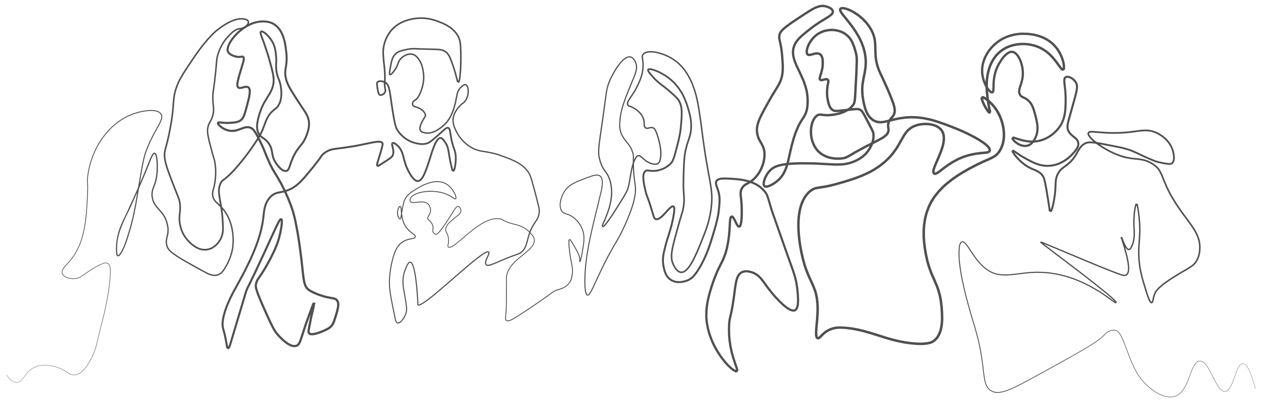
3.3.4 Urban planning and crime

Cul-de-sacs create twisted and complex systems of roads that does not lead anywhere, it is difficult to make public transport available in these areas. Some urban planners believe that cul-de-sac is poor urban planning, however looking at the context it does work for suburban planning.

Croydon in the southwest of London was in 2021 the most dangerous and crime haunted area, the most common crimes were violence, theft, and vehicle offences (Most Dangerous Borough, Areas in London, 2022). Looking at the streets of Croydon appendix 02, there are multiple cul-de-sac areas. Looking on one of these streets we see the car dominating the street.

Within neighbourhoods, the intended usage of the streets varies depending on to facilitate movement within and between neighbourhoods, where others are configured to facilitate resident access alone. The cul-de-sacs are often designed to be the latter. If permeability is associated with crime risk, the spatial distribution of crime should vary in such a way that it mirrors the connectivity of places (Johnson and Bowers, 2009).

3.4 The client



Ill. 48. Family

3.4.1 A building community

Building communities are not a widespread phenomenon in Denmark however it has been around for some time. Building communities is very known in Germany, called a baugemeinschaft or baugruppen, where entire residential areas and cities are built according to this principle.

A building community can be described as a "resident-driven housing project" that arises on private initiative without a commercial developer. Building communities can cover many different projects with widely differing designs, purposes, and housing typologies, it is completely dependent on the families and individuals who want to build the building together and what their wishes and ambitions are for it.

Once the project has been built, the building community will be transformed into an ordinary owners' association, cooperative or public housing association. Regardless of which form of ownership is chosen, there is a lot of advantages in the process itself of building together, which has created a basis for a special community and ownership of the buildings and one's home. In addition, a good process can often help to save around 10-30% on the market price of the building cost.

Furthermore, experience shows that this form of building contributes to some of the housing policy challenges that Denmark faces and that building communities help to create variation in the cityscape and architectural quality with a focus on sustainable construction that gives residents an anchorage and belonging to their home and neighbour. This helps to promote a socially sustainable living environment that creates a framework for the community that provides varied and long-lasting neighbourhoods (Byggefællesskaber, 2019).

3.4.2 Building community - cases

The task to make a neighborhood where people live near and have close connections within each other is not easy. The resident is dependent on the architecture and the space adjacent to the house to feel safe to encourage interactions. There are several unique examples of residential areas that create a distinct atmosphere, and a neighborhood where people are close collectively, live together and is inclusive. Two examples will be examined, to point out what makes a good quality sustainable living community and how a building community can be done.

The cooperative society in Hjortshøj

Dwellings: 120

Living groups: 8

Area: 65.000 m²

Area pr. dwelling unit: 541 m²

The cooperative society in Hjortshøj was created in 1992 and they describe themselves as a "living laboratory for a sustainable lifestyle" (Andelssamfundet i Hjortshøj 2019 a).

The goal was, and still is, to create an ecological community where several sustainable initiatives are studied, a place where one interacts in a close social community but with respect and coherence to the added society. This project is in a huge scale and are divided into eight "bogrupper" which translates to living groups. The focus was to create a loving community, green areas between the houses, agricultural purposes as well as sustainable building practices, as they experiment with building materials, energy use, shapes, and colours. This is also one of the reasons why this living community appears beautiful and calm (Andelssamfundet i Hjortshøj 2019 b). The eight living groups, each use different sustainable techniques and materials, but inside the building community the overall aesthetics is the same. This results in a diversified area since it includes a variety of housing options, including rented housing, shared ownership property, privately owned homes and homes for people with special needs. The residents have varied degrees of control over the space in front of the houses, creating a subtle divide between public and private space.

Building community from Braunschweig

Apartments: 9

Area: 2547 m²

Area pr. Apartment: 120-160 m²

The building community from Braunschweig was created in 2009 and their mission was to live in a sustainable new building. The group consisted of different family types and sizes, whom all wanted to live in an apartment building.

The mission was to see if it was possible to build without a developer and still have a successful project. The architects Ruth Scheurer & Gerold Perler managed the design, and they created the nine apartments and an integrated townhouse in the local community. The apartments were financed individually because the demands and wishes for the layout, size and equipment varied.

They made safety precautions in case a member decided to leave. However, this was not the case, the project ran without problems and in 2011 the building was put into use. The same year the building was qualified for" sustainable housing" and they won the title awarded by the Federal Ministry of Construction in Germany. (Siegel and 2011, 2022)

3.4.4 Newcomers remarks

A couple who previously lived in an apartment in Nørrebro in Copenhagen, where it was a hectic everyday life, each with their own full-time job, children in institution and a life in the capital, where cultural and social opportunities were at the front door every single day.

The couple has always lived in the big city and had never imagined having to move outside of Copenhagen. However, as so many others have experienced, priorities changed automatically after the couple had their first child. They no longer use the city and its eternal possibilities to the same extent. In fact, the daily crowds of people, cyclists, and cars began to become an element of irritation for the family.

When child number two was on the way, it was even clearer for the couple they were looking for something completely different from where they lived in Copenhagen and the opportunities it had to offer. The dream was a simpler everyday life with nature rather than asphalt and most importantly peaceful environment for the family life. The idea of moving to Sorø came from friends who also moved away from Copenhagen to Sorø, the friends also valued nature and quite surroundings which were to be found in Sorø.

Like many others, we sat with a concern about what really awaited us if we moved so far away. What would our everyday life look like, what are the institutions and schools like, who lives in Sorø, and are there any job opportunities at all, or will we both have to commute to Copenhagen?

Still with worries, but with inspiration from their friends, they could not overlook the need for other surroundings anymore and decided to buy their dream house and move to Sorø. The couple has been very surprised at how well things have gone in the new surroundings since they moved to Sorø, where job opportunities and good well-being for the whole family have happened quite naturally.

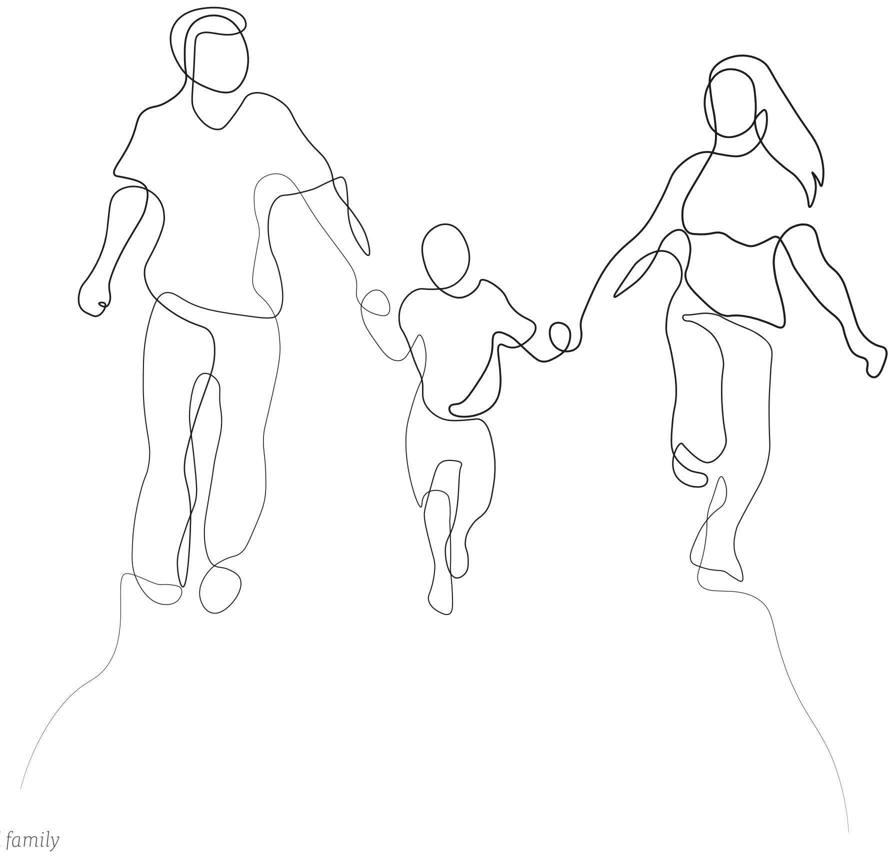
However, I must say that it has gone better than expected. We just enjoy being so close to both forest and lake, with a house directly next to the forest. We like it so much and have never regretted moving to Sorø.

Another family with a comparable history to the family in the big city, the choice also ended up moving from Copenhagen to Sorø, where nature and quiet surroundings were one of the crucial elements to move from the asphalt jungle.

There is beautiful nature in many places in Denmark, but there are not many places where you can have nature as close to everyday life as in Sorø. For me, there is a huge quality of life in being able to use the forests and lakes in their everyday life. It provides peace of mind, which is a valuable antidote to the busy work life.

In addition to the good natural surroundings, one of the things that surprised the family was the great hospitality they experienced in the municipality and all the social services in the local community, which consists of a lot of newcomers and volunteers, which provides a good starting point for creating a local network. In addition, the quality and amount of job opportunities there are so many and varied for the highly educated in the city. Also, very attractive that Sorø is nearby cities with the short commute time for cycling, public transport, or car (Sorø - det danske smørhul, 2020).

“Sorø Municipality offers beautiful nature, a rich history and a great business environment, which is very successful in attracting and creating new jobs together with the local companies. Important elements that provide fantastic opportunities for a good work and family life in the municipality”- Sorø municipality



Ill. 49. Small family

3.4.3 Future occupants

When families start to have children, they often seek out from dense urban areas like Copenhagen and Odense, it is the typical family with mom, dad and two children who is the primary mover. The last couple of years the age group twenty to forty and children under ten who moves away. One speculation for the increase the last couple of years is the lessor need for presence on the workplace.

A popular destination for the urban migraters Is Sorø, Sorø have seen an increase of newcomers the last couple of years. Sorø has a lot to offer for families with children, having both school, day cares, and multiple leisure opportunities locally available. Moving to the suburbs is also the need for nature, the site have both good connection with suburban facilities and raw nature.

When determining where to move most families find that the biggest factor is the need of the children. The one-story house is the most picked type of dwellings for the typical families settling in suburban areas. Children and their needs keep becoming a bigger part of the family priorities and lifestyle. More than 76% of parents believes children requires their own bedroom (Dieckmann and Dieckmann, 2022). To understand the user group properly the requirements children, have, needs to be identified. The space where children can play, investigate and be with friends are very important for children. When living far from urban areas with lots of space, friends is often wanted, when living in densely populated areas common playground areas are needed (Dieckmann and Dieckmann, 2022).

The age-group 25-35, who have finished education, starting to earn money, want to build a safe future for their children. This can be interpretated in two ways, physical safety by having a good quality home but also by looking into sustainable living, to secure save future. The younger generation tend to act more sustainable than the previous older ones. (Danskerne om bæredygtighed: Det er vores ansvar, 2022)

3.6 Inspiration

3.6.1 Urban

Key words: Shared spaces, wild nature, functionality

As inspiration for the urban atmosphere and layout, green and wild was investigated. The urban layout covers the road, the space between the houses and the garden itself. The project wants to challenge the detached house garden by allowing less controlled elements to roam. Streams and plants placed to have a functional purpose but create a specific aesthetic.

3.6.2 Nordic architecture

Key words: Simple, minimalistic, focus on materials

The concept of Nordic architecture located in a suburban Danish context rather than on a Norwegian cliff side may seem odd. But Nordic architecture focuses on materials, simplicity, and common sense. The material focusses on this project goes hand in hand with the Nordic architecture style, using the full potential of a material properties, like weight, colour, atmosphere, and tactility.

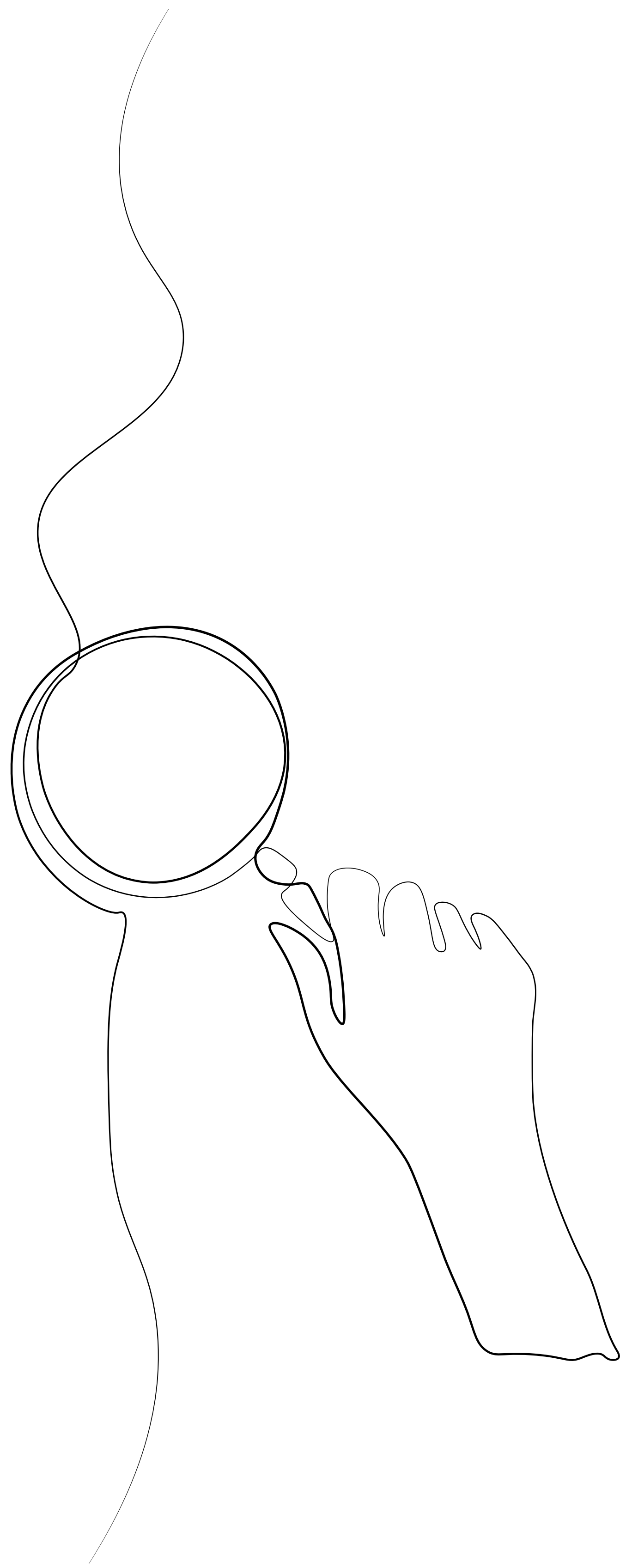
3.6.3 Materials

Key words: Light, natural, visible structure

As the projects focuses on the material reusability and quality it makes sense to investigate Nordic architecture. Looking at the atmospheres wanted with-in the house different functions there are different needs for materials. The living room and kitchen, needs to be light and spacy, having shared space with room for everyone. The bathroom and utility room are more practical therefor having tougher materials and less colour is wanted. The bedrooms need to be private yet light and airy, having small windows for privacy and light materials for calming effects.

3.7 Analysis conclusion

To conclude the analysis chapter a summary is made. The topography on site varies little, but the height difference is large enough to be exploited; the project seeks to enhance the current natural shaping rather than control it. Driving to and from the site is difficult because the residential area is large, the main road is long and curved. The area encourages the use of bicycles and pedestrians, well connected with paths and bicycle lanes. The area's typology is dominated by single detached housing, and the aesthetics of the surrounding houses are diverse, with few restrictions on project appearance. However, the district plan analysis generated ideas that will serve as the foundation for some of the urban concepts. The analysis also revealed the need for locally handled rainwater distribution and solar panel integration. Concerning the PV discussion and the integration of PV panels on a roof can have multiple complications, the first is having the roof angle and orientation in a way so the biggest amount of energy can be produced. Another is the technical installation on the roof, if “integrated” having the PV panel surface equal to the exterior roof layer risk of overheating which results in lower efficiency. For the street to be safe, there should be less foreign activity, and the street should be designed exclusively for residents. Simplified, this means that if the same people are walking the streets, there will be less crime. However, transportation to and from the street should be simple, so that the street does not force the use of mechanical vehicles. Using a network of paths to increase connectivity and promote pedestrian and bicycle transportation. Based on the two case studies. The new building community in Frederiksberg, Sorø, will consist of groups divided into new families and older generations. Collectively the group wants to create a sustainable neighbourhood with space for play, enjoyment of life, and nature. The community wants to reduce energy demand, both by living in technical sustainable buildings but also by performing rational sustainable everyday behaviour. The people moving from Copenhagen to Sorø are the typical families and the older generation seeking space, peace and quiet. To capsulate the target groups the people of the new neighbourhood will be new families and the older generation. Mixing the two groups benefit both in multiple ways. Taking the user group into consideration, the household size can be narrowed down to a one to five people span housing, which can be divided into three types of units. The units should accommodate single & couple, small families, and big families. The project user group will be consisting of new families, ages 25-35 and children aged 0-4 furthermore including the older generation who can live independently, in the age 55-70. It will be important to address the different needs of the user group, having the high energy children, the busy parents, and the gentler older generation. The houses should address the need for flexibility, either in family size growth or replacement of residents. As the focus is on detached single-family homes, the qualities of these needs to be focused on addition.



Ill. 50. Analysis conclusion

4.0 Summary

4.1 Conclusion

To recap the main topics and all the knowledge established through state-of-the-art theory, analysis and collected empirical experience of the site and its surroundings are reduced to design criteria for this project. Design criteria made out from the research and investigations will guide the design to satisfactory architectural quality and environmentally aware thesis design. The design criteria are made specific for this project to design in the sub-urban context in Sorø surrounded by nature located in a newly residential area. The building industry is currently a big contributor to greenhouse gasses and energy consumption which also reduction is possible by promoting sustainability. Building materials currently used are often "produce, use, dispose" which originates in a fast-growing, high demand business model. This project will investigate available market materials that can be part of the circular building industry. To make sure the materials can be recycled and have later purposes the design will incorporate elements of design for disassembly. The architecture will incorporate a sustainable agenda coherent with the Danish traditions, the natural setting and Nordic characteristics with the simplicity, harmony and solid materials in a minimalistic composition. The new buildings set the context of a social interacting building community that through co-determination and considerations is creating a sustainable area, where they can build their own individual homes and collectively a social sustainable community.

4.2 Vision

This master thesis vision proposes a cluster of sustainable single-family houses for a building community that has a strong architectural quality and awareness in its context and time with its settlement. The design takes responsibility for the extent of its environmental impact and is a frontrunner within its typology, creating a context for its residents to fully understand and be aware of the environmental proportion a regular household has when construction and operational energy use are considered. The understanding comes through carefully material selection, construction and the implementation of passive and active strategies into the design of the settlement to lower its overall energy consumption and embedded CO_2. In extension on behalf of the building community, that recognize the importance of social aspect and the significance, to create a good neighbourhood and a community where everyone can thrive. The chosen location is a place with the same values as the thesis, a municipality with values regarding family life, the preservation of nature and importance of being environmentally conscious about one's actions.

4.3 Design criteria

Strive to use materials that are in circular sustainable processes (Cradle to Cradle).

The way of assembly should be made minimum, reduce unnecessary layers and combine technical remedies to simply wall and design for the materials to be easily assembled and disassembled.

The materials shall take its fundamentals in the Nordic context and its tradition to essential utilize surfaces, textures and tactility of the materials to increase an affiliation to context and foundations of a home.

The material selection should add to better indoor climate, reduction of sound, stability in humidity, unreflective materials and minimum outgassing.

The materials should be longlisting and durable, have low maintenance and cleaning needs, thus be places so natural patina is part of the design.

The shape and structure of the house should be made in a minimalistic design, increasing the functionality, flexibility of the interior and connections to the natural elements.

The rooms of the house should be designed to have a natural identity but also allow the resident to create a home, by own influence.

The space in-between the houses should accommodate play, small social gatherings, green areas and natural flora.

The cul-de-sac should be designed to guard the family privacy but increase social behavior, making the resident have a feeling of belonging.

5.0 Presentation

5.1 Urban

5.1.1 Masterplan

Welcome to Chikorievænget, the new area build with nature and in nature. The site is located just south of Sorø with great options for pendler opportunitie. The new area is build next to a forest and among small lakes, Sorø makes a virtue of the wild nature and so does this project. With twenty new houses ranging from 81 m² to 136 m² and a new common house available for the adjacent property residents. Chirkorievænget have focused on the circularity of building materials and energy optimization to give the new inhabitants a leading place in the fight for sustainable future. The site is interconnected with pathways for residents to enjoy the wild Danish nature.

Ill. 58. Masterplan 1:1000

The masterplan shows the urban layout and the common house placement. The area sorrounding the site three big lakes and a small forest to the north.

5.1.2 Urban presentation

The urban layout of Chikoriveænget have three key words, wild, nature, biodiversity. The project focus on the natural flora and local indigenous trees and plants, working with elements that thrive when left untouched. The perfect garden has a different meaning in this area, it welcomes wild life and untrimmed edges. Chikorievænget have investigated the use of materials in the popular Danish tract houses to see how the process behind construction can be more circular. The design of these houses is inspired by Nordic architecture, using fine lines, strong elements, and natural materials. All the units have their own terrace oriented towards the garden. The masterplan incorporates both wild nature and human living, striving for holistic coexisting. Every unit have its own plot, but the lines are blurred. The future residents have come together to form a building community, a community focusing on healthy wellbeing and sustainable living alongside the joy of living in a suburban setting with space and nature.

Site are: 26.300 m²

Building plot total area: 8157 m²

Plots sizes: 350 - 600 m²

Unit 1: empty nesters or elder living 82-90 m²

Unit 2: Families 91-110 m²

Unit 3: bigger families 111-136 m²

Total residential: 2235 m²

Common house area: 220 m²

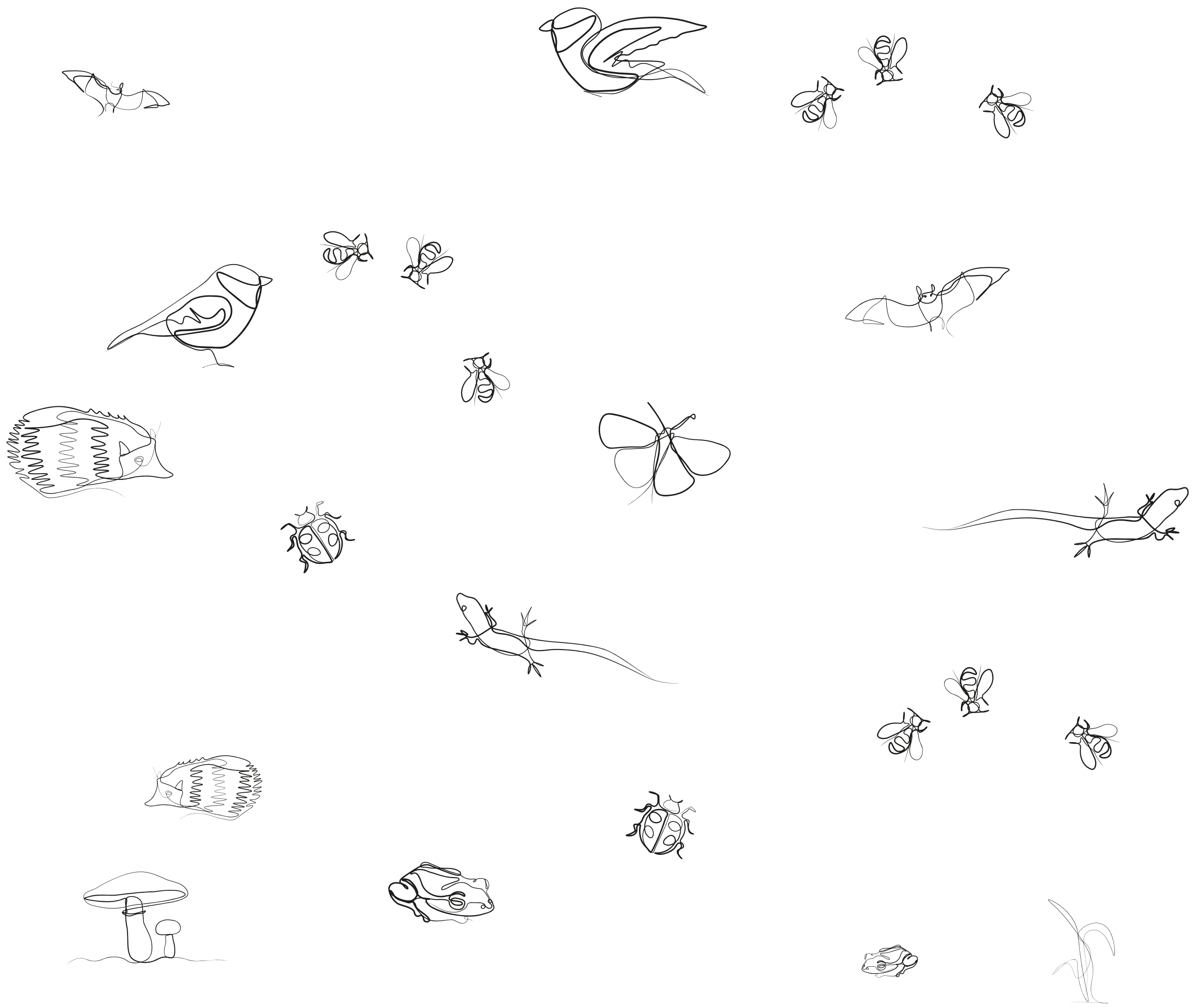
Building percentage: 28,5%

Ill. 60. Urban West elevation render

Ill. 59. Urban North elevation render

Ill. 61. Urban render

Ill. 62. Urban render



5.1.3 Save the nature!

Nature is meant to be wild; the green yard garden may be aesthetically pleasing, but the trimming, cutting of edges, and grass reduces area for biodiversity. Untamed gardens and logs provide safe havens for mushrooms, plants, and small animals.

The urban layout was driven by a natural rainwater collection concept. Water is essential for life and thus for biodiversity; having small water streams that are not too deep and allow them to dry in between rains provides beneficial breeding areas for toads rather than mosquitos.

This area's standard bush will not be the traditional privet hedge. The area focuses on easy gardens with lots of variety, with bushes that flower and attract insects but don't require constant attention. Insects such as bees, butterflies, and hover flies are beneficial to the garden and thrive in flowering areas.

Placed around in gardens and next to the pathways are small hills made of dirt, rocks, or sand. These can in a sunny location have a higher temperature than the surrounding area, attracting bees and other creatures such as lizards. The project is a biodiversity fighter.

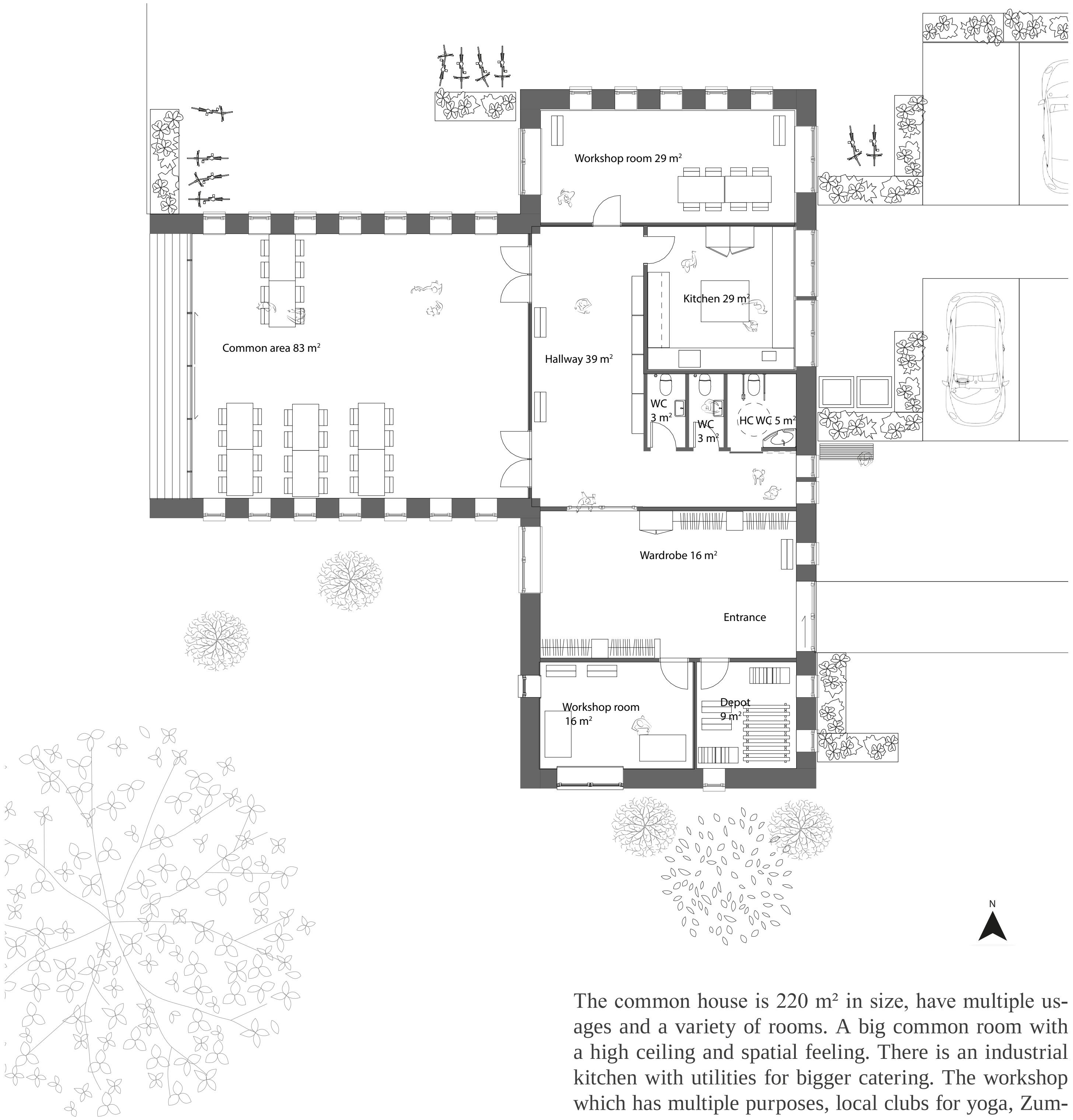
Designated areas for old branches and sticks form mazes in which lesser bird and animal species breed. During the day, the hedgehog can rest in these, while insects and mushrooms feast on the smaller twigs.

In addition to natural elements, there are also man-made animal nesting options.

Nest boxes will be placed in and around the garden to attract various bird species; the birds control insect populations and other creepy crawlies, providing significant benefits to the natural balance.

Insect hotels are beneficial to biodiversity because they provide insects with dry and sunny places to sleep during the winter. The hotels are designed to house ladybirds and butterflies, but they can also host lonely bees and green lacewings (Dac.dk ,2022).

5.2 Common house



Ill. 63. Commmon house plan 1:100

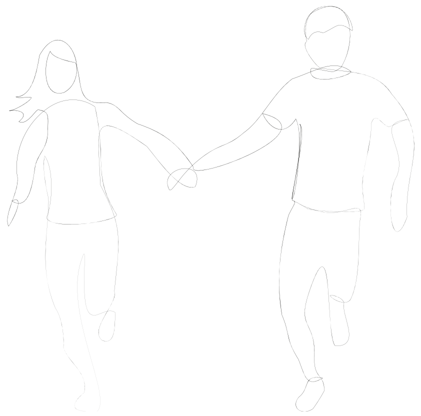
The common house is 220 m² in size, have multiple usages and a variety of rooms. A big common room with a high ceiling and spatial feeling. There is an industrial kitchen with utilities for bigger catering. The workshop which has multiple purposes, local clubs for yoga, Zumba, taekwondo, and other activities are hosted here during the week. An entrance connected with a big wardrobe to store outerwear and others. The workshop rooms and common room needs extra storage due to activity change, so a storage room is placed. Next to the kitchen is some toilets, a special need toilet and a niche.

It is meant to be a public safe space for surrounding residents to utilize. During weekdays the common room are open for all to stay and enjoy the view of the urban scenario. In weekend's events are happening being big or small.

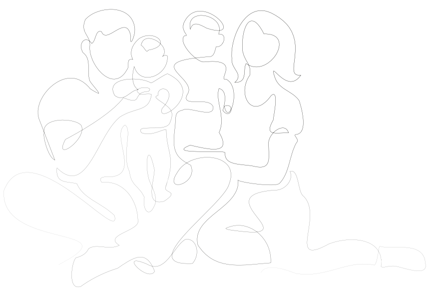
Ill. 66. Common house and public area render

Ill. 64. Common house east elevation 1:200

Ill. 65. Common house south elevation 1:200



Ill. 67. Empty nesters



Ill. 68. Family

Ill. 69. Elder

5.4 House presentation

The three houses presented are of the sizes 81 m², 98 m² and 136 m². The house plan ideology is similar in the different houses, what varies is the size, additional functions, and orientation. The three sizes is meant to accommodate three types of people groups, empty nesters, family and elder. The house plans work with a big light and combined kitchen, dining, and living room. The houses work with separated children and adult sections, giving the family privacy. The separation makes it possible to not disturb the children when the parents go to bed later and when the children become teenagers, they won't disturb the parents. A secondary entrance leads into the utility room, where all the technical elements are located. The utility room is always located next to the shared shed where there is also placed a covered drying rack where cloths can dry during all seasons.

In connection with the kitchen and dining area are the living room and adult section. The house is well connected with minimum walls to block light and to create a coherent feeling. The kitchen is the heart of the house, this is where there is enough room for all family members. In the kitchen, there is a big island with a big sink for practical use. Next to the kitchen island, there is space for a big dining table, with a view of the garden. Through a big gliding door, the food can be carried out to be enjoyed on the big terrace, which works as a smooth transition between garden and house.

The materials in the houses consist of broad surfaces of wood and clay plaster. Both materials have tactile surfaces, one with the woodgrain and the other porous minerals. The combination of colours in the materials are dimmed and natural, easy tones for the eye to glide over when admiring the walls and ceiling. In the ceiling the construction is visible, the wooden beams run along the ceiling reaching the skylights in a smooth meeting.

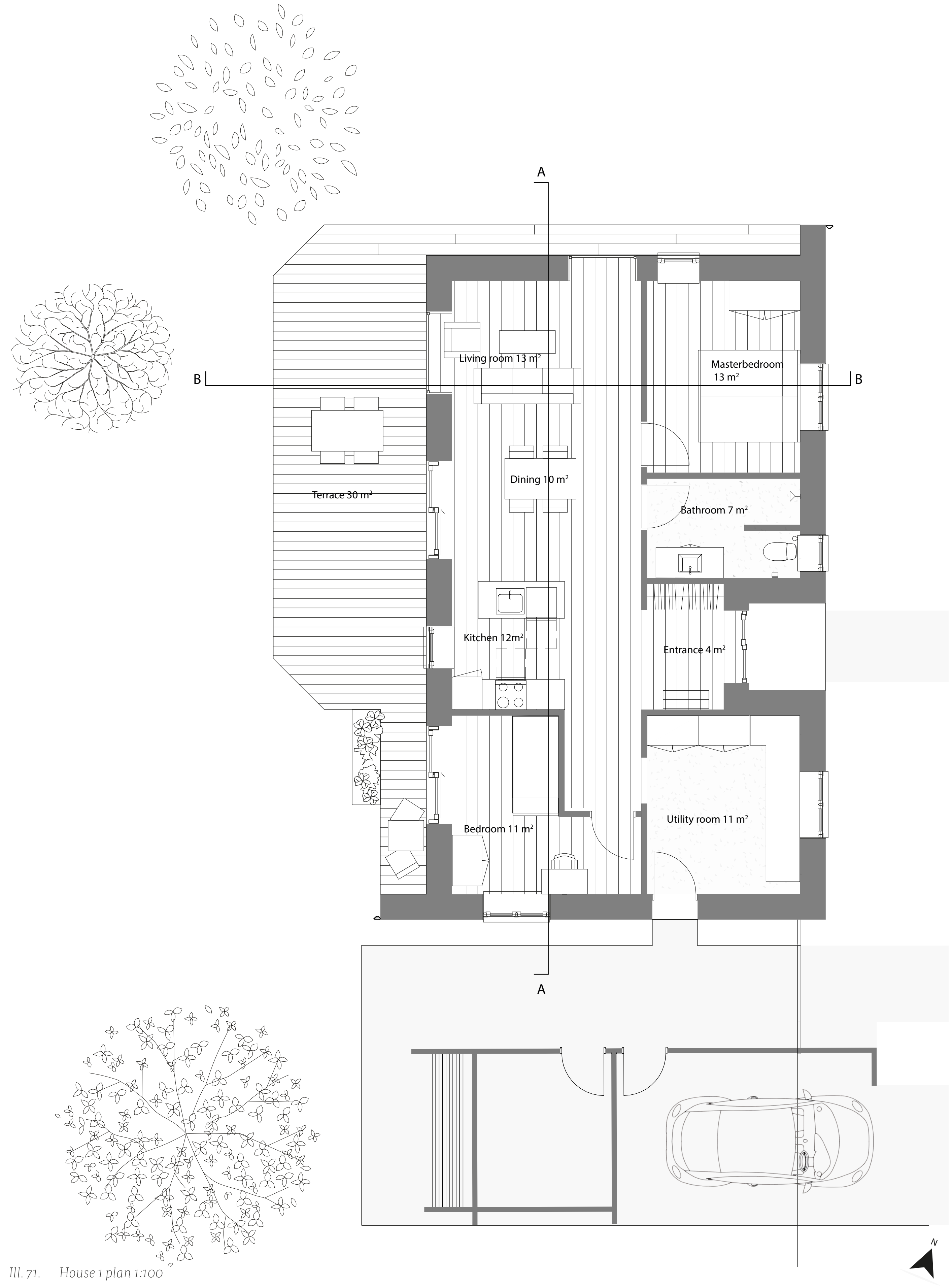
House one is designated for the elder people or empty nesters. The house has a main bedroom connected to the living room. The living room is then connected to the kitchen dining area which opens to the terrace. A bathroom is placed between the main entrance and master bedroom. In the southern part of the house there is a spare bedroom or office, next is the utility room. The utility room have the secondary entrance used for dirty laundry and messy errands. The secondary entrance leads to the shared shed where parking and shares garden tools and bike parking is placed.

House two is designed for a family of four. The house has two bedrooms and a master bedroom with a private bathroom. The main entrance leads into the house central transition zone, the hallway. In the hallway the two bedrooms are placed and a spacious bathroom. The hallway has inbuilt closet space and wardrobe to put the outerwear. The bedrooms also have inbuilt closets to increase usability of the floor area. From the entrance one can look straight through the house and into the garden.

House three is built for the family in need of space. The entrance is located close to the road to minimize the front garden to have a bigger private garden. Next to the entrance, there is a storage unit, further, in the house, the kitchen/dining area is located. On one side is the hallway well-lit by skylights and this leads down to the children's section with two big rooms, a bathroom and a utility room. At the other end of the house the adult section is located, the master bedroom with a separate bathroom.

Ill. 70. House placement

5.4.1 House A



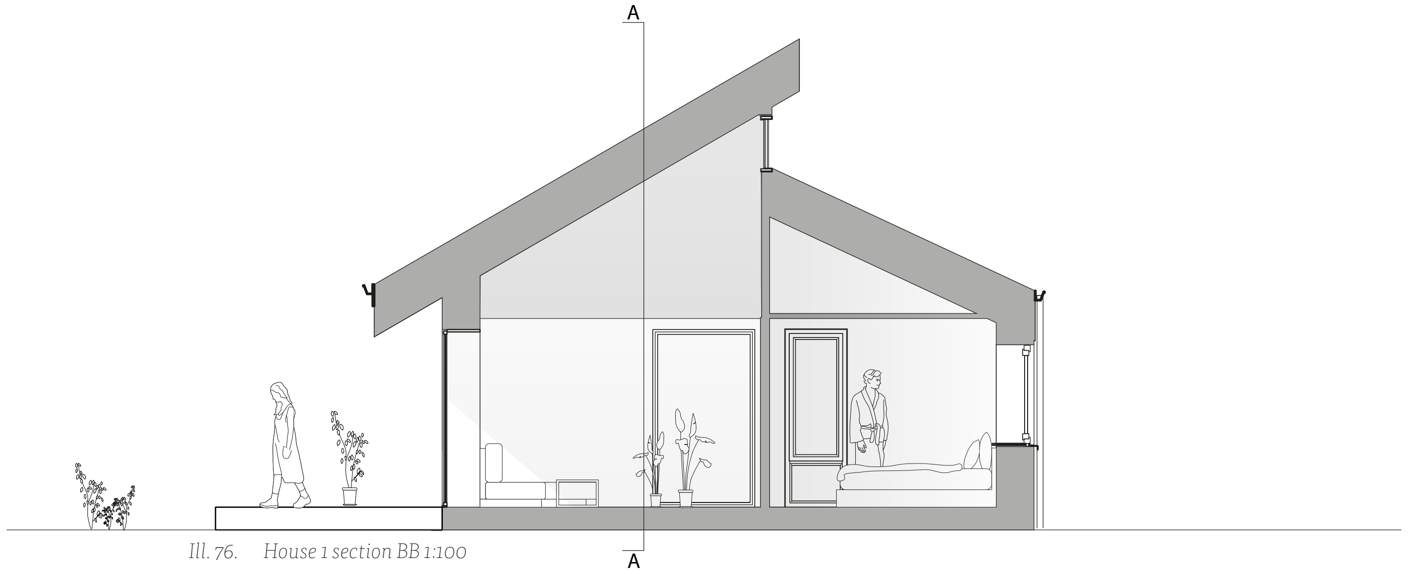
Ill. 71. House 1 plan 1:100

Ill. 73. House 1 South elevation

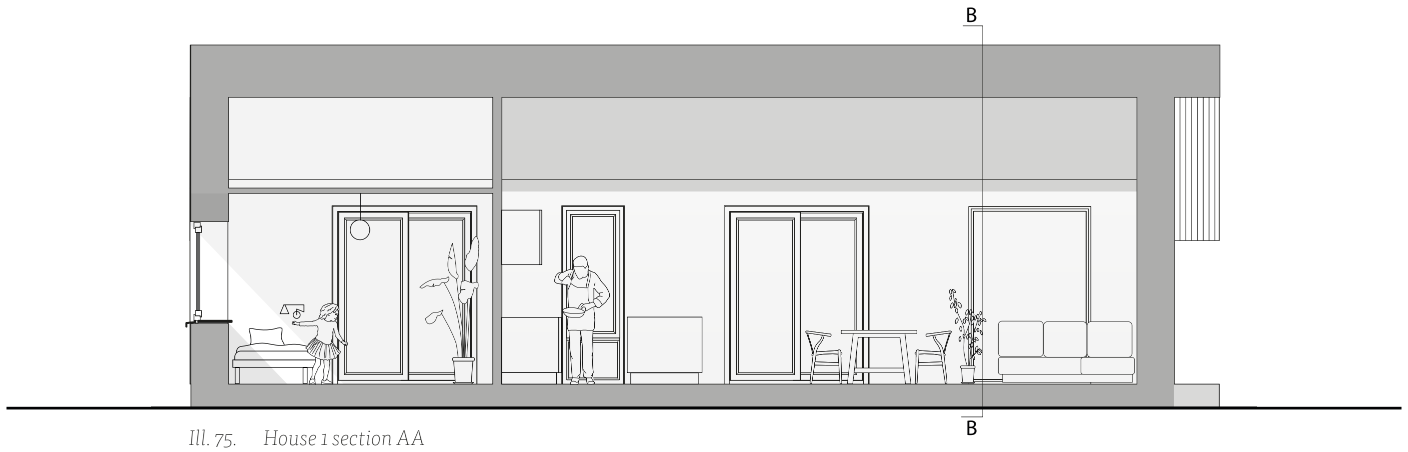
Ill. 72. House 1 East elevation 1:100

Ill. 74. Street render.

The untamed nature meet the street at the edge. The houses have brown exterior cladding made out of clay, the stone patina in a natural setting and tempo



Ill. 76. House 1 section BB 1:100



Ill. 75. House 1 section AA

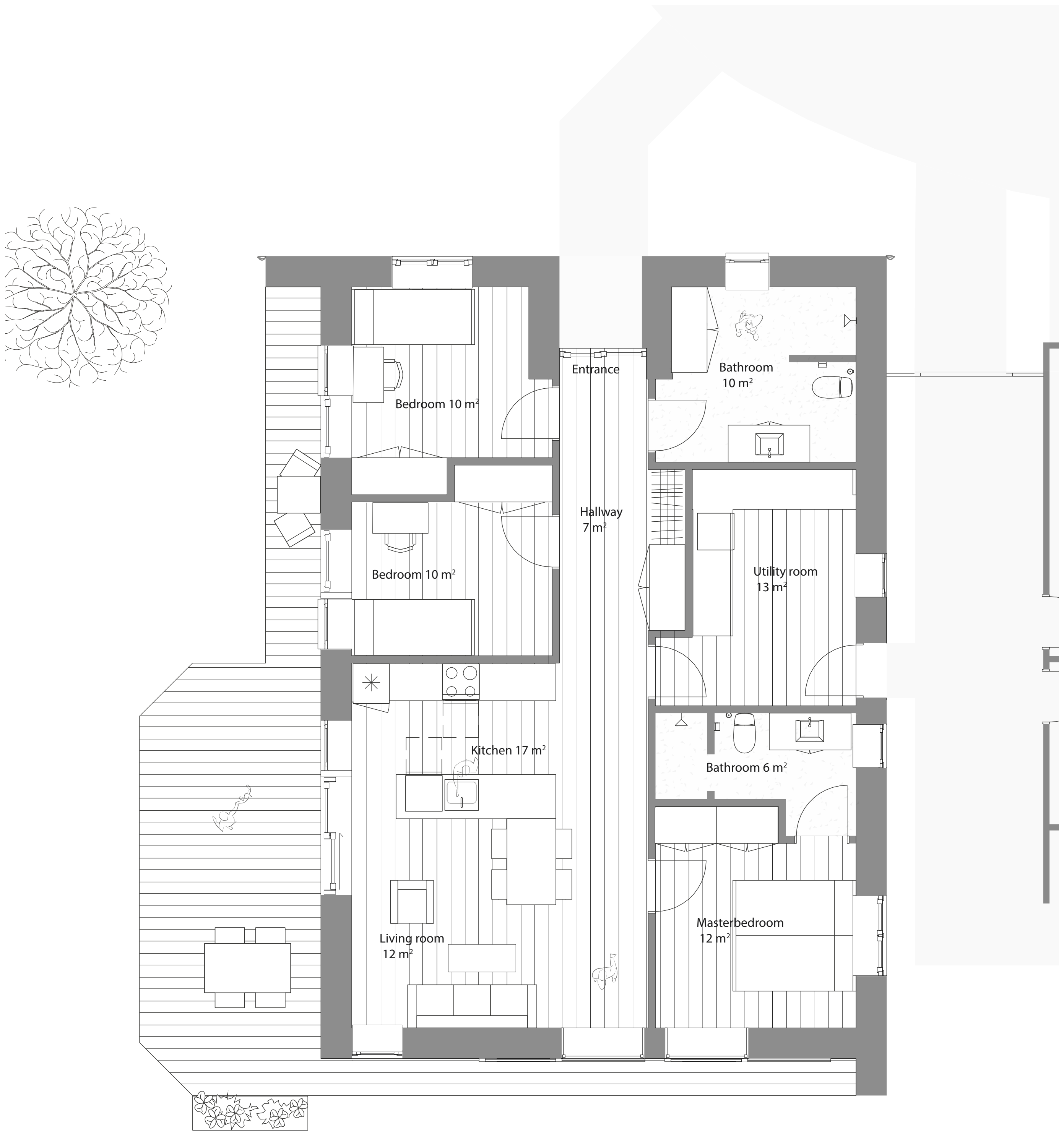
Ill. 77. House 1 North elevation 1:100

Ill. 78. House 1 West elevation 1:100

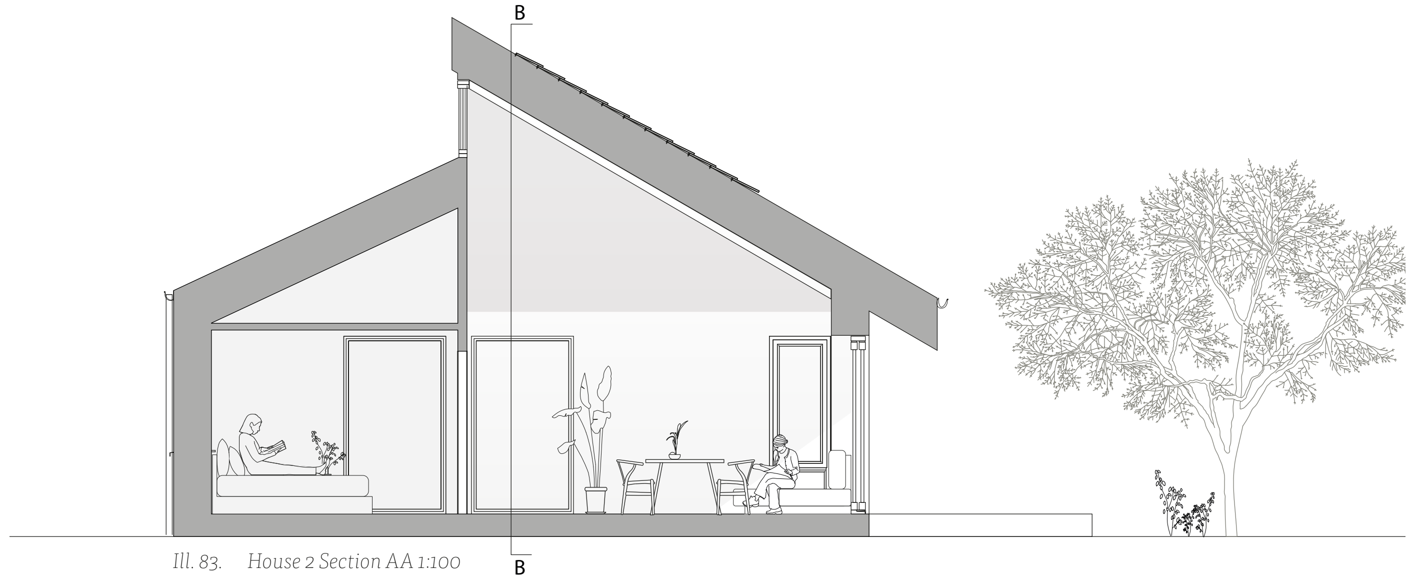
Ill. 79. Street render.

The street have designated areas where social gatherings can happen and children can play. Next to the pathway is placed some wooden stubs for activity and benches for resting

5.4.2 House B

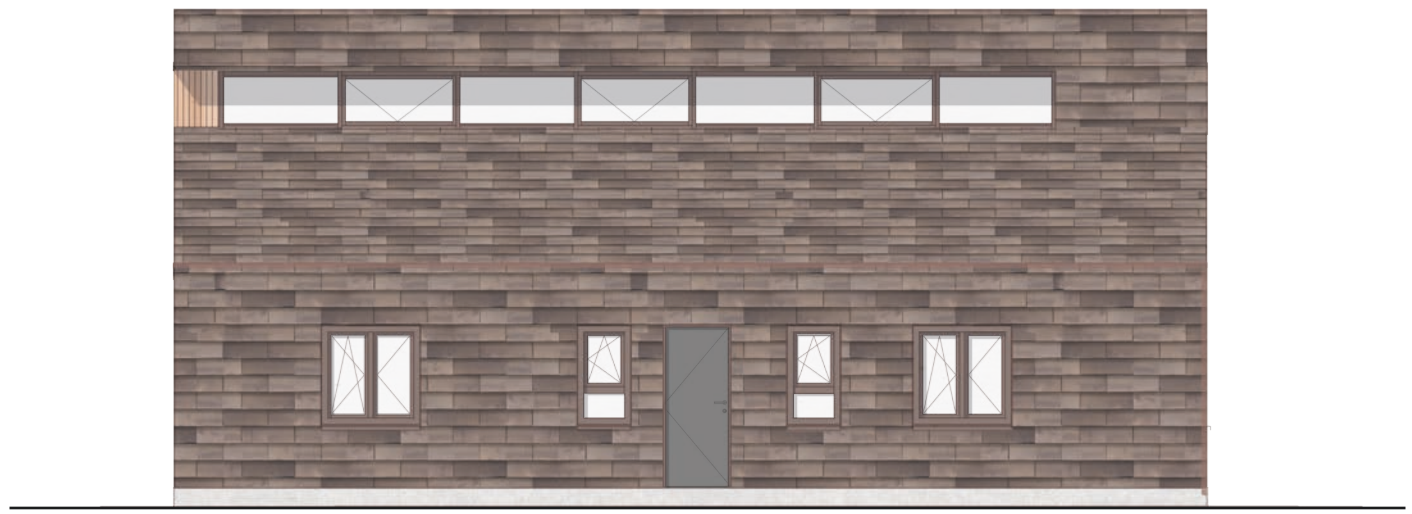


Ill. 80. House 2 plan 1:100



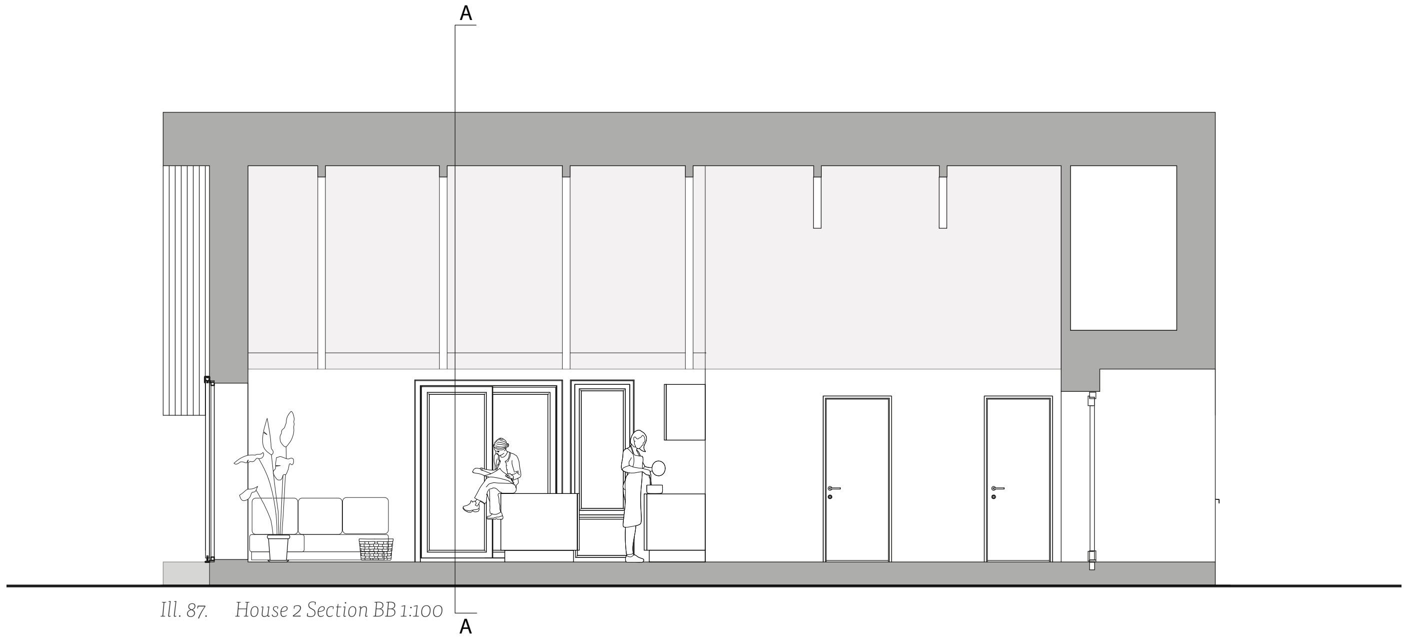
Ill. 83. House 2 Section AA 1:100

Ill. 81. House 2 North elevation 1:100



Ill. 82. House 2 East elevation 1:100

Ill. 85. Urban render



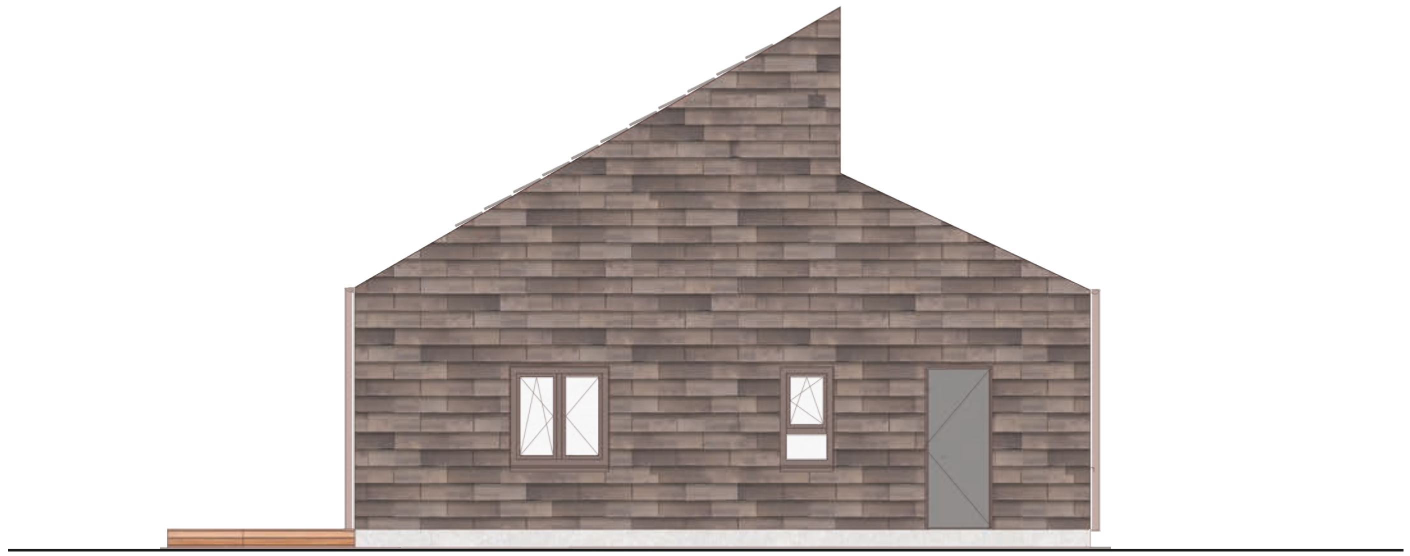
Ill. 87. House 2 Section BB 1:100

Ill. 84. Urban render

Ill. 86. House 2 West elevation 1:100

5.4.3 House C

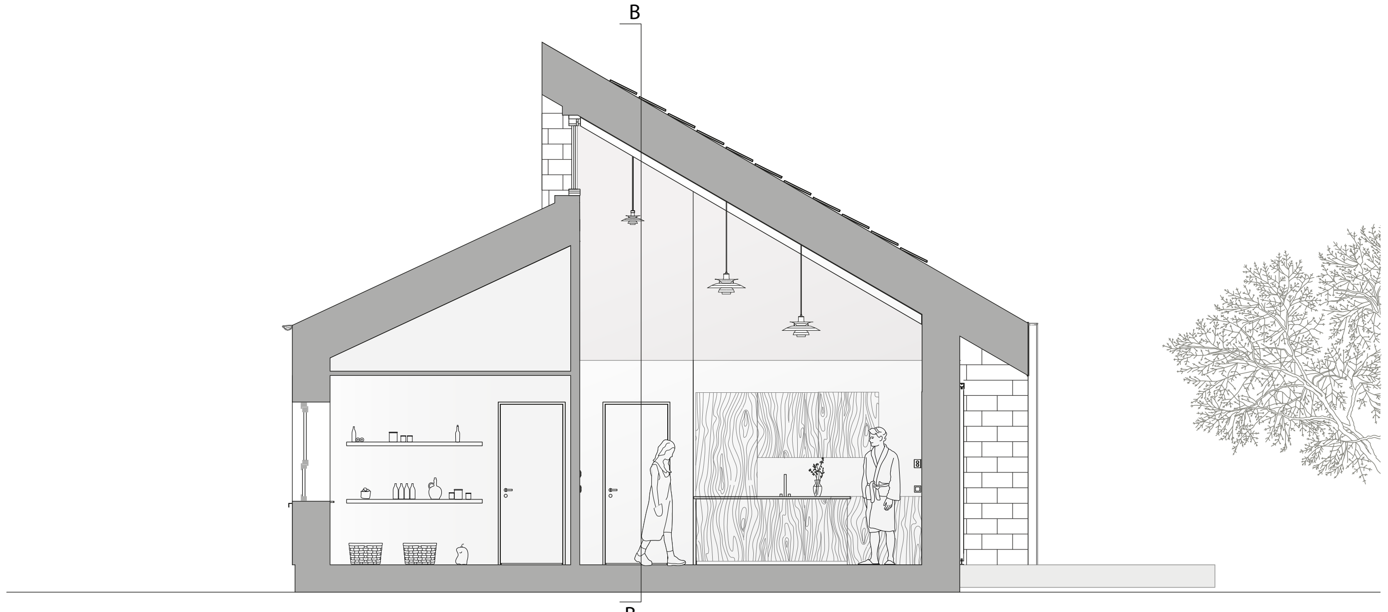
Ill. 88. House 3 plan 1:100



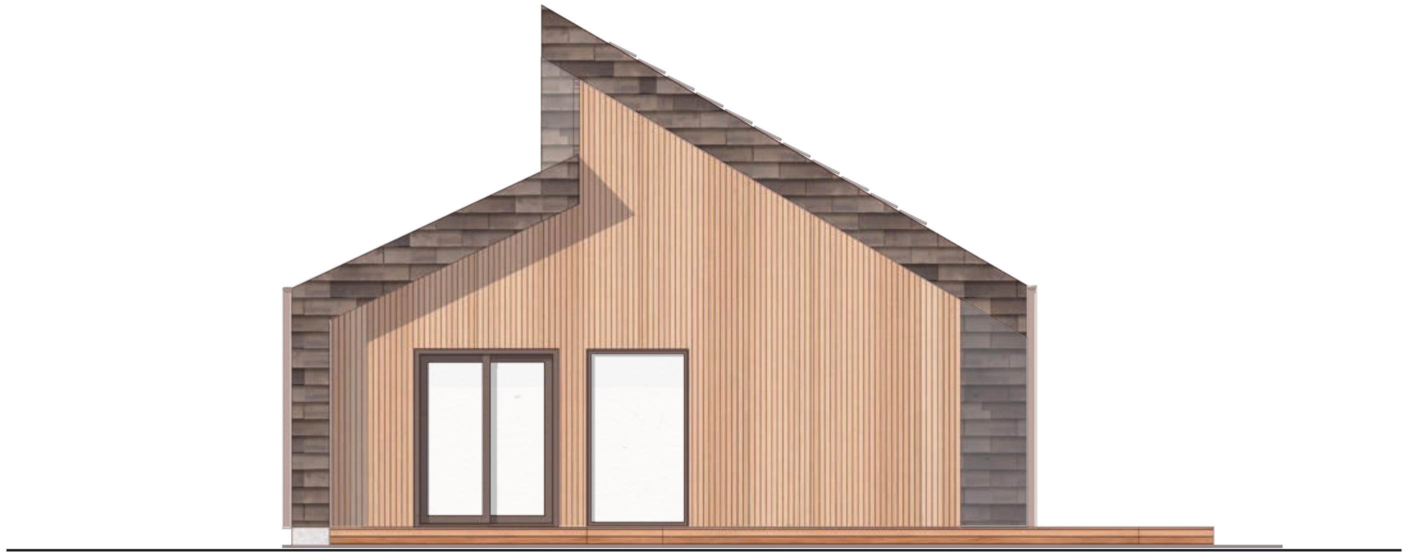
Ill. 89. House 3 East elevation 1:100

Ill. 90. House 3 North elevation 1:100

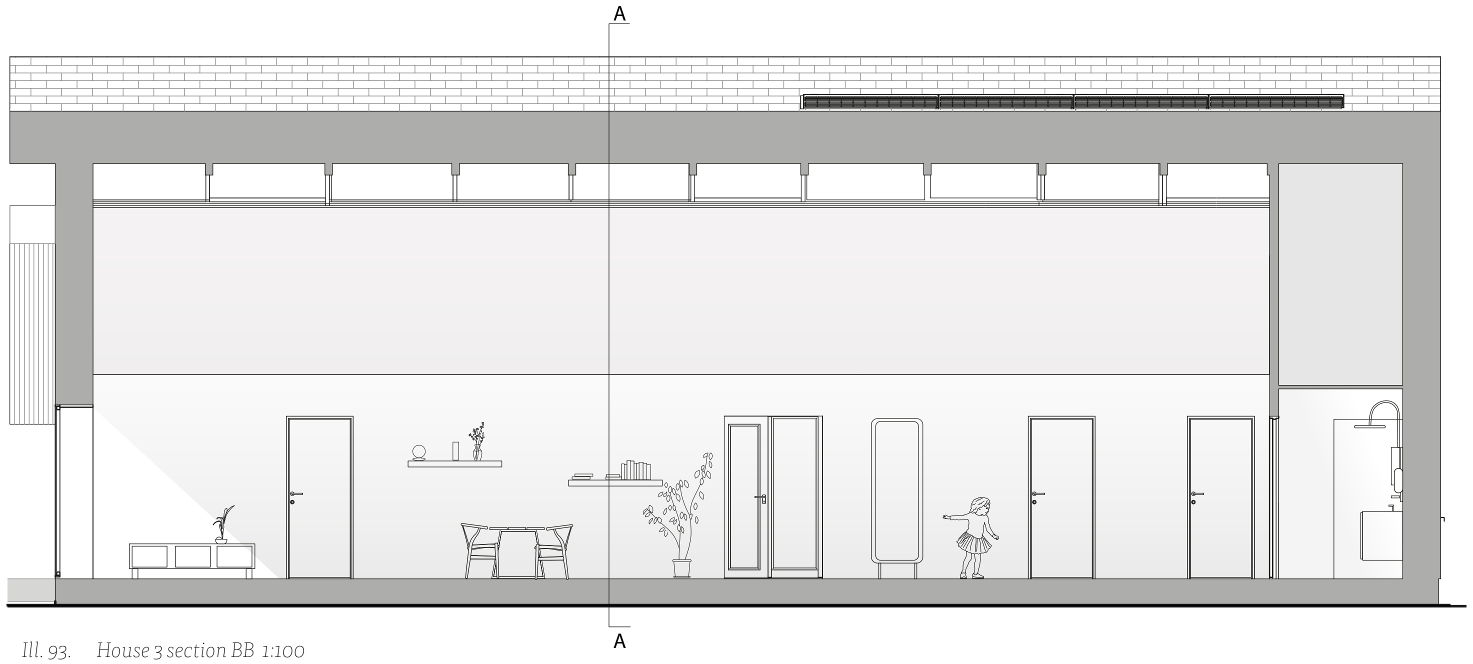
Ill. 91. Interior render.
The kitchen is made out of light oak wood, which goes well with the lighht coloured walls. The natural material is durable and strikes as elegant and timeless.



Ill. 92. House 3 section AA 1:100



Ill. 95. House 3 West elevation 1:100



Ill. 93. House 3 section BB 1:100

Ill. 94. House 1 South elevation 1:100

Ill. 96. Living room render.

The livingroom is spacious and can host a variety of different furniture. The exterior shading have two purposes, darken the room and block unwanted heat gain from the sun.

5.4 House performance

The houses are similar in plan layout but vary in rotation, surroundings, and size. Having the house be in different locations they all perform different; on this page the indoor comfort of the houses will be explained.

Excess overheated hours are emphasized in the thermal comfort, CO_2 level in the atmospheric comfort, reverberation time in the acoustic comfort, and daylight factor in the visual comfort.

5.4.1 Thermal comfort

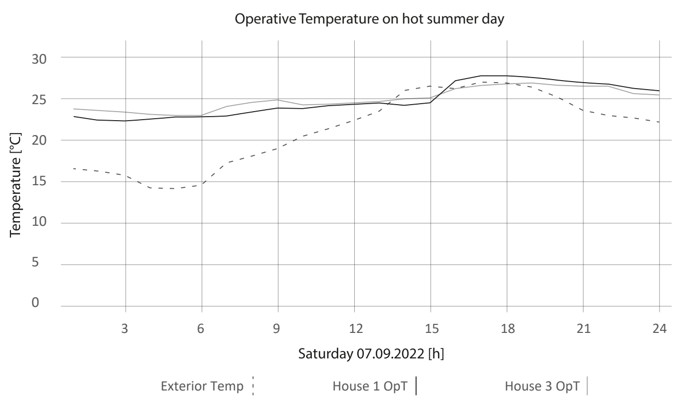
The thermal comfort of the houses was achieved using hybrid ventilation, active and passive shading. To avoid wasting energy during the winter, the mechanical ventilation system recycles up to 80% of the heat from the air. The critical season is during the summer, when outdoor temperatures reach indoor temperatures, and passive solar gain is undesirable. The use of active shading allows the resident to reduce incoming solar energy and keep their home cool. Even when the outside temperature reaches twenty-five degrees, the indoor temperature doesn't rise to critical levels, thanks to effective natural ventilation se ill 97. These days the air change of the living room stays on a steady 4,8.

The initial criteria for summer comfort were the threshold of 27 and 28 degrees, however future weather data showed that summers will be more extreme and therefor the house should perform well under these conditions as well. By lowering the threshold, the future performance of the house and critical sizzling summer days will be less hot. °C

5.4.2 Atmospheric comfort

House 2 has the most people in a smaller space and is thus at risk of poor indoor air quality. Because of the high ceiling, the living room has a large air volume, which acts as a buffer because there is more air to absorb contamination.

Even when all four members of the family are present, the CO_2 level does not exceed 1200 ppm. The ill 99 depicts how mechanical ventilation reduces CO_2 levels to outside levels within a few hours of people leaving the room; once the CO_2 levels have stabilized, the ventilation rate is reduced. During the non-heating season, natural ventilation keeps CO_2 at bay because high ventilation rates are used to reduce temperature in the building see ill 100. The air change of the room is high and therefor also the airflow, look appendix 19 to see buoyancy driven natural ventilation calculation.



Ill. 97. Hot summer day interior OpT house 3 livingroom

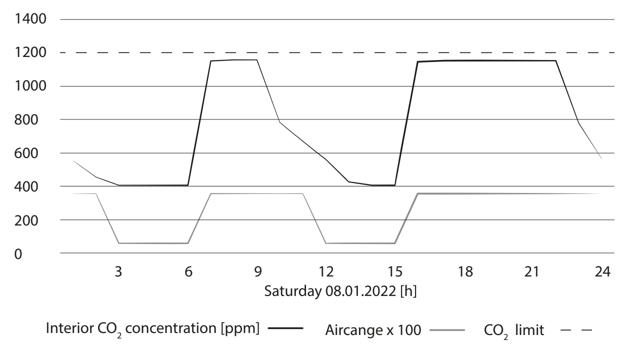
House 3:

Year 2022 (41 h > 26°C & 15 h >27°C)

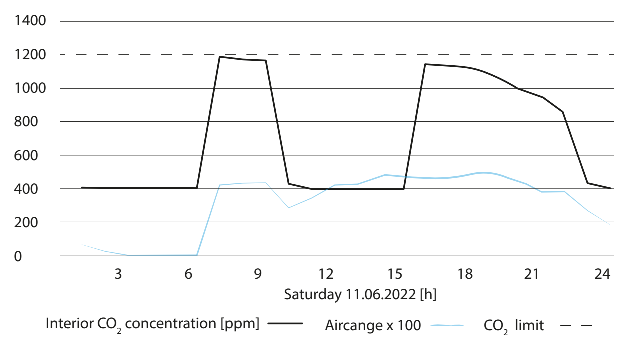
Year 2050 (67 h > 26°C & 26 h >27°C)

Year 2090 (125 h > 26°C & 36 h >27°C)

Ill. 98. Summer comfort - excess hours of heat

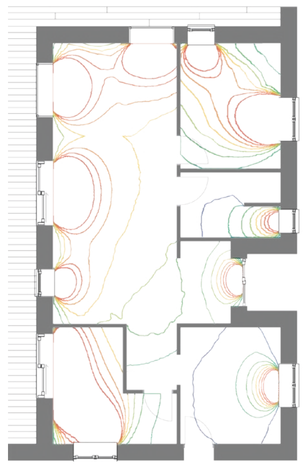


Ill. 99. Mechanical ventilation performance



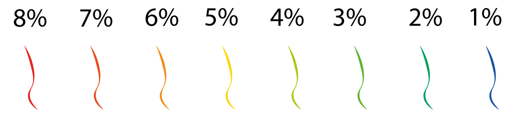
Ill. 100. Natural ventilation performance

5.4.3 Visual comfort

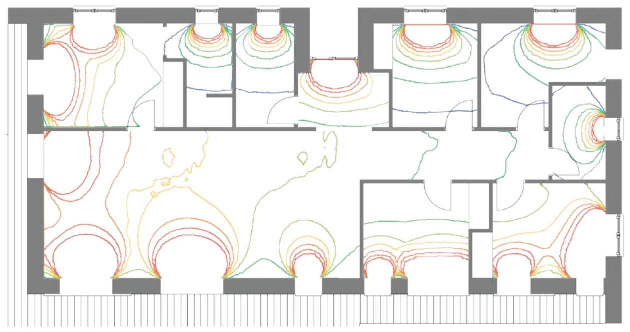


Ill. 101. House 1 Df - off scale

Ill. 102. House 2 Df - off scale



Ill. 104. Daylight factor indication

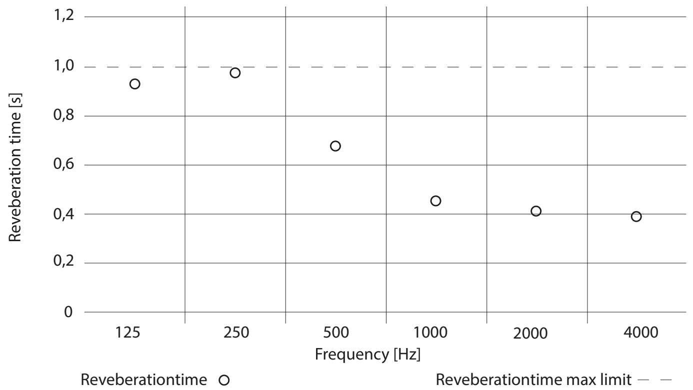


Ill. 103. House 3 Df off scale

Because of the large window area, including the vertical skylights, the visual comfort of the houses are satisfying. Having matt materials often results in a lower DF, but the clay walls are light in color and thus reflect some light, and the light wood also helps to spread the light. The house's design promotes visual comfort by providing long views and a strong connection to the outside world. The houses all have more than 2% of DF In 50% all living spaces, see simulation ill 101-103 for house DF. The blue line and area outside of these have a DF of < 1 which is where the medium of the DF would be decreased.

5.4.4 Acoustic comfort

The living room, dining area, and kitchen are all in the same room due to the house's design, and the high ceiling provides a large air volume for sound to travel without being reflected. As a result, the living room has the potential for a long reverberation time. House 3 has the largest room and thus the greatest risk of echo even when occupied. The reverberation time without furniture in the house is on average just under 1 s due to the use of wood on joists, visible structure, and porous clay walls, as shown in ill 105. Because the houses share materials, the other houses would outperform them.



Ill. 105. House three livingroom reveberation time

5.4.5 Energy performance

Due to diversity in size, placement and rotation, the energy consumption of the houses varies. The results for building operation values kWh/m²/year will be presented with and without solar panels. The optimization of the houses, the wall thickness, the window size, window placement, window type all affected the energy required for building operation look appendix 05 for Be18 results.

H82	H98	H136
23,3 kWh/m²/year	24,5 kWh/m²/year	21,7 kWh/m²/year

Ill. 106. House building operation energy

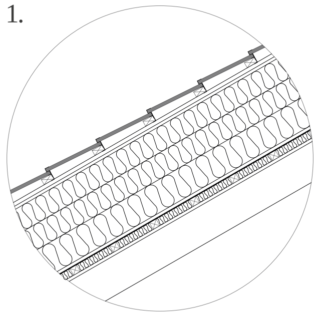
H82	H98	H136
-1,7 kWh/m²/year	-0,5 kWh/m²/year	-3,3 kWh/m²/year

Ill. 107. House building operation energy with solar panels

It was initially wanted to reach the 20 kWh/m²/pr using passive strategies and a few active strategies such as mechanical ventilation and exterior shading not solar panels and heat pumps. Even through varies of iterations and potential nonfunctional wall thickness it was not possible to reach it. The house shaping seems to limit the potential energy saving for single family houses. The new energy and material optimized houses add to Danish houses being environmentally sustainable.

5.5 Detailing

1.



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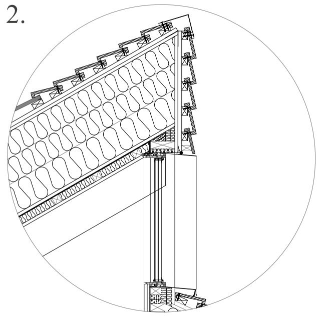

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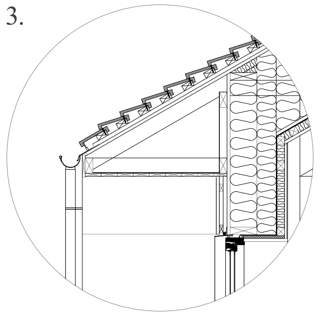

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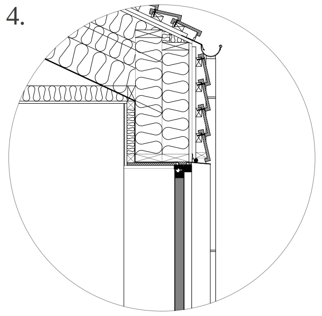

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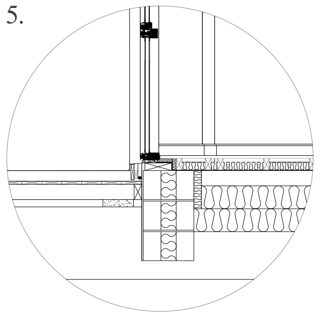
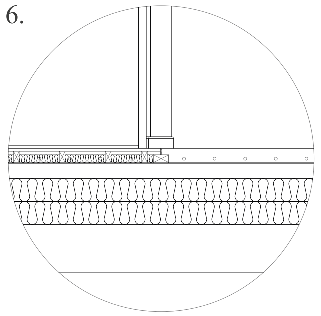
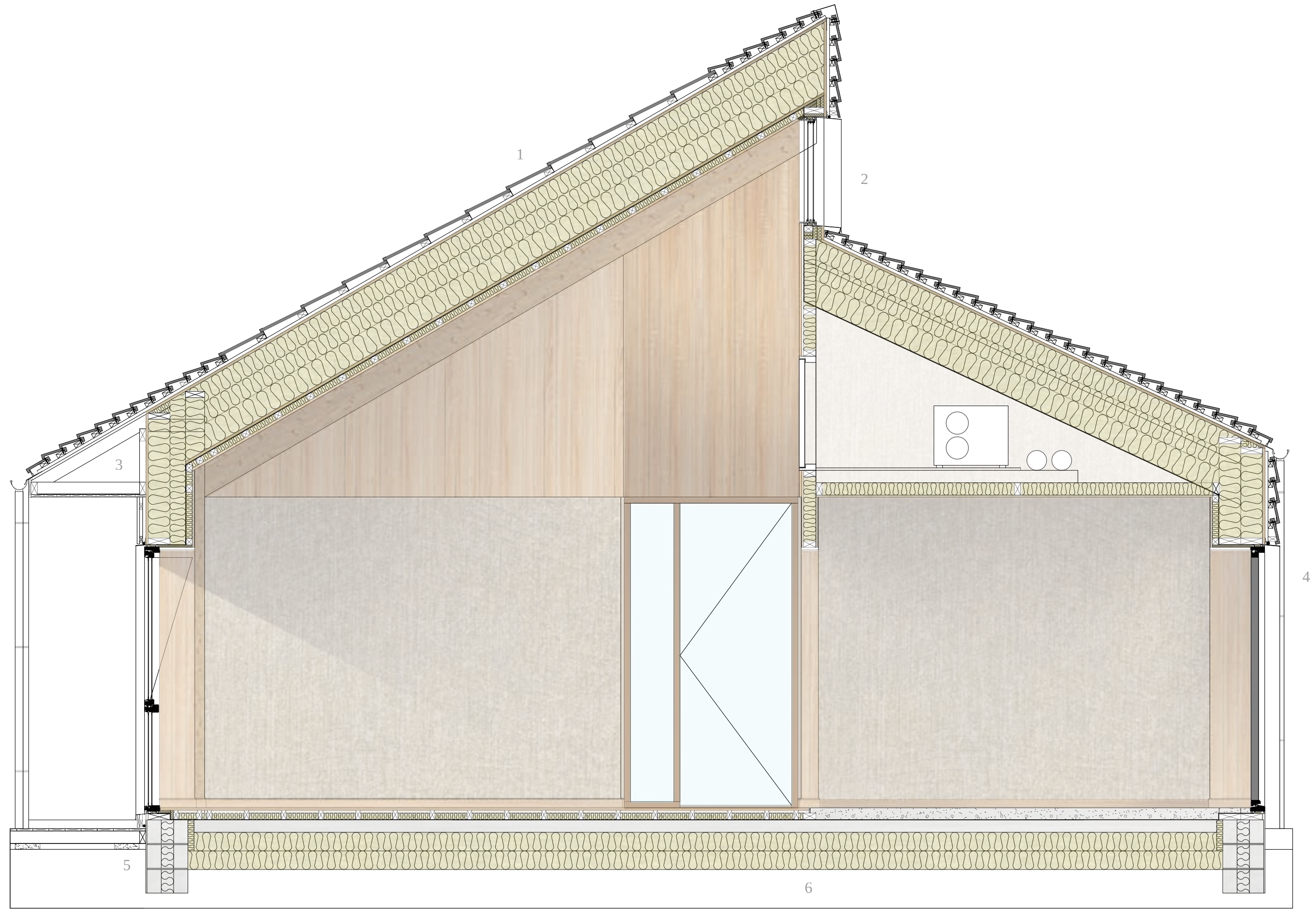


6.



Ill. 108. *Details of construction*

Relevant construction details are shown Ill.108 and described at the bottom of the bulletin. The construction is categorized as a light-weight wood construction. After thorough material combination investigations multiple walls and construction possibilities were approved for use in this project. This gives a variety and resident choice to pick and choose which kind of interior architectural quality they prefer. The different scenarios have their own pros and cons, working with visible structure in ceiling, walls, hidden structure or a combination. The balance between the material choices is consistent and comprehensive throughout the construction, with clear lines and division of the materials giving a clear indication of the natural materials and their use, furthermore how they complement each other in transitions and shades through the house. The house skylight located in the hallway, kitchen area and living room draws a pleasant, diffused light into the room with high ceilings. The surrounding rooms have a ceiling the attic space is where the ventilation pipes are placed without them becoming visible in the interior rooms, taking up space and disturbing the minimal surfaces.



Ill. 109. *Details of construction*

1. Roof detail with integrated solar cells.

Exterior	
22 mm	Solar tile modules (108 W)
38 mm	Counter batten (ventilated level)
25 mm	Batten (ventilated level)
20 mm	Solid decking
150 mm	Insulation
150 mm	Insulation
150 mm	Insulation
20 mm	Solid decking
0.2 mm	Vapor barrier
300 mm	Visible rafter (load-bearing structure)
45 mm	Insulation & counter batten
20 mm	Wood board
Interior	

2. Roof window detail.

Exterior	
35 mm	Façade tile
38 mm	Counter batten (ventilated level)
25 mm	Batten (ventilated level)
20 mm	Wood board (Wind barrier)
200 mm	Construction layer with insulation, roof window and covering (load-bearing structure)
Interior	

3. Overhang and wall (backside) detail.

Exterior	
-	Overhang construction in wood, with visible gutter.
25 mm	Counter batten (ventilated level)
25 mm	Batten (ventilated level)
20 mm	Wood board (Wind barrier)
175 mm	Insulation (load-bearing structure)
125 mm	Insulation
0.2 mm	Vapor barrier
150 mm	Visible pillar (load-bearing structure)
45 mm	Insulation & counter batten
15 mm	Clay board
5 mm	Clay plaster
-	2-part window with covering
Interior	

4. Wall (frontside) detail.

Exterior	
-	Visible gutter.
35 mm	Façade tile
38 mm	Counter batten (ventilated level)
25 mm	Batten (ventilated level)
20 mm	Wood board (Wind barrier)
175 mm	Insulation (load-bearing structure)
175mm	Insulation (load-bearing structure)
0.2 mm	Vapor barrier
45 mm	Insulation & counter batten
15 mm	Clay board
5 mm	Clay plaster
-	Utility room door with covering
Interior	

5. Foundation detail.

Exterior	
-	Wood terrace
20 mm	Covering board
25 mm	Counter batten (ventilated level)
25 mm	Batten (ventilated level)
-	Insect stop
10 mm	Plinth plaster
330 mm	Foundation blocks (load-bearing structure)
0.5 mm	Radon barrier
50 mm	Edge insulation
Interior	

6. Floor detail between two floors with underfloor heating.

Interior	
20 mm	1. Parquet floor 2. 93 mm terrazzo floor
73 mm	1. Batten
23 mm	1. Stationary air (unventilated)
50 mm	1. Insulation
0.2 mm	Vapor barrier
100 mm	Concrete
150 mm	Insulation
150 mm	Insulation
-	Stable gravel
Exterior	

5.5.1 LCA results

The concept of sustainability, which has become a major area of interest and focus within the building policy strategy and the key to reducing the building's climate footprint is by using life cycle assessments (LCA), which have been used to clarify the overall environmental impact across several parameters for some years.

With this development and in connection with the entry of the Voluntary Sustainability Class in 2020 and the planned implementation of the building regulations in 2023, LCA in the construction industry will go from being an interest to a necessity. New constructions and the guarantee of quality assurance determined by LCA help to create a more environmentally sustainable construction industry.

Based on this, greater demands are also made for the tools and methods that are used in the process of determining the building's climate footprint. These databases and information sources in question help to create the basis for the calculations of climate impacts. The data process and material information need to be handled with care in order to give results that are always valid. Also, have an innovation in materials and methods of the construction industry to continue to raise the development and the sustainable quality that is important for our common planet.

In all this lies the importance of having a sustainable agenda through one's project development, according to the collection of knowledge and the design process to achieve a good result and the argumentation of a sustainable construction. The final life cycle assessments for the 3 presented houses of H82, H98 and H136 square meters, respectively, are measured in m² / year, based on having a further basis for comparison with other respective buildings that can be clarified as sustainable.

The values are calculated through LCAbyg 5 with associated databases and in coherence with the established material library, where material properties and environmental product declaration (EPD) have been investigated, selected, and added to LCAbyg. This is done to document the reality of the buildings and create a strong basis for the result.

Two different scenarios have been calculated where the focus has been on global warming potential (GWP). All environmental impact parameters are shown in Appendix 06.

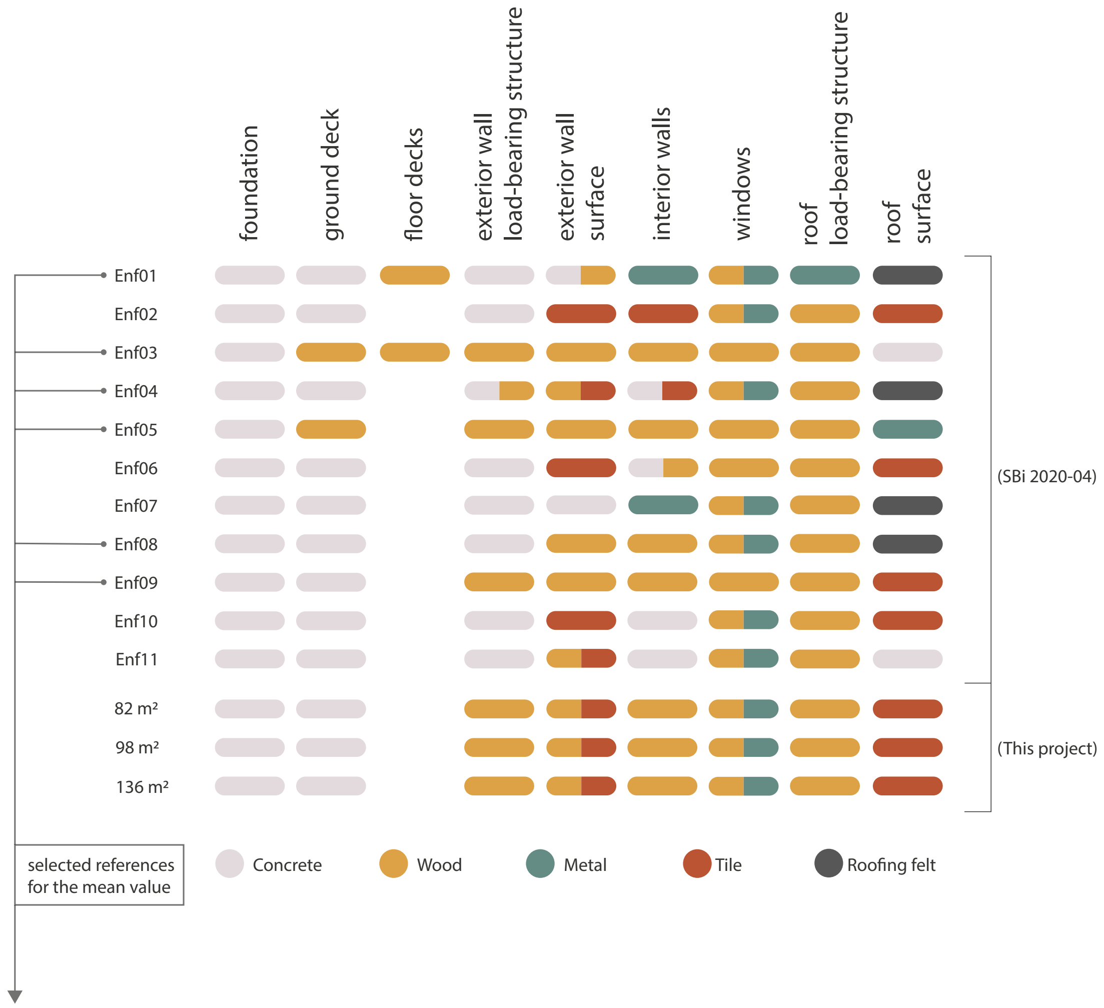
The first calculation uses the most updated data, about material lifetime and how the waste management takes place. It is a more generic process of the materials with the methods used based on the current knowledge, but it still resulted in a low GWP in kg CO_2-eq. / M² / year.

H82	H98	H136
6,31 kg CO_2-eq./m²/year	6,37 kg CO_2-eq./m²/year	6 kg CO_2-eq./m²/year

The second calculation review has been made based on possible savings in waste management (C3-4) and that as many materials as possible are included in a recycling process outside the project (D). This is not a definitive result as there are many other factors and data that are not included or available at the present. The values for the potential savings scenario are.

H82	H98	H136
0,592 kg CO_2-eq./m²/year	0,85 kg CO_2-eq./m²/year	0,559 kg CO_2-eq./m²/year

The building's life cycle assessments (LCA) consist of 5 divided phases and 17 modules, of which 10 of the modules are in the Voluntary Sustainability Class. The missing 7 modules are currently not included based on missing data; however, it is expected over time that they will be included. In addition, the D-phase does not form an actual part of the life cycle and is calculated separately from the other results, this is where there is a great potential for savings and minimization of environmental impacts. However, this requires alternative thinking, method changes and how the life of the materials are processed and treated. There must be a focus on recycling and let it be part of a larger circular system, which considers the large environmental impact of the construction industry. This new thinking is presented and justified in a larger context on the next bulletin.



Ill. 110. Reference buildings

Name	Materials emision GWP [kg CO_2-eq./m²/year]	Br	Energy class [kWh/m²/year]	Solar panels [-/x]	Area [m²]	Constructiontype	Weight [t]
Multiple	6,36	15/20	<30/20	-	<1000	Heavy light	101,775
H81	6,31	2020	23,3	x	82	Light	88,42
H98	6,37	2020	24,5	x	98	Light	107,656
H136	6	2020	21,7	x	136	Light	142,749

5.5.2 Reference buildings

To assess the extent of global warming potential (GWP), data has been obtained from relevant homes to compare results and to be put into perspective and scale. This has been done by reviewing a major report, that analyses the climate impact of 60 buildings that conclusively creates reference values for each individual dwelling type (SBi 2020-04).

The extracted values referred to 11 single-family houses that have been selected based on DGNB-certified projects, external projects and life cycle assessments carried out by the State Building Institute (SBi). The parameters of the 11 case houses are described in Appendix 06, in addition, an updated version of this report has been published which includes updated databases and new environmental product declaration (EPD), which helps to provide a relevant figure to compare with (SBi 2021-13).

Out of the 11 case houses, 6 houses have been selected which match the buildings of this project the most, relating to construction and material compositions. The selection is made matching with relevant material types and discarding buildings that are unsimilar to avoid unrealistic result, there is are calculated a mean value, as seen in Appendix 06. Deriving from the climate footprint in GWP, kg CO_2-eq. / m² / year, the reference mean value and the result from this project corresponds respectable and it is assessed that the newly built project is in the category of sustainable nature.

5.6 Material phase D

As mentioned at the beginning of the report, the construction industry accounts for a very large part of the total CO_2 emissions globally and a quarter of this comes from the building materials. Therefore, the importance of making recycling a focus topic and finding new methods and ideas to improve the quality of recycling and retain the value of materials is seen, in addition, Denmark is already a good at recycling, but there is greater potential underlying in this topic.

With life cycle assessments (LCA) becoming part of the building regulations from 2023, there will be greater requirements for the buildings and solutions must be found to incorporate a process that also includes recycling as an important sustainability factor in a greater extent. To realize this requires a comprehensive documentation and handling of the materials in the demolition phase and towards the recycling purpose.

According to documentation, it is obvious in the context of the registration of material type and quantities in life cycle assessments to compile a data sheet for the purpose of documenting end of life (C3-4) and the specific purpose of the recycling phase (D), this can also be referred to as a material passport or material bank. In addition, the handling of the material according to the specific method and process it is processed in order to obtain the optimal degree of utilization, the qualification of the material in question is an important assessed process that can be taken based on environmental, architectural, technical or economic qualifications, I.e. the current material is reviewed and the potential for recycling within different fields is assessed. Here, materials can then go through one of 4 different categories, direct recycling, recycling, up-cycling and down-cycling. These 4 categories are an improvement, considering that the material still has a potential and greater value by than going to landfill or incineration. The solutions are illustrated through the displayed diagrams and deals with a recycling hierarchy, recycling purpose and possible recycling options.

The recycling hierarchy dictates a downward recycling pattern which tries to meet legislation and building regulations in the best possible way. It is divided into three categories, where new materials primarily start at the top and continue down through until the value of the material has expired and or is forced to go to landfill or incineration. Furthermore, then the 3 categories are divided based on function and size that help to realize possible recycling considerations to conformities. In addition, there is a required percentage of recycled materials, here the specific definition is indefinable and determined based on what is possible in the project, it can be from a load-bearing structural parts, insulation and interior from floor to ceiling surfaces.

5.7 Embedded CO_2

Building materials have a lot of embedded CO_2 which would be bound to this project if the materials were not reused, recycled, upcycled or downcycled. To show how much embedded CO_2 there is a illustration of potential reuse of building materials have been set up. The scenarios cover what the materials could be used for after the building life span of 50 years. For estimations and calculations look appendix 07.

The clay tile is a dominant material use in this project covering roof and two exterior facades. The project uses 3800m² of clay tile, embedded CO_2 is 96 tons

Reuse & recycle

Direct reuse in another building project as roof or exterior wall cladding

Construction wood already has embedded CO_2 because of the natural CO_2 storage wood possesses. The project uses 3800 meters of wood for construction, this gives an embedded CO_2 of 4,16 tons

Reuse and upcycle

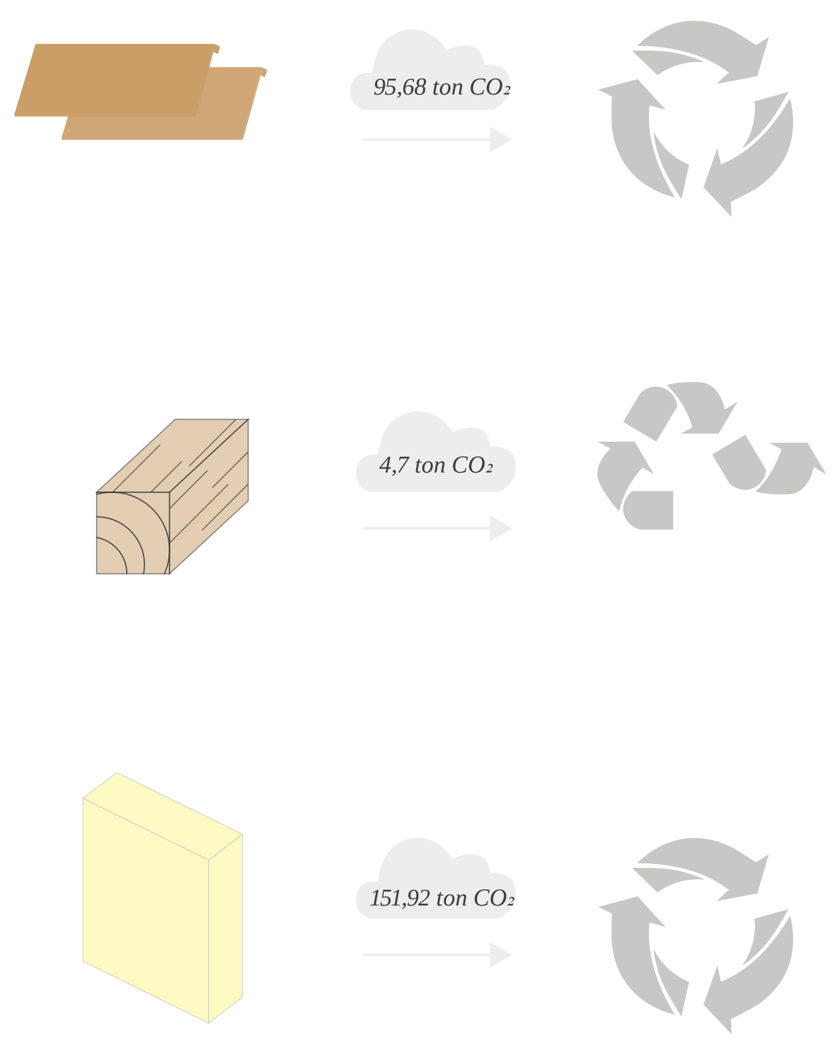
Used for structure in a lessor project

Upcycled for furniture, flooring or cladding

The amount of rockwool insulation used in this project all together is 2769 m³ and The embedded CO_2 is 151,92 tons

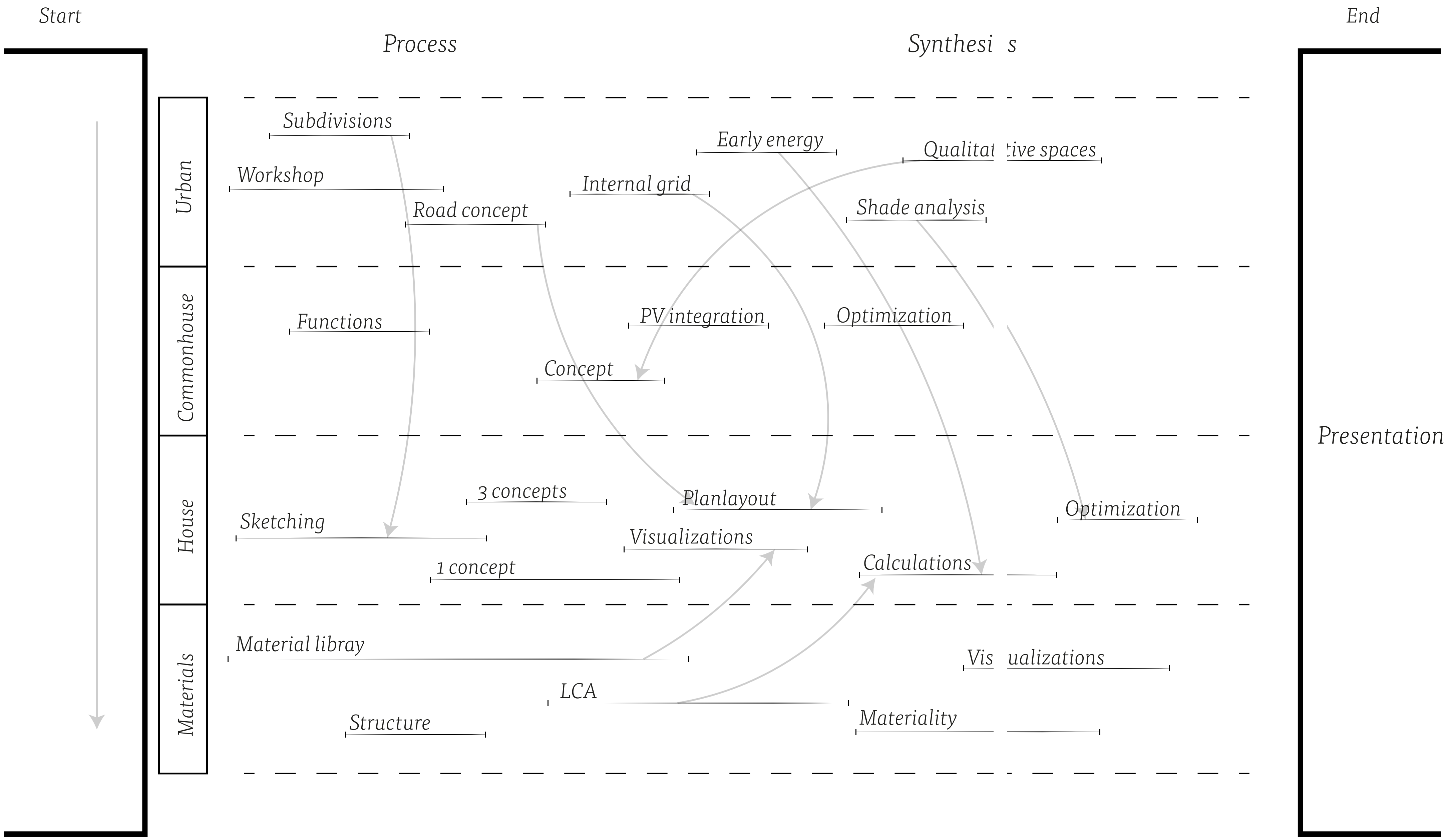
Recycle

Rockwool industry recycle into new rockwool batten



Ill. 111. Collectected possible CO_2 savings

6.0 Design development



Ill. 112. Illustrative way of presenting the design process out of scale

6.1 Introduction

The design process begins in the presented analysis and is shown throughout by the underlying research. As a result, the concept and future revisions and detailing will be shown during this chapter. As the project works in four paths, the design development will have four topics, urban, common house, houses, and materials.

The design process is presented in favour of the reader, but it is more complex than presented. The order of the design development attempts to communicate the investigations and decisions as effectively as possible, however, the process consists of iterations, many of the exercises and analyses are independent and decisions are made parallel.

6.1.1 Word mind map

Society
- *Neighbours*
- *Community*
- *Belonging*
- *Social gatherings*
- *Public, shared & private spaces*

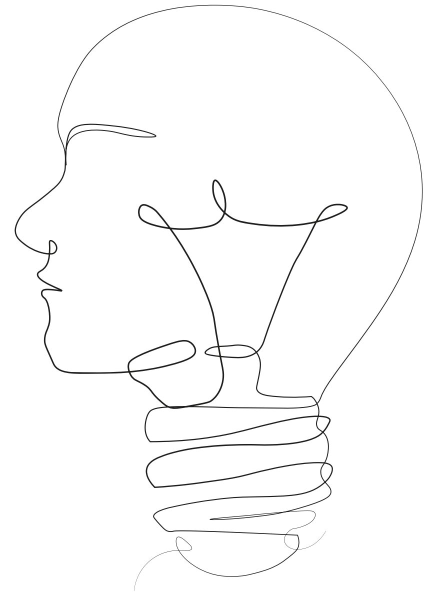
Concept
- *Formed by nature*
- *Private gardens*
- *Familiar*
- *Inviting*
- *Microclimate*
- *Context*

Soceity
- *Gift to local community*
- *part of something bigger*
- *Feeling wanted*

Solar power farm
- *Energy*
- *Sharing the load*
- *Giving back*

Functionality
- *Day care*
- *Zero waste shop*
- *Multifunctional*

History
- *Farmhouse*
- *Save the trees*
- *Remembering*



Ill. 113. Ideas

Unconstricted nature
- *Space for insects*
- *Imperfect*
- *Interesting*
- *Bringing natural views to the buildings*
- *Close connection with nature*

Urban

Common house

Project title

Houses

Materials

Construction
- *Weight*
- *Volume*
- *Non-toxic*
- *Organic*
- *Non-adhesive*

Nordic design
- *Clean lines*
- *Functional*
- *Reason & logic*
- *Aesthetics*
- *Critical regionalism*

Atmosphere
- *Qualitative spaces*
- *Raw use of materials*
- *Designed for family*

Materiality
- *Contrasts*
- *Rough*
- *Raw*
- *Matte*
- *Tactility*
- *Touchable*
- *Robust*

Envelope
- *Transmission*
- *Energy*
- *Tightness*
- *Thickness*

Indoor climate
- *Hybrid ventilation*
- *Less controlled house*
- *Guided rather than constricted*

House a home
- *Personal*
- *Independent*
- *Place for refuge*
- *Feelings & emotions*
- *Sustainable behavior*

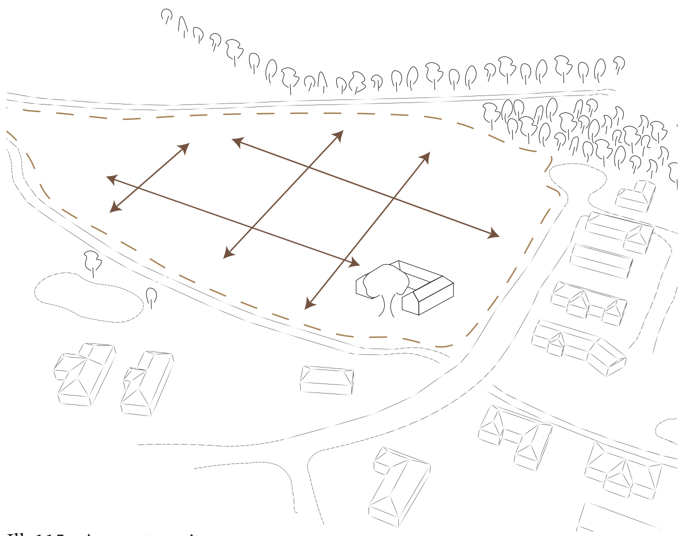
Relation to nature
- *Healthy indoor climate*
- *Views & connection to outdoors*
- *Use of materials*

LCA
- *Material bank*
- *Recyclability*
- *Availability*
- *Environmental impact*
- *Local impact*

Structure
- *Simple*
- *Logical*
- *Design for disassembly*
- *Visible*

6.2 Urban

Ill. 114. Amounts units



Ill. 115. Amounts units

6.2.1 Urban workshop

A physical model was created with a map and existing housing in foam to gain an understanding of the site area and context. To investigate different urban layouts, small foam bricks the size that simulates the floor area of the houses are used. The urban layout revolves around the topic of cul-de-sacs, which can be done in a variety of ways. The various configurations are the result of design criteria, plot sizes ranging from 400 to 600 m², and 20 single-detached units. To begin, the units and plot sizes were cut out to put them into context look appendix 08 for physical model pictures.

The purpose of the task is to understand the different scenarios and complications that follow along the development. In this workshop some themes and concepts have been sketched and developed.

Community house

The purpose of the community house is to provide a shared space for indoor activities. There should be other functions apart from social gatherings, like day-care. The community house should serve the existing local community as well as the new neighbourhood. This concludes at the designated location in the south-east corner.

Less car more bike

A concept of reducing the space the automobile requires, not only for parking but also for street. The typical tract house has a designated car parking area, and a garage included a luxury for car owners. This concept works with no designated parking area.

Street

Part of the cul-de-sac is the safe street; the road is no longer only used for traffic only but as a space for play and social gatherings. This concept works with areas on the street and in-between the houses, spaces suitable for safe play.

Cut the green lawn

With a typical tract house, a garden surrounded by a shrub is often included. This leads to a grid and strict controlled urban development. This project wanted to avoid the green stringy lawn and introduce more wild gardens. A concept would be to relive plot lines and let the boundary lines correlate and create interesting gardens. This would allow untraditional plot shapes and introduce blossoming urban development. This could be done in multiple ways, but the direction is wild and organic.

6.2.2 Three concepts

As the form was growing three concepts were evoked.

First one inspired by the district plan, the plot divided into four division, a place for three cul-de-sacs and a common house. The house and plot compositions created a very tight and grid like structure which didn't have room for wild nature in between houses and adjacent neighbours. The concept worked with three clusters where a social community could be imagined having thrived.

Ill. 116. Concept 1

Second was to collect all shared space and common house in the middle and push housing to the edge of the plot. This idea pushed the private garden to be smaller decreasing the amount of personal owned space to increase public shared spaces. An idea of all neighbours and children would communicate and interact across the public spaces, all to meet in the middle. This was a very different urban plan layout than the rest of the residential area.

Ill. 117. Concept 2

Third was shaped by an idea of rainwater collection, as the project focus' on nature to allow the urban plan a natural shaping. The natural shaping and utilization of the current typography seemed like a qualitative way of urban planning which focused on thriving wild nature. This created a different idea of a private backyard with a shared stream

Ill. 118. Concept 3

Ill. 119. Urban concept 1

Pros

Calm and safe roads dead end roads

Strong concept with rainwater streams, good urban quality

Good quality private backyards

Small niches in the urban for public spaces

Cons

Less space for common house plot and parking

Pros

Lots of potential for wild nature in the middle

One big community

Space for sport collective and social gatherings

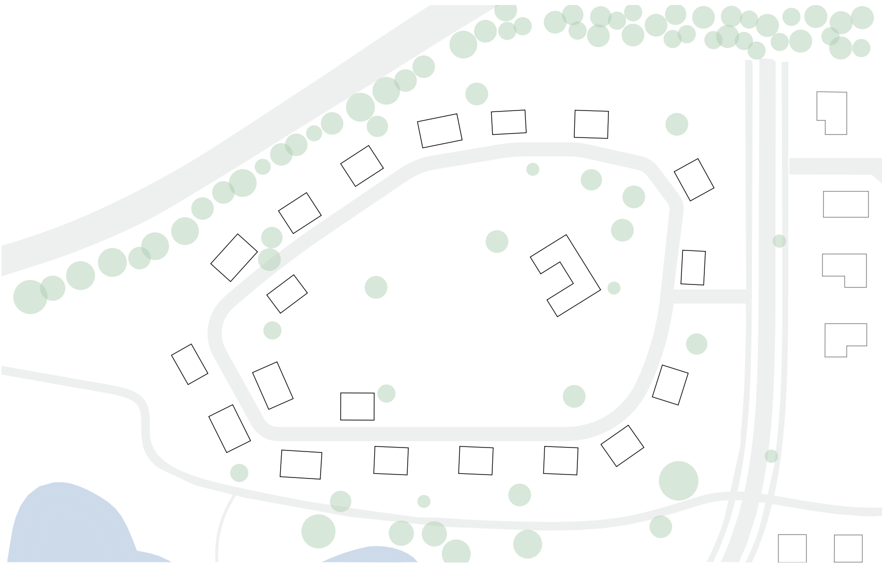
Cons

Potential risk of busy road

Common house is surrounded, cuts of the other neighbourhoods

Risk of less qualitative gardens

Social level might be overwhelming



Ill. 121. Urban concept 2

6.2.3 Urban concepts

Three urban concepts were created out from model and sketching iterations. The specific sizes of the plots and houses were visualized to see the relation between the houses and the quality of the concepts.

Working with plot sizes in the range of 400-600 m² and twenty units plus a common house the relation to the garden, the road and neighbours were investigated. A shadow analysis helped to grant an understanding of the garden sun hours and possible future problems of plots look appendix 09. The concepts went in different direction and therefor had different values.

To continue the design process one concept had to be picked, listing the pros and cons of the concepts helped to navigate and reason the choice.

The first concept grew from an idea of a natural shaping parameter, rainwater, creating streams in the backyard as natural rainwater collection.

The second concept worked with a combined big space in the middle of the site, pushing all house to the edge of the site.

The third concept was inspired by the surrounding urban areas, continuing the format, and keeping it simple.

Pros

Calm and safe roads dead end roads

Potential for social gatherings

Good location for shared common house

Cons

Safe choice, less adventures

Little space for wild nature

Ill. 120. Urban concept 3

6.2.4 Urban concept iterations

Ill. 122. First urban iteration

Ill. 123. Second urban iteration

Ill. 124. Third urban iteration

Ill. 125. Fourth urban iteration

The third concept was chosen because of its benefits. The idea was inspired by conceptual rainwater streams, which arose from a topography model based on gravity and elevation levels (see appendix 08: model pictures 3). The rotation of the plots and houses provided an opportunity to incorporate the use of solar panels; the roof design allowed the solar panels to be placed on either the southwest or southeast roof side. Different scenarios were created as the urban areas and plot sizes were tightened and iterated. The idea was to have the rainwater streams flow naturally through the site and the houses conform to this. However, for the plots to be reasonable sizes and shapes to be sold and know who owns what, the streams had to be edited. The stream should work as additional urban quality and sometimes work as plot divider, having neighbours share stream and possibly a bridge.

First iteration worked with three bulbs who shared the same road as the common house, pushing the roads away from the houses Ill. 122.

Second iteration re-established the road and located it near to the road north of the site. The new house pattern created more gardens directed towards south gaining more sunlight hours hitting the garden Ill. 123.

Third iteration work with a combined clove road, reducing road area and allowing more free space for nature areas to thrive. This iteration continues in the same direction as the previous one Ill. 124.

Fourth iteration combined the clove with a roundabout to create zoning and division between the cul-de-sac's, social identity, and independence Ill. 125.

6.2.5 Urban qualities

Public - semi public – private

The urban public and private zones were sketched in the different iterations to visualize placements of benches, recreational areas like, playgrounds, outdoor fitness, small landscapes and public petite gardens.

Ill. 126. Public private zones

Rainwater iterations

Rainwater streams began as a form shaping element, but as the process progressed, the houses and practical placement of the stream had to be changed. Creating a controlled but useful rainwater collection system that will be used as plot sectioning in conjunction with a variety of bushes for a less typical tract house garden sensation.

Ill. 127. Rain water streams

Walking connections

The cul-de-sac have previously been criticised for being confusing and petulant when it comes to transport, the focus of the urban concept has also been on the connections and paths that can be used by pedestrians and cyclist. The car is a secondary transport option for the residents of the project, the focus is on the human scale transport choices.

Ill. 128. Walking connections

6.3 The Common house

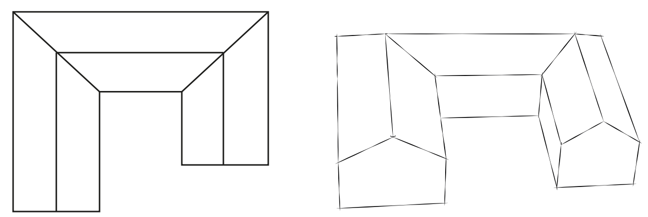
To give the whole neighborhood something to gather around and have more possibilities that they do not have in their own houses, a common house was introduced. The common house will have functions that could be used during the week for different types of social gatherings. The purpose is to introduce rooms that can accommodate functions for a daycare, a couple of external office spaces, a small fitness, large common room for social events, different workshop rooms and an industrial kitchen, usable for anyone in the common house.

The idea and sketching for the common house take its beginning from the history in the context, with an old farmhouse that have been demolished and next to it was a large oak tree that have been giving the status of conservation value. The value of this is important and it is related to the natural importance of Sorø municipality and should not be excluded as a factor in a design process.

Furthermore, in conjunction with the municipality's values the common house creates the context for social community that thrives in coherence with each other. The common house key values are socializing and nature in a sustainable perspective.

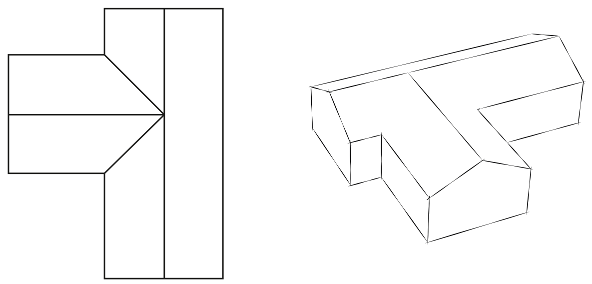
6.3.1 Concept

First concept mimicked the layout of the old farmhouse, working with zones around the common house with a sheltered semi courtyard which could be used as exterior zones for social events. This concept was related to the surrounding history of farmhouses, remembering the agricultural history and use of livestock in Sorø.



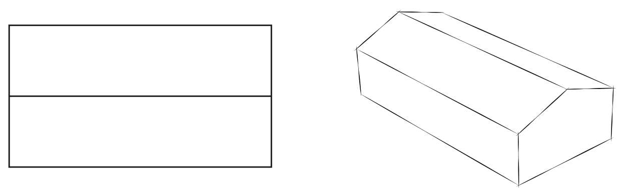
Ill. 129. Commonhouse concept 1

Second concept is a modifed version of concept one, using the same type of roof, but morphing the form into a more compact house. This concept creates zones around the houses which could be used as an extension of the house during summer.



Ill. 130. Commonhouse concept 2

Third concept was a simple form which reminded of the new houses, the interior should be designed to have different functions planned to work coherently. The roof was inspired by the old farmhouse having tall gables.



Ill. 131. Commonhouse concept 3

6.3.2 Ideas and function

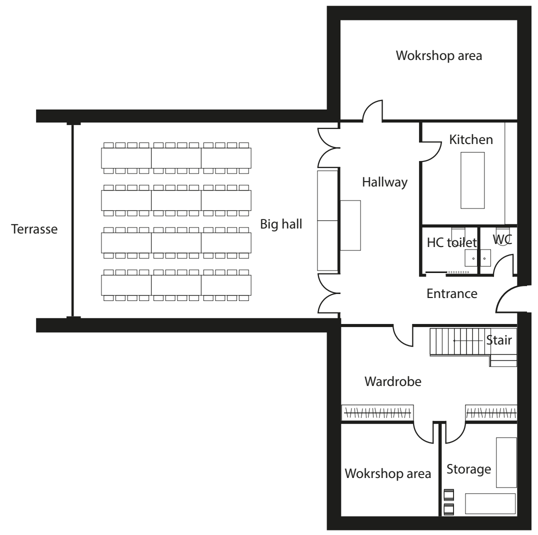
The idea and purpose for the communal house and its functions are to set an example for a sustainable agenda in the neighborhood with an environmentally sustainable house in terms of materials and energy consumption, that can with flexible spaces have different functions and workshops the focuses on social and environmental sustainability. This could be as following:

Ill. 134. Common house placement

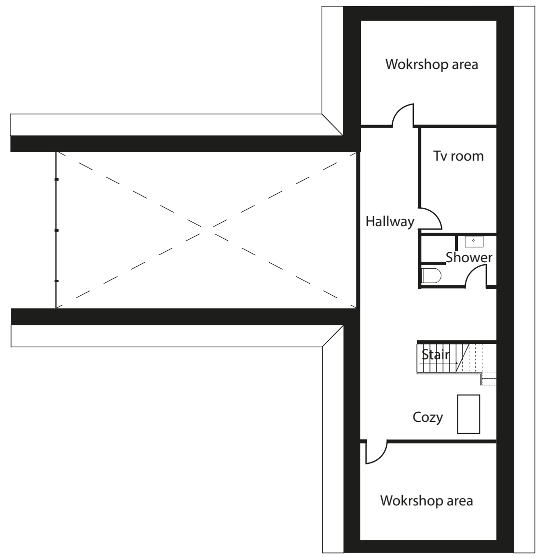
Social sustainable. Functions/workshops with sustainable purpose: Clubhouse, events and social gatherings + kitchen, Rentable office space

Fitness, Daycare, Natural outside/urban area with space to fun (playground, small field + some goals) and smaller spots to relax and enjoy nature

Environmentally sustainable. Functions/workshops with sustainable purpose: Recycling station of old stuff that is not broken and other useful stuff (book, chair, glass etc. and materials), gardening, food waste, rainwater collection,"handyman" workshop, learn to build stuff



Ill. 132. Common house 1st floor

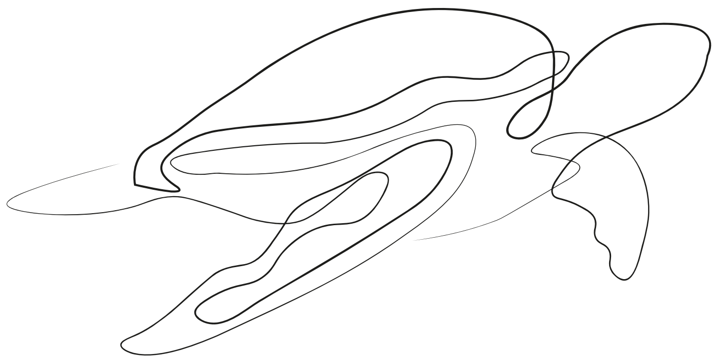


Ill. 133. Common house 2nd floor

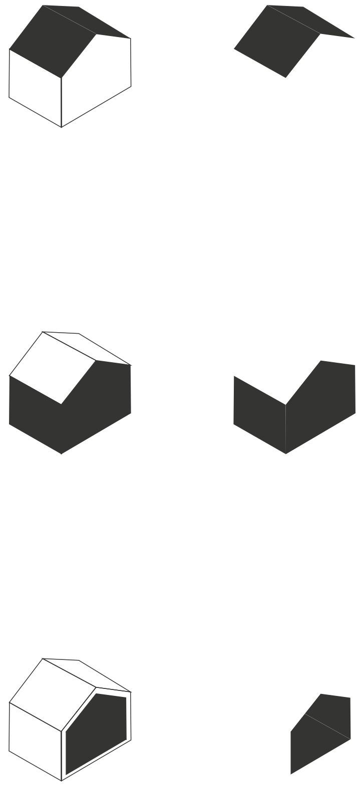
6.3.3 Integration of pv

With the idea about the communal house as a good example and frontrunner for sustainability with is purpose, functions and workshops to the community, so they can learn and hopefully bring some knowledge back home in their own home. Furthermore, have the building a low energy consumption at 25 kWh/m² year with its passive and active technical parameters as shown. The rest of the energy consumption is balanced by solar cells so that it reaches 0 kWh/m² year see appendix 11. The chosen solar panels are integrated modules for tiled roofs interlock with any concrete or clay tile. The tiled solar roof panels have a peak power of 108W and an efficiency of 19%. The needed area of solar panels is calculated in the following section.

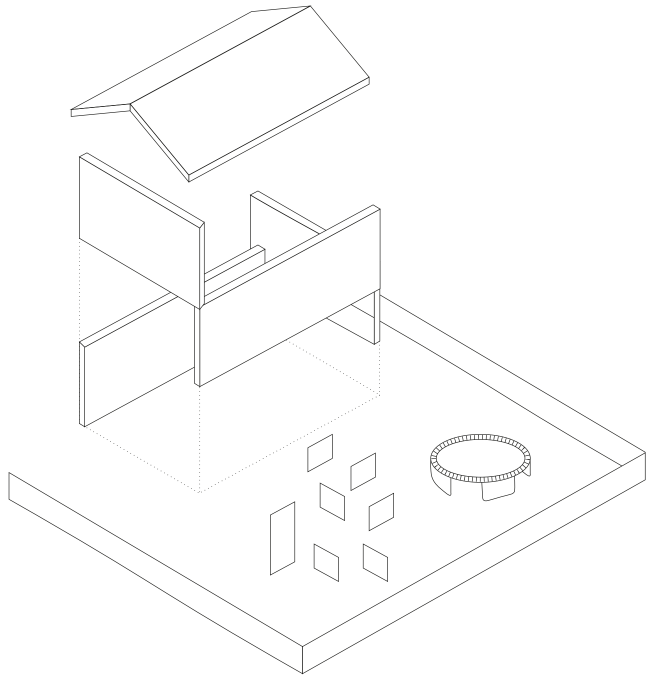
6.4 The House



Ill. 135. Turtle illustration



Ill. 137. House layers



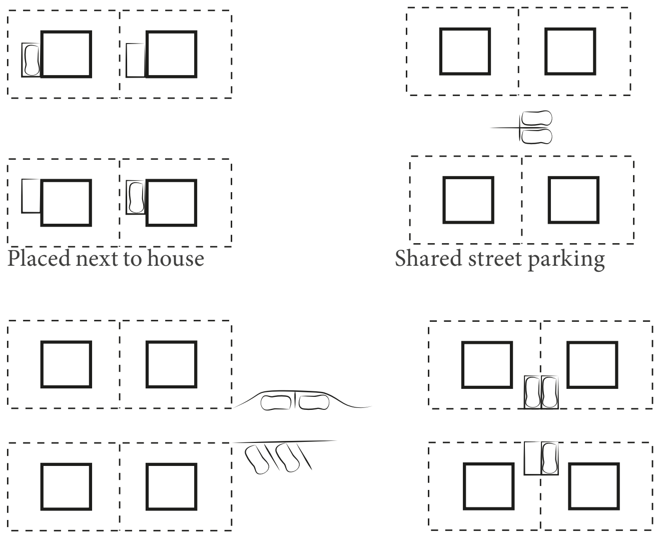
Ill. 136. House components

6.4.1 House concept

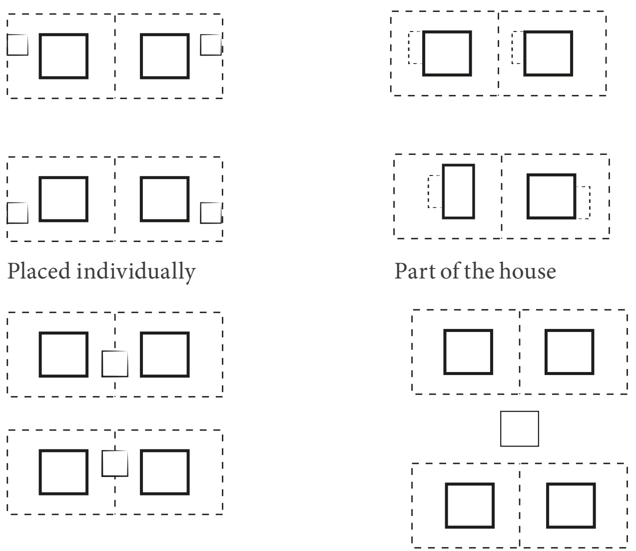
The house concept was initially motivated by the clever use of materials and the consideration of design for disassembly. This formed the foundation for the concept, dividing the house layers, roof, walls, and interior. The plan was to build a shell into which the family could retreat when they wanted to spend time together; the house would then have a soft backside towards the garden. The shell should be composed of tough, dense materials, while the backside consists of softer, organic materials. As the wall evolved into the roof, it became a part of the shell as well. The street had an organic shape, and the house shells were cut into the plots with straight lines intersecting at a perpendicular angle. The shell should also protect the soft side by acting as an overhang to help the organic materials last longer.

6.4.2 Concept iterations

To reuse the building materials, they need to be deconstructed from each other without the material losing quality. Initially, the oncept of protecting walls grew alongside the one façade facing the street, creating zones Infront and behind this wall. This concept grew and consumed the roof and one exterior wall. Working with different plan solutions it was at one point an external unit with designated utility room. One concept was to have a dense heat capacity wall running down the centre of the house, emphasizing the passive system of absorbing and releasing energy reducing indoor temperature fluctuations.



Ill. 141. *Parking opportunitets*



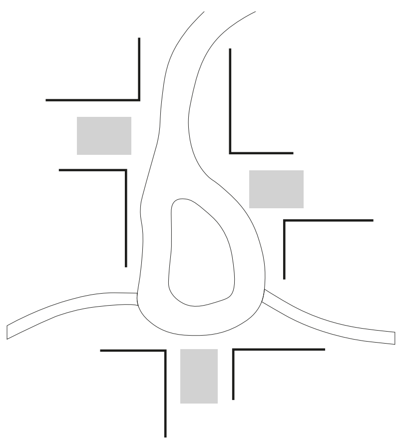
Ill. 142. *Parking oportunities*

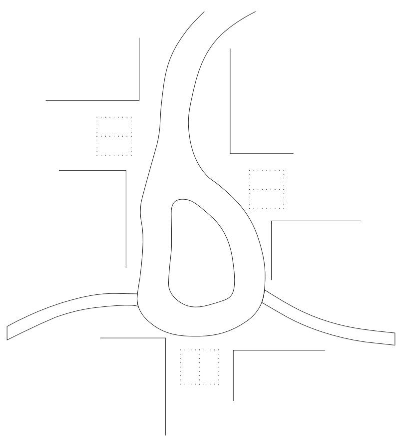
6.4.3 Parking

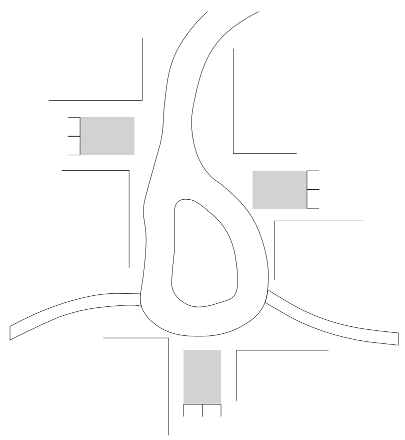
The parking considerations was sketched to investigate different solutions. Having a focus on sustainability and the use of alternative transportation methods, the car parking was shared. Sharing spaces and reducing the covered areas allowing more green areas but still providing parking. The parking should be practical and benefit the residents, so daily life like groceries doesn't become an irritation.

6.4.4 Tool shed

As owning a plot and living in the suburban area, it requires more space to stock tools, bikes and other. The storage unit does not need to be heated and therefore the shed can be either part of or separated from the house. Garden utilities and other tools which can be shared, should be shared with the neighbour, encouraging less use of material good and social behaviour. The project wants to design for sustainable behaviour a covered drying rack was also sketched.


Ill. 138. *House placement*


Ill. 139. *Parking indication*

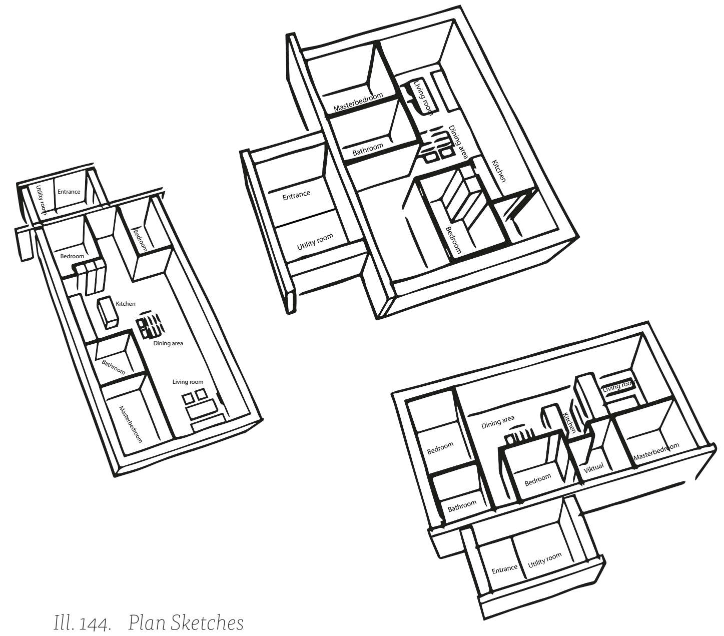

Ill. 140. *Shared tool shed & drying rack*

6.4.5 Unit sketching

The plan solution sketching originates in the typical track house plan, considering the different aspects of privacy, logistic, exterior, and interior connections. Integrating the different parts of successful plan with microclimate and energy consideration. Other things to include in the design development of plan are biophilic design, flexibility and the amount of people living there. Plans from tract houses and Nordic architectural villas were used as inspiration, look appendix 12 for plan inspiration. Looking at what appeared to be good solutions and comparing the two types of plan solutions.

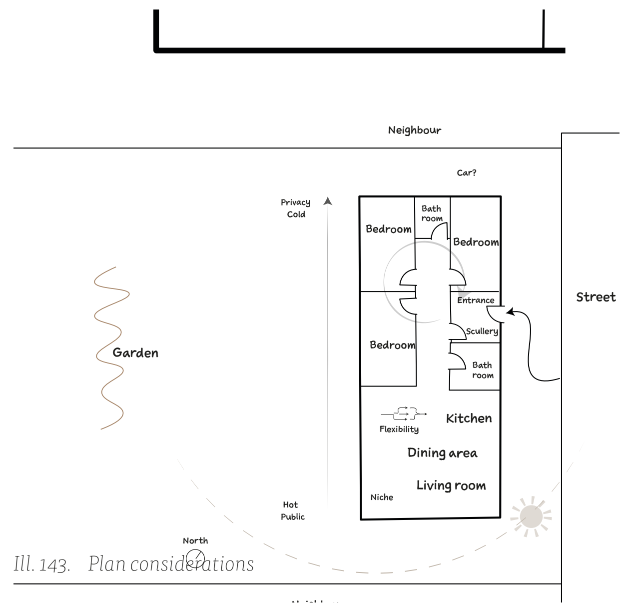
The development of the house plan has been a lengthy process influenced by functionality, privacy layout, energy optimizations, masterplan layout, and so on. Many ideas have been tested to determine which type of layout would be successful. Size, flexibility, biophilic design, and window placements were all factors to consider when designing. Some of the ideas were presented here, but for more sketching, see the appendix 13. The shaping of the concept made it, so the long house has become the general shape of the houses.

Ill. 145. *Initial plan sketching*

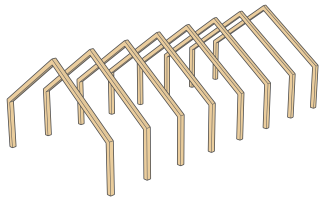

Ill. 144. *Plan Sketches*

6.4.6 Iterations

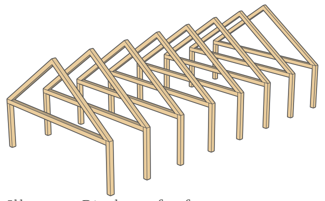
The initial round of sketching focus on the layout of the houses, fitting in the function for the different units' sizes of 90 m², 110 m² and 130 m². The analysis started with examples of tract house plans, analysing what works and what doesn't. The problem was that the examples didn't consider the orientation of the house and the placement of other than car and street. Nordic architecture focuses on the surroundings, microclimate, and views. Is it possible to incorporate Nordic design ideologies with Danish suburban location? The project wanted to focus on plan layouts that were designed to the specific microclimate and plot location. Considering the rooms position and use throughout the day, the level of privacy and intimacy. The task was done with simple lines in Illustrator, paint, and 3D models all drawn in either Revit or Sketchup.



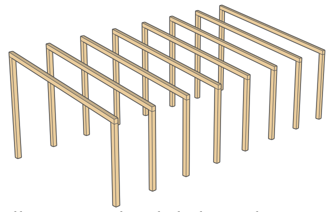
Ill. 143. *Plan considerations*



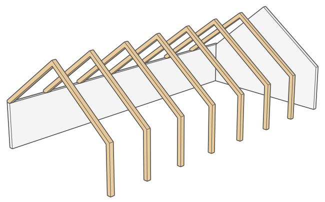
Ill. 146. Pitched roof wood structure



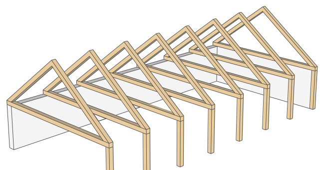
Ill. 147. Pitch roof raft structure



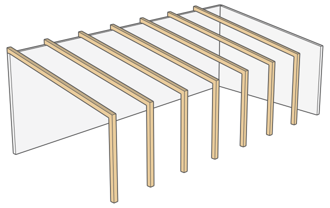
Ill. 148. Single sided tilt wood structure



Ill. 149. Pitched roof combined strucutre



Ill. 150. Pitch roof raft and wall structure



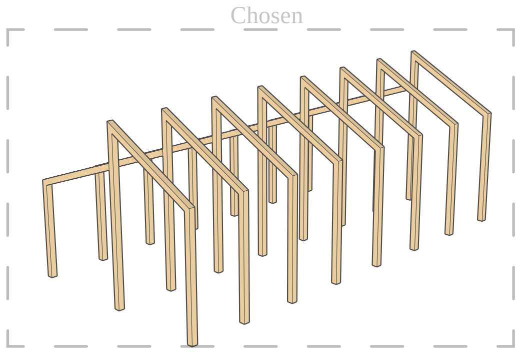
Ill. 151. Single sided tilt mixed structure

6.4.7 Tectonic

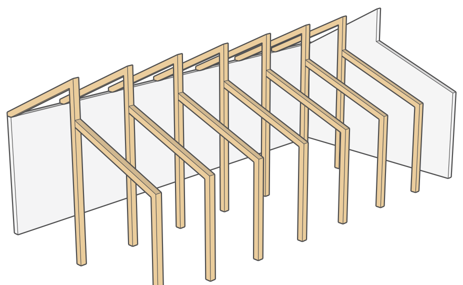
The tectonic of the house were considered next to material selection, the chosen material dictates the tectonic concept. Two main concepts were circulated during the longest of the process, a structure purely of wood and one mixed with heavy walls. The heavy wall could be made of any heavy material and was part of the original house concept of bringing a denser structure. The reason for having a dense wall was the idea of reused bricks, the reused brick has many benefits including a high thermal mass.

The classic masonry brick was replaced with a clay tile during the process, which has other benefits. Due to this exchange, the structural use of the heavy wall was excluded.

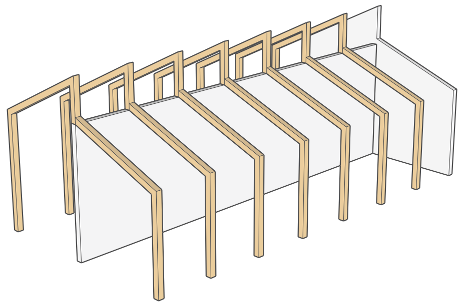
Considerations for the connection between the wall and the roof, as well as the detail. The connection between the wall and the roof has been subjected to a scenario of multiple solutions. The idea was to use a full masonry wall, where the need for a vapor barrier is less important than in other structures, such as a wood roof. The structural connection between the two should be made not only for aesthetic reasons, but also to avoid future rain, snow, and wind problems Ill. 155-157.



Ill. 152. Staggered pitch roof wood

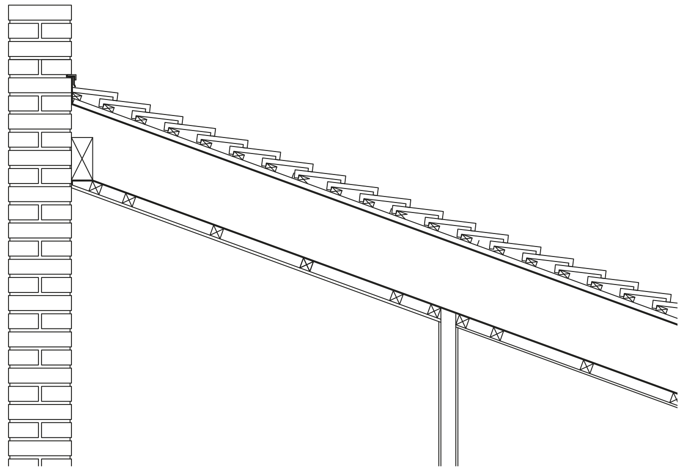


Ill. 153. Staggered pitch roof mixed

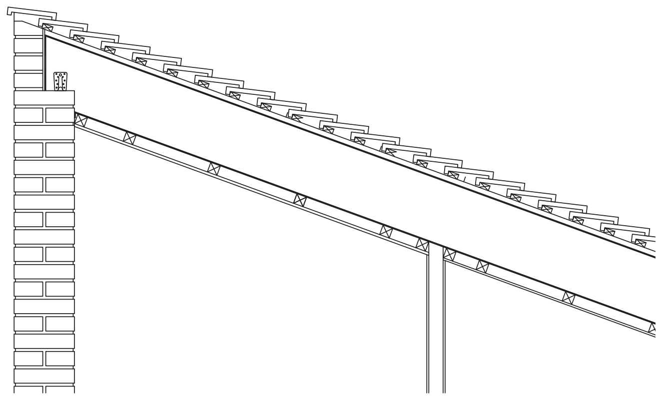


Ill. 154. Staggered pitch roof heavy wall mid

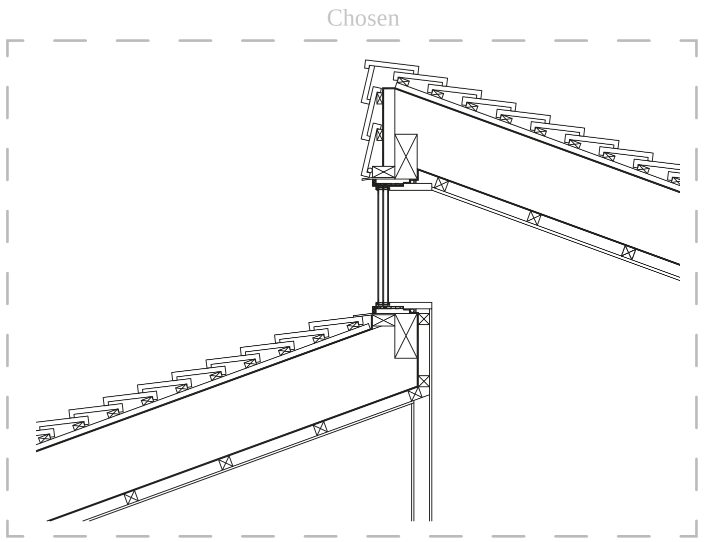
6.4.8 Connections



Ill. 155. One-sided roof slope, mounted on the wall



Ill. 156. One-sided roof slope, optimized solution on the wall



Ill. 157. Two-sided roof slope, staggered

Concept constructions are investigated and roof slope and roof ridge solutions are assessed.

1. One-sided roof slope, mounted on the wall

2. One-sided roof slope, optimized solution on the wall

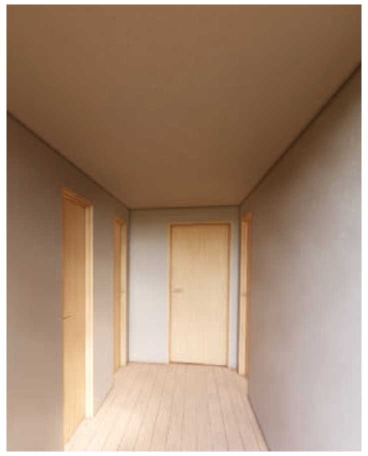
3. Two-sided roof slope, staggered

The goal of the study with the roof construction is to end up with an overall similar roof structure that can adapt to the context and the specific plot, so the house can be optimized. That is, the house roof construction is not locked design-wise too early to avoid possible complications further in the design process.

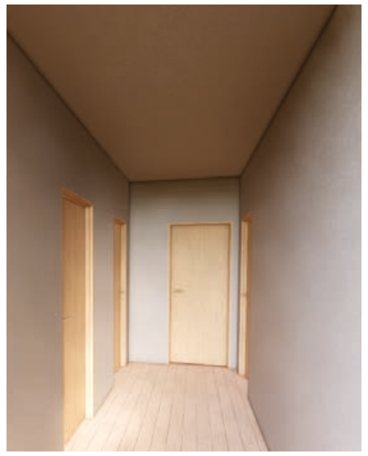
The development in the concept works with surfaces and clarification in the indication of materials to bring out the qualities of the material. At this stage, work was done on the concept that weight should be an indicator for creating clear lines and producing quality in heavy and light elements, here we work with a heavy front and the joint with the roof. The adaptations of the concept come in the possible problems that may occur in the solution of "One-sided roof slope, mounted on the wall" and the limited adaptations to different orientations and the internal influences that come based on this. The detail is further investigated in an optimized construction solution in "One-sided roof slope, optimized solution on the wall", but by creating own parameters to push the design in composition with the context and floor plans. Thereby it is assessed that there must be a concept change in the roof shape and "Two-sided roof slope, staggered" is introduced where opportunities for qualitative ventilation and daylight solutions are opened, in addition, to greater adaptation options to the individual building plots to achieve the full potential for all buildings.

6.4.9 Realtime render

During the design process, real-time render was used to visualize the editing and changes made in the model. The size of the furniture, the spacing and zoning of the living room was investigated using real-time render. The quality of the space depends on so many things and the combinations of materials is big part of Nordic architecture.

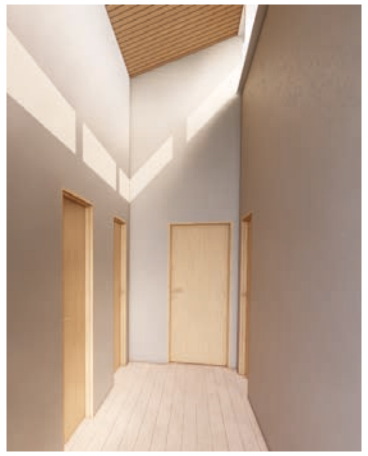


Ill. 163. Hallway low ceiling.
A ceiling height of 2500mm



Ill. 158. Hallway ceiling.
A ceiling height of 3000mm

Chosen



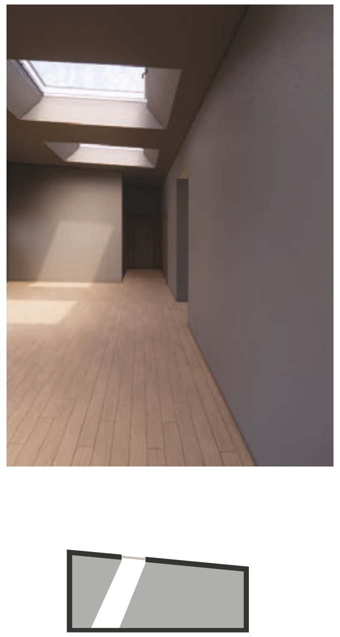
Ill. 159. Hallway open ceiling
It was tested to open up

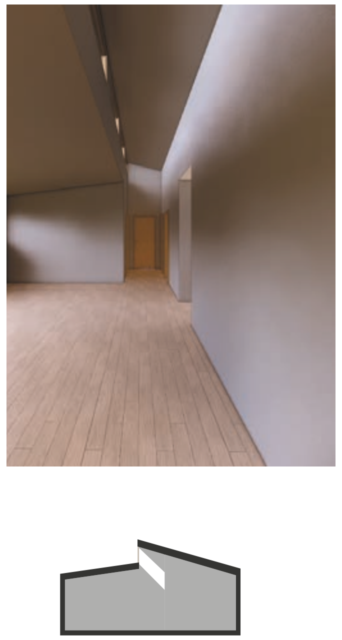
Ill. 162. Living room
The space of the livingroom was tested

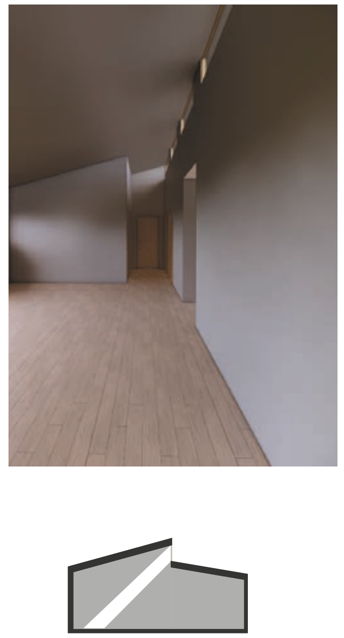
Ill. 161. Living room
The atmosphere of the living room with materials

Ill. 160. Living room and kitchen visible
Looking into the affect of visible structure

Chosen







	Single sided	Vest oriented roof	East oriented roof
Hours > 27	186	152	156
Hours > 28	73	53	49

Ill. 164. Single sided

Ill. 165. Vest oriented roof

Ill. 166. East oriented roof

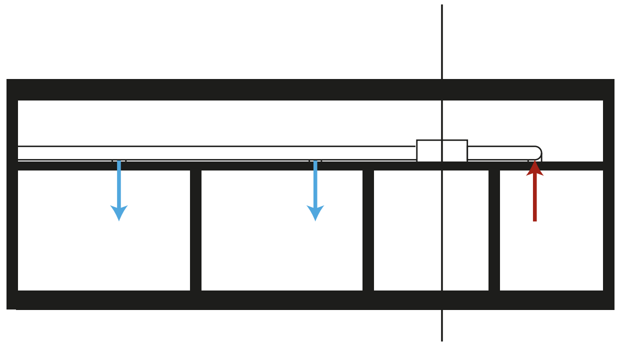
6.4.10 Roof solution

The initial roof formats originated in typical housing roofing, with an inspiration from Danish building traditions. The hip and half hip roof have been a great part of the house process. The individual appearance of the roof, the connection with the neighbour's roof and the interior ceiling opportunities the different roof types gave was part of the selection tools.

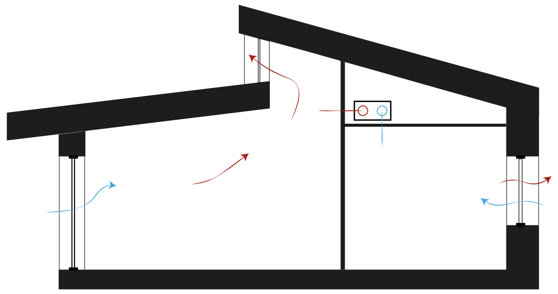
The installation of a skylight or a window just below the roof has numerous advantages. The introduction of thermal buoyancy ventilation, which allows hot air to be exhausted through these windows, is one example. Another advantage is the abundance of passive solar gain and natural light. The windows can also be used to make a statement or to highlight a particular architectural feature. The modern envelope has grown in thickness, and the window is very thin, creating a contrast that can either conceal or highlight a detail.

A workshop was held to examine the integration of high-level placed windows and skylights in order to better understand the various factors. The task focuses on the amount of energy saved during the winter, the risk of overheating during the summer, and the amount of daylight factor. To compare solutions, values are assigned to each, including not only energy but also architectural aesthetic and atmosphere. The various scenarios are contrasted with one that does not have any roof windows.

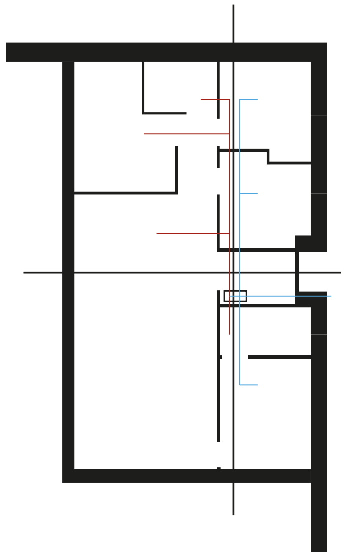
The roof can be moulded in a variety of ways, but a composition with staggered kip, allowing for a vertical openable window, seems appropriate for this project.



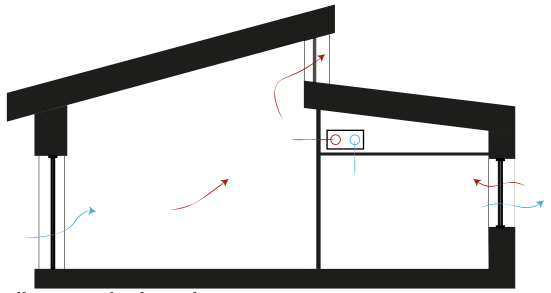
Ill. 167. Mechanical ventilation



Ill. 168. Hybrid ventilation



Ill. 169. Mechanical ventilation plan



Ill. 170. Hybrid ventilation

6.4.11 Ventialtion princip

With hybrid ventilation, the emphasis on natural ventilation and concealment of mechanical ventilation has been possible, as has the design and layout of units. A high ceiling was expected to improve the quality of the living room and kitchen while also utilizing buoyancy in the natural ventilation system. Natural ventilation was thought to be a low-energy cooling method during hot summer days because hot air circulates and escapes, creating cool breezes. Appendix 21 contains a scenario of the efficiency of a natural ventilation system based on window area, window opening area, neutral plane, pressure difference, and airflow.

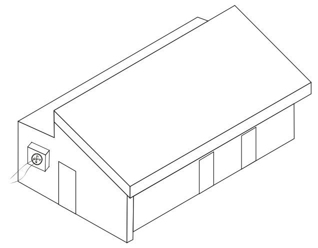
Mechanical ventilation is required due to the need of heat recovery. When incorporating the system into the house designs, there were a few factors to consider. The systems were always intended to be concealed and to attract as little attention as possible. The pipes should be designed so that the air travels the shortest possible distance, keeping the system as efficient as possible. To avoid recirculation of contaminated air, the intake and exhaust positions should be at least two and a half meter apart if horizontally placed and one meter if vertically placed (DGNB-System Denmark Bæredygtighedscertificering af nybyggeri og omfattende renoveringer, 2020).

Then, in the center of the house, a central aggregation system should be installed. Because of the potential for noise and irritation, the aggregate should not be placed over bedrooms. In terms of frequent filter changes and other maintenance, the system should be easily accessible. The obvious place to hide the ventilation system was in the ceiling, but a desire for high ceilings complicated matters. There were several iterations of aggregate placement as well as roof format.

6.4.12 Active strategies

Depending on the system chosen, active strategies are used to reduce the energy use of the building as well as the energy cost from external sources such as heat and electricity. It is possible to help reduce carbon emissions over the life of a building by utilizing these systems. Some systems provide a level of independence that can be useful in certain situations; the systems actively help to reduce the energy demand of the house, reducing the pressure on the grid, which will be very beneficial in the future.

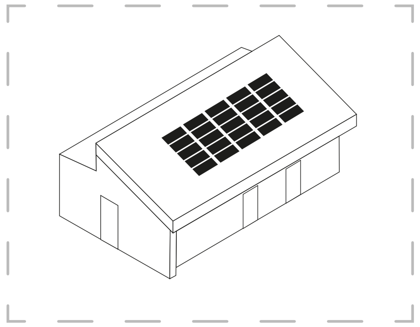
Air-to-air pumps are simple to install and disassemble, but they require extensive maintenance and are noisy. Furthermore, the aesthetic aspect must be considered, as they are quite visible both on the interior and exterior. The source of heat comes through blowing in hot air, to some is annoying.



Ill. 171. Air to air heat pump

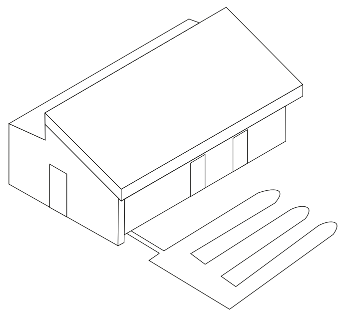
Photovoltaic panels draw energy from the sun, which dictates the placement and angle of posotioned surface. The panels produce a lot of energy when little energy is needed, during the summer most houses produce more energy that they use, the energy can then be send back to the grid strengthening the local electricity network.

Chosen



Ill. 172. Photo voltaics

Geothermal heat pumps extract heat that has been heated by the sun from the ground. Heat is transported through fluid-filled pipes buried beneath the earth's surface. The heat pump consumes energy to circulate but produces four to five times the amount consumed. The pipes are a significant investment, and they must be installed on a large amount of earth.



Ill. 173. Geothermal heat pump

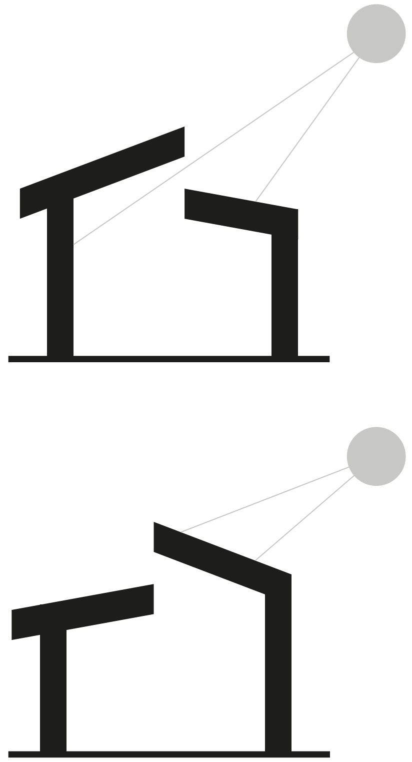
6.5 Optimization

6.5.1 Roof direction

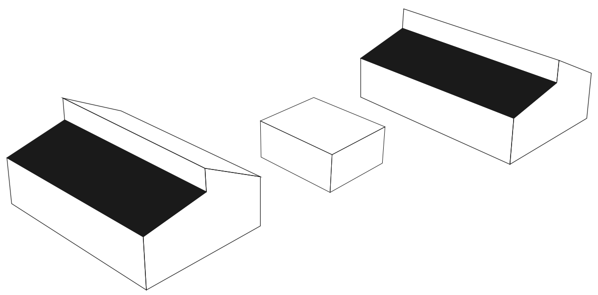
There was a discussion of having the roof window orient towards south or west to contribute to passive heat gain and allowing the suns light to travel through the day on the ceiling and walls of the house. The problem was that the angle of the roof determines potential solar panels efficiency, having the ceiling windows directed towards south, made it so the solar panels had a small area, and the angle were low.

The roof could be flipped to have the angle window point towards east and north, this window would gain very little passive solar gain, but would contribute with dimmed diffuse northern light. The northern light would become brighten the room in a calm way and not have the dramatic effect of the sunlight walk through the day.

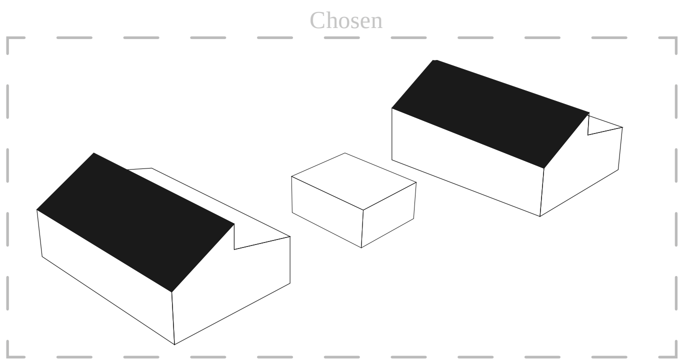
To help choose between the two options solar radiation analysis were made, simply having the low angle towards south and west in the first analysis and then mirrored having the steeper roof oriented towards south and west (Look ill 166-167).



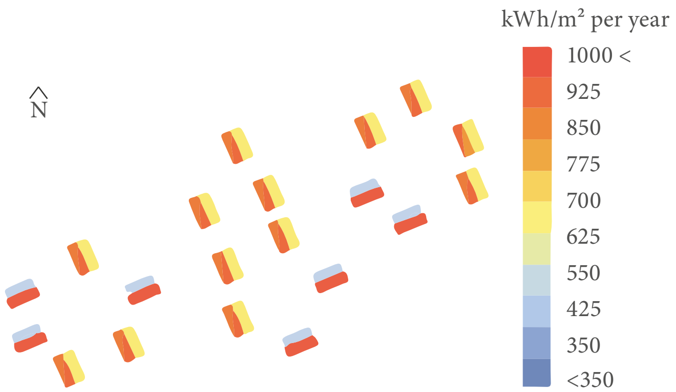
Ill. 178. Roof orientation



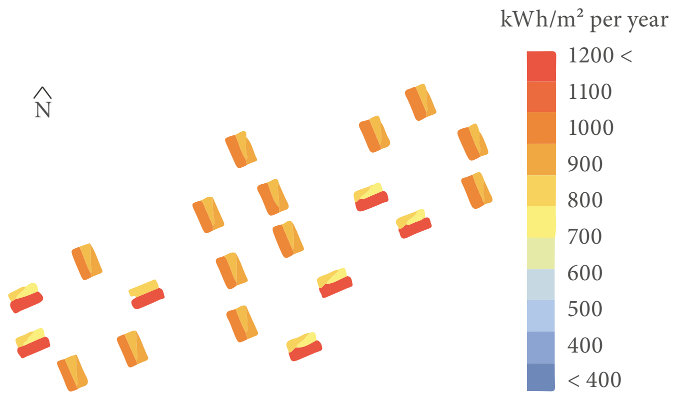
Ill. 176. Low angle south oriented roof



Ill. 177. High angle south oriented roof



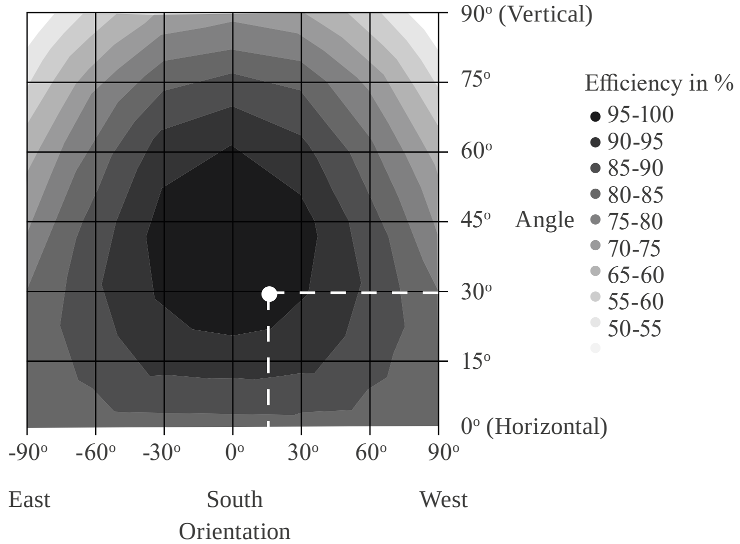
Ill. 174. Low angle south oriented roof.
Initially there is nothing wrong with amount of sunlight hitting the low sloped roof.



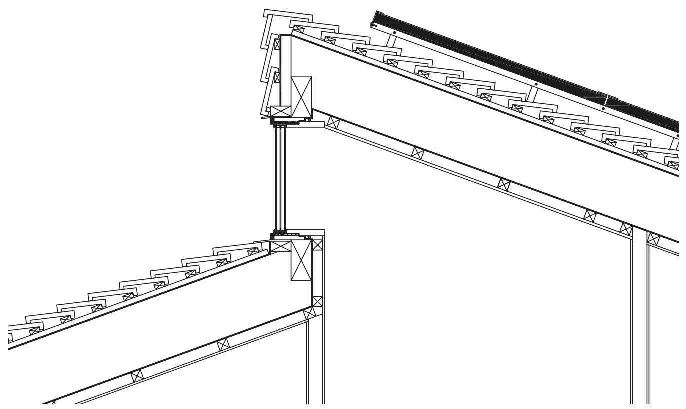
Ill. 175. High angle south oriented roof.
The scale of the solar radiation is bigger comparing to the other graff, this shows an important difference.

6.5.2 Pv integration

The amount of energy collected is determined by the angle and direction of the solar panels. The amount of efficiency that can be obtained with a given angle and orientation can be read from the graph. The angle of the project houses roof varies between 17 and 24 degrees, with a south and west orientation and a rotation of 22.5 degrees. This results in an efficiency of around 90%; it could be argued that if placed, why not pursue the full potential. To discuss, various solar panel attachment solutions were analyzed and drawn.

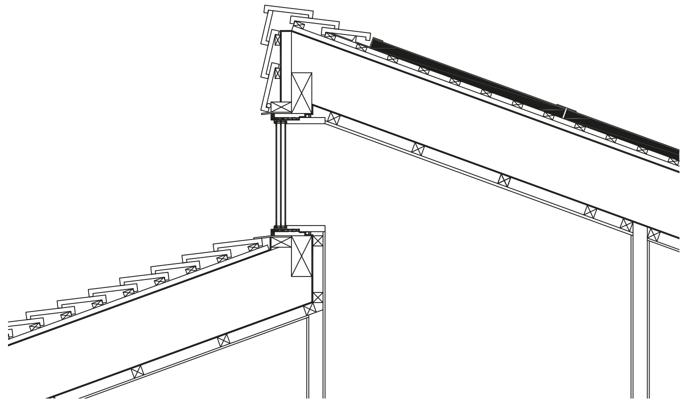


Ill. 182. Solar panel efficieny chart Source on



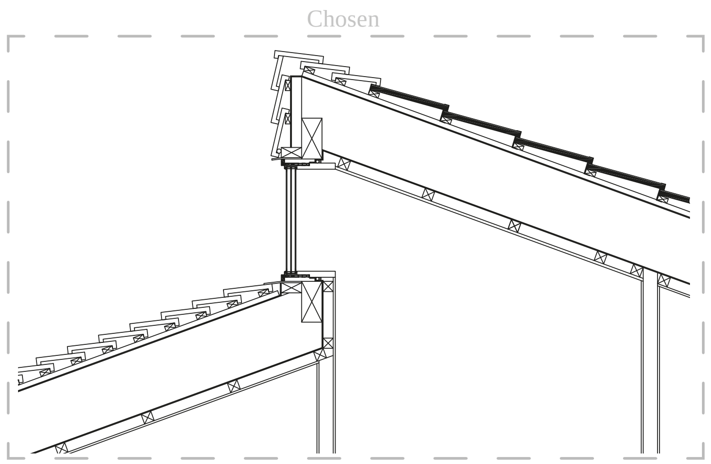
Ill. 179. Solar panel detail

The adding of solar panels mounted on top of the roof have both pros and cons. The mounting system gives the possibility for an individual angle for the panels, which can be beneficial. This system is very visible and steals a lot of attention for the wrong reasons.



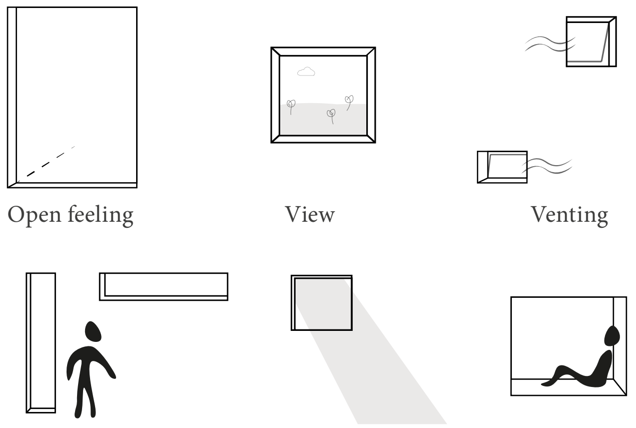
Ill. 180. Solar panel detail

The integration of solar panels into the roof links the angle to the roof. Because of the less distracting solar panels, the appearance of this solution is much more appealing. This creates additional issues because the roof structure must accommodate the additional ventilated space beneath the solar panels. If this is not done correctly, the solar panels may overheat and lose efficiency.

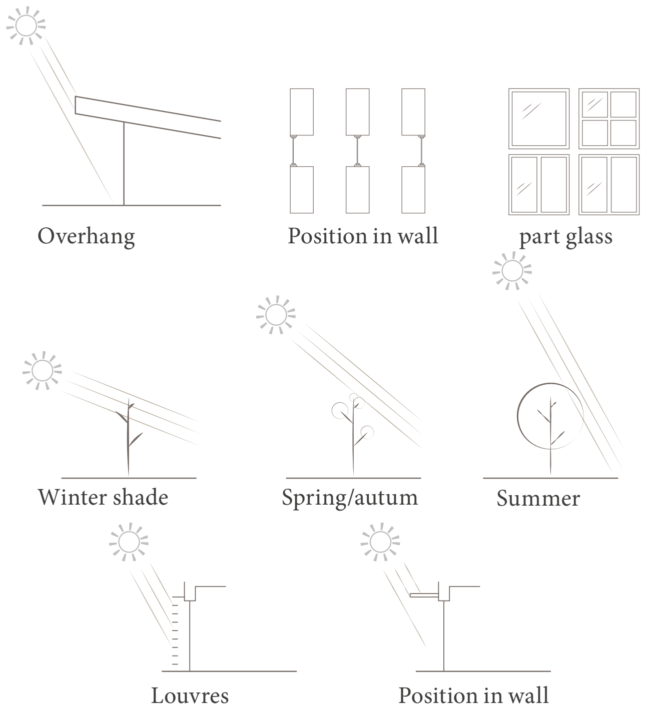


Ill. 181. Solar panel detail

Using new technology, a solar panel shaped like a roof tile can be integrated into the structure of the roof, giving it an integrated appearance while avoiding the problems associated with extra ventilation gaps (Tiled solar roof – Solarstone, 2022). The amount of energy that can be harvested is determined by the angle of the roof.



Ill. 183. Windows



Ill. 184. Shading options

6.5.3 Detail workshop

Throughout the design process, smaller sketching sessions were held as needed. The themes are varied, and more could have been included, but they served as a springboard for the process and were chosen because of project direction. Individual sketches can also be used to contrast and compare different solutions.

Windows

As the windows place a huge roll in both appearance and energy demand, the process of this Is vital to create a low energy project. Working with different sceneries allow a holistic and integrated design solution.

Windows serve a variety of functions, including passive solar energy, allowing for ventilation, and providing a view of the outside world. They can also be used for other purposes such as sitting and transition zones. Windows commonly have the job of ventilation and natural daylight; it is however important to keep privacy where it is needed.

Sun shading

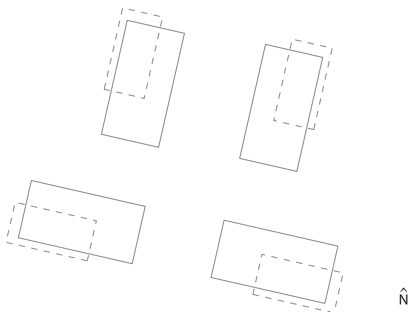
During the heating season, free energy from the sun is more than welcome; however, with high exterior temperatures, the risk of overheating is desired to be avoided. Solar shading should be considered to avoid receiving too much solar energy during the summer while still receiving enough during the winter to use as passive heating. It can be built into the shape of the building or added later as shades or vegetation. This factor is extremely important when it comes to lowering operational energy demand throughout the year. Different scenarios were discussed and sketched.

6.6.4 Indoor comfort

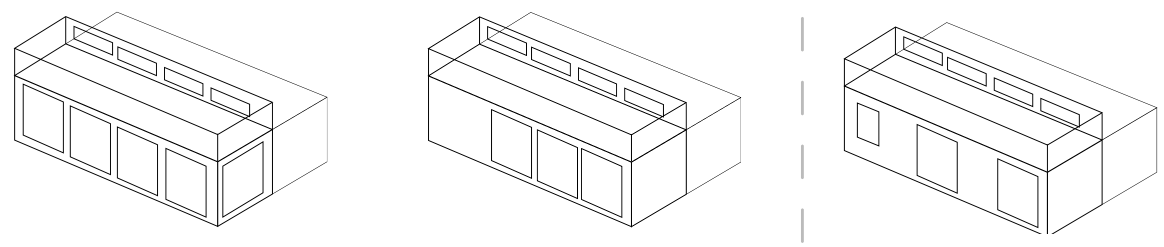
The living room and kitchen-dining area are the most vulnerable room in terms of overheating during the summer because they are oriented west and south. To analyse different iterations, simulation models were created. Bsim was used to calculate the amount of excessive heat hours, and velux was used to simulate the daylight factors. Even with an overhang, the simulated house overheated due to the large window areas. The window area was reduced, but this ruined the desired aesthetics and daylight factor.

The window was designed to be as parallel to the exterior façade as possible, providing more space on the interior floor area and a less complicated façade. This only applied to the windows that started at the floor. The frame shade would reduce passive solar gain by pulling the window to the interior side, but this appearance would be undesirable on the garden-facing façade.

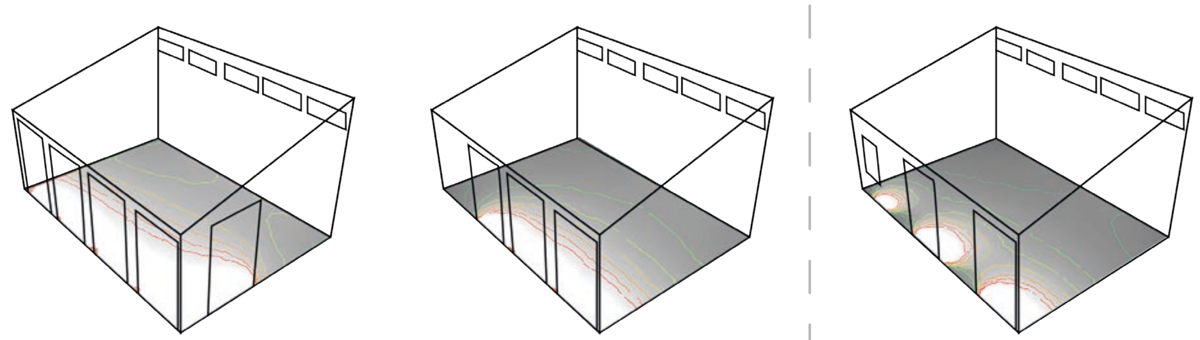
The boundary conditions for the daylight simulations are an overcast sky, implying that the direction of the sun has no effect on the daylight factor of the rooms. Room overheating is, however, highly dependent on orientation. While the daylight factor and window area on each house are similar, the amount of shading on each house is not. External shading is required for the floor-to-ceiling windows facing south and west.



1. Iteration	2. Iteration	3. Iteration

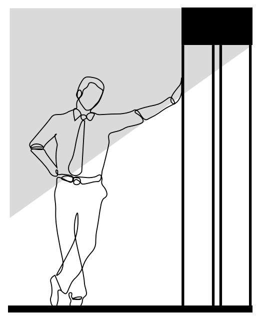

Ill. 185. Bsim model

1. Iteration	2. Iteration	3. Iteration
Results	Results	Results
Hours above 26: 303 h	Hours above 26: 97 h	Hours above 26: 78 h
Hours above 27: 193 h	Hours above 27: 67 h	Hours above 27: 16 h


Ill. 186. Daylight factor

1. Iteration	2. Iteration	3. Iteration
Results:	Results:	Results:
Daylight factor 7,8%	Daylight factor 5%	Daylight factor 3,7%

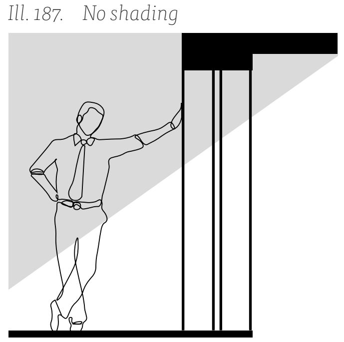
Chosen


Ill. 187. No shading

Results

Hours above 26: 97 h

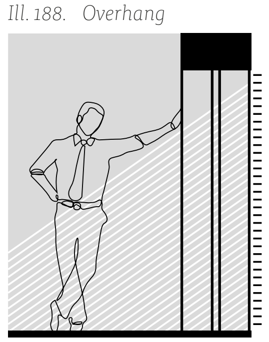
Hours above 27: 67 h


Ill. 188. Overhang

Results

Hours above 26: 88 h

Hours above 27: 33 h


Ill. 189. Vertical slats

Results

Hours above 26: 53h

Hours above 27: 7 h

6.6.5 Future conditions

The summer comfort of the house was discussed what category would be sufficient, looking at the number of excess hours the category 3 limits 25 hours above 28 degrees and 100 hours above 27 seemed reasonable. 100 hours may be less than a week of excess hours, which may be tolerable for some, but these data come from older Danish weather data, and future weather data and temperatures may be more extreme due to global warming, resulting in the house having a lot of excess hours in the future. The same model's weather data was exchanged for estimated 2050 and 2090 weather data files. The same model with the same scenarios predicted decreased summer comfort in the future: in 2050, there were 302 hours above 26 and 170 above 27, and in 2090, there were 502 hours above 26 and 200 above 27.

These future conditions are not far away, therefore extra exterior shading needs to be incorporated. Different scenarios with multiple types of shading were made, tested both in Basim and Be18 to see the relation between energy and summer comfort, look appendix 14. Exterior shading was needed to reduce the energy demand and keep summer comfort, vertical slats will be used in the design and must be integrated to keep the minimalistic appearance of the façade.

6.6 Building materials

The materials library's foundation is an exploration of the technical and aesthetic parameters of relevant building materials for this specific context. The technical part is based on life cycle assessment (LCA), specifically the environmental impact, recycling, and circular purpose of the various material categories. Examining various environmental product declarations (EPD) and reports on recycling and possible circular solutions for specific materials leads to a better understanding. Furthermore, based on the materials chosen, the aesthetic factor is visually analysed through images dealing with colours, shades, surfaces, patterns, harmony, treatment, and relationships to achieve greater coherence with the context and between the technical and architectural aspects. Appendix 15 contains the material library.

Life cycle assessment (LCA) is a comprehensive method of assessing the environmental impact of products or product systems over their entire life cycle. The life cycle calculation consideration is 50 years, but the actual or expected life of the building may differ from the theoretical calculation period.

The environmental impacts are measured in relation to several environmental categories, global warming potential, stratospheric ozone depletion, tropospheric ozone formation, acidification, Eutrophication. Using the LCA method and thus accounting for all environmental exchanges, such as consumption of energy, raw materials, and other resources, emissions to air, water, and soil, as well as waste streams throughout the life cycle.

With these results, it is possible to identify specific risks or problem areas surrounding the material choice. Incorporating the LCA assessment into the design process, it is then possible to create an overview of the total environmental impact. To then minimize and reduce construction emissions before it becomes a problem in the project phase.

In practice, LCA is a valuable tool for analysing and comparing different alternatives when designing products or processes and helps to identify hotspots in the form of critical processes or materials that can give spikes in major environmental decays.

More specifically, such as the lifespan of a building, it is a tool for assessing a more complex level of all underlying processes. Where the use phase of a building extends significantly further than the production phase of the building itself and its materials, in addition, demolition and waste management must also be included. This is where LCA as a design tool can shed light on how environmental loads are throughout the building's lifetime. Which makes it possible to minimize critical areas and subsequently assess the circular economy options that are discussing waste management and the possibilities for load savings in different recycling options.

The required data on which the final LCA results are based on is collected through Environmental Product Declarations (EPD). However, EPDs are far from available for all construction products used in Denmark and it can sometimes be problematic to calculate a realistic result which covers all phases. In these cases, a generic data is typically used within a comparison material EPD, the Danish datasets mostly take starting point in the German database Ökobaudat.

By reviewing over 120 EPDs which are part of the basis for the technical analysis of the material library, a basic understanding of different material types and categories has been formed. This insight into materials and EPDs highlights to some extent a great lack and diversity of quality and sustainability in the EPDs, which can make it difficult to compare them. The information can sometimes be difficult to see understand or are insufficient which gives the impression of a unvalid source of information.

The only affects the sufficient quality requirements for an EPD, which are as follows: Validity: EPDs expire after 5 years. Data quality: EPDs must comply with DS / EN 15804 and be third-party verified. Scope: EPDs include as a minimum phase Product (A1-3). Production site: The production site can have a major impact on results, including in terms of energy supply. Application: Describes the application to which the EPD applies. Functional unit: Indicates the unit in which the results are calculated. (LCA i praksis, 2021)

A question about who the forerunners of a more sustainable approach can be asked and briefly assessed that it is a joint effort for everyone involved in the construction industry. In this case with an EPD, the manufacturers must focus on a more sustainable conversion of their products and processes, in addition have an EPD that makes all parameters visible to their side, then the designers must use that information properly to promote sustainable and circular building projects.

With the library founded, material combinations in the roof, wall and floor and how certain material compositions affect the structure, performance and visual atmosphere of the structure are first investigated (see next page). In addition, the material library's information is subsequently used during all relevant processes concerning material selection, construction and visual surfaces. overall, it forms the basis of the final design of the presentation and the possible circular solutions for the different material categories. The following 2 reports have been the basis for the knowledge, inspiration and assessment of circular solutions that have been presented during the presentation.

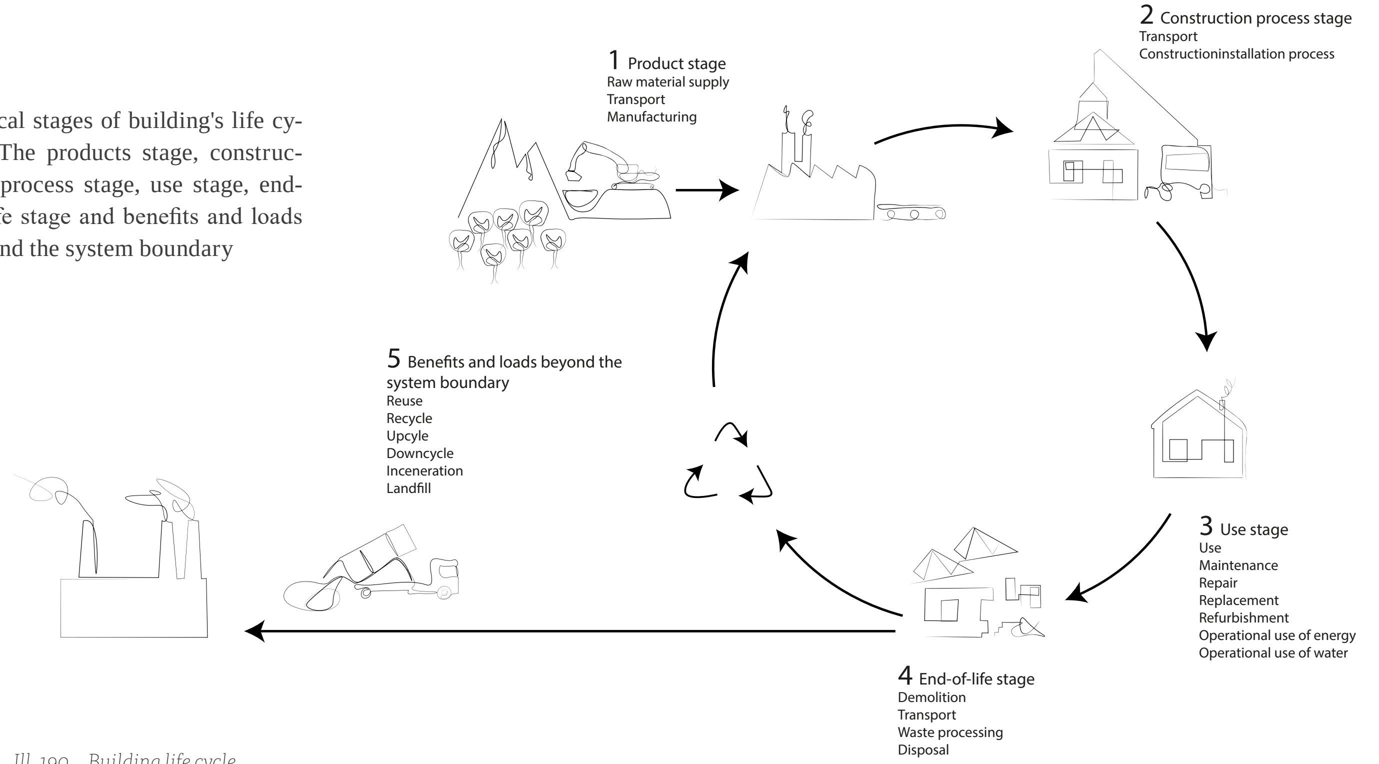
(SBI 2019:08) - SBI 2019:08. Livscyklusvurdering for cirkulære løsninger med fokus på klimapåvirkning. (2019)

(KAB-Fællesskabet, 2022) - Potentialer for genbrug og genanvendelse af byggematerialer i KAB-Fællesskabet. (2022)

1. Product	2. Building process	3. Use	4. End lifetime	5. Outside project
A1 Raw materials	**A4 Transport**	B1 Use	C1 Dismantling / demolition	**D. Potential for reuse, recycling and recovery**
A2 Transport	**A5 Construction / assembly**	B2 Maintained	C2 Transport	
A3 Manufacture		B3 Repair	**C3 Waste treatment**	
		B4 Replacement	**C4 Disposal**	
		B5 Renovation		
		B6 Energy consumption for operation		
		B 7Consumption for operation		

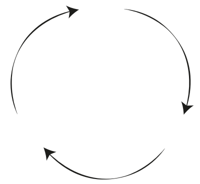
Ill. 191. Phases 1-5. Modules A-D.

Typical stages of building's life cycle: The products stage, construction process stage, use stage, end-of-life stage and benefits and loads beyond the system boundary



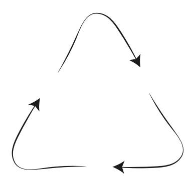
Ill. 190. Building life cycle

(Styrelsen, 2016)



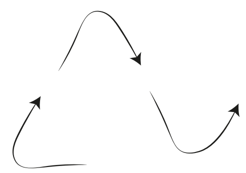
Ill. 192. REUSE

After a cycle of use, a material or product is used for the same function. Materials or products are subjected to a light mechanic process at most



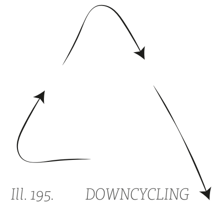
Ill. 193. RECYCLING

When a material or product is decomposed or comminated into raw materials and then recovered for use in the manufacture of new products. The recovered materials are used to create products that are like or completely different from the originals.



Ill. 194. UPCYCLING

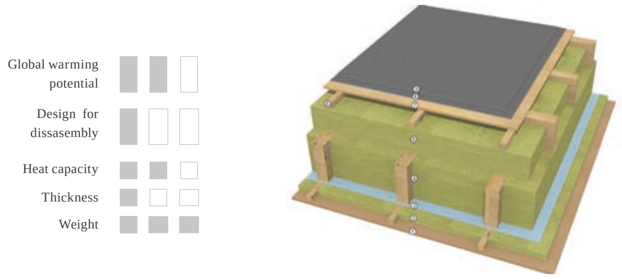
When building materials or components are transformed, refined, or transformed into new and more valuable building materials and components (increase in value in relation to economy and service life).



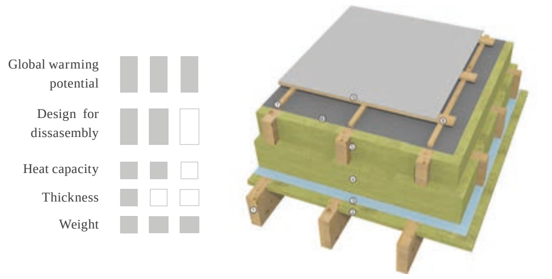
Ill. 195. DOWNCYCLING

When building materials or components are transformed or transformed into new, lower-valued building materials and components (impairment in relation to economy and service life).

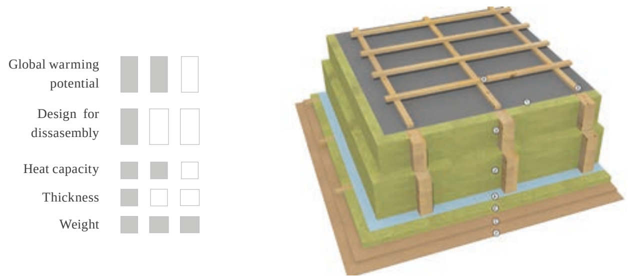
6.6.1Roof



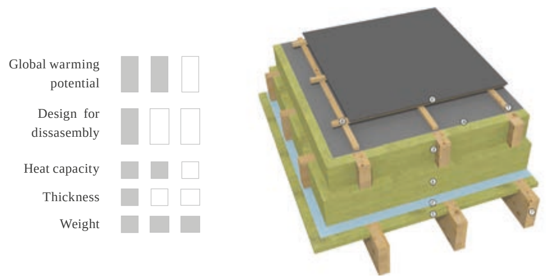
1.4



1.6

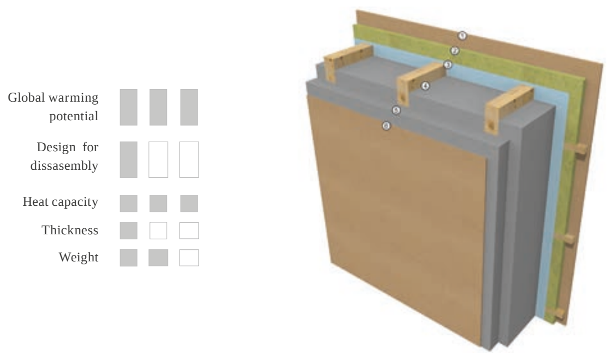


2.2

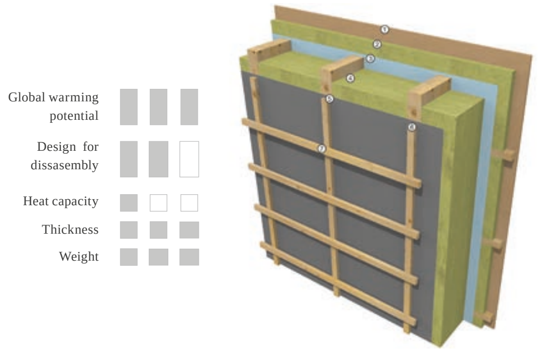


2.5

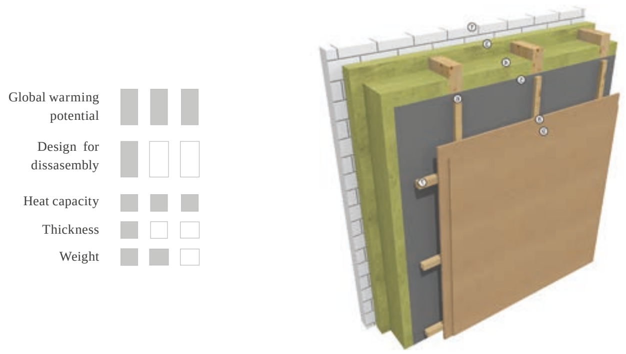
6.6.2 Wall



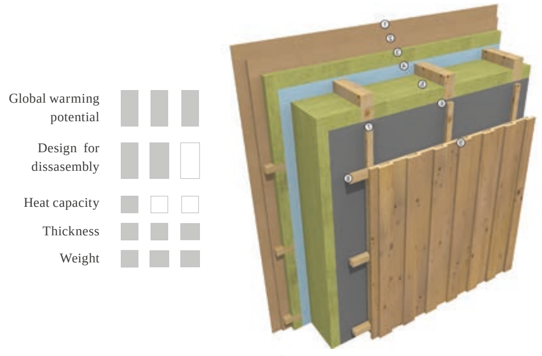
1.2



1.4

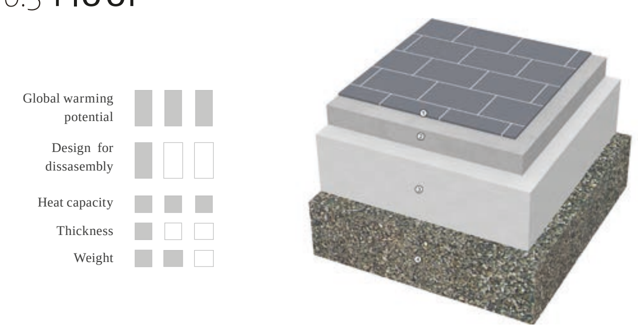


2.3

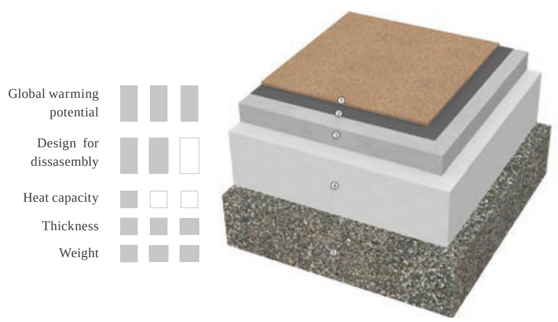


2.6

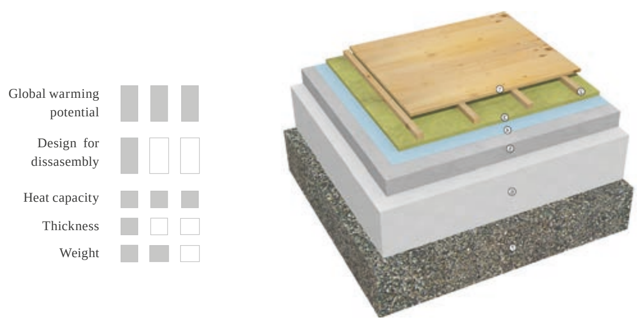
6.6.3 Floor



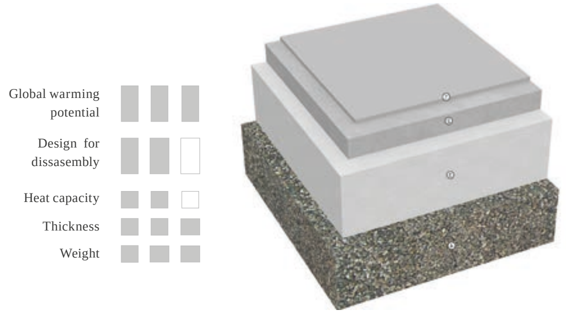
1.1



1.5



2.2



2.3

Rating system

The analysis has undergone a rating system:

Material selection: Roof, Wall, Floor
Technical rating systems consistsing of primary and secondary rating which influenced by project direction:

Primary
Design for disassembly - The ease of disassembly and the preservation of quality when disassembled, the better the grading.

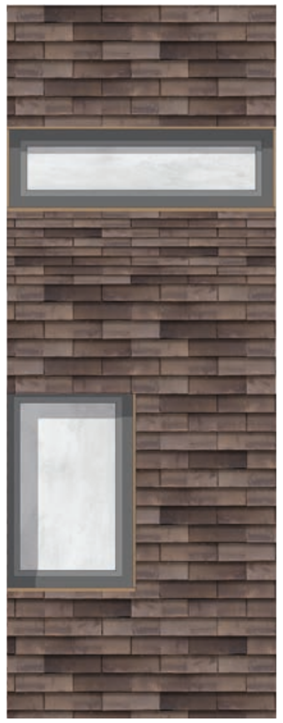
Potential for global warming - Greenhouse gas emissions When the data is compared, low values receive high marks.

Secondary
Heat capacity - Specific heat capacity of the construction, high heat capacity gives high grades
Thickness - efficient material use, thicker walls get less points
Weight - in kg, the weight category gets a good score if the structure is light

All the different construction proposals comply with current requirements for construction and technical parameters so that no problems occur, and they are assessed based on the same performance. In addition, the summary of the design proposals governs the assessment form, but in addition, the location of the steam set and the visual expression using the material library are still part of the considerations. The construction combination process has undergone 2 rounds which, by means of the first round, specified the second round to a greater extent. Throughout the process, the assessment form's topics are complied with, but at the same time put together construction options that create a higher aesthetic quality that matches the design direction, here the focus is on the material's surfaces and a visible construction in either ceiling or wall. The following proposals are a selection of the 2 processes, to see all combinations, see Appendix 16.

6.6.4 Exterior expressions - Front

Ill. 196. Facade 1 - front



Ill. 197. Facade 2- front

Chosen

Ill. 198. Facade 3- front

6.6.5 Exterior expressions - Back

Ill. 199. Facade 1- back

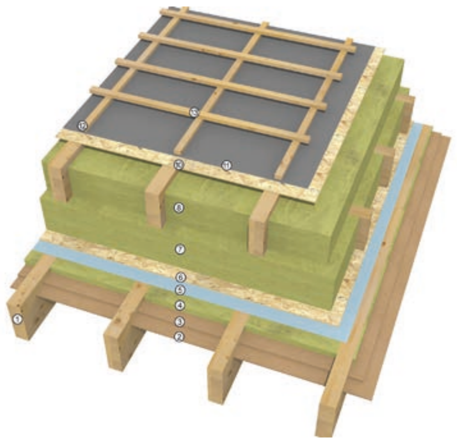
Ill. 200. Facade 2- back

Chosen

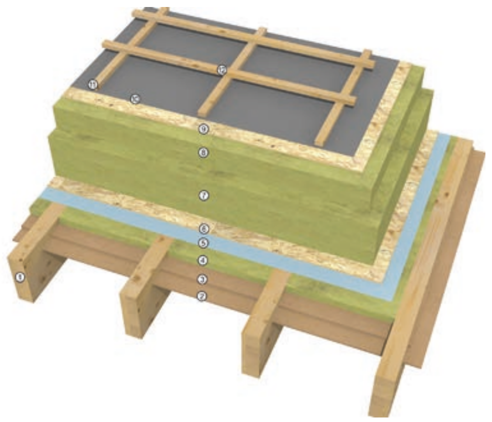
Ill. 201. Facade 3- back

The front and rear facades must help to strengthen the building's character and the emphases, the transitions and the focus around the current area. The front facade should protect the house and define the transition from the public to the private, but still be inviting and create a printed and inviting neighbourhood with attractive outdoor area among the individual single-family houses. The material choice in question is a facade tile that goes from the foundation plinth to the gutter and continues up the roof, the chosen solution is based on a clean and concrete aesthetic solution with the facade and takes almost goes in one, in addition it has been a reservation to the construction and separation process, as well as the processing of the recyclable material. At the back, the facade tile is used to a lesser extent and is replaced by wooden slats, as the focus and atmosphere change direction towards the nature-rich gardens and the building opens up more with large window openings and a functional wooden terrace. Colours and shades are explored through the material library and various manufacturers in the construction market. The three proposals presented have been selected and examine the general expression of the front and rear façade with how shades, surfaces, direction and openings relate to each other.

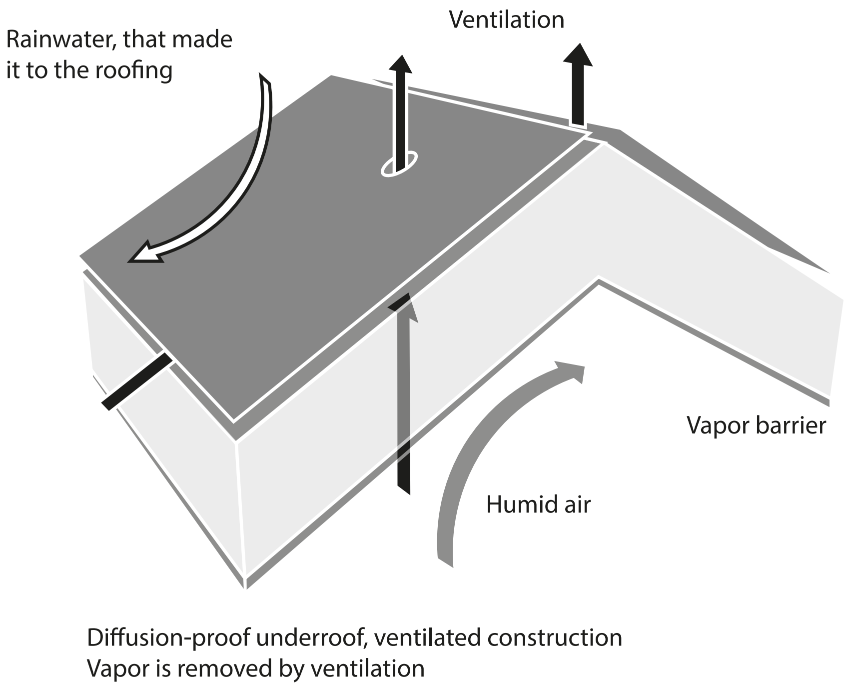
6.6.6 Concstruction detail



Ill. 202. Roof construction



Ill. 203. Roof construction



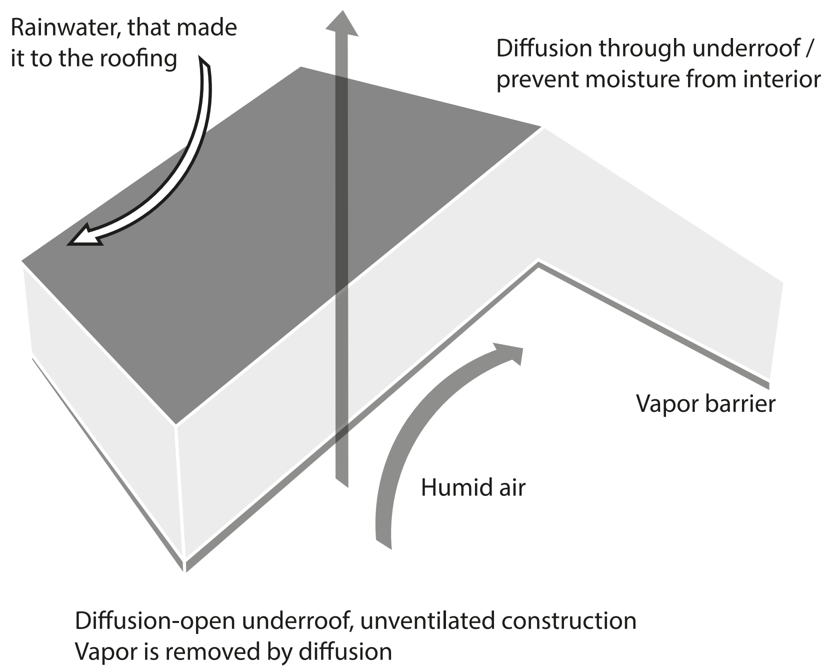
Ill. 204. Ventilated roof

The level of detail of the roof and the solution of the construction are investigated based on options with a vapour barrier, under-roof barrier in the roof to avoid any occurring moisture problems in the construction.

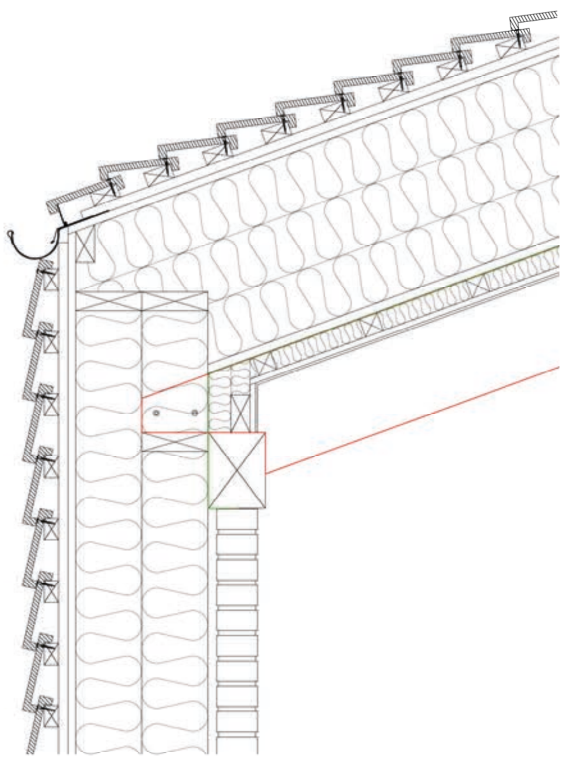
The first solution is built with a diffusion-tight under roof barrier and ventilated construction, in this case, the moisture is removed by a ventilated space under the under-roof barrier, where the moisture can be ventilated either through the roof ridge or through ventilation caps installed in the under-roof barrier.

The second solution is built with a diffusion open under-roof barrier and unventilated construction, where the moisture is removed by diffusion, through the materials. In this case, all materials on the outside of the vapor barrier must be open to diffusion so that no formation of condensation or moisture penetrates the structure, and thus has the possibility of dehumidification.

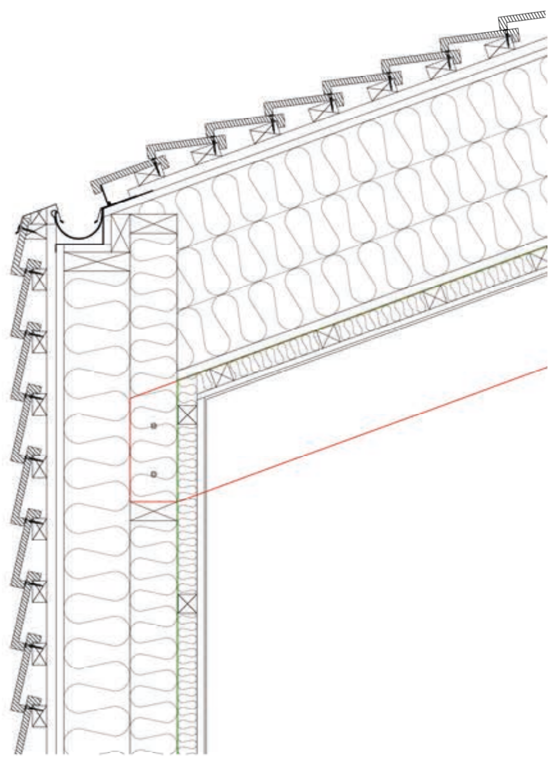
The further detailing works with a diffusion open under-roof barrier based on the simplicity of the construction structure and subsequently the possibility of material selection, in addition to specific material quantities in the proposal.



Ill. 205. Unventilated roof



Ill. 206. Exterior gutter



Ill. 207. Integrated gutter

6.6.7 Connections

The following 12 drawings (Ill 200-207) must be seen in conjunction, as it is a summary of the construction. Technical solutions and appearance help to create a greater understanding and the review is the basis for selection and adaptations to the house solutions.

Gutter. (Ill. 206-208)

Here, the three following solution proposals are examined. 1. Exterior (Ill. 206), 2. Integrated (Ill. 207) and 3. Specially made (Ill. 208). In comparison, all three fulfil the individual function by dewatering the roof and leading it on to the ground, but by further reviewing the 3 proposals and set up scenarios around large amounts of rain, fallen leaves and what possible consequences this could have. This brings certain complications with proposals 2 and 3 as they are integrated in the roof and / or facade construction and thereby require extra care when designing and sealing the gutter and how it is installed. This leads to the conclusion that it should not be made more complicated than it is and give space to the elements to get the most out of its function without emerging problems.

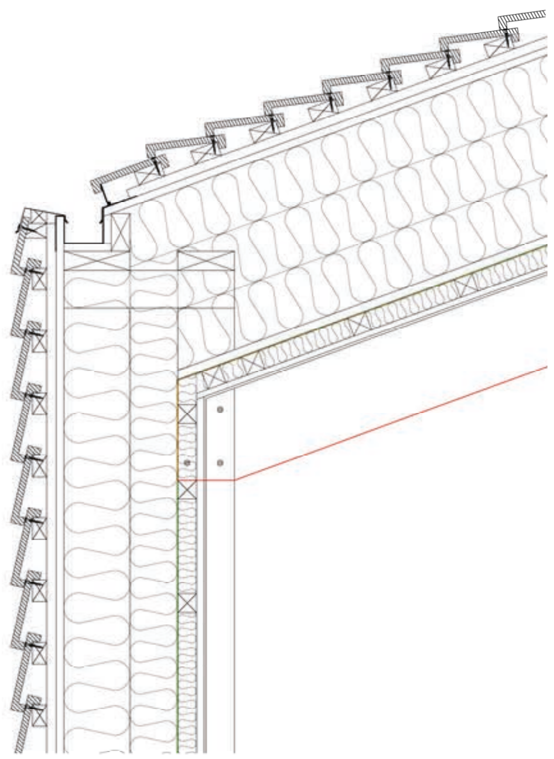
Rafter, wall and vapour barrier. (Ill. 206-208)

Here, the location of the load-bearing structural elements and possible attachment of a vapour barrier is examined, all three proposals share the parameters around a lightweight wood structure and partially visible rafters (red line = rafter and green line = vapour barrier).

In Ill. 200, an inner wall of brick is shown, which is selected based on its technical preconditions and spatial qualities. The rafter is laid on a horizontal beam that lies on top of the brick wall and is attached to the wooden structure behind, as a single stone wall is not load-bearing. Placement of the vapour barrier and rafter, in this case, means that a "clean line" of the vapour barrier is broken and must be cut around the rafter and taped, in which case the execution of the work must be of high quality to achieve current requirements within air tightness.

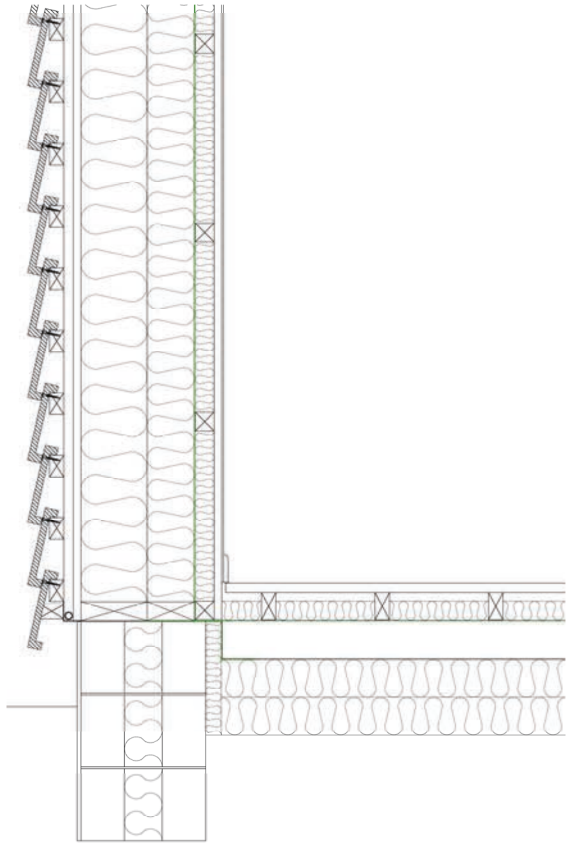
In Ill. 207 repeats the same principles as the previous proposal; however, the inner wall is replaced with an installation wall of 70 mm, with 50 mm insulation, 15 mm clay plate and 5 mm clay plaster, respectively, in order to maintain a different expression but still some of the technical qualities. This proposal requires a vapour barrier all the way from floor to ceiling and with the location of the load-bearing wall structure; it ends up with the same solution as the previous proposal according to the vapour barrier.

In Ill. 208, another solution is given in terms of avoiding, breaking the vapour barrier. This is solved by moving the load-bearing wall structure further into the room and still maintaining the mounting of the rafter and the installation wall, thereby the vapour barrier is placed on the back of these elements and enabling the vapour barrier to be installed all the way around without being broken. When retracting the construction, this also gives a different spacious feeling and quality to question in which it is possible.

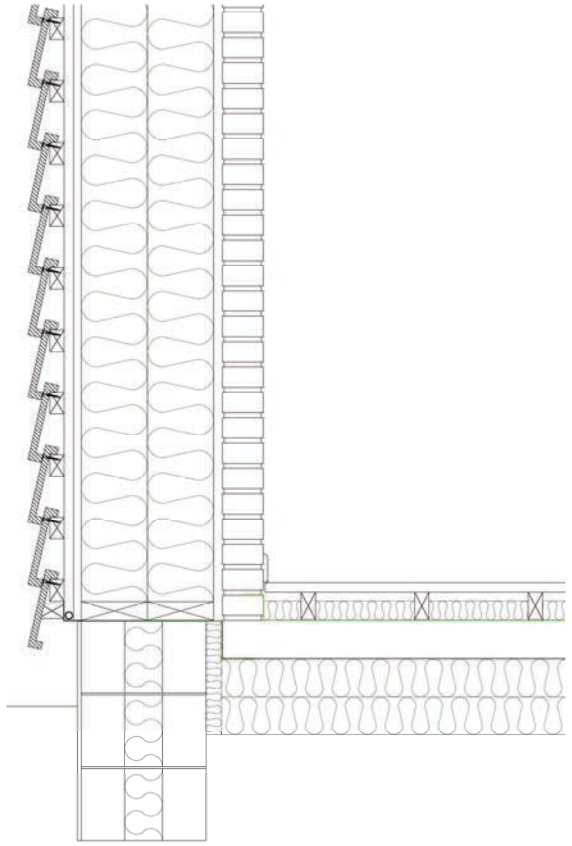


Ill. 208. Custom made gutter

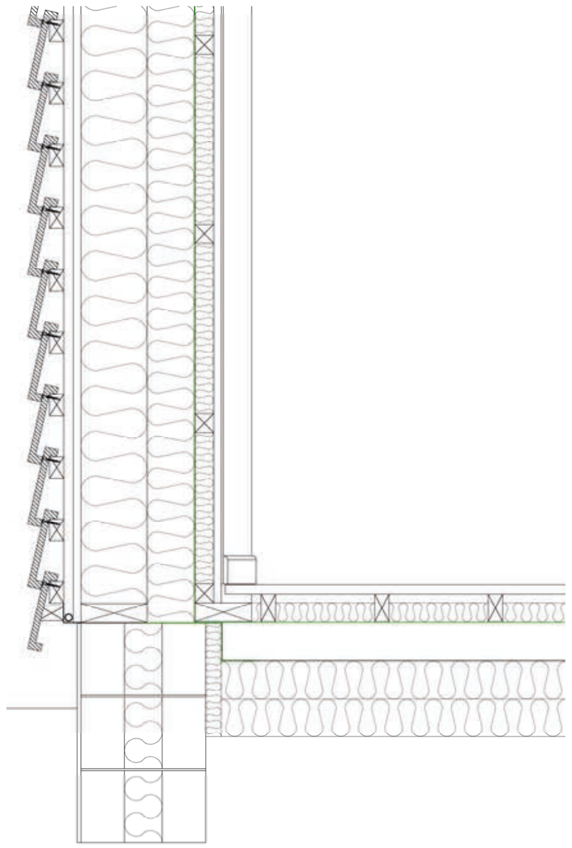
6.6.8 Connections



Ill. 209. *Wall and floor connection*



Ill. 210. *Wall and floor connection*

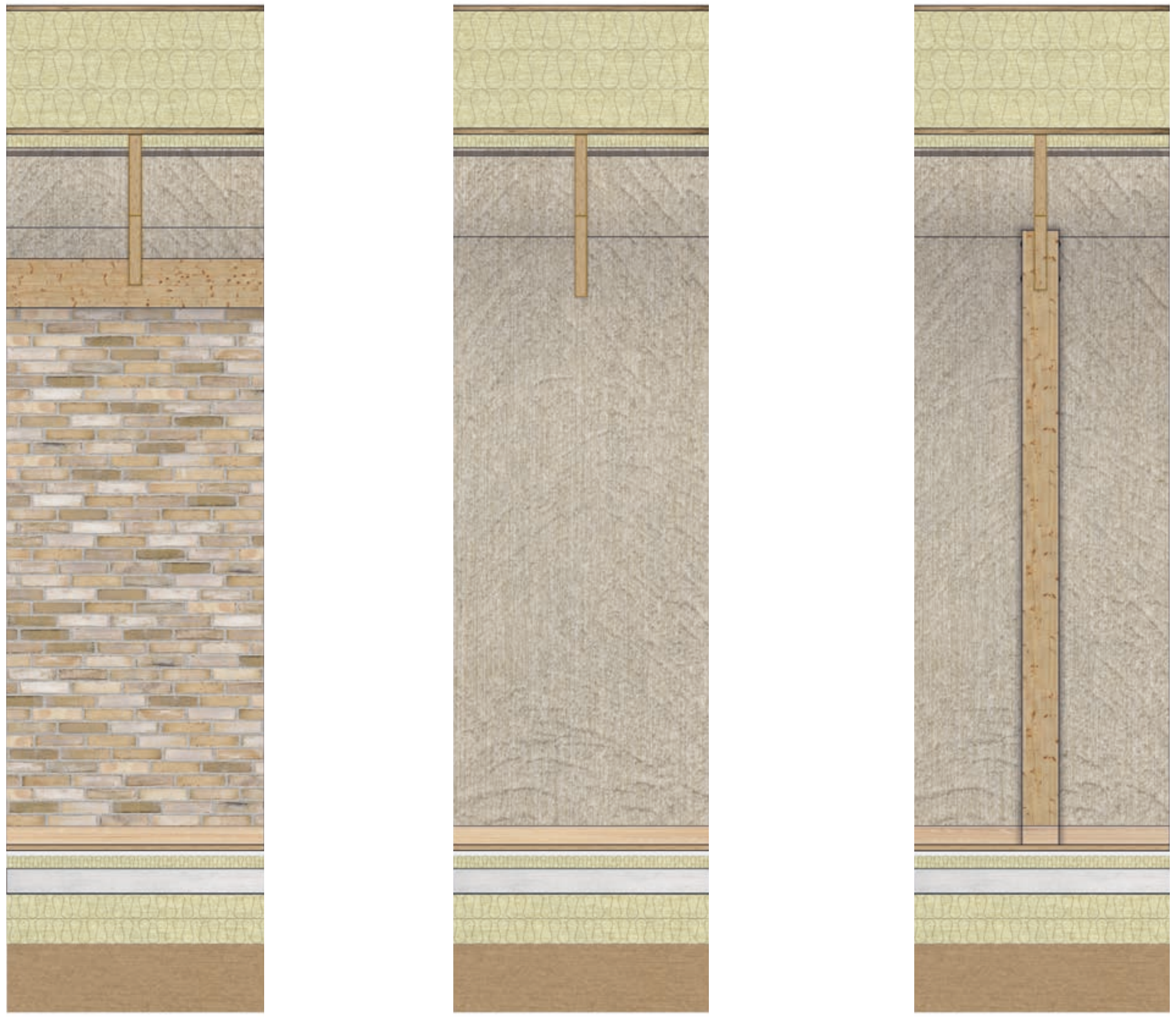


Ill. 211. *Wall and floor connection*

Construction and surface. (Ill. 209-213)

Here, the previously described constructions are followed up and how they are assembled with the floor, the placement of the vapour barrier, surfaces and visual qualities, and finally horizontal sections to create a greater understanding of the construction and its various layers and compositions. As mentioned at the beginning, these drawings must be seen together with the previous roof details in order to be able to gather the basic understanding of the different constructions and how the changes affect the construction. This study and resulting information help to extract individual parts from each drawing and topics that in combination have been passed on to shape final wall choice.

6.6.6 Interior expression - living room



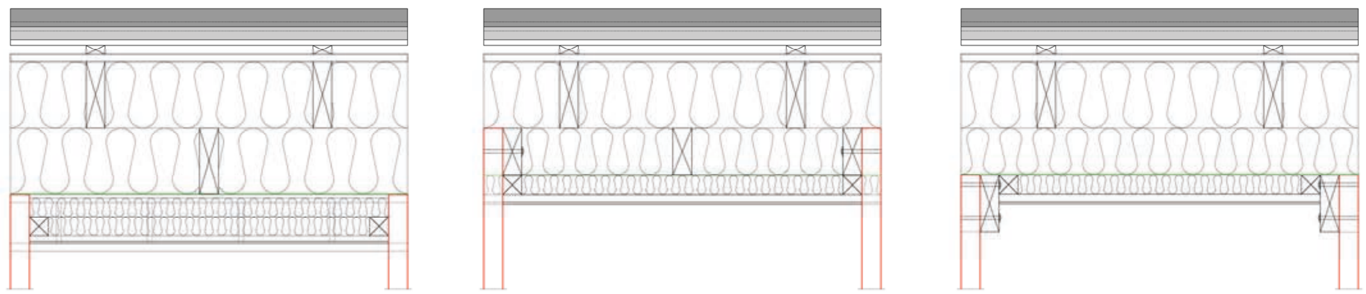
Ill. 212. *Vertical sections*

Estimations yellow brick:
Reflektans: 0,35
Absorbtion coefficient: 0,03 - 0,07

Estimated Plastered clay wall:
Reflektans: 0,4
Absorbtion coefficient: 0,14 - 0,04

Estimated Clay and wood combi:
Reflektans: 0,35
Absorbtion coefficient: 0,0,15 - 0,08

6.3.1 Wall sections



Ill. 213. *Horzisontal*

6.7 Conclusion

The project's aim has been to investigate the right sustainable material choice for new buildings that will be included into a circular economy as material banks while still increasing the architectural quality of the single-family home. The house design was also to be elevated by inspiration from Nordic architecture, to bring back the quality of Danish houses. All this led to a final design consisting of three bulb cul-de-sacs hosting 20 single-family homes and a separate common house on the site.

The constructions elements consist of layers that are easy to separate without losing quality and can therefore be either reused, recycled, upcycled, or downcycled to then reduce the emissions and need for virgin materials for future projects. The project is a sustainable participant in the field of circular economy and integrated building design, being projected as a tract house and allowing it to be disassembled into other purposes. The emphasis on building materials' environmental impacts was included as a tool to help with climate mitigation, whilst the building was modified to meet the 2020 energy standards. The building's values are rooted in Danish building tradition, with a strong focus on detailing, visible structure and minimalistic atmosphere that goes together with the theme of Nordic architecture.

In the same context with Danish traditions, the brick was a big part of the early concept's idea for its technical values, such as being used as structure, heat capacity, exterior cladding and aesthetic appearance, but because material theory emphasizes design for disassembly the choice led to a clay tile instead for its same features, but easier to separate and gave space for a larger wooden structure, that is more sustainable than other conventional structural materials. With the importance of climate adaptation, the building envelope can be assembled in simple layers that allow the building to be disassembled from one material layer to another, providing the best opportunity to reuse or recycle each material.

Inspiring the residents to make sustainable choices through their daily routine has been part of the essence of these houses, shaping the physical framework for sustainable choices. Creating a covered exterior drying rack area, eliminating the need for a dryer. The plan solution has some of the key features of a single-family home, having child and parents' sections, a big terrace, direct access to nature, a big open kitchen, and a utility room with a separate entrance used for dirty cloth situations. Living on Chikorievænget, one is part of a bigger community, sharing with neighbours, relaxed garden compositions and great place for social life for all generations.

6.8 Reflection

The houses show great results in both energy optimization, documentation of material EPD for reduction of virgin materials in future building process and pleasing aesthetic appearance. Looking at the scale of the project so many aspects could have been included and therefore results could have been improved.

Further iterations of the common house have been made, and the shape and placement of this is what have been worked the most with. The wanted functions, optimized plan solution and detailing could have benefited from more work.

Regarding urban layout, the group is satisfied with the placement of functions however it could have been interesting to dive into the typography and use the small difference in height, to completely use the current urban landscaping only touching the build area rather than editing every corner.

Even though plan solution could have used more iterations, the house would especially have benefited from a specific user, making it more interesting to hear what they want. Individuals and people of diversity who prefer an east-oriented terrace and south-located bedrooms, listen to their needs and design specific houses instead of multiple similar ones. Using tools like Bsim and Be18 there is always something to be improved in terms of detail and reduction of energy use. The Bsim model quickly becomes advanced when detailing further, this leaves the program to collapse and ruin files. When using these tools, it is always a medium of simplicity and specification, to get useful simulation results to be integrated into the design process.

Reflecting on tools, LCAbyg must also be mentioned, the program and initiatives behind is what the future needs and Denmark is going to be a frontrunner for many countries. However, the material EPD available primarily focuses on the cradle to gate, which is typical for the building industry. A fast-growing and fast-moving industry, but what happens to the building materials after their lifespan is not documented, which is why the project needed to create a theoretical process and material handling. Taking in the scale of the material EPD results can vary in so many ways, looking at the scale of the process, process efficiency, local availability, and machine vs. human power making it risky to conclude on results without very specific process detailing. This was a big part of the thesis where maybe too much energy was used on material investigations.

The group members were situated in two different parts of the country, making physical group work sparse. The importance of physical side-by-side group work was underestimated in this thesis. Previous work has been done online due to the covid-19 situation and group members being in South Africa, the group thought that post covid thesis still could be written in this manner. The problem was the delay in information sharing and the planned updates during the workdays. The efficiency and concluding effect group work has been reduced leading to lose ends and unfinished jobs.

The integration of active strategies was only kept on a conceptual level, the different scenarios were discussed and calculated but wasn't forced to be a bigger part of the design. The current situation in Ukraine and the increasing need for alternative energy resources made it clear that active systems needed to be part of the design, even if the efficiency would have been higher placed in another country. The thesis discussed if virgin materials used for photovoltaic solar panels placed in a Danish context would be a waste comparing the energy return if the solar panels were placed in a country like Egypt.

The final thing that could have been done differently is the general shape of the house and placement. The house concept became quite clear and different iterations were made with this concept; however, the project would have profited from a step back, and more concept ideas had been investigated. The use of two-story buildings and the healthy benefits of living in such a house have a lot of potential but was discarded due to the roof shape concept. The cul-de-sac was given a lot of attention however the single-family homes could have been placed in so many ways. The benefit and downside of the cul-de-sac was the face of the house had to orient the street, this made it challenging to put rooms and areas accordingly to our plan ideology. If all the houses had been oriented the same way the typical functions of the house could have been placed optimally on all the houses, this resulting in a lag of diversity which is a downside. Looking at traffic and the idea of reducing cars could have been pushed much further, it is already now down to one static parking space per house unit, which is below recommended spots. The site and the city it is located in, has so much potential for relieving the family of a car and only use the bike as transportation. However, the practicality of a car in the daily life of a family with small children, is not to be underestimated and the designated parking area was integrated.

To summarize, this thesis was difficult but also educational. Further development would benefit the project, but the understanding of the circular economy, material passports and potential use after material lifetime is on the path to a sustainable future.

6.9 Illustrations list

All illustration not mentioned in this list is of own production

Ill. 05 DGAR, 2022. Edgar.jrc.ec.europa.eu. EDGAR - The Emissions Database for Global Atmospheric Research. [online] Available at: <https://edgar.jrc.ec.europa.eu/> [Accessed 17 February 2022].

Ill. 06 EDGAR, DK, 2022. Edgar.jrc.ec.europa.eu. EDGAR - The Emissions Database for Global Atmospheric Research. [online] Available at: <https://edgar.jrc.ec.europa.eu/country_profile/DNK> [Accessed 18 February 2022].

Ill. 07 BUILD, 2022. SBi-anvisninger — FAQ. [online] Build.dk. Available at: <https://build.dk/anvisninger/Pages/Faq.aspx> [Accessed 18 February 2022].

Ill. 08 NCEI.Monitoring.Info@noaa.gov (2022). April 2002 Global Climate Report | National Centers for Environmental Information (NCEI). [online] Noaa.gov. Available at: https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/200204 [Accessed 23 May 2022].

Ill. 12-13 jrn.se. 2009. Villa Överby. [online] Available at: <https://www.jrn.se/#/overby/> [Accessed 15 March 2022].

Ill. 14-15 Mettelange.com. 2015. Vacation house - Island - mettelange. [online] Available at: <https://www.mettelange.com/Vacation-house-Island> [Accessed 9 March 2022].

Ill. 16-17 LUNDBERG, H., 2015. JUNISKÄR. [online] hhl.se. Available at: <https://www.hhl.se/projects/juniskar/> [Accessed 16 March 2022].

Ill. 18 Brand, S., 1994. How buildings learn. pp.13-14.

Ill. 19 Issuu. (2016). Building A Circular Future. [online] Available at: https://issuu.com/3xnarchitects/docs/buildingacircularfuture/283 [Accessed 23 May 2022].

Ill. 20 Issuu. (2016). Building A Circular Future. [online] Available at: https://issuu.com/3xnarchitects/docs/buildingacircularfuture/283 [Accessed 23 May 2022].

Ill. 23 van den Brom, P., Meijer, A. and Visscher, H., 2017. Performance gaps in energy consumption: household groups and building characteristics. Building Research & Information, 46(1), pp.54-70.

Ill. 24 Kleis, B., 2014. Kvotehuset. [S.l.]: Realdania Byg.

Ill. 31 (De 4 lokale temaer, 2022) Soroe.viewer.dkplan.niras.dk. 2022. De 4 lokale temaer. [online] Available at: <https://soroe.viewer.dkplan.niras.dk/plan/6#/3137> [Accessed 23 March 2022].

Ill. 32 Soroe.viewer.dkplan.niras.dk. 2019. the main structure of the municipal plan. [online] Available at: <https://soroe.viewer.dkplan.niras.dk/plan/6#/3006> [Accessed 2 March 2022].

Ill. 45 Cappelen, J. and Jørgensen, B. (n.d.). DANISH METEOROLOGICAL INSTITUTE Observed Wind Speed and Direction in Denmark -with Climatological Standard Normals, 1961-90 Observeret vindhastighed og -retning i Danmark -med klimanormaler 1961-90. Page 135 [online] Available at: https://www.dmi.dk/fileadmin/user_upload/Rapporter/TR/1999/tr99-13.pdf

6.10 Literature reference

01 intro

Andersen, U., 2017. Byggematerialer belaster klimaet mere end opvarmning. [online] ingeniøren. Available at: <https://ing.dk/artikel/byggematerialer-belaster-klimaet-mere-end-opvarmning-205985> [Accessed 18 February 2022].

Berlingske.dk. 2022. Sådan bygger du bæredygtigt. [online] Available at: <https://www.berlingske.dk/bolig-bil-og-baad/saadan-bygger-du-baeredygtigt> [Accessed 18 February 2022].

BUILD, 2022. SBi-anvisninger — FAQ. [online] Build.dk. Available at: <https://build.dk/anvisninger/Pages/Faq.aspx> [Accessed 18 February 2022].

Cepos.dk. 2020. Danmark står for 0,1 pct. af verdens samlede drivhusgasudledning. [online] Available at: <https://cepos.dk/abcepos-artikler/0286-danmark-staar-for-0-1-pct-af-verdens-samlede-drivhusgasudledning/#> [Accessed 18 February 2022].

EDGAR, 2022. Edgar.jrc.ec.europa.eu. EDGAR - The Emissions Database for Global Atmospheric Research. [online] Available at: <https://edgar.jrc.ec.europa.eu/> [Accessed 17 February 2022].

EDGAR, DK, 2022. Edgar.jrc.ec.europa.eu. EDGAR - The Emissions Database for Global Atmospheric Research. [online] Available at: <https://edgar.jrc.ec.europa.eu/country_profile/DNK> [Accessed 18 February 2022].

Henriksen, L., 2015. Byggeformand advarer: Vi bygger for grimt og for dårligt i Danmark uden tanke på fremtiden. [online] Kristeligt Dagblad. Available at: <https://www.kristeligt-dagblad.dk/debat/byggeformand-advarer-vi-bygger-grimt-og-daarligt-i-danmark-uden-tanke-paa-fremtiden> [Accessed 1 March 2022].

Innovationsfonden, 2020. Nye forskningsmidler skal gøre byggesektoren grønnere. [online] Innovationsfonden. Available at: <https://innovationsfonden.dk/da/nyheder-presse-og-job/nye-forskningsmidler-skal-gore-byggesektoren-gronnere> [Accessewd 18 February 2022].

Itabok.iasaglobal.org. 2022. Architecture Methodologies and Frameworks – IasaGlobal. [online] Available at: <https://itabok.iasaglobal.org/itabok/capability-descriptions/architecture-methodologies-and-frameworks/> [Accessed 15 February 2022].

KEFM, 2021. Første officielle vurdering af Danmarks globale klimaaftryk. [online] Kefm.dk. Available at: <https://kefm.dk/aktuelt/nyheder/2021/apr/foerste-officielle-vurdering-af-danmarks-globale-klimaaftryk> [Accessed 18 February 2022].

Knudstrup, M. (2004): Integrated Design in Problem-Based Learning. The Aalborg PBL Model: Progress. Diversity and Challenges, Aalborg Universitet, Aalborg, Denmark.

Poulsen, M. and Lauring, M., 2019. The Historical Influence of Landscape, Ecology and Climate on Danish Low-rise Residential Architecture. International Journal of Design & Nature and Ecodynamics, 14(2), pp.91-102.

02 theory

Brand, S., 1994. How buildings learn. pp.13-14.

Englund, M., 2005. Skandinavisk stil. 2nd ed København, Denmark - Aschehoug, pp.6-11.

Ibler, M., 2017. Cool nordiske boliger >> Selected Projects. 1st ed. Aarhus, Denmark - Archipress M, pp.6-8.

Historiske Huse. 2022. Bedre Byggeskik - Historiske Huse. [online] Available at: <https://historiskehuse.dk/stilblad/bedre-byggeskik/> [Accessed 17 March 2022].

Andersen, L. and Jensen, M., 2019. Parcelhusets arkitektur og historie. [online] Bolius.dk. Available at: <https://www.bolius.dk/parcelhusets-arkitektur-og-historie-17537> [Accessed 14 March 2022].

Kiersgaard Espersen, M., 2021. 5 typiske udfordringer i typehuset - og hvordan du løser dem. [online] Danske Boligarkitekter. Available at: <https://www.danskeboligarkitekter.dk/boligreportager/billedserier/5-typiske-udfordringer-i-typehuset-og-hvordan-du-loeser-dem/> [Accessed 13 March 2022].

Glass - Ibler, M., 2017. Cool nordiske boliger >> Selected Projects. 1st ed. Archipress M, pp.9-34.

jrn.se. 2009. Villa Överby. [online] Available at: <https://www.jrn.se/#/overby/> [Accessed 15 March 2022].

Gaisset, I., 2011. Designing Buildings for Disassembly: Stimulating a Change in the Designer's Role. Department of Civil and Environmental Engineering in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING IN CIVIL AND ENVIRONMENTAL ENGINEERING AT THE MASSACHUSSETS INSTITUTE OF TECHNOLOGY, p.14.

(Brand, S. 1994). [online] ResearchGate. Available at: https://www.researchgate.net/figure/Shearing-layers-of-Change-Brand-S-1994_fig1_228865622 [Accessed 23 May 2022].

Wood- Ibler, M., 2017. Cool nordiske boliger >> Selected Projects. 1st ed. Archipress M, pp.35-102.

Mettelange.com. 2015. Vacation house - Island - mettelange. [online] Available at: <https://www.mettelange.com/Vacation-house-Island> [Accessed 9 March 2022].

Brick - Ibler, M., 2017. Cool nordiske boliger >> Selected Projects. 1st ed. Archipress M, pp.103-151.

LUNDBERG, H., 2015. JUNISKÄR. [online] hhl.se. Available at: <https://www.hhl.se/projects/juniskar/> [Accessed 16 March 2022].

Statista. 2022. Share of U.S. C&D waste by material | Statista. [online] Available at: <https://www.statista.com/statistics/504126/share-of-construction-demolition-waste-generation-in-us-by-material/> [Accessed 7 February 2022].

Wei, Y., Han, R., Wang, C., Yu, B., Liang, Q., Yuan, X., Chang, J., Zhao, Q., Liao, H., Tang, B., Yan, J., Cheng, L. and Yang, Z., 2020. Self-preservation strategy for approaching global warming targets in the post-Paris Agreement era. Nature Communications, 11(1).

McDonough, W. and Braungart, M., 2010. Cradle to cradle =. Aravaca, Madrid: McGraw Hill, p.4.

Zumthor, P. (2006), Atmospheres, Birkhäuser, Publishers for Architecture, Boston. Page 11

Pallasmaa, J. (1995), Chapter 7: Identity, Intimacy and Domicile i The Home: words, interpretations, meanings and environments, Page 133

Browning, W., Ryan, C., Clancy, J. (2014), 14 Patterns of Biophilic Design, New York: Terrapin Bright Green llc

DeGroff, H. McCall, W. (s. d.), Biophilic Design - An Alternative Perspective for Sustainable Design in Senior Living.

Lawrence, R., 1987. What Makes a House a Home?. Environment and Behavior, 19(2), pp.154-168.

Vacher, M. (2010) 'Et hjem er noget man gør', in Bolig og Velfærd. København: Center for bolig og velfærd, pp. 12–15. Available at: https://boligforskning.dk/sites/default/files/editorfiles/Bog_Bolig_velfaerd_280110%283%29.pdf (Accessed: 22 February 2022).

Kirsten Gram-Hanssen & Claus Bech-Danielsen (2004) House, home and identity from a consumption perspective, Housing, Theory and Society

Bloch, K. and Rasmussen, P., 1983. Fleksibilitetsformer i boligbyggeriet. [Kbh.]: Kunstakademiets Arkitektskole, Laboratoriet for Boligbyggeri.

Poulsen, M. and Lauring, M., 2019. The Historical Influence of Landscape, Ecology and Climate on Danish Low-rise Residential Architecture. International Journal of Design & Nature and Ecodynamics, 14(2), pp.91-102.

Realdaniabyogbyg.org. 2022. The Adaptable House | Realdania By & Byg. [online] Available at: <https://www.realdaniabyogbyg.org/projects/the-minico2-houses-the-adaptable-house> [Accessed 14 March 2022].

Magdziak, M., 2019. Flexibility and Adaptability of the Living Space to the Changing Needs of Residents. IOP Conference Series: Materials Science and Engineering, 471, p.072011.

Rietveld Schröder House. 2022. Rietveld Schröder House – Unesco World Heritage in Utrecht. [online] Available at: <https://www.rietveldschroderhuis.nl/en> [Accessed 14 March 2022].

U.S. Environmental Protection Agency. 1989. Report to Congress on indoor air quality: Volume 2. EPA/400/1-89/001C. Washington, DC.

van den Brom, P., Meijer, A. and Visscher, H., 2017. Performance gaps in energy consumption: household groups and building characteristics. Building Research & Information, 46(1), pp.54-70.

Realdania.dk. 2022. Mini-CO2 husene. [online] Available at: <https://realdania.dk/projekter/mini-co2-husene?imagename=foranderlig_slider-jpg.jpg&showgallery=topgallery> [Accessed 28 March 2022].

Architects, A., 2019. Arkitektur - der fremmer bæredygtig adfærd. 2nd ed. Alexandria instituttet, p.12.

Kleis, B., 2014. Kvotehuset. [S.l.]: Realdania Byg.

03 Analysis

2022. Danskerne om bæredygtighed: Det er vores ansvar. [online] Available at: <https://www.arla.dk/om-arla/nyheder/2018/pressrelease/danskerne-om-baeredygtighed-det-er-vores-ansvar-2543742/> [Accessed 13 March 2022].

Andelssamfundet i hjortshøj (2019 a), Velkommen til andelssamfundet i Hjortshøj, Andelssamfunde.dk [online]. Available through: http://www.andelssamfundet.dk/da1 (Last visited 9. marts 2022)

Bofællesskab.dk (s. d.), Andelssamfundet i Hjortshøj, Bofællesskab.dk [online]. Available through: https://bofaellesskab.dk/bofaellesskaber/se-bofaellesskaber/andelssamfundet-i-hjortshoj?fbclid=IwAR0kvbTvKYzCxcafCsbKbxaSx-Z_QxG30FGqa4IgQbEXleJj_HW-udh6pbY (Last visited 9. marts 2022)

Cappelen, J. and Jørgensen, B. (n.d.). DANISH METEOROLOGICAL INSTITUTE Observed Wind Speed and Direction in Denmark -with Climatological Standard Normals, 1961-90 Observeret vindhastighed og -retning i Danmark -med klimanormaler 1961-90. Page 135 [online] Available at: https://www.dmi.dk/fileadmin/user_upload/Rapporter/TR/1999/tr99-13.pdf.

DAS HAUS. 2022. Baugemeinschaft: So baut man als Gruppe. [online] Available at: <https://www.haus.de/geld-recht/bauen-der-baugemeinschaft-die-vorteile-der-baugruppe-25681> [Accessed 9 March 2022].

Dieckmann, M. and Dieckmann, M., 2022. Har børn og babyer behov for eget værelse?. [online] Bolius.dk. Available at: <https://www.bolius.dk/hvornaar-har-boern-behov-for-eget-vaerelse-91471> [Accessed 13 March 2022].

politikenadvertorial. 2020. Sorø - det danske smørhul. [online] Available at: <http://politikenadvertorial.dk/6842012> [Accessed 2 March 2022].

Realdaniabyogbygklubben.dk. 2019. Byggefællesskaber - beboerdrevet boligbyggeri i byudvikling. [online] Available at: <https://www.realdaniabyogbygklubben.dk/udgivelser/boeger/udgivelser/beboerdrevne-byggef%C3%A6llesskaber/2307> [Accessed 2 March 2022].

Siegel, V. and 2011, Q., 2022. Nachhaltigkeit im Wohnungsbau - NaWoh - Qualitätssiegel 2011. [online] Nawoh.de. Available at: <https://www.nawoh.de/vergebene-siegel/qualitaetssiegel-2011> [Accessed 9 March 2022].

Soroe.viewer.dkplan.niras.dk. 2019. Guidelines and statement. [online] Available at: https://soroe.viewer.dkplan.niras.dk/plan/6#/3056 [Accessed 2 March 2022].

Soroe.viewer.dkplan.niras.dk. 2019. the main structure of the municipal plan. [online] Available at: <https://soroe.viewer.dkplan.niras.dk/plan/6#/3006> [Accessed 2 March 2022].

United Nations Sustainable Development. 2022. United Nations Sustainable Development. [online] Available at: <https://www.un.org/sustainabledevelopment/> [Accessed 2 March 2022].

04 recapitulation

Bygningsreglementet.dk. 2022. BR18. [online] Available at: <https://bygningsreglementet.dk/Tekniske-bestemmelser/22/Vejledninger/Generel_vejledning/Kap-1_1> [Accessed 18 March 2022].

Bygningsreglementet.dk. 2022. BR18. [online] Available at: <https://bygningsreglementet.dk/Tekniske-bestemmelser/18/Vejledninger/Generel_vejledning/Dagslys> [Accessed 18 March 2022].

Bygningsreglementet.dk. 2022. BR18. [online] Available at: <https://bygningsreglementet.dk/Tekniske-bestemmelser/09/Vejledninger/Boligindretning/Lydforhold> [Accessed 18 March 2022].

Dansk Standard (2019) 'DS-EN 16798-1:2019 - Bygningers energieffektivitet - Ventilation i bygninger - Del 1: Indeklimamæssige inputparametre til beregning og evaluering af bygningers energieffektivitet i forbindelse med indendørs luftkvalitet, termisk miljø, belysning og akusti'. København: Dansk Standard. Available at: file:///C:/Users/W530/Downloads/DS_EN 16798-1_2019 - Danish Values (1).pdf (Accessed: 27 February 2020).

05 presentation

Dac.dk. 2022. [online] Available at: <https://dac.dk/wp-content/uploads/2021/09/Dansk_Arkitektur_Center_Hjaelp_naturen.pdf> [Accessed 18 May 2022].

(SBi 2020-04) Zimmermann, R. K. et al. (2020) SBI 2020:04 Klimapåvirkning fra 60 bygninger. Lyngby: Polyteknisk Boghandel og Forlag ApS.

(SBi 2021-13) Tozan, B., Brisson Jørgensen, E., & Birgisdottir, H. (2021). Klimapåvirkning fra 60 bygninger: Opdaterede værdier baseret på nyere data og danske branche EPD'er. Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet. BUILD Rapport Nr. 2021:13 https://sbi.dk/Pages/Klimapaavirkning-fra-60-bygninger_.aspx

06 design development

Varmepumpe.dk. 2022. Jordvarme: Fordele og ulemper. [online] Available at: <https://varmepumpe.dk/jordvarme-fordele-ulemper> [Accessed 11 May 2022].

2020. DGNB-System Denmark Bæredygtighedscertificering af nybyggeri og omfattende renoveringer. Stuttgart: Green Building Council Denmark / Deutsche Gesellschaft für Nachhaltiges Bauen, pp.SOC 1.2 page 16.

Solarstone.ee. 2022. Tiled solar roof – Solarstone. [online] Available at: <https://solarstone.ee/en/tiled-solar-roof/> [Accessed 12 May 2022].

Solarstone.ee. 2022. [online] Available at: <https://solarstone.ee/wp-content/uploads/2022/04/Tiled-solar-roof-108W-datasheet_compressed.pdf> [Accessed 12 May 2022].

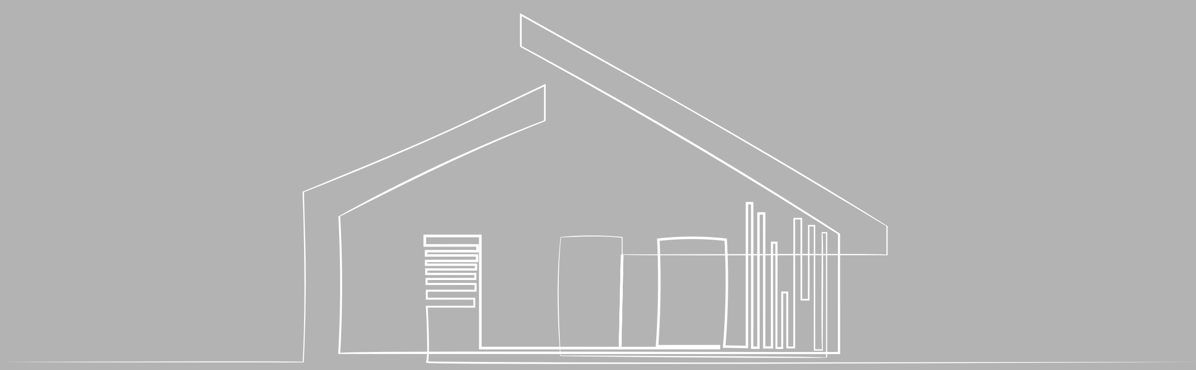
(LCA i praksis, 2021). LCA I praksis, Introduktion og eksempler på livscyklusvurderinger i byggeprojekter. 1st ed. Kanafani, K. and Birgisdottir, H., 2021. Trafik-, Bygge- og Boligstyrelsen.

(SBI 2019:08). Livscyklusvurdering for cirkulære løsninger med fokus på klimapåvirkning. 1st ed. Polyteknisk Boghandel og Forlag ApS: Statens Byggeforskningsinstitut.

(KAB-Fællesskabet, 2022). Potentialer for genbrug og genanvendelse af byggematerialer i KAB-Fællesskabet. 1st ed. kab-bolig and Lendager.

Styrelsen, B., 2016. Introduction to LCA of Buildings. Danish transport & construction agency, 1, p.5.

Appendix



Chikorievænget

The inhabitable material banks

Aalborg university
Msc04 - Sustainable architecture
Arch 15

May 2022

Niklas Dahl Petersen
Emil Pøckel Hemmingsen

Appendix - content

Appendix 01: LCA assumptions

LCA assumptions

LCAbyg is very relient on the specific amounnt and unit of a material. EPD does not always have the same values in them, so in order for us to compare materials, assumptions must be made.

Structure

Reused bricks: there is 66 bricks to 1 m², EPD is in ton/1000kg. The weight of one brick is 2,4kg. 2,4kg·66=158,4kg. The bricks need motar to stick and form a structure, the need is one kg for every brick. 66·1kg=66kg

Construction wood: How much wood is used per m². Estimate of 1 beam per 0,6m per 1 m² we estimate to 1,66 beam of a size 5x10cm. 1.66·(5·10·100)=8000cm³=0,008m³, An estimastion of 6 screws per 6m² (From EPD)

CLT beam: would be estimated to one beam per 1 m with the size 10x10mm. 10·10·1000=10000cm³=0,001m³, An estimastion of 6 screws per 6m² (From EPD)

Concrete wall element: Wall element of 15cm thick inforced concrete. 1m²=0,15m³

Insulation

The chosen insulation material EPD does all work with a m² unit description, however the specific need for insulation may vary in terms of u-value. To make the material EPD more compareable and without to many complications, a thickness of material is chosen. This means that all of the comparisons is based on the fundamentation of the volume of the material .

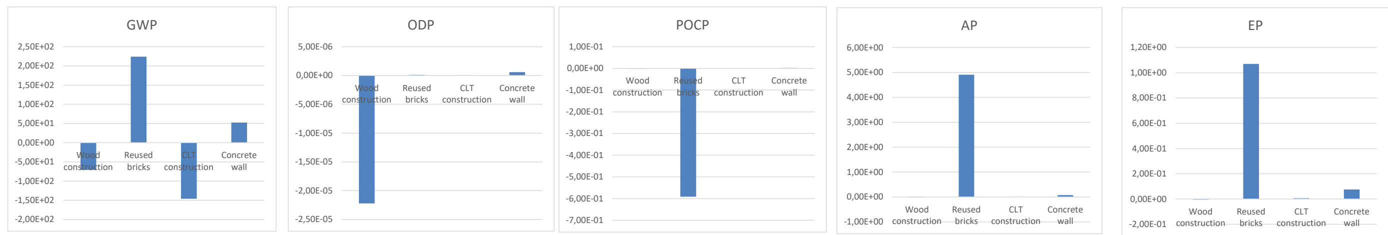
This might not be the best way, because some of the materials perform better in therms of heat resistance.

Exterior cladding

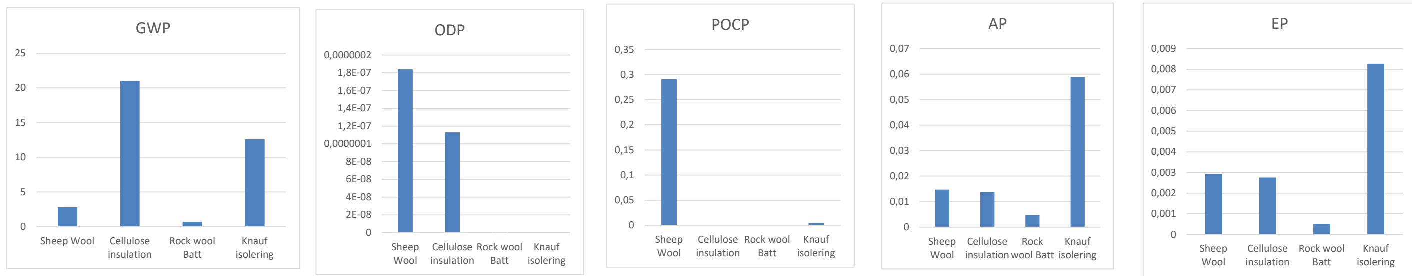
The given unit of exterior cladding is either in 1 piece or 1 m²

The EPD dictates the amounts used for a m²

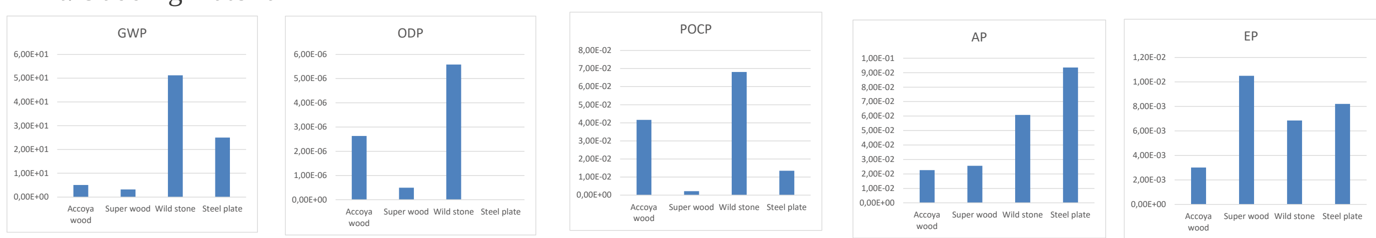
Structure material



Insulation material



Ext. cladding material



Appendix 02: Street format

Crime and neighbourhood

Three streets of Croydon were picked out, 1. through street, 2. dead cul-de-sac and 3. the bulb cul-de-sac. Comparing the images there is a substantial difference in the atmosphere, amount of green and feeling of security. Looking at the pictures it is not hard to see where the most crime would occur. The three streets all lie in the same neighborhood, less than a 500m distance from each other. However, the difference of quality living is obvious. The atmosphere appear very different in the three streets and one dominant factor is the amount of green taking the space.

The safety of a neighbourhood depends on a large variety of factors not only the street format. For the street to be safe there must be less foreign activity, the street should be designed for the residents only.

However, it should be easy to get to and from the street in terms of transport, so the street doesn't force a higher use of mechanical vehicles. Utilizing a grid system which creates a higher sense of connectivity and promotes a walkable neighborhood.

Ill. 04. Croydon satalite view

1


Ill. 05. Croydon satalite through street

2


Ill. 06. Croydon satalite dead end

3


Ill. 07. Croydon satalite bulb cul de sac


Ill. 01. Croydon through


Ill. 03. Croydon dead end


Ill. 02. Croydon cul-de-sac

Appendix 03: Inspiration pics

Appendix 04: Room program

Unit A	Number	Size [m²]
Entrance	1	5
Living space	1	20
Kitchen dining area	1	20
Bathroom	1	6
Master bedroom	1	12
Bedroom	1	10
Utility room	1	8
Total	7	81

Unit B	Number	Size [m²]
Entrance	1	7
Living space	1	35
Kitchen dining area	1	15
Bathroom	1	8
Master bedroom	1	12
Bedroom	2	10
Utility room	1	8
Total	8	95

Unit C	Number	Size [m²]
Entrance	1	7
Living space	1	35
Kitchen dining area	1	25
Bathroom	1	8
Master bedroom	1	12
Bedroom	2	10
Utility room	1	8
Toilet	1	4
Total	9	119

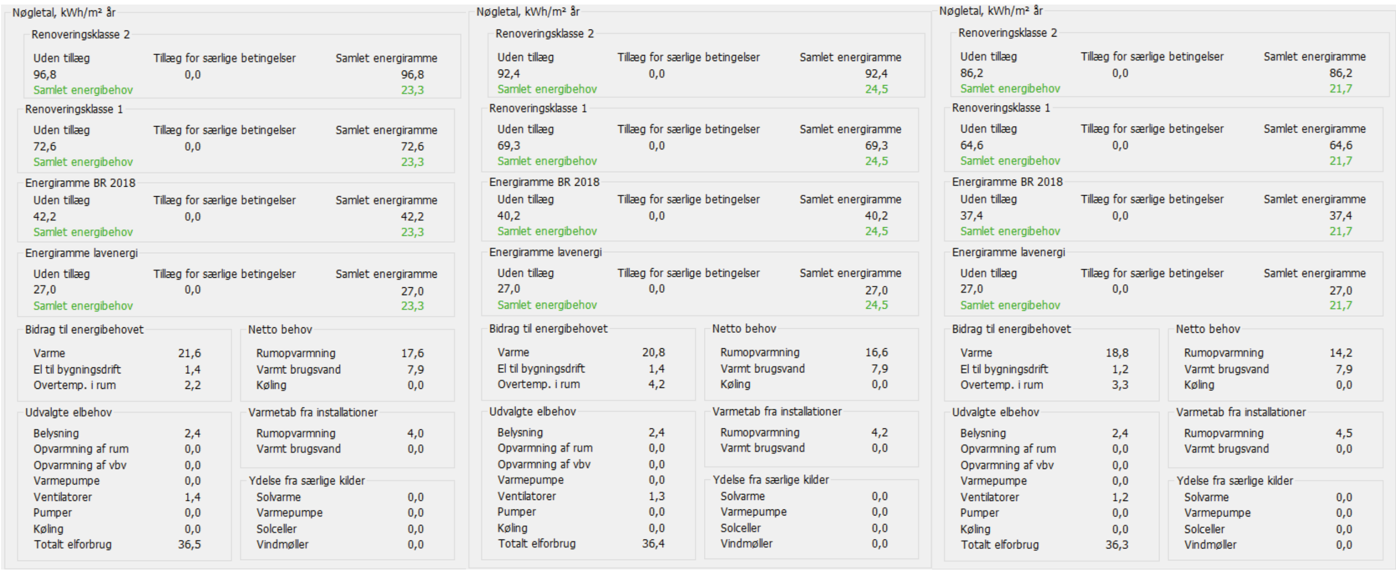
Room - houses	Architecthural qualities	Functional qualities
Living space	Ceiling height above 2,5m	Flexible in terms of decoration
	Connected to the kitchen	
	Direct access to garden	
Kitchen dining area	Center of the house	Practical functions
	Nordic style	Social gathering
Bathroom	Neutral colours	Durable surfaces
		Easy cleaning
Bedroom	Practical planlayout	Walls must be used for decoration
Entrance	Clean	
	Used for guests	
Scullery	Hidden entrance	Table for chores
	Allowed to get dirty	

Common house	Number	Size [m²]
Main room	1	75
Workshop area	3	27
Toilet	4	4
Entrance	1	12
Wardrobe	1	12
Depot	1	14
Technical room	1	10
Kitchen	1	20
Total	8	325

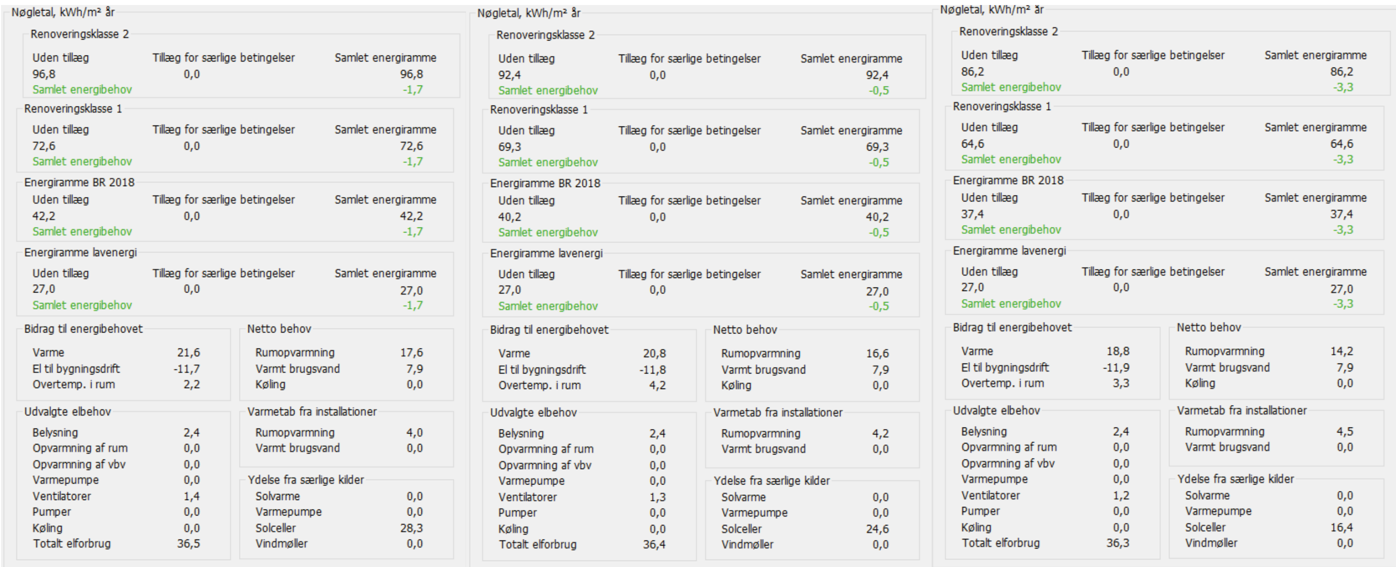
Room - common house	Architecthural qualities	Functional qualities
Main room	Ceiling height above 2,5m	Flexible in layout
		Moving walls
	Direct access to garden	
Kitchen	Industrial	Practical functions
		Easy to clean
Toilet	Neutral colours	Durable surfaces
		Easy cleaning
Entrance	Welcoming	Walls must be used for decoration
	Open	
Wardrobe	Public storage	Easy to circulate in
Workshop area	Spacious	Used for different functions
	Flexible	

Atmospheric	Visual	Thermal	Acoustic
CO^2 levels (Cat 2)	Average visual DF > 2,1%	Summerperiod	Reveberation time T < 1,0 s
Social rooms Maximum 800 ppm over outdoor air		Maximum 100 hours above 26 °C and 25 hours above 27 °C	
Bedrooms maximum 500 ppm over outdoor air			
Mechanical ventilation	Minimum 15% glas to floor area in living room	Operativ temperature range winter:	Sound category C
Opportunity for overide	Minimum 5% glas to floor area in hallways	20-25 °C	
During heating season minimum 0,3 l/s per m²		Operativ temperature range summer:	
Heat recoveryof 70-80%	Walls opposite windows max reflectans of 0,7	23-26 °C	
Minimum exhaust air	Operational interior and exterior shading		
Kitchen 20 l/s			
Bathroom 15 l/s	Minimum 2 hours of direct sunlight in livingroom		
Scullery 10 l/s	(21 of marts]		
Natural ventilation	View to outdoor		
During non-heating summer 0,9 l/s pr m²	View to nature		
(DGNB, version 2020.2.0.0) (BR18, 2022)	(DGNB, version 2020.2.0.0)	(DGNB, version 2020.2.0.0)	(DGNB, version 2020.2.0.0)

Appendix 05: House energy, solar.



House A House B House C



Appendix 06: Life cycle assessment results

Life cycle assessment results

Results over three houses with data from specific Environmental Product Declaration, Lcabyg 5 and ökobaudat

Scenarios	Final outcome			reuse investigation		
	name	*value*	*unit*	*name*	*value*	*unit*
82 m2	GWP	**6.31E+00**	kg CO_2-eq./m²/år	GWP	**5.92E-01**	kg CO_2-eq./m²/år
	ODP	2.69E-08	kg CFC11-eq./m²/år	ODP	2.69E-08	kg CFC11-eq./m²/år
	POCP	5.00E-03	kg ethene-eq./m²/år	POCP	4.83E-03	kg ethene-eq./m²/år
	AP	1.57E-02	kg SO_2-eq./m²/år	AP	1.37E-02	kg SO_2-eq./m²/år
	EP	2.62E-03	kg PO_4^{3}-eq./m²/år	EP	2.18E-03	kg PO_4^{3}-eq./m²/år
	ADPe	8.39E-04	kg Sb-eq./m²/år	ADPe	5.92E-04	kg Sb-eq./m²/år
	ADPf	6.89E+01	MJ/m²/år	ADPf	5.95E+01	MJ/m²/år
	PEtot	1.52E+02	MJ/m²/år	PEtot	1.28E+02	MJ/m²/år
	Sek	1.90E+00	MJ/m²/år	Sek	1.90E+00	MJ/m²/år
	name	*value*	*unit*	*name*	*value*	*unit*
98 m2	GWP	**6.37E+00**	kg CO_2-eq./m²/år	GWP	**8.50E-01**	kg CO_2-eq./m²/år
	ODP	2.33E-08	kg CFC11-eq./m²/år	ODP	2.33E-08	kg CFC11-eq./m²/år
	POCP	5.07E-03	kg ethene-eq./m²/år	POCP	4.90E-03	kg ethene-eq./m²/år
	AP	1.58E-02	kg SO_2-eq./m²/år	AP	1.37E-02	kg SO_2-eq./m²/år
	EP	2.63E-03	kg PO_4^{3}-eq./m²/år	EP	2.17E-03	kg PO_4^{3}-eq./m²/år
	ADPe	7.80E-04	kg Sb-eq./m²/år	ADPe	5.51E-04	kg Sb-eq./m²/år
	ADPf	6.92E+01	MJ/m²/år	ADPf	6.00E+01	MJ/m²/år
	PEtot	1.48E+02	MJ/m²/år	PEtot	1.26E+02	MJ/m²/år
	Sek	1.93E+00	MJ/m²/år	Sek	1.93E+00	MJ/m²/år
	name	*value*	*unit*	*name*	*value*	*unit*
136 m2	GWP	**6.00E+00**	kg CO_2-eq./m²/år	GWP	**5.59E-01**	kg CO_2-eq./m²/år
	ODP	1.82E-08	kg CFC11-eq./m²/år	ODP	1.82E-08	kg CFC11-eq./m²/år
	POCP	4.86E-03	kg ethene-eq./m²/år	POCP	4.70E-03	kg ethene-eq./m²/år
	AP	1.48E-02	kg SO_2-eq./m²/år	AP	1.29E-02	kg SO_2-eq./m²/år
	EP	2.49E-03	kg PO_4^{3}-eq./m²/år	EP	2.06E-03	kg PO_4^{3}-eq./m²/år
	ADPe	7.73E-04	kg Sb-eq./m²/år	ADPe	5.51E-04	kg Sb-eq./m²/år
	ADPf	6.55E+01	MJ/m²/år	ADPf	5.66E+01	MJ/m²/år
	PEtot	1.43E+02	MJ/m²/år	PEtot	1.21E+02	MJ/m²/år
	Sek	1.81E+00	MJ/m²/år	Sek	1.81E+00	MJ/m²/år

Life cycle assessment results

Relevant buildings for comparison (single family houses)
find relevant buildings for comparison and conclude an average value for global warming potential (GWP) kg CO_2-eq./m²/år
the information is obtained from Icabyg 5 and SBi 2020-04 (+update version SBi 2021-13)
The case buildings originate from DGNB-certified projects, external projects and life cycle assessments carried out by SBi.
consideration period of 50 years

	program	database	database year	name	materials kg CO_2-eq./m²/år	BR	energy class kWh/m2/år	solar panels	area m2	construction	weight tons
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	**Enf01**	**6.13E+00**	**2015**	**< 30**	**-**	**<1000**	**heavy**	**91.416**
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	Enf02	7.10E+00	2015	< 30	-	<1000	heavy	210.289
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	**Enf03**	**5.79E+00**	**2015**	**< 30**	**-**	**<1000**	**light**	**44.656**
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	**Enf04**	**7.40E+00**	**2015**	**< 30**	**-**	**<1000**	**heavy**	**133.246**
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	**Enf05**	**3.67E+00**	**2015**	**< 30**	**-**	**<1000**	**light**	**30.907**
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	Enf06	7.98E+00	2015	< 30	-	<1000	heavy	202.899
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	Enf07	7.62E+00	2015	< 30	-	<1000	heavy	220.505
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	**Enf08**	**9.36E+00**	**2015**	**< 30**	**-**	**<1000**	**heavy**	**145.838**
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	**Enf09**	**6.60E+00**	**2020**	**< 20**	**-**	**<1000**	**light**	**164.589**
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	Enf10	8.52E+00	2015	< 30	-	<1000	heavy	227.346
SBi 2020-04	Icabyg 4.0 (beta)	Ökobaudat	2016	Enf11	9.12E+00	2020	< 20	x	<1000	heavy	174.504
SBi 2021-13	Icabyg 5	Ökobaudat	2020	**Enf01**	**5.25E+00**						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	Enf02	7.13E+00						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	**Enf03**	**6.26E+00**						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	**Enf04**	**6.35E+00**						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	**Enf05**	**5.34E+00**						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	Enf06	8.38E+00						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	Enf07	7.46E+00						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	**Enf08**	**8.58E+00**						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	**Enf09**	**8.51E+00**						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	Enf10	8.85E+00						
SBi 2021-13	Icabyg 5	Ökobaudat	2020	Enf11	1.01E+01						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	**Enf01**	**5.36E+00**						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	Enf02	7.27E+00						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	**Enf03**	**5.84E+00**						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	**Enf04**	**6.27E+00**						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	**Enf05**	**4.07E+00**						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	Enf06	8.33E+00						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	Enf07	7.62E+00						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	**Enf08**	**8.52E+00**						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	**Enf09**	**8.11E+00**						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	Enf10	8.51E+00						
SBi 2021-13	Icabyg 5	EPD + Ökobaudat	2020	Enf11	9.55E+00						

average at SBi 2020-04	Öko 16
total	selected houses
Enf01-11	Enf01/03/04/05/08/09
7.21E+00	6.49E+00

average at SBi 2021-13	Öko 20
total	selected houses
Enf01-11	Enf01/03/04/05/08/09
7.47E+00	6.72E+00

average at SBi 2021-13	Öko 20 + EPD
total	selected houses
Enf01-11	Enf01/03/04/05/08/09
7.22E+00	**6.36E+00**

Appendix 07: Embedded CO_2

Project collected exterior areas:

roof=3800 m^2

Exterior wall total=2200m^2

Exterior wall clay tile=1140 m^2

Embedded CO_2 in materials

Rockwool insulation

Exterior wall insulation amount

2200m^2*0,395m=869·m^3

Roof insulation amount

3800m^2·0,5m=1900·m^3

Insulation Rockwool epd declared unit

1m^2·0,037m=0,037·m^3

Amount of GPW per declared unit

per unit=2,03E+00

Amount of embedded energy in project insulation

(869m^3+1900m^3)/(0,037m^3)·2,03≈151920,8 kg CO_2

Embedded CO_2 in project insulation 151,92 t

Clay tile

Amount of clay tile on roof and wall

3800m^2+1140m^2=4940·m^2

Declared unit

1000 kg

GWP per declared unit

416 kg CO_2

Embedded CO_2 in project

12,12·3,85kg=46,662·kg

46,662·4940≈230510,3

230510/1000=23051/100=230,51

230·416kg CO_2=95680·CO_2·kg

Embedded CO_2

95,68 t

Wood structure

Amount of construction wood

3800 m

Construction wood dimension

100mm·300mm

Declared EPD unit

1 m^3

GWP per declared unit (EPD, 2020)

41,9 kg CO_2

Amount of construction wood in project

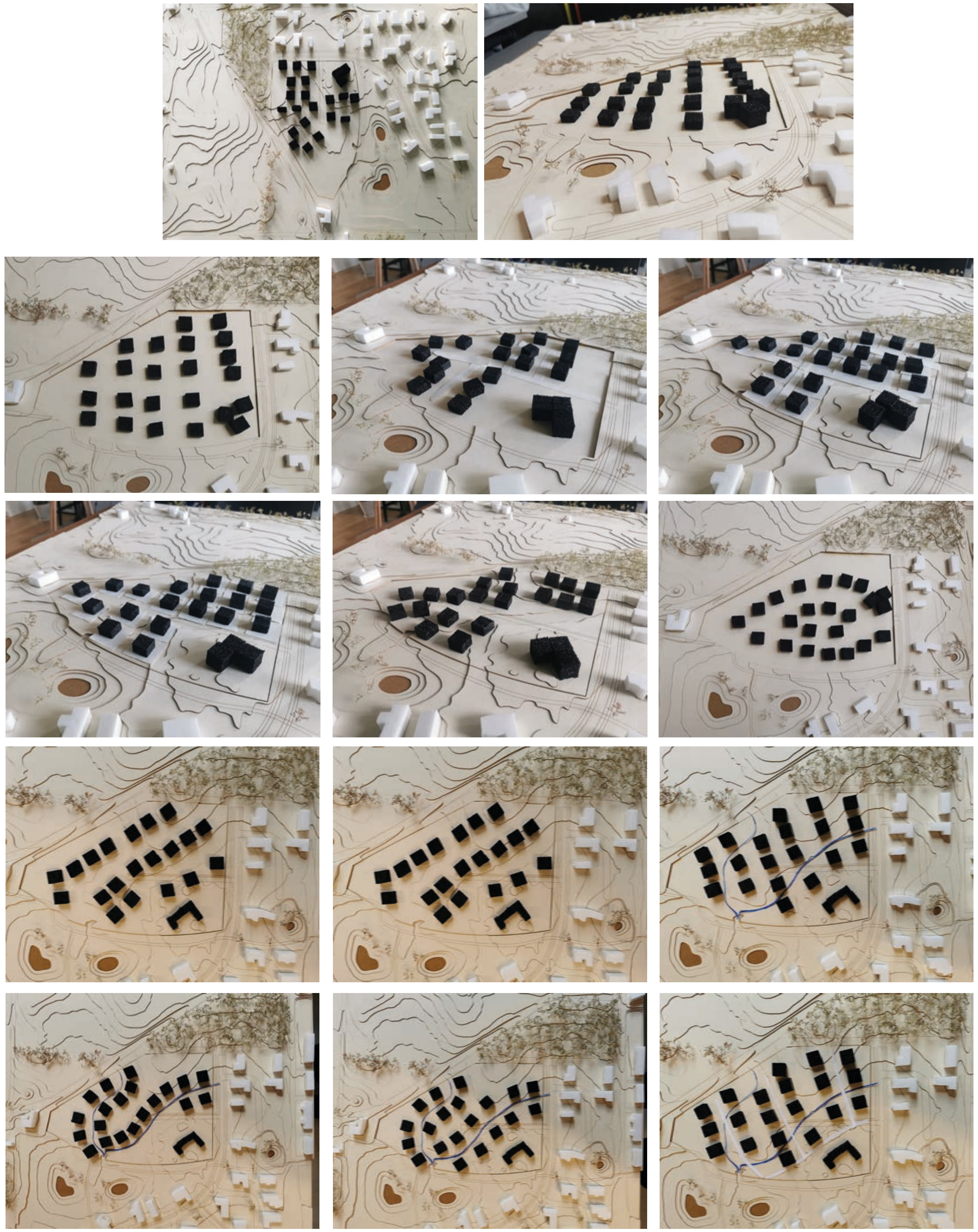
0,1m·0,3m·3800m=114·m^3

Amount of Embedded CO_2

114·41,9kg CO_2=4776,6·CO_2·kg

4,7 t

Appendix 08: Working model pictures



Ill. 08. Model picture

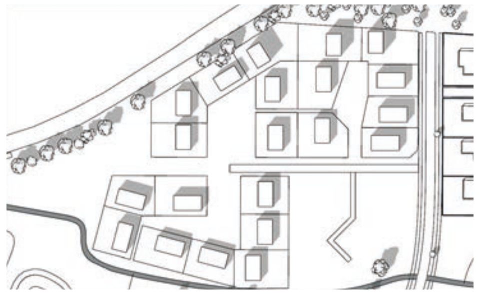
Appendix 09: Urban concept shadow analysis

Urban concept 1 shadow analysis

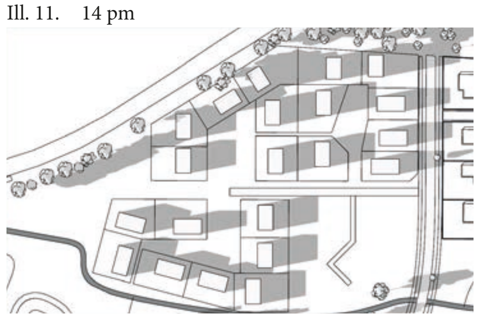
Equinox

Ill. 09. 8 pm

Ill. 10. 11 pm

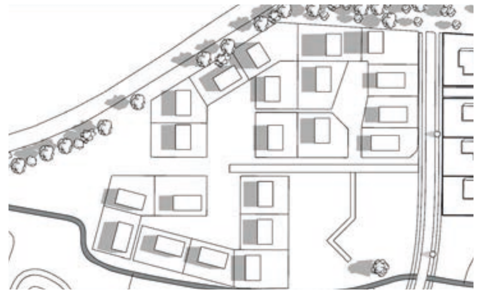


Ill. 11. 14 pm



Ill. 12. 17 pm

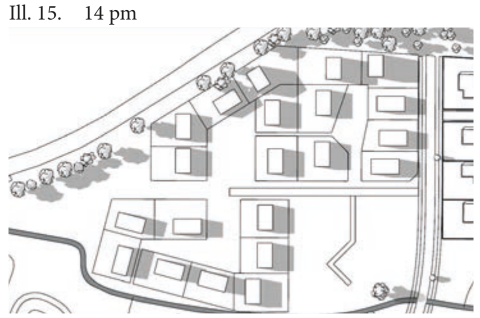
Summer solstice



Ill. 13. 8 am

Ill. 14. 11 am

Ill. 15. 14 pm



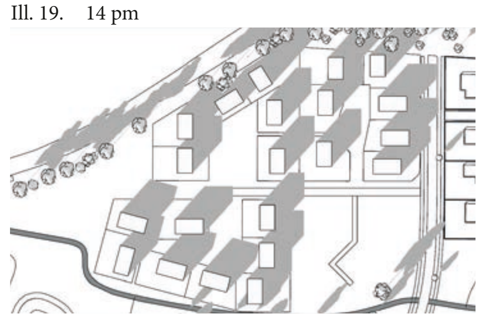
Ill. 16. 17 pm

Winter solstice

Ill. 17. 9 am

Ill. 18. 11 am

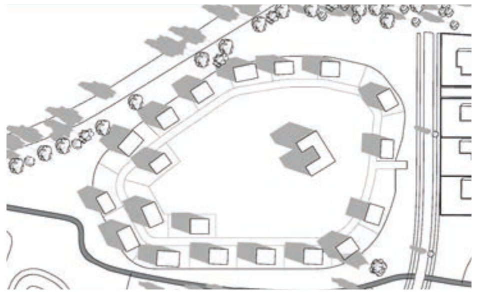
Ill. 19. 14 pm

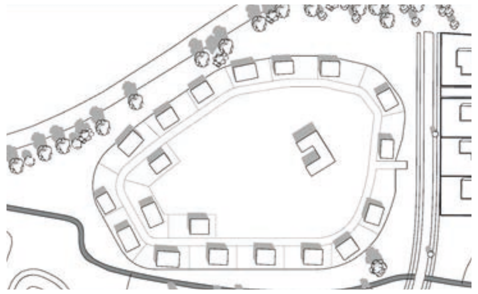


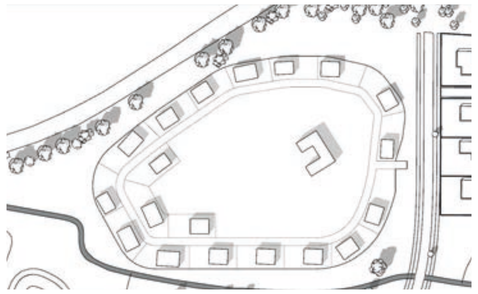
Ill. 20. 17 pm

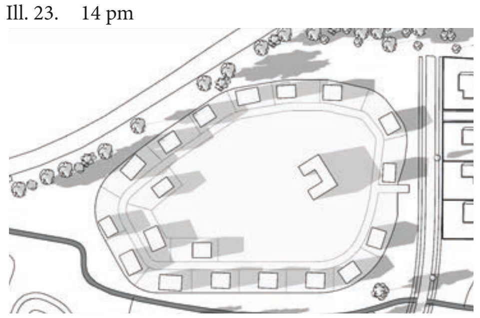
Urban concept 2 shadow analysis

Equinox solstice

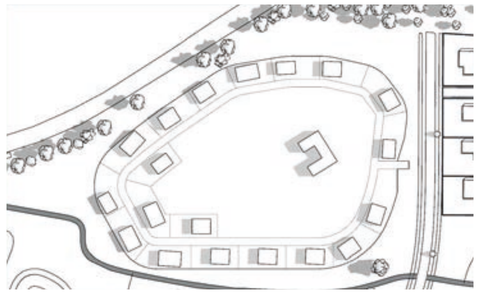

Ill. 21. 8 pm


Ill. 22. 11 pm


Ill. 23. 14 pm


Ill. 24. 17 pm

Summer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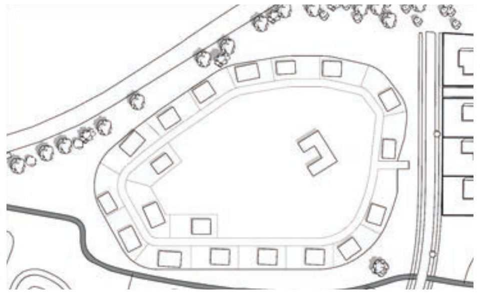
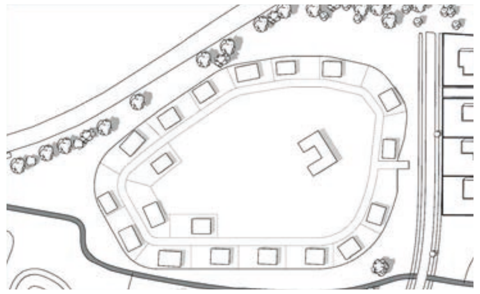
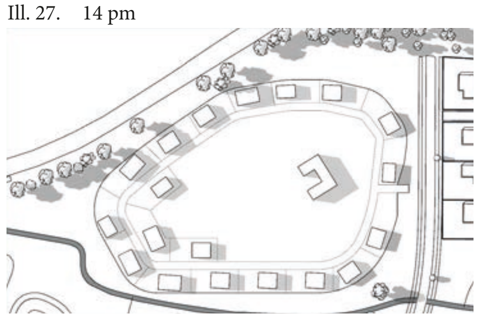
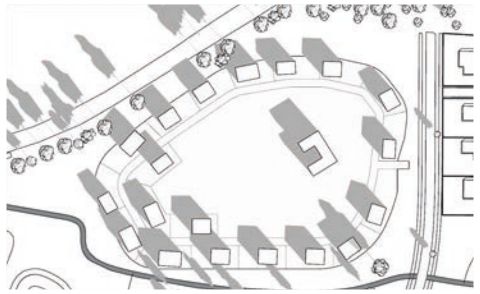
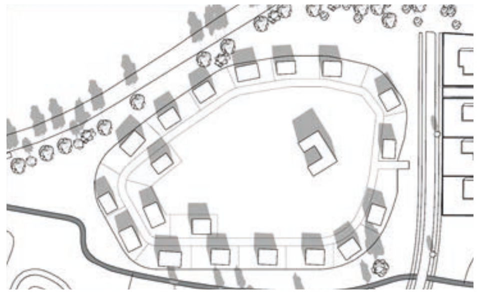

Ill. 26. 11 am

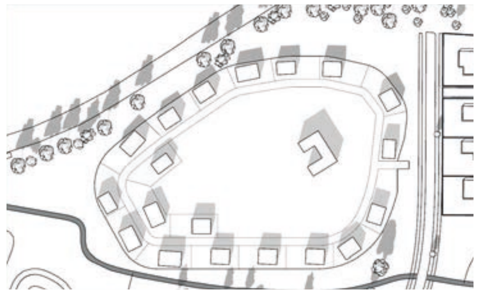

Ill. 27. 14 pm

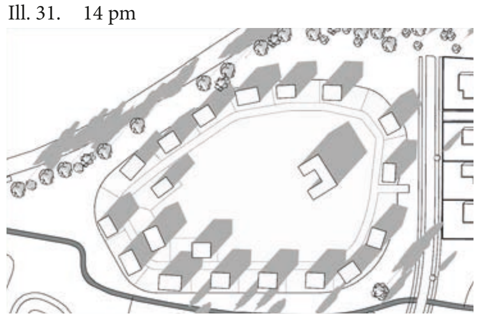

Ill. 28. 17 pm

Winter solstice


Ill. 29. 9 am

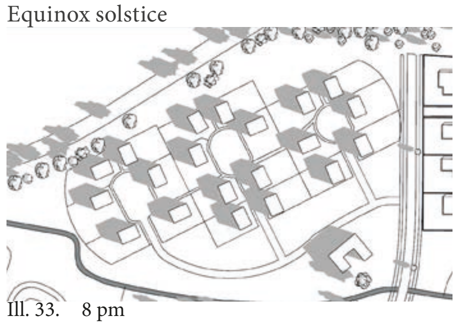

Ill. 30. 11 am

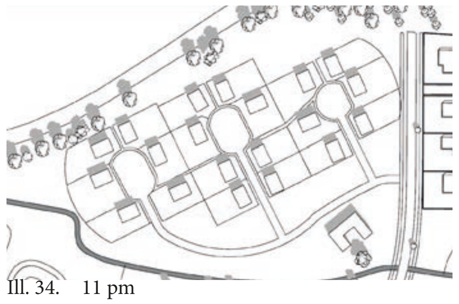

Ill. 31. 14 pm


Ill. 32. 17 pm

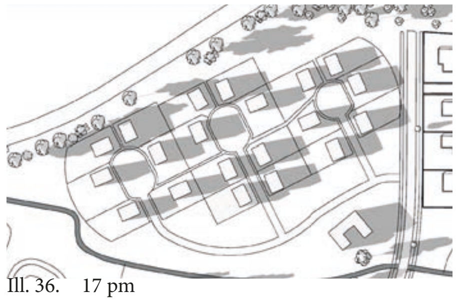
Urban concept 3 shadow analysis

Equinox solstice

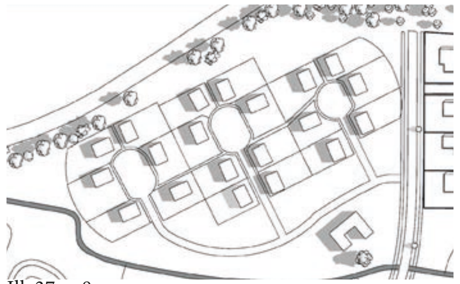

Ill. 33. 8 pm


Ill. 34. 11 pm


Ill. 35. 14 pm

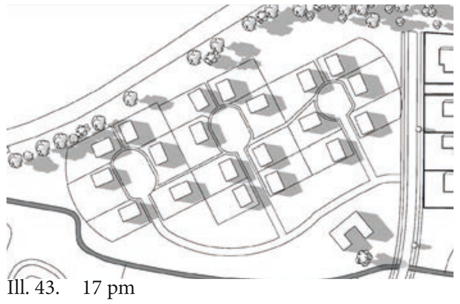

Ill. 36. 17 pm

Summer


Ill. 37. 8 am


Ill. 39. 11 am


Ill. 41. 14 pm


Ill. 43. 17 pm

Winter solstice

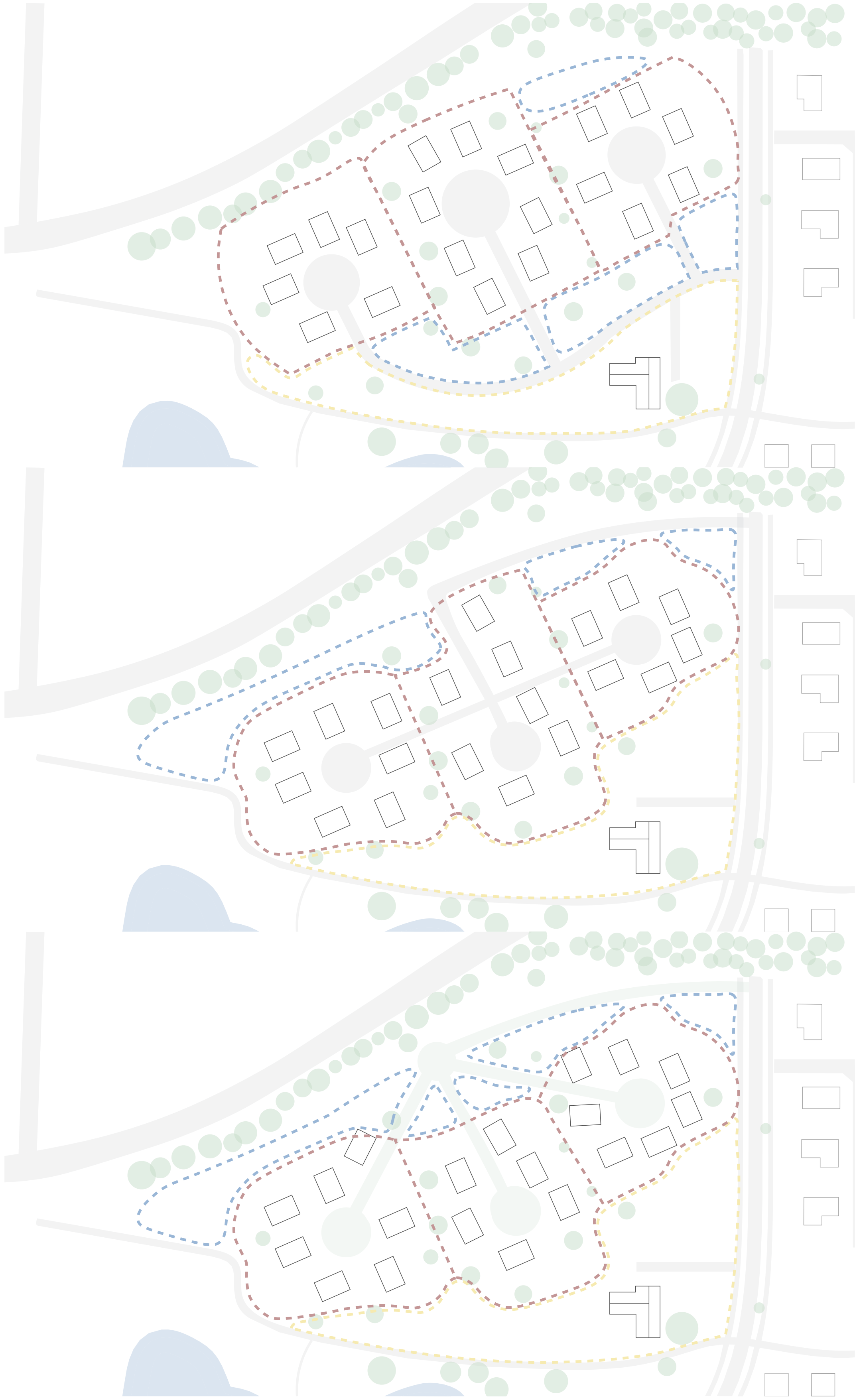

Ill. 38. 9 am


Ill. 40. 11 am


Ill. 42. 13 pm


Ill. 44. 15 pm

Appendix 10: Urban areas



Appendix 11: Common house energy

Data on common house

Build area = 240

Floor area = 370

Window to floor area = 20 %

roof = 360m² and 0,08 W/m²K

wall = 250 m² and 0,12 W/m²K

floor = 240m² and 0,10 W/m²K

Ventilation = 0,3 l/s m² + natural summer ventilation

not mentioned energy contributions and consumption factors are set to standard values in comparison to a new building and in mind with the scale and functions of the communal house.

Beskrivelse: Nyt solcelle anlæg

Solceller

71	Panel areal, m²
0,108	Peak Power (RS), kW/m²
0,8	System virkningsgrad (Rp), -

Orientering og skygger

sv	Orientering, S, SØ, Ø, ... eller grader, S=180
40	Hældning, °, 0, 10, 20, 30, ...
10	Horisont afskæring, °
0	Skygge til venstre, °
0	Skygge til højre, °

Nøgletal, kWh/m² år

	Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme	Samlet energibehov
Renoveringsklasse 2	75,9	0,0	75,9	25,0
Renoveringsklasse 1	57,0	0,0	57,0	25,0
Energiramme BR 2018	32,7	0,0	32,7	25,0
Energiramme lavenergi	27,0	0,0	27,0	25,0

Bidrag til energibehovet		Netto behov	
Varme	18,5	Rumopvarmning	17,0
El til bygningsdrift	4,9	Varmt brugsvand	7,2
Overtemp. i rum	0,0	Køling	0,0

Udvalgte elbehov		Varmetab fra installationer	
Belysning	11,5	Rumopvarmning	1,5
Opvarmning af rum	0,0	Varmt brugsvand	0,9
Opvarmning af vbv	2,1	**Ydelse fra særlige kilder**	
Varmepumpe	0,0	Solvarme	0,0
Ventilatorer	2,0	Varmepumpe	0,0
Pumper	0,7	Solceller	0,0
Køling	0,0	Vindmøller	0,0
Totalt elforbrug	22,4		

Nøgletal, kWh/m² år

	Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme	Samlet energibehov
Renoveringsklasse 2	75,9	0,0	75,9	0,0
Renoveringsklasse 1	57,0	0,0	57,0	0,0
Energiramme BR 2018	32,7	0,0	32,7	0,0
Energiramme lavenergi	27,0	0,0	27,0	0,0

Bidrag til energibehovet		Netto behov	
Varme	18,5	Rumopvarmning	17,0
El til bygningsdrift	-8,3	Varmt brugsvand	7,2
Overtemp. i rum	0,0	Køling	0,0

Udvalgte elbehov		Varmetab fra installationer	
Belysning	11,5	Rumopvarmning	1,5
Opvarmning af rum	0,0	Varmt brugsvand	0,9
Opvarmning af vbv	2,1	**Ydelse fra særlige kilder**	
Varmepumpe	0,0	Solvarme	0,0
Ventilatorer	2,0	Varmepumpe	0,0
Pumper	0,7	Solceller	14,5
Køling	0,0	Vindmøller	0,0
Totalt elforbrug	22,4		

kWh/m² year from electricity and energy frame (22,4*1,9) +(24,2*0,85) = 63,13 kWh/m² year

Elec = 1.9, district heat = 0.85 ,Electricity = 22,5 kWh/m² year, District heat = 24,2 kWh/m² year

kWh/m² year total in electricity 63,13 / 1,9 = 33,22 kWh/m² year

Total electricity kWh year for the building (33,22*370) + 111 = 12404,74 kWh/year

Low energy = 0,3 kWh/m² year

Floor area = 370 m²

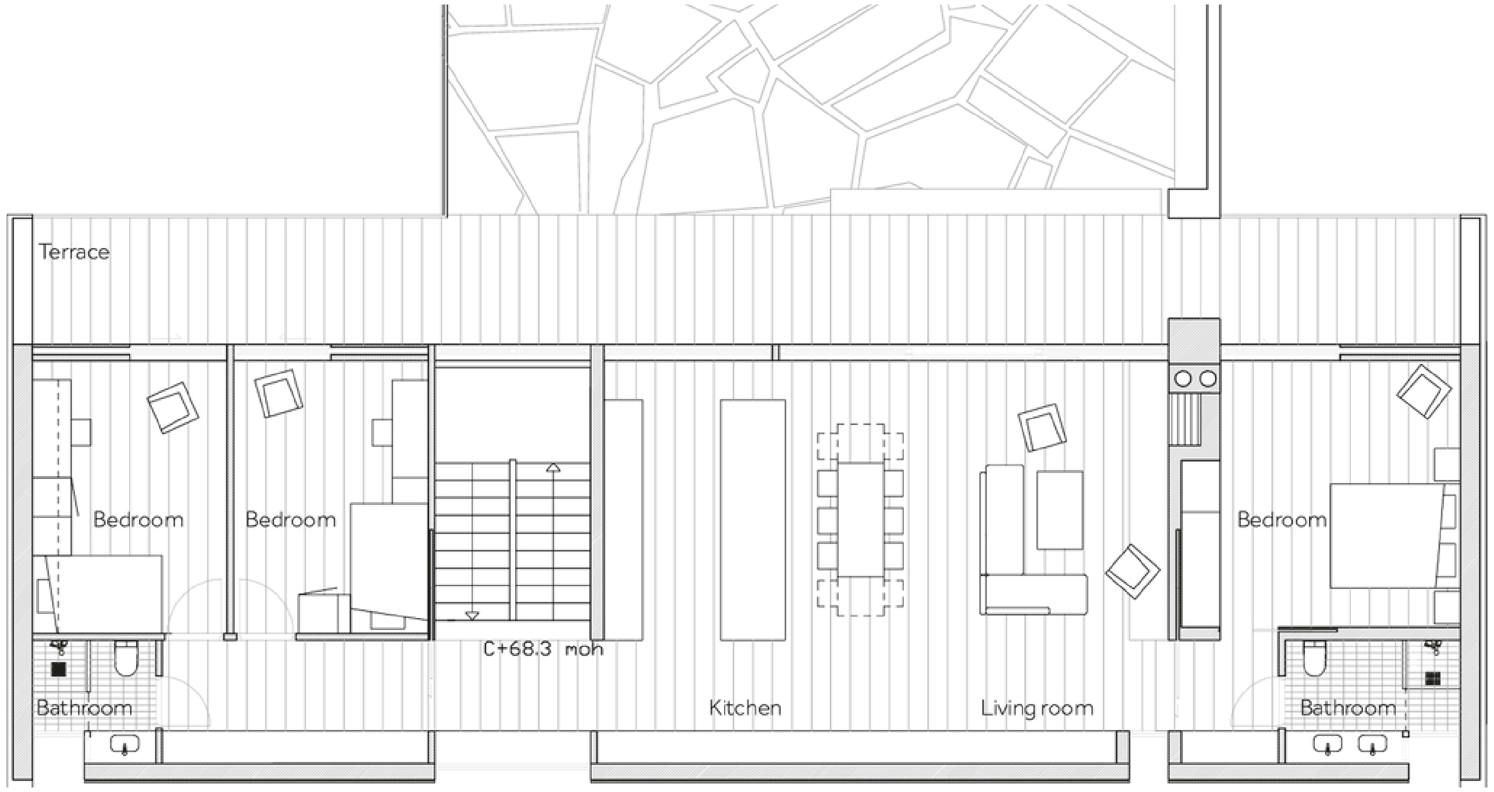
Use from house = 111 kWh/year

C = Installed power 12404,74 / (0,8*1050) = 14,76 kW peak E = 1050 kWh/m² (solar radiation intensity) D = 0,8 (system setup), C = Annual yield / D * E, B = Module efficiency, (19*108) / 100 = 0,20 kW Peak power = 108 W

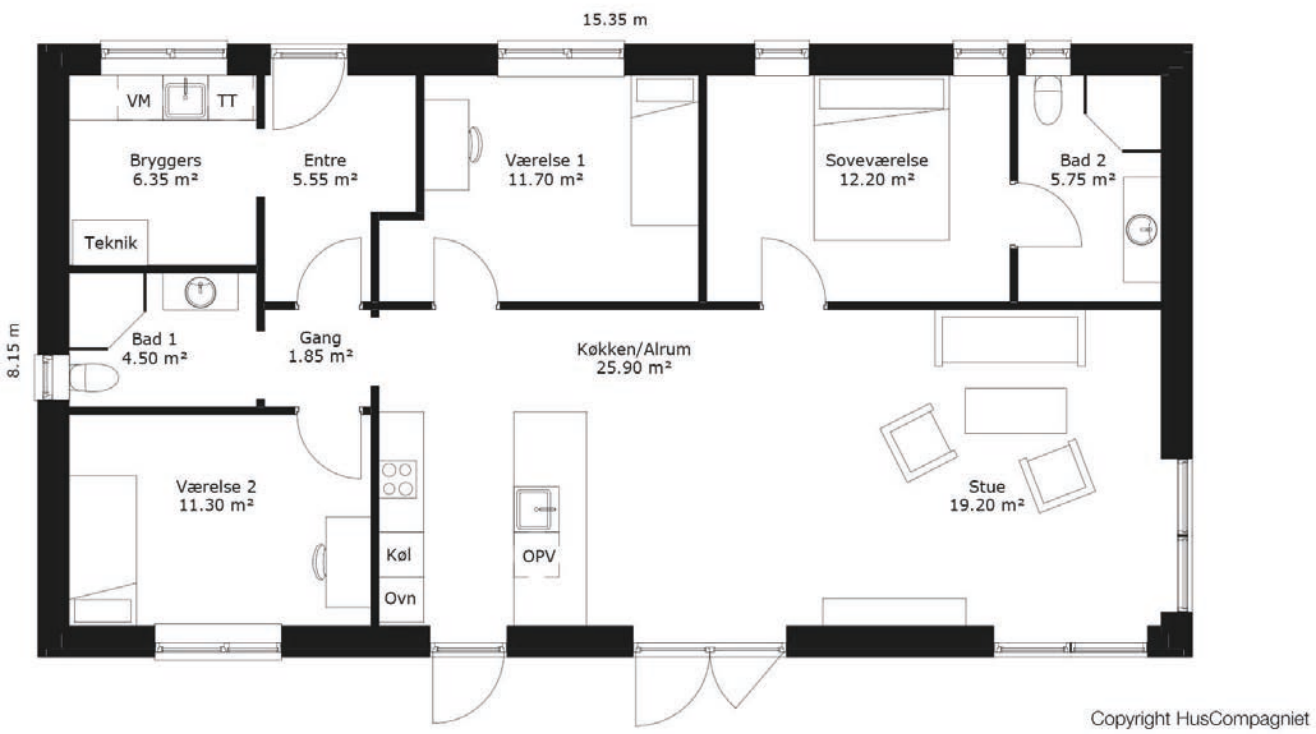
module efficiency = 19 %,

A = Solar panels area 14,76 / 0,20 = 71 m² A = C / B

Appendix 12: Plan inspiration

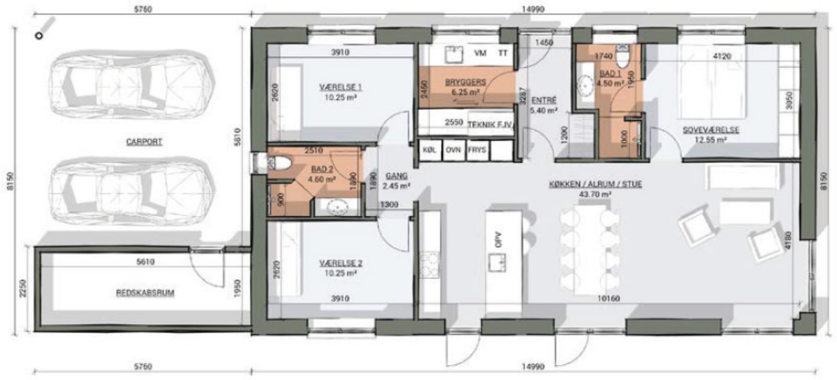


Ill. 46. Villa Vatnan, second storey plan 1:100



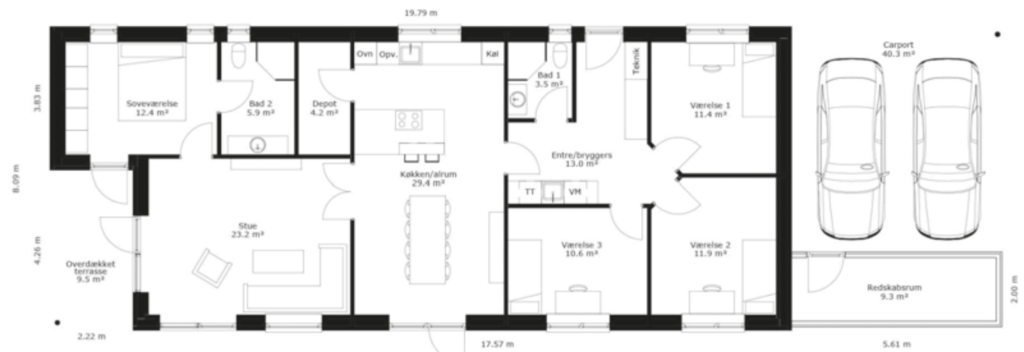
Ill. 45. Huskompagniet 100 m² long house 1:100

Ill. 50. Hybel 100 m² anglehouse 1:200



Ill. 49. Hybel 100 m² longhouse 1:200

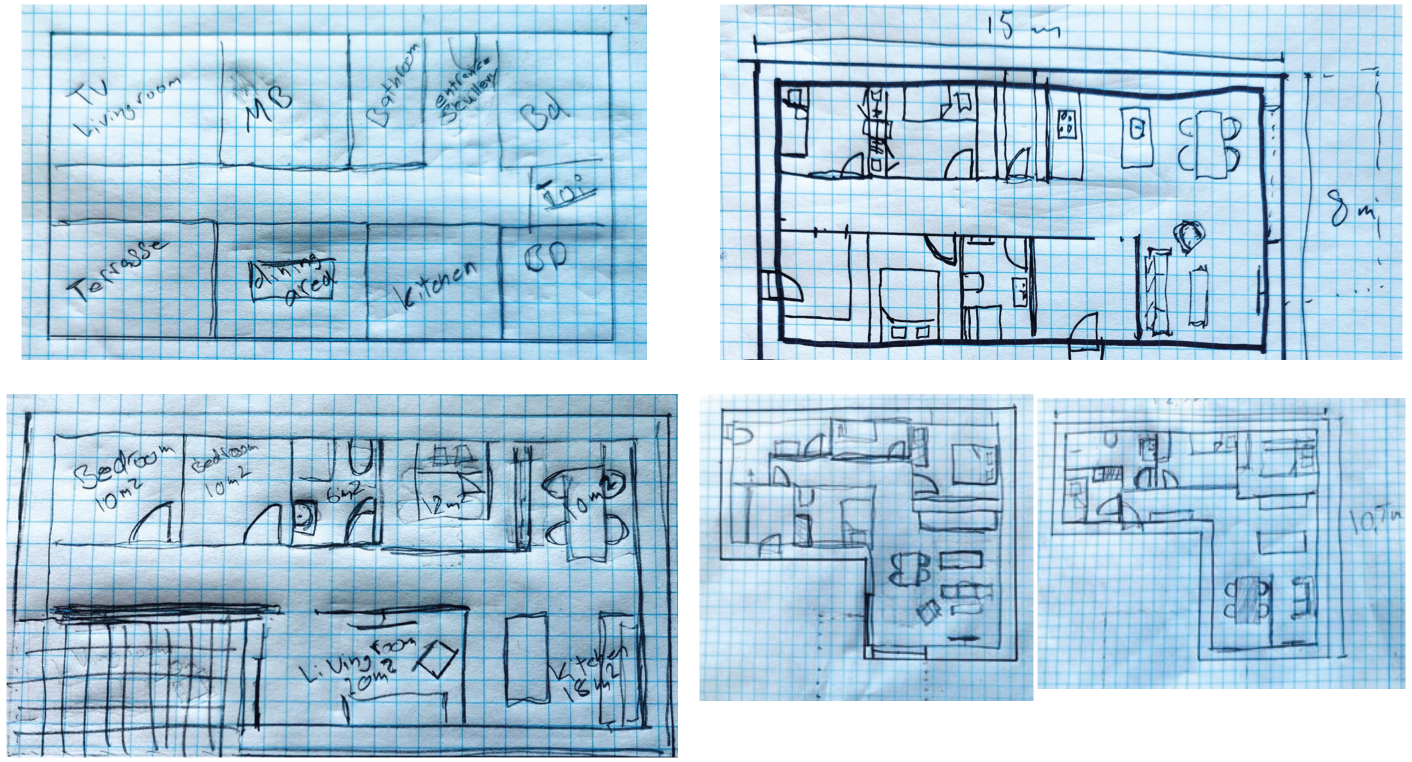
Ill. 48. Huskompagniet 110 m² longhouse 1:200



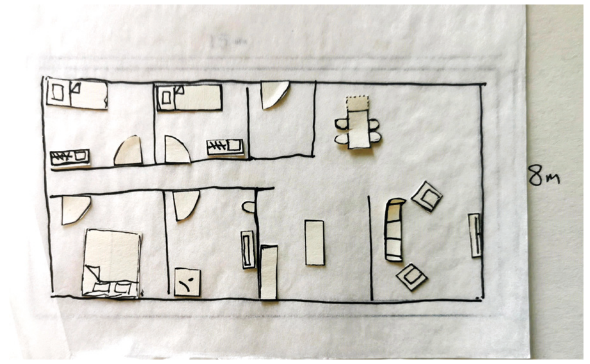
Ill. 47. Huskompagniet 130 m² long house 1:200

Appendix 13: Unit sketching

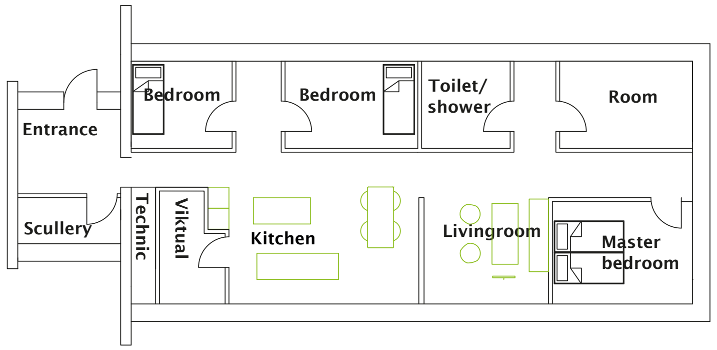
Placement of rooms



Ill. 51. *Plan hand sketches*



Ill. 53. *Moveable analog furniture*



Ill. 52. *Plan iterations placement of primary entrance and utility room*

Appendix 14: Be18 shading results

First round, no edit.

Hours > 20	3841
Hours > 27	156
Hours > 28	49
Hours < 18	2

Energiramme lavenergi

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
27,0	0,0	27,0
Samlet energibehov		32,8

Bidrag til energibehovet		Netto behov	
Varme	27,6	Rumopvarmning	24,4
El til bygningsdrift	1,6	Varmt brugsvand	7,9
Overtemp. i rum	6,2	Køling	0,0

Second round, Light curtains

Hours > 20	3839
Hours > 27	153
Hours > 28	48
Hours < 18	2

Energiramme lavenergi

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
27,0	0,0	27,0
Samlet energibehov		32,6

Bidrag til energibehovet		Netto behov	
Varme	27,6	Rumopvarmning	24,4
El til bygningsdrift	1,6	Varmt brugsvand	7,9
Overtemp. i rum	6,0	Køling	0,0

Third round, Manual shutter

Hours > 20	3822
Hours > 27	123
Hours > 28	35
Hours < 18	1

Energiramme lavenergi

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
27,0	0,0	27,0
Samlet energibehov		32,2

Bidrag til energibehovet		Netto behov	
Varme	27,6	Rumopvarmning	24,4
El til bygningsdrift	1,7	Varmt brugsvand	7,9
Overtemp. i rum	5,6	Køling	0,0

Fourth round, automatic shutters

Hours > 20	3800
Hours > 27	29
Hours > 28	3
Hours < 18	1

Energiramme lavenergi

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
27,0	0,0	27,0
Samlet energibehov		28,9

Bidrag til energibehovet		Netto behov	
Varme	28,8	Rumopvarmning	25,6
El til bygningsdrift	1,8	Varmt brugsvand	7,9
Overtemp. i rum	1,0	Køling	0,0

Appendix 15: Material EPD investigation

material library / EPD understanding	category	manufacturer	Declared unit	life span	transport	GWP (A1-A3)	density
	product	name	1	years	country	kg CO2-eq	kg / m3
load-bearing construction	Precast concrete wall elements (15 cm / 11% cut-out)	betonelement foreningen	m2	100	denmark	5.31 E+01	320,9
	Precast concrete wall elements (18 cm / 13% cut-out)	CRH Concrete	m2	100	denmark	6.29 E+01	374
	Precast concrete wall elements (18 cm / 5% cut-out)	MBE	m2	100	denmark	6.45 E+01	378
	Precast lightweight concrete wall element (15 cm / 10% cut-out)	betonelement foreningen	m2	100	denmark	3.86 E+01	242,4
	In situ concrete (Passive C25 / 30 ready-mix)	unicon cementir holding	m3	100	denmark	2.31 E+02	2230
	Aereated concrete solid / leca block	betonelement foreningen	m3	100	denmark	1.92 E+02	600
	clay blocks with air infill (honeycomb)	Ziegel industrie	m3	150	germany	1.12 E+02	575
	clay blocks with stone wool (honeycomb)	Ziegel industrie	m3	150	germany	1.41 E+02	605
	caly Blocks filled with mineral granules (honeycomb)	Ziegel industrie	m3	150	germany	1.46 E+02	605
	black/grey bricks with manganese oxide based on Danish yellow/red-firing clay using certified biogas.	Egernsund Wienerberger	t	150	denmark	1.39 E+02	1775
	brown bricks based on Danish red-firing clay with manganese oxide. Produced using certified biogas.	Egernsund Wienerberger	t	150	denmark	9.05 E+01	1450-2000
	brick (Kolumba) and/or roof tile/brick (Cover) produced by use of biogas and burn manganese oxide	Petersen Tegl	t	150	denmark	1.86 E+02	1600-2050
	brick (D-bricks) produced by use of biogas and burn manganese oxide	Petersen Tegl	t	150	denmark	2.57 E+02	1600-2050
	red bricks with iron oxide produced by use of biogas	Randers Tegl	t	150	denmark	9.93 E+01	1500-2000
	red bricks with manganese oxide produced by use of biogas	Randers Tegl	t	150	denmark	1.01 E+02	1600-1900
	yellow bricks produced by use of biogas	Randers Tegl	t	150	denmark	1.28 E+02	1600-1800
	yellow-red/rosé bricks and certified green electricity to production	Strøjer Tegl	t	150	denmark	2.00 E+02	1750
	yellow bricks and certified green electricity to production	Strøjer Tegl	t	150	denmark	2.06 E+02	1700
	yellow subdued bricks and certified green electricity to production	Strøjer Tegl	t	150	denmark	3.49 E+02	1700
	red bricks produced by use of biogas	Matzen Tegl	t	150	denmark	9.21 E+01	1550-1650
	yellow bricks produced by use of biogas	Matzen Tegl	t	150	denmark	1.54 E+02	1550-1650
	used bricks (whole and half), which are machine cleaned and hand sorted	Gamle Mursten	t	unknown	denmark	2.70 E+00	unknown
	Cross Laminated Timbe	træ information	m3	60	austri / germany	-6.64 E+02	470
	glulam construction wood in various dimensions	lilleheden	m3	60	denmark	-6.10 E+02	500
	Manufacturing of cross laminated timber of spruce	crosstimbersystems	m3	60	Latvia	-5.67 E+02	420
	CLT	södra	m3	60	sweden	-6.70 E+02	500
	Glulam construction wood (pine and spruce)	træ information	m3	60	denmark	-6.10 E+02	500
	planed construction wood products of coniferous wood.	træ information	m3	60	denmark	-6.52 E+02	536
	Planed construction wood products of pine and spruce.	træ information	m3	60	sweden / norway	-6.70 E+02	456
	I-beam H300s	Masonite Beams AB	m	50-60	sweden	-4.82 E+00	unknown
	I-beam H300	Masonite Beams AB	m	50-60	sweden	-4.65 E+00	unknown
	STEICOwall / STEICOjoist I-joist	STEICO SE	m	50-60	germany	-3.71 E+00	620
insulation	stone wool thermal insulation general	rockwool	m2	60	denmark	3.90 E-01	30
	stone wool thermali nsulation toprock	rockwool	m2	60	denmark	2.03 E+00	75
	granulate thermal insulation	rockwool	m2	60	denmark	4.07 E-01	28
	grass insulation 100 mm	grami therm	m2	50	Belgique	-7.84 E+00	40
	straw isulation boards 43 mm	vesta eco	m2	60	poland	-5.99 E+00	140
	Expanded Insulation Corkboard	amorim cork insulation	m3	50-60	Portugal	-1.98 E+02	115
	wood fibre Insulation air-injected	STEICO SE	kg	50	germany	-1.36 E+00	40
	wood fibre insulation boards manufactured in a wet process	STEICO SE	m3	50	germany	-3.81 E+02	237
	Wood fibre insulation boards manufactured in a dry process	STEICO SE	m3	50	germany	-1.85 E+02	140
	flexible wood fibre cavity insulation	STEICO SE	m3	50	germany	-7.14 E+01	50
	Hemp blocks / Hempcrete / Hempcrete blocks	isohemp	m3	60-150	belgium	2.12 E-01	275
	sound absorption board	Hunton Fiber AS	m2	60	norway	-2.11 E+00	250
	Wood Fibre Insulation Board	Hunton Fiber AS	m2	60	norway	-2.38 E+00	50
	wood fibre Insulation air-injected	Hunton Fiber AS	m2	60	norway	-1.83 E+00	27-40
	EPS Insulation boards from recycled expanded polystyrene	BEWI Denmark	m2	60	denmark	9.51 E-01	15
	EPS Insulation boards G80	BEWI Denmark	m2	60	denmark	1.77 E+00	15
	EPS Insulation boards 80	BEWI Denmark	m2	60	denmark	2.21 E+00	15
	EPS Insulation	Sundolitt	m2	60	norway	1.68 E+00	15
	ISOVER Robust Lamel	Saint-Gobain	m2	60	denmark	1.39 E+00	49
	ISOVER Formstykker λ30	Saint-Gobain	m2	60	denmark	1.41 E+00	60
	ISOVER Murfilt λ30	Saint-Gobain	m2	60	denmark	1.42 E+00	60
	Cellulose insulation	Papiruld Danmark	kg	unknown	denmark	1.54 E-01	40
Exterior wall / facade	solid wood panelling and cladding (abodo)	Frøslev Træ	m3	25+	new zealand	-3.48 E+02	450
	solid wood panelling and cladding (forest pine)	Frøslev Træ	m3	20+	finland	-4.41 E+02	430
	Ubehandlet kledning av gran og furu	Hasås	m2	60	norway	-1.39 E+01	430-490
	vannfast brannimpregnert kledning av Termofuru.	Moelven Industrier	m2	60	sweden / Estland	-5.16 E+00	375-435
	Vannfast Brannimpregnert kledning av furu	Moelven Industrier	m2	60	sweden / norway	-9.17 E+00	425
	BT Brandskyddat ytterpanel av cederträ, vattenfast brandskyddsimpregnering	Moelven Industrier	m2	60	sweden / denmark	-3.95 E+00	360
	NORD kledning - trykkimpregnert gran	Bergene Holm	m2	60	norway	-1.15 E+01	442
	Sibirsk lerk	Moelven Industrier	m3	60	denmark	-6.88 E+02	650
	Utvendig kledning Ubehandlet overflate	Superwood	m3	60	norway	-5.19 E+02	437
	Planed timber made of spruce or pine	Sandåsa Timber	m3	50-60	sweden	-7.31 E+02	384
	Ubehandlet kledning av gran	InnTre Kjeldstad	m2	60	norway	-1.26 E+01	467
	Natural stane quartzite schist, even thickness, with broken edges	Minera Skifer	t	60	norway	1.83 E+02	2700
	Natural stane quartzite schist, natural cleft surface, with broken edges	Minera Skifer	t	60	norway	8.60 E+01	2700
	Naturstein av skifer, naturplan/polert/slipt overfOate, saget kant	Altaskifer	t	60	norway	1.17 E+02	2710
	Granitt G654 fasade- og gulvtstein	Naturstein Montering	t	100	China	1.57 E+02	2800
	Granitt (G-358) fasade- og gulvstein	Naturstein Montering	t	100	China	1.02 E+02	2800
	fibre cement facade board with a thickness of 8mm	Cembrit Holding	m2	30	Hungary	1.62 E+01	1300
	Grossformatige Faserzementplatten	Swisspearl Group	t	30	germany	1.07 E+03	1850
	Kleinund mittelformatige Faserzementplatten	Swisspearl Group	t	30	germany	1.16 E+03	1825
	Large-size fibre cement plates. Pigmented plate coated	Swisspearl Group	t	30	germany	1.28 E+03	1850
	Composite wood cladding board	Silvadec	m2	40	france	2.37 E +00	733
	composite timber product	INNOWOOD	m2	40	Australia	1.44 E+02	424
	clay tiles Façade	KOMPROMENT	t	150	Italy	4.61 E+02	1600
	bricks, hempcrete and plaster included under this topic	-	-	-	-	-	-
Roof	Thatched roof, including reed material, fireproofing membrane and fastening system	Carlo F. Christensen	m2	50	denmark	-5.04 E+01	65
	Two systems of PTM reinforced bitumen membrane for roof waterproofing	Phønix Tag Materialer	m2	60	denmark	3.64 E+00	650
	Bituminous roofing material	Imperbel NV/SA	m2	60	Belgium	3.21 E+00	650
	Faserzement-Dachplatten	Cembrit Holding	t	30	denmark	9.70 E+02	1850
	Roof board / Roofing slate "Eternit"	Swisspearl Group	t	30	germany	1.07 E+03	1800-1950
	durchschnittliche BRAAS Dachsteine ("model 1")	Braas GmbH	t	50	germany	2.92 E+02	2050-2300
	durchschnittliche BRAAS Dachziegel (model 2")	Braas GmbH	t	50	germany	2.55 E+02	2100
	clay tiles Roof	KOMPROMENT	t	150	Italy	4.61 E+02	1600
	Urban cladding tiles	ZZ Wancor AG	m2	50	germany	1.36 E+01	1770
	ProtanTurf Roof Membrane (Green roof)	Protan AS	m2	40	norway	5.05 E+00	unknown
	Wood, slate, clay materials and fibre cement included under this topic	-	-	-	-	-	-
interior	Solid hardwood 2-strip parquet (oak, 14 x 129 mm)	junckers	m3	50	Scandinavian	-1.01 E+01	665-770
	Spruce plywood, uncoated.	træ information	m3	60	finland	-5.99 E+02	480
	Acoustic panel 25 mm - unpainted	Troldtekt A/S	m2	75	denmark	1.29 E+00	449
	Acoustic mats for walls and ceilings.	Søuld ApS	kg	unkown	Denmark	-3.64 E-01	137
	Recycled particle boards from Denmark,	Kronospan ApS	kg	unkown	Denmark	-1.36 E+00	550-750
	Spaandex particle boards	Kronospan ApS	kg	unkown	Denmark	-1.36 E+00	550-750
	Clima Board	Knauf	m2	60	Denmark	1.67 E+00	8
	Classic Board	Knauf	m2	60	Denmark	1.23 E+00	9
	Hunton Silencio Underlay	Hunton Fiber AS	m2	60	poland	-1.16 E+00	250
	Ubehandlet panel av gran eller furu	InnTre Kjeldstad AS	m2	60	Norway	-1.13 E-01	500
	straw boards 280	vesta eco	m2	60	poland	1.33 E+02	280
	Terrazzo	Ellingard Gruppen	m2	200	Sweden	9.27 E+00	2100
	Plaster,boards, wood materials and clay bricks included under this topic	-	-	-	-	-	-
doors and windows	Malt dørsett av furu	Combiwood Barkevik	1	60	Estland	-6,63E+00	430
	outward opening sideswing, side & top hinged window	NorDan	1	40	Poland	8.59E+01	-
	outward opening topswing windows	NorDan	1	40	poland	1.08E+02	-
	patio door	NorDan	1	40	poland	5.26E+02	-
	Solid Core Climate Door	Jeld-Wen	1	unkown	sweden	1.34e+1	-
	Solid Wood 93mm Frameset	Jeld-Wen	1	unkown	sweden	-2.42e+1	-
	Solid Core Door	Jeld-Wen	1	unkown	sweden	-1.65e+1	-
	Fasad® with triple glass-REDUXA	HSHansen	m2	unkown	Denmark	1,28E+02	-
	Fasad® with emalite glass-REDUXA	HSHansen	m2	unkown	Denmark	1,66E+02	-
	Fasad® with panel-REDUXA	HSHansen	m2	unkown	Denmark	1,41E+02	-
sealing materials	wind boards fibrecement	Cembrit	m2	30	Finland	9,36E+00	1555
	vapor barrier	Baca dampsperre	m2	60	Norway	4,06E-01	933
	wind boards	Hunton Vindtett	m2	60	Norway	-3,60E+00	227-281
	Polyurethane foam	Sika Deutschland	kg	10	Germany	3,18E+00	1250-1650
	Silicone-based sealant	Soudal	kg	10	Belgium	7,08E+00	1000-1500
	Mortar joint	VM mørtel	t	100	Vrå, Denmark	1,62E+02	1341
	cement grout	TCNNA	kg	50	USA	6,77E-01	1590
surface treatment	limestone	Armourcoat	kg	50	England	2,15E-01	1300
	plaster (Spartlemasse)	Finja	kg	50	Sweden	1,87E-01	1200
	Habito Joint Mix	Saint-Gobain	kg	50	Sweden	2,28E-01	1200
	Silicate paint	Keim	kg	100	Denmark	1,62	1000-1700
	Linseed oil paint - for outdoor	Teknos	l	5	Finland	2,1	1200

Appendix 16: Construction opportunities

material comp - construction	roof (U = 0.08)						wall (U = 0.12)						floor = (U = 0.10)					
layers / category / insulation * / mm	**741**	**757**	**977**	**700**	**697**	**977**	**580**	**585**	**492**	**512**	**460**	**512**	**707**	**781**	**734**	**714**	**719**	**722**
first interratoin	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
outer layer	brick batten furring sheet	tile batten furring sheet	slate batten furring sheet joist *	felt underlay board	shingles batten furring underlay	eternit batten furring sheet joist *	brick	plaster hempcrete	planks counter joist furring wind	shingles counter joist furring wind	slate counter joist furring insulation *	eternit counter joist furring wind	gravel insulation * radon barrier	gravel insulation * radon barrier	gravel insulation * radon barrier	gravel insulation * radon barrier	gravel insulation * radon barrier	gravel insulation * radon barrier
middle layer	rafter *	rafter *	joist *	rafter *	rafter *	joist *	weep / binders *	column *	column *	column *	concrete	column *	concrete	concrete	concrete	concrete	concrete	concrete
inner layer	vapor barrier joist * board	vapor barrier joist * board	vapor barrier rafter*	vapor barrier joist * board	vapor barrier joist * board	vapor barrier rafter *	brick	joist * board	vapor barrier joist * board	vapor barrier joist * board		vapor barrier joist * board	tile	vapor barrier joist * hardwood	sheet laminate	sheet vinyl	sheet cork	terrazzo
layers / category / insulation * / mm	**1021**	**801**	**1032**	**812**	**977**	**757**	**580**	**527**	**599**	**542**	**638**	**556**	**707**	**781**	**742**			
second interratoin	1	2	3	4	5	6	1	2	3	4	5	6	1	4	6			
outer layer	brick batten furring sheet joist *	brick batten furring sheet	tile batten furring sheet joist *	tile batten furring sheet	slate batten furring sheet joist *	slate batten furring sheet	brick	brick insulation *	plaster board counter joist furring wind	plaster board counter joist furring wind	wood counter joist furring wind	wood counter joist furring wind	gravel insulation * radon barrier	gravel insulation * radon barrier	gravel insulation * radon barrier			
middle layer	joist *	rafter *	joist *	rafter *	joist *	rafter *	weep / binders *	column *	column *	column *	column *	column *	concrete	concrete	concrete			
inner layer	vapor barrier rafter *	vapor barrier joist * board plaster	vapor barrier rafter *	vapor barrier joist * board plaster	vapor barrier rafter	vapor barrier joist * board plaster	brick	vapor barrier joist * board plaster	insulation * brick	vapor barrier joist * board plaster	insulation * brick	vapor barrier joist * board plaster	tile	vapor barrier joist * hardwood	terrazzo joist * hardwood			

first interratoin	roof	wall	floor
average (mm)	808,1667	523,5	729,5

second interratoin	roof	wall	floor
average (mm)	900	573,6667	743,33333

first	*mm*
brick	54
batten	38
furring	25
sheet	2
rafter *	500
vapor barrier	2
joist *	100
board	20
	741
tile	65
batten	38
furring	30
sheet	2
rafter *	500
vapor barrier	2
joist *	100
board	20
	757
slate	10
batten	38
furring	25
sheet	2
joist *	250
joist *	300
vapor barrier	2
rafter *	350
	977
felt	5
underlay	3
board	20
rafter *	600
vapor barrier	2
joist *	50
board	20
	700
shingles	10
batten	38
furring	25
underlay	2
rafter *	550
vapor barrier	2
joist *	50
board	20
	697
eternit	10
batten	38
furring	25
sheet	2
joist *	250
joist *	300
vapor barrier	2
rafter *	350
	977

second	*mm*
brick	54
batten	38
furring	25
sheet	2
joist *	250
joist *	300
vapor barrier	2
rafter *	350
	1021
brick	54
batten	38
furring	25
sheet	2
rafter *	600
vapor barrier	2
joist *	50
board	20
plaster	10
	801
tile	65
batten	38
furring	25
sheet	2
joist *	250
joist *	300
vapor barrier	2
rafter *	350
	1032
tile	65
batten	38
furring	25
sheet	2
rafter *	600
vapor barrier	2
joist *	50
board	20
plaster	10
	812
slate	10
batten	38
furring	25
sheet	2
joist *	250
joist *	300
vapor barrier	2
rafter	350
	977
slate	10
batten	38
furring	25
sheet	2
rafter *	600
vapor barrier	2
joist *	50
board	20
plaster	10
	757

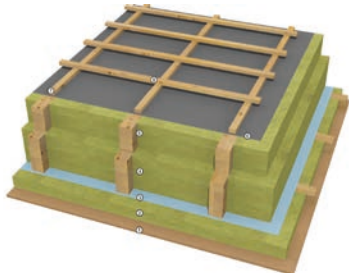
first	*mm*
brick	115
weep / binders *	350
brick	115
	580
plaster	5
hempcrete*	110
column *	400
joist *	50
board	20
	585
planks	40
counter joist	50
furring	25
wind	5
column *	300
vapor barrier	2
joist *	50
board	20
	492
shingles	60
counter joist	25
wind	5
column *	350
vapor barrier	2
joist *	50
board	20
	512
slate	10
counter joist	25
furring	25
insulation *	300
concrete	100
	460
eternit	10
counter joist	50
furring	25
wind	5
column *	350
vapor barrier	2
joist *	50
board	20
	512

second	*mm*
brick	115
weep / binders *	350
brick	115
	580
brick	115
insulation *	130
column *	200
vapor barrier	2
joist *	50
board	20
plaster	10
	527
plaster	10
board	20
counter joist	50
furring	25
wind	5
column *	250
insulation *	124
brick	115
	599
plaster	10
board	20
counter joist	50
furring	25
wind	5
column *	350
vapor barrier	2
joist *	50
board	20
plaster	10
	542
wood	44
counter joist	50
furring	25
wind	5
column *	300
insulation *	99
brick	115
	638
wood	44
counter joist	50
furring	25
wind	5
column *	350
vapor barrier	2
joist *	50
board	20
plaster	10
	556

first	*mm*
gravel	300
insulation *	300
radon barrier	2
concrete	100
tile	5
	707
gravel	300
insulation *	300
radon barrier	2
concrete	100
vapor barrier	2
joist *	57
hardwood	20
	781
gravel	300
insulation *	320
radon barrier	2
concrete	100
sheet	2
laminate	10
	734
gravel	300
insulation *	300
radon barrier	2
concrete	100
sheet	2
vinyl	10
	714
gravel	300
insulation *	300
radon barrier	2
concrete	100
sheet	2
cork	15
	719
gravel	300
insulation *	300
radon barrier	2
concrete	100
terrazzo	20
	722

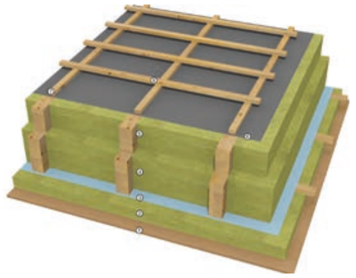
second	*mm*
gravel	300
insulation *	300
radon barrier	2
concrete	100
tile	5
	707
gravel	300
insulation *	300
radon barrier	2
concrete	100
vapor barrier	2
joist *	57
hardwood	20
	781
gravel	300
insulation *	320
radon barrier	2
concrete	100
terrazzo	20
	742

roof



Heat capacity
Lca
Dfd
Thickness
Weight

1.1

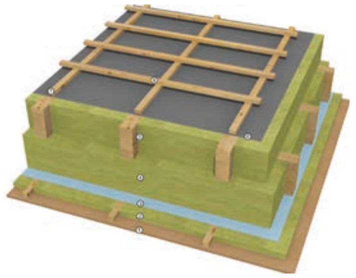


Heat capacity
Lca
Dfd
Thickness
Weight

1.2

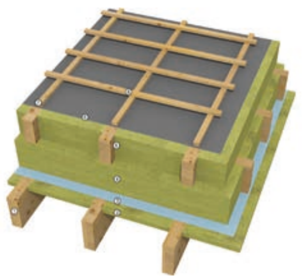
Heat capacity
Lca
Dfd
Thickness
Weight

1.3



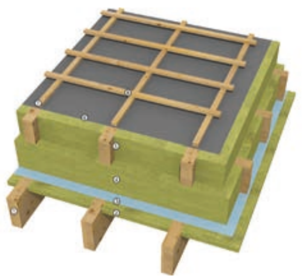
Heat capacity
Lca
Dfd
Thickness
Weight

1.5



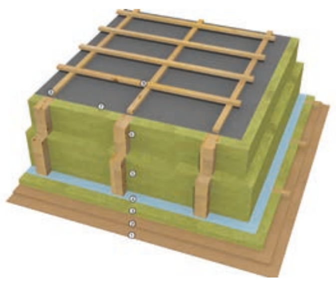
Heat capacity
Lca
Dfd
Thickness
Weight

2.1



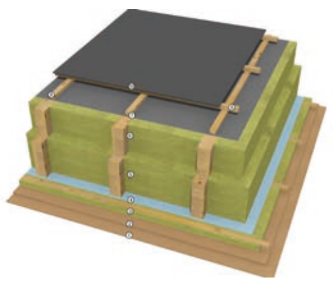
Heat capacity
Lca
Dfd
Thickness
Weight

2.3



Heat capacity
Lca
Dfd
Thickness
Weight

2.4



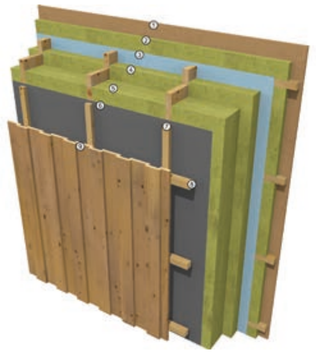
Heat capacity
Lca
Dfd
Thickness
Weight

2.6

wall

Heat capacity
Lca
Dfd
Thickness
Weight

1.1

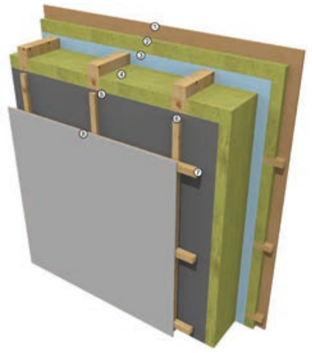


Heat capacity
Lca
Dfd
Thickness
Weight

1.3

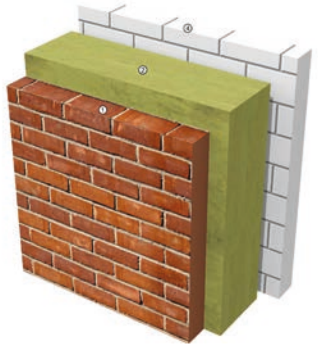
Heat capacity
Lca
Dfd
Thickness
Weight

1.5



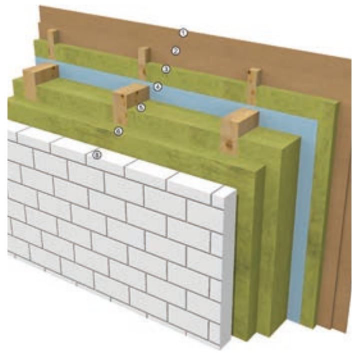
Heat capacity
Lca
Dfd
Thickness
Weight

1.6



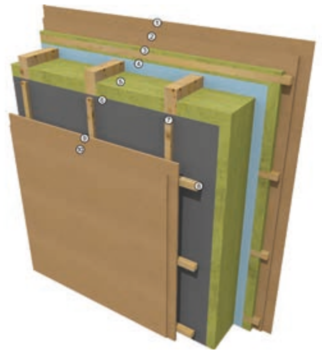
Heat capacity
Lca
Dfd
Thickness
Weight

2.1



Heat capacity
Lca
Dfd
Thickness
Weight

2.2



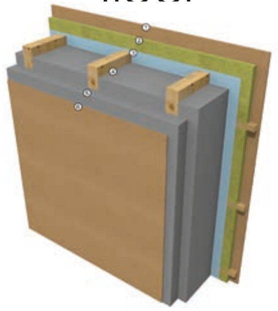
Heat capacity
Lca
Dfd
Thickness
Weight

2.4

Heat capacity
Lca
Dfd
Thickness
Weight

2.5

floor

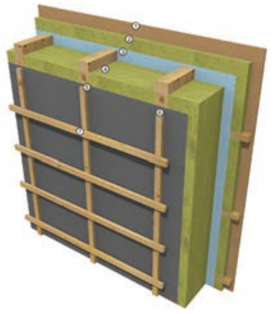


1.2

Heat capacity
Lca
Dfd
Thickness
Weight

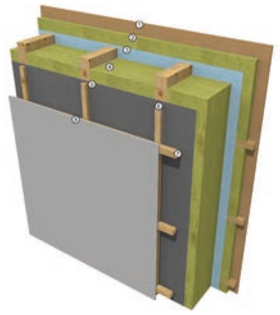
1.3

Heat capacity
Lca
Dfd
Thickness
Weight



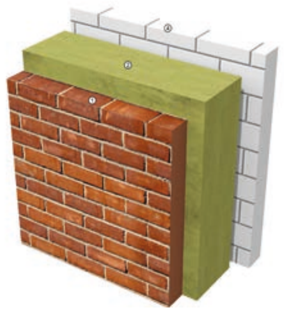
1.4

Heat capacity
Lca
Dfd
Thickness
Weight



1.6

Heat capacity
Lca
Dfd
Thickness
Weight



2.1

Heat capacity
Lca
Dfd
Thickness
Weight

Appendix 17: Materials scoring

floor	heat	co2 kg	dfd	mm	kg	score	score	score	score	score
1,1	258	70	2	71	806	2	1	2	3	2
1,2	250	29	3	78	804	1	3	3	1	2
1,3	248	37	3	73	792	1	2	3	2	3
1,4	253	84	1	71	800	2	1	1	3	2
1,5	239	48	2	71	789	1	2	2	3	3
1,6	281	53	2	72	826	2	2	2	2	1
2,1	390	65	2	71	806	3	1	2	3	2
2,2	401	31	3	78	804	3	3	3	1	2
2,3	422	51	2	74	826	3	2	2	2	1

roof	heat	lca	dfd	mm	kg	score	score	score	score	score
1,1	47	-7,5	3	72	154	1	1	3	3	1
1,2	47	-14	3	75	135	1	1	3	2	2
1,3	55	-48	2	98	118	2	2	2	1	3
1,4	54	-40	1	69	104	2	2	1	3	3
1,5	34	-54	1	70	100	1	3	1	3	3
1,6	55	-66	2	97	108	2	3	2	1	3
2,1	55	-37	2	100	159	2	2	2	1	1
2,2	72	-7,5	3	78	175	3	1	3	2	1
2,3	55	-44	2	103	141	2	2	2	1	2
2,4	72	-12	3	81	157	3	1	3	2	1
2,5	55	-62	2	98	114	2	3	2	1	3
2,6	72	-31	3	76	130	3	2	3	2	2

wall	heat	lca	dfd	mm	kg	score	score	score	score	score
1,1	184	73	2	58	455	3	1	2	1	1
1,2	120	-36	1	59	197	3	3	1	1	2
1,3	28	-13	3	48	54	1	3	3	3	3
1,4	37	-43	2	51	77	1	3	2	3	3
1,5	228	16	3	46	295	3	2	3	3	1
1,6	37	-21	3	51	77	1	3	3	3	3
2,1	173	60	2	58	421	3	1	2	1	1
2,2	53	27	2	52	295	2	2	2	2	1
2,3	192	15	2	59	253	3	2	2	1	2
2,4	54	-16	3	54	109	2	3	3	2	2
2,5	196	-3	2	63	234	3	3	2	1	2
2,6	54	-30	3	55	85	2	3	3	2	3

Appendix 18: Natural ventilation

The aim for the ventilation is to keep the atmospheric comfort at a reasonable level. Looking at the critical room and critical hour the ventilation should be able to withstand the pressure. The atmospheric comfort level aiming for is below 1200 ppm which is the second category of indoor climate in the DGNB . Assuming the airquality of the outside air is around 400ppm the parameters can be set.

Parameter	Value	Unit
Hour day, START	0	Hours
Hour day, END	24	Hours
Days/week	7	Days
Hours/Day	24	Hours
Hours/year	8760	Hours
Occupants	4	Person
Appliances	2,4	W/m²
CO_2 production	68	l/h
Min T,op	19	°C
Max T,op	28	°C
Ventilation rate (min)		0,3 l/m²
Max CO_2 concentration above outdoor air 800ppm		

To define the needed ventilation rate the

The area (Livingroom/kitchen-dining room): 45 m²

People in the room: 4

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

$$Q_h = 10 \cdot \frac{G_h}{C_{h,i} - C_{h,0}} \cdot \frac{1}{\varepsilon_v}$$

$Q_h = Ventilation\ rate\ \left(\frac{l}{s}\right)$
$G_r = The\ pollution\ (olf)$
$C_{c,i} = Desired\ indoor\ quality\ (decipol)\ set\ to\ 1{,}4dp$
$C_{c,0} = Perceived\ outdoor\ air\ quality\ (decipol)$
$\varepsilon_v = Ventilation\ effectiveness$

The following loads are used:

People - 1 $\frac{olf}{person}$

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

The perceived outdoor air quality is to 0,01 dp

The ventilation efficiency is set to 1.

$Dp = 1\ olf/10 \cdot \frac{l}{s}$

The ventilation rate is calculated:

$$Q_h = 10 \cdot \frac{4 \cdot 1\ olf + 45m^2 \cdot 0{,}1\frac{olf}{m^2}}{1{,}4dp - 0{,}01dp} = 61{,}15108 \cdot \frac{olf}{dp} = 6{,}1\ l/s$$

The same is done for category b which states the maximum CO2 pollution must not exceed 800 ppm above outdoor air, shared spaces, and 550 ppm over outdoor air, bedrooms. With the estimated value of 400 ppm outdoor air quality, it becomes 1200 ppm for kitchen living room and 950 ppm for bedrooms.

Following the same system as before new values for pollution must be set.

The CO2 pollution caused by humans can be calculated with following formula:

$$q_{v,CO2} = 17 \cdot 1{,}2\ met = 20{,}4\ l/h$$

The ventilation rate is

$$Q_h = 10 \cdot \frac{4 \cdot 20{,}4\frac{l}{h}}{((800ppm + 400ppm) - 400ppm) \cdot 10^{-6}} = 28{,}3\ l/s$$

The standard for living spaces is either 0,5 h^{-} or 0,3 $\frac{l}{s}/m^2$

Or the $\frac{0{,}3\frac{l}{s}}{m^2} \cdot 50m^2 = 15 \cdot \frac{l}{s}$

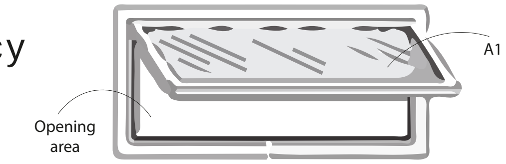
The standard air change is not high enough to keep a satisfactory pollution level. To check the CO2 level the dilution equation is used.

$$c = \frac{q}{n \cdot V} \cdot (1 - e^{-n \cdot t}) + (c_0 - c_i) \cdot e^{-nt} + c_i$$

$c = concentration\ of\ pullotion\ [ppm]$
$q = pollution\ source\ \left[\frac{m^3}{h}\right]$
$n = airchange\ [h^{-1}]$
$V = room\ volume\ [m^3]$
$t = time\ [h]$
$c_0 = start\ concentration\ [ppm]$
$c_i = outdoor\ air\ concentration\ [ppm]$

$$c = \frac{\frac{20{,}4l}{s}}{0{,}5h^{-1} \cdot 150m^3} \cdot (1 - e^{-0{,}5^{-1} \cdot 8h}) + \left(400\left(\frac{m^3}{m^3} \cdot 10^{-6}\right) - 400\left(\frac{m^3}{m^3} \cdot 10^{-6}\right)\right) \cdot e^{-0{,}5h^{-1} \cdot 8h} + 400\left(\frac{m^3}{m^3} \cdot 10^{-6}\right) = 1200ppm$$

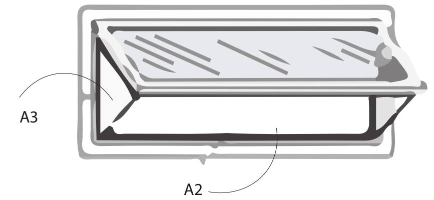
Appendix 19: Natural ventilation - thermal bouyancy



The calculations are based upon SBi 202 looking on thermal buoyancy.

Thermal buoyancy

Inlet window
Area: 0,5 m^2
Opening area (A_{eff}):



$$\left(\frac{1}{A_{eff}}\right)^2 = \left(\frac{1}{C_{d,1} \cdot A_1}\right)^2 + \left(\frac{1}{C_{d,2} \cdot A_2 + 2 \cdot C_{d3} \cdot A_3}\right)^2$$

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

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

$$\left(\frac{1}{A_{eff}}\right)^2 = \left(\frac{1}{0{,}7 \cdot 0{,}75m^2}\right)^2 + \left(\frac{1}{0{,}7 \cdot 0{,}28m^2 + 2 \cdot (0{,}7 \cdot 0{,}05m^2)}\right)^2$$

$$\Updownarrow$$

$$A_{eff} = 0{,}2372815 \cdot m^2$$

The opening height is $H_1 = 1{,}5$ and inside summer temperature is $T_{i,s} = 24{,}5$ °C

Outlet window

Area: 0,75m^2
Opening area is: 0,33m^2
Opening height is 3,5m
Outside temperature: 21°C

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

$$Inlet: Q_1 = C_{d1} \cdot A_1 \sqrt{\frac{2\,|\Delta p_1|}{p_u}}^{\frac{1}{2}}$$

$$Outlet: Q_2 = C_{d2} \cdot A_2 \sqrt{\frac{2\,|\Delta p_2|}{p_1}}^{\frac{1}{2}}$$

$$C_d = Outflow\ coefficient$$

$$A = area\ of\ window$$

$$\Delta p = pressure\ of\ inlet\ and\ outlet\ air$$

$$\rho = Air\ density\ to\ 1{,}225\frac{kg}{m^3}$$

$$Inlet: \Delta p_1 = \rho_u * g * (H_0 - H_1) * \frac{T_i * T_u}{T_i}$$

$$outlet: \Delta p_2 = \rho_i * g * (H_0 - H_2) * \frac{T_i * T_u}{T_i}$$

$$\rho_u, \rho_i = Density\ of\ outside\ and\ inside\ air, Outdoors, 1{,}225\frac{kg}{m^3}, indoor\ 1{,}18\ kg/m^3$$

$$g = gravitational\ acceleration\ 9{,}82\ m/s^2$$

$$H_0 = Height\ of\ neutral\ plane$$

$$H_1, H_2 = height\ of\ inlet\ and\ outlet\ window$$

$$T_i, T_u = Temperature\ inside\ and\ outside$$

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

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

$$H_0 = \frac{0{,}5^2 * 1{,}5 + 0{,}75^2 * 3{,}5}{0{,}5^2 + 0{,}75} = 2{,}34375$$

The pressure of inlet and outlet air is:

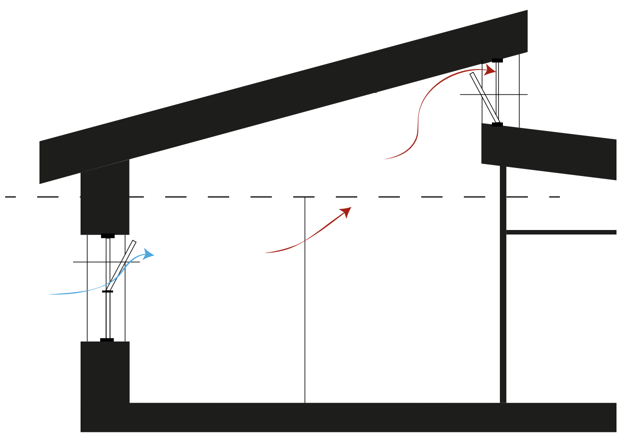
$$Inlet: \Delta p_1 = 1{,}225 \frac{kg}{m^3} * 9{,}82 \frac{m}{s^2} * (2{,}34375m - 1{,}5m) * \frac{24{,}5°C - 21°C}{24{,}5°C} = \frac{1{,}449984 \cdot kg}{m \cdot s^2}$$
$$= 1{,}449984 \cdot kg \cdot m^{-1} \cdot s^{-2} = 1{,}45\ Pa$$

$$Outlet: \Delta p_2 = 1{,}18 \frac{kg}{m^3} * 9{,}82 \frac{m}{s^2} * (2{,}34375m - 3{,}5m) * \frac{24{,}5\ °C - 21°C}{24{,}5°C} = \frac{-1{,}914023 \cdot kg}{m \cdot s^2}$$
$$= -1{,}914023 \cdot kg \cdot m^{-1} \cdot s^{-2} = -1$$

The air flow of the windows are calculated:

$$Q_1 = 0{,}7 * 0{,}234m^2 * \sqrt{\frac{2 * 1{,}45 \frac{\text{kg}}{m \cdot s^2}}{1{,}18 \frac{kg}{m^3}}}^{\frac{1}{2}} = 0{,}205\ m^3/s$$

$$Q_2 = 0{,}7 * 0{,}33m^2 * \sqrt{\frac{2 * 1{,}914 \frac{\text{kg}}{m \cdot s^2}}{1{,}225 \frac{kg}{m^3}}}^{\frac{1}{2}} = 0{,}307\ m^3/s$$



Ill. 54. Thermal bouyancy