The Village

”An ordinary home - just a little bigger”

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Colophon

The Village
"An ordinary home - just a little bigger"

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Abstract

This Master Thesis report presents the work and outcome of designing a 24-hour care centre for marginalized children and adolescent. The work is conducted as the final part of the Master's education in Architecture from the Department of Architecture & Design at the Aalborg University.

The aim of the project is to design a sustainable orphanage located on Egholm. Based on the Integrated Design Process, the project is a reinterpretation of the classical institution, now focusing on architectural qualities, zero energy demands securing a highly comfortable indoor environment. Hence, both aesthetic, functional and technical aspects are taken into consideration to create a holistic solution. The parameters are reflected in an iterative design process with underlying methodologies and analyses, which focus on site characteristics, the defined user group and their needs, and on sustainability and the strategies to reach this.

The outcome of this is the concept, "The Village", takes its starting point in the existing typology and appears as a guest in relation to the existing architecture. The design is based on architectural and engineering parameters, which contributes to the concept of several units relating to the surrounding nature. The essence of the concept is the diversity of architectural spatial perception and experience influencing its residents and users. The building contains a grid structure, which creates the focal point for both the architectural spaces and the load bearing system, based on considerations for flexibility and design for disassembly, future proofing the buildings robustness for the inevitable climate changes.

Motivation

Getting consistency and continuity in life has always been difficult for placed children and adolescent. At the earlier orphanages there was a greater tradition for the children to spend their whole childhood in one place – or even in some cases their whole youth. In this way there was some kind of continuity and entity in children and young people's lives.

Today the institutions have become more specialized, both in terms of what they offer but also who they offer it to. However, this has severely affected the continuity, and the entity is disappearing from the lives of children placed. Life is experienced as fragmented, and the child or young person's history is marked by numerous breaks and changes. It is therefore no coincidence that from the social professional side for many years has highlighted the need to create greater cohesion and continuity in the children and young people's lives. To this end, it is desired to focus on how the good life of children at institutions can be organized - a new ambition of making a sustainable orphanage that set the boundaries for the children's well-being and that they are ensured a sense of home and being a part of a community, this refers as something permanent and stable, safe and embracing. When talking about a home - a childhood home - we all know what this means. It is this meaning of life the children and young people must have in "The Village".

The 'built environment' consists of different levels: architecture, interior architecture, and interior architectural objects. Together they form an entity that is understandable and controllable, but that should also be inspiring, meaningful, and empowering from the viewpoint of the people that inhabits the space. In our daily routines we encounter the architecture that surrounds us, and experiences how these architectural settings inhabitants different functional purposes, additionally as we live among the architecture, it has potential in appealing to and transforming our emotions, moods and senses, and thereby enhance or influence the state of our minds, we find ourselves in.

No matter if we are conscious of it or not, we relate ourselves to the architectural spaces as we interact, as a result of the sum of all elements inside that particularity space, both tangible and transcendental. As different event takes place in our lives, we place different demand of the spaces we engage ourselves with, at times we need spaces for loneliness, community, rest, stagnation, contemplation, or even breaks. From this aspect we find motivation, in highlighting these influencing parameters and the function of the architectural spaces. Furthermore the design has to respond to the inevitable climate changes; the orphanages needs to both relate to the present climate while still stand strong to the most stressed occurrences coming in the future.

Within the design the orphanage should address the children's needs in this break in existence as they have been neglected. For this reason, the project amongst other aspects revolves around how the design for the orphanage and its interior and exterior spaces, can influence the children through the process and implementation of the totality of architecture. Expressed in its atmosphere, composed by tangible elements such as shape, materials, color and spatial perception and on the other hand transcendental elements relating to light, sounds and haptic senses. In the forming of architecture I want to stress the importance of how the architecture can act as a powerful narrator of the stories both visible and invisible for the attenders and for that reason investigate the power of simple architectural elements - the embracing and surrounding character of light, walls and sound, the sublimity of the dimensions within a space complimented by structural and lighting aspects, the earthbound character in regards to how the architecture itself is situated on the landscape, the roof as a protective source, as we seek shelter underneath and at last the door as an element for transition between spaces.

Reading guide

This report contains 6 chapters, each focusing on different areas of the project.

CHAPTER 1: PROLOGUE
This chapter introduces the methods and theories that have been utilized through the different phases of the project.

CHAPTER 2: ANALYSIS
This chapter contains the gathered infomation through various analyzes to create an understanding for the further process.

CHAPTER 3: PRESENTATION
In this chapther, the final design will be presented through various illistrations.

CHAPTER 4: DESIGN PROCESS
This chapter details the design process of the building. It appears chronologically in the chapter, but this is not the case, since the design process is a long iterative process, going forth and back.

CHAPTER 5: EPILOGUE
This chapter contains the closing statements about the project as well as a reflection.

CHAPTER 6: ANNEX
This chapter contains additional information about the project.

All illustrations are indicated with illustration numbers and the reference style is followed by the Harvard Method.

Content

Methodology

The methodology applied for this project derives from the Integrated Design Process (IDP); a holistic approach developed by Mary-Ann Knudstrup. The purpose of the IDP is to combine architecture and engineering, in other words merging commodity, firmness and delight, the Vitruvian trinity; integrating aspects of human needs, contemporary technological solutions and aesthetics.

Through this approach, the researched literature and empirical data is gained through both qualitative and quantitative studies, like journals, interviews and books.

Prologue

This chapter introduces the methods and theories that have been utilized through the different phases of the project.

Methods and tools

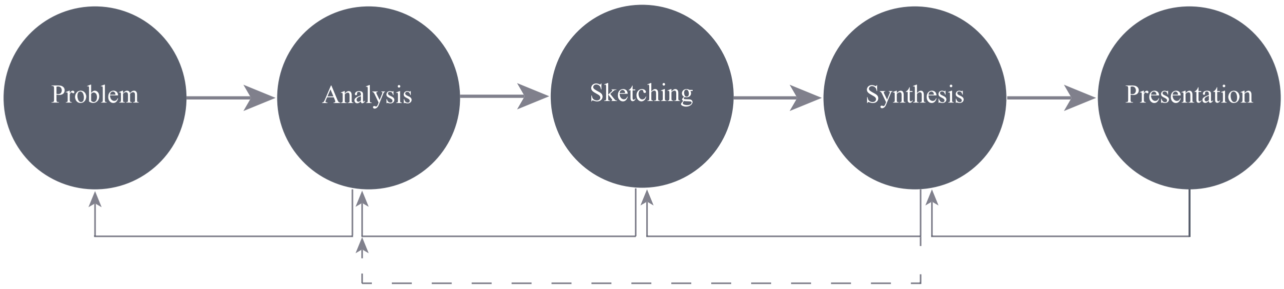
The methods and tools, which have been used during the various phases of research and design is presented here. Having established the general motivation and framework for this project, this section structures the steps to be taken in order to assist the reader in understanding the creative design process taken to reach the project solutions.

Tools	Description	How to use it	Purpose
Analysis phase			
Diagrams	This method is used to illustrate graphically information about the site.	Diagrams are generated to communicate different information about the site (eg. serial vision, typologies, infastucture and green areas).	The method is used to illustrate the material graphically. This allows visualizing elements with a single diagram, rather than a long explanatory text.
3D Modelling	This method is used to 3D model the area and examine the environmental micro climate.	Modelling the context in 3D, enables sun path and shadows studies on the site.	These analysis summarizes information of the site that can be interpreted for use in the design and sketching phase.
Sketching phase			
Hand sketching	This method is used to make quick drawings to communicate ideas and design.	Freehand drawings to visualize an idea.	A quick way of showing ideas, usefull for discussing design solutions.
Models	A simple representation of a shape, or expression.	Making simple models in foam to review different building shapes.	Gives a spatial representation of a desired design.
Enviromental design	Using computer software such as Velux daylight, Be18 and Bsim to see the enviromental impacts on the building design.	Modelling and simulating different design solutions in the various programs.	To analyze how aspects suchs as daylight impact the building.
Synthesis phase			
Simulation software	Simulations made in Be18 and BSim to see if the building is within requirements.	Using the software, insert building geometry and information such as various systems and metrics.	For documentation of the technical requirements such as energy consumptions, thermal and atmospheric comfort. Assists in improving building sustainability to industry standards.
Calculations	Equations for air change rate, and u-values to determine numeric values.	Use variable numeric values to test different solutions, for thermal conductivity, and other techincal measurements of windows.	To see if the building meets set criteria for energy efficiency and building code requierments.
Presentation phase			
3D Modelling	A 3D model for representation of the building	Using software to generate a 3D model, used to produce renders and technical drawings.	To visualize the final design-proposal.
Diagrams	Visualizing information graphically.	To present information in a graphic instead of an explanatory text.	To easily show design details concerning the building.

Phenomenological

Cartographic

Method	Description	How to use it	Purpose
Analysis phase			
Sense of place	The human senses are used to explore and further understand human experiences. Pallasmaa noted that architecture became highly visual and that all sense are needed to understand the environment. [Pallasmaa, J. 1996]	The site is visited and studied while paying attention to every detail in the area, observing the site with all the senses. The observations are then noted in prose to summarize the experience.	This method provides an understanding of the explored area to support the cartographic 2D studies of the environment. The method is used to understand the sense of atmosphere and the character of the site.
Serial Vision	This method is used to explore density and spatial variation in an area along certain routes. It pays attention to the changes in openness and closeness in urban spaces. [Cullen, G. 1961]	Significant routes leading to the site are examined for difference in spatiality. While chronologically walking the routes, photos taken in series are documenting the changes.	To experience the different possible approaches to the site and how that may effect the experience upon arrival. This can assist in deciding the form and spacial access to the site to complement the arrival.
Mapping	This method is used to describe the physical surroundings and conditions on the site.	A number of physical or measurable observations have been made, which are visualized on a map.	This method is used for a simple overall understanding of the site and its location in context, and illustrates potential problems.
Questionnaire with primarily closed answers	A questionnaire survey with a combination of closed and open questions gives quantitative data that can easily be compared and translated into numbers. [Bejder, A. 2, 2014]	The questionnaire is sent out to x number of people and the results are processed and analyzed.	Based on the questionnaire, a number of design criteria are prepared for the project
Semi-structured interview	The qualitative semi-structured interview provides ”soft” data, with the possibility of comprehensive and profound answers. [Bejder, A. 2, 2014]	An interview guide is prepared, which the interviewer uses during the interview of a representative from the orphanage. It contains guidelines in the form of questions for the interview, but the interviewer asks further questions depending on the intervieweer’s answer.	The semi-structured interview is used to determine the users wishes and needs for the design.
Literature study	A literature study is an applied method for gathering already existing knowledge about a specific topic or problem. This information can be found in various sources, such as journal articles, books, newspapers, dissertations and archival material.	In order to gain a deeper understanding of relevant topics, various sources such as websites and books has been read.	Based on the literature studies, insight into existing knowledge and theories related to the project has been established.
Case study	This method is used to describe a building design, based on interior and exterior dimensions, and the context as well. [Riis, V. 2011].	Based on Vita Riis analysis ellipse a case was analyzed to get a deeper understanding.	Vita Riis’ analysis ellipse has been used for analysing of the case studies, to get a good understanding of the design.



Ill. 1 The Integrated Design Process

The integrated design process

Integrated design process (IDP) is based on the concept of combining cross-disciplinary knowledge in solving design problems and challenges. The method consists of five phases and brings knowledge and methods from construction and trades, architecture, operations, maintenance and mechanical engineers to the design, right from the project start. This ensures one coherent design holistically created with the competencies of the entire project team. The method is based on problem-based learning, and the five phases work in an iterative process, which continuously revisit previous phases to ensure consistency and flawless integration.

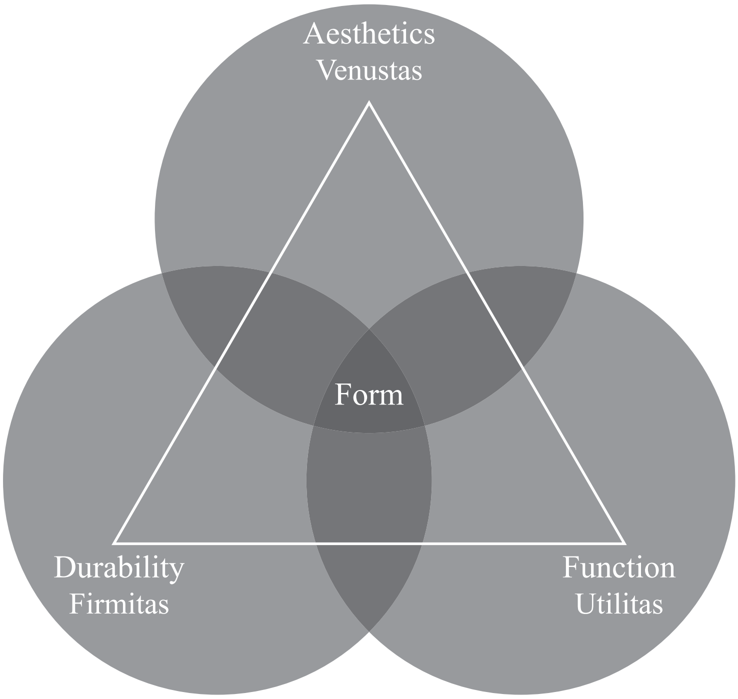
The first phase, the problem phase, analyzes the problem that the project would like to solve. In this case the challenge is to design an orphanage on Egholm. The approach to the project is specified, through a description of which methods and theories is relevant topics within the set problem.

The second phase, the analysis phase, is where empirical data is collected for use in the analysis. In this project an understanding of what an orphanage is and what it requires - through various site and theme analyzes and case studies. The analysis phase results in a problem statement, design criterias and a vision.

In the third phase, the sketching phase, different solutions are developed for the design, seeking to meet the set criteria and requirements. Here, sketching, models and 3D modeling are used to assess and make different choices, including shape, floor plans and facade expressions, while intergrating simulations and technical solutions.

The fourth phase, the synthesis phase, is where plan solutions, technical parameters, and strategies are applied, simulations are modeled to verify if requirements have been met.

In the last phase, the presentation phase, the design is presented in the form of technical drawings, renders and diagrams that presents the final product [Knudstrup, M., 2005].



Ill. 2 The vitruvian triad

The vitruvian triad

The essential aspects for creating high quality architecture can be defined as a relation between technology, function and aesthetics. This relation originates from the Roman architect Marcus Vitruvius Pollio and his Ten Books on Architecture, where he describes Firmitas, Utilitas and Venustas [Bech-Danielsen, 2013].

Firmitas concerns the durability of the building, which focus on the choice of materials and construction. Hence, the building should be resistant to forces, such as the climate conditions.

Utilitas addresses the functionality of architecture. In the current understanding of the concept it addresses the buildings' ability to respond to the needs from the actual users and from the surrounding community.

Venustas defines the aesthetics, which relates to the design and the architectural expression.

Each of the three corners in the Vitruvian triad sets up different demands and ideals, that must be met in the architecture - and it is vital in the creation of architectural quality, that the requirements of the three corners interact and creates a wholeness.

Problem statement

How to create a modern and sustainable orphanage, focusing on the technical and the aesthetical design solutions that sets the boundaries for the well-being of the users of the building, the children, adolescent and staff, while at the same time securing the existence of the building in the future?

Site analysis

During this chapter, the site and the surrounding area are studied in order to understand the context, in which the project will be influenced and affected by detailing the site's physical and phenomenological constraints.

The chapter starts out with a mapping of the surrounding area, describing the atmosphere and generating a deeper understanding of the area. Next, the different typologies found on Egholm is analysed and the user group investigated. It ends in the formulation of design criteria and a vision for the rest of the design process.

Denmark · Aalborg · Egholm

Ill. 3 Map of the location

History & location

Egholm is a small island in the eastern part of the Limfjord, West of Aalborg and Nørresundby. The flat island is formed under the stone age and measures approx. 6 km² with the highest natural point just 1.5 meters above the sea level. Due to the low altitude, the first dike was built in 1909, and today most of the island has gradually been confined.

Most of the island is cultivated, but also habitats such as salt marshes, uncultivated areas and forests constitute a significant part of the magnificent nature found on Egholm. A completely unique plant and bird life is associated with these areas. The agricultural land is run organically and thereby the citizens and institutions of the municipality have the opportunity to buy local organic goods in the center of town. There is many ongoing exciting activities aiming for a more sustainable community e.g. composting and non-toxic gardenings. Easy access to the island's natural scenery with e.g. bird tower, several hiking routes and trials with bicycles for the citizens and tourists visiting. These are all current projects, which is supported by Aalborg Municipality.

Previously, most residents worked within agriculture, but today many are commuters. Egholm is connected to Aalborg via a ferry connection with a crossing time of approx. 5 minutes. Each year, the island is visited by up to 100,000 citizens and tourists in Aalborg Municipality.

The first written source on Egholm can be found in King Valdemar Sejr's Landbook of the Crown's estate from 1231, where the island is called "Æggiæholm, et hus". Æggiæholm can probably be attributed to the fact that the locals in the Middle Ages collected large amounts of eggs - especially seagull eggs. "Et hus" can be interpreted as the king's hunting lodge and that the king used Egholm to hunt when he visited North Jutland.

During the Middle Ages Egholm had several different owners - both kings, gentlemen and Vor Frue Kloster in Aalborg. The first residents established themself on the island around 1500. Several of the oldest farms on Egholm still exists, for instance Damgård in Egholm, where there is built a cairn according to old Faroese traditions. In the years of 1809-10 the residents bought the land for self-ownership. The land was distributed in 6 almost equal farms. In the period of 1818-28, a further development took place for 20 farms. Today, the number is reduced to 11 farms. Today Egholm have approx. 50 residents.

The first motorized postboat came to the island in 1914, and the State Bridge at Nørredyb was built in 1918, partly financed by state resources. A ferry service to Aalborg was established in 1972. In 2014, a new and larger ferry was deployed to transport more than 100,000 passengers annually to and from the island. Previously there were dairy, school, smithy and a telephone exchange to be found on the Island. Today the school works as a camp [Aalborg Kommune, 2018].

Ill. 4 Mapping of the island

Mapping

In order to get an overview of the context to the site, the functions and accessibility is mapped to figure out if there are facilities the orphanage can benefit from.

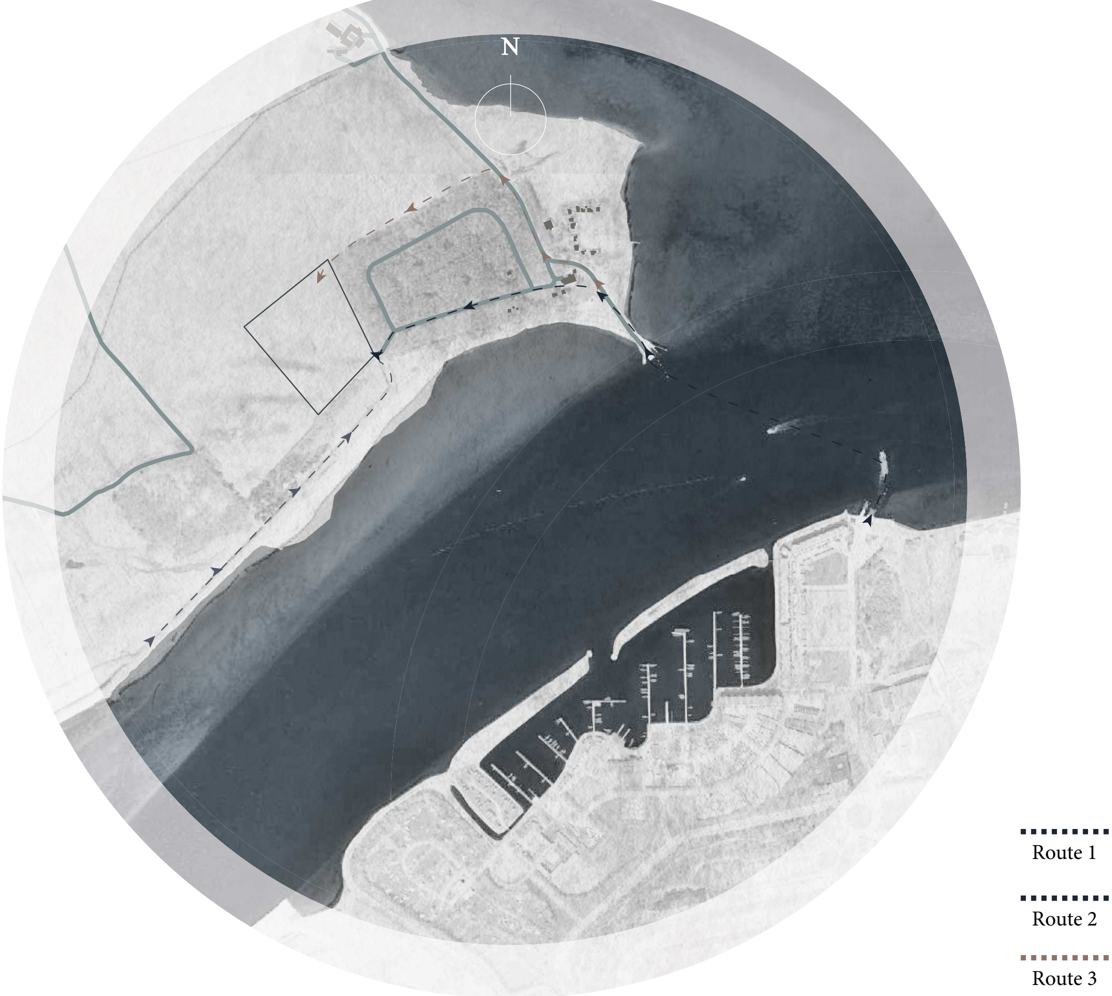
The scenery is characterized by fields and scattered clusters of trees, the terrain is primarily flat and there are detached one storey buildings and old farms scattered around on Egholm. To the South-East of the site a small beach area is to be found, with a view across Limfjorden towards Skudehavnen.

In a near proximity of the site is to be found a restaurant and a camp area in the forest. There are currently no roads reaching the site, or parking nearby. On a more general notice there is to be found a Egholm vestergård, and Gl. skole, which are rent able for larger gatherings.

Accessing the island can be done easily by either, car, bicycle or as a pedestrian, public transportation is close by the ferry terminal on the side of Aalborg that facilities further commute into the city center, only 5 minutes away, here one can find all facilities they need (school, kindergarten, shops, green public areas etc.) before heading home to the peaceful surroundings.

CONCLUSION

Having a clear and unimpeded view, makes a future building visible from Aalborg, and can function as a visual landmark, that facilitates the wayfinding towards the building easier for commuters. However, the building should still be designed in relation to the site.



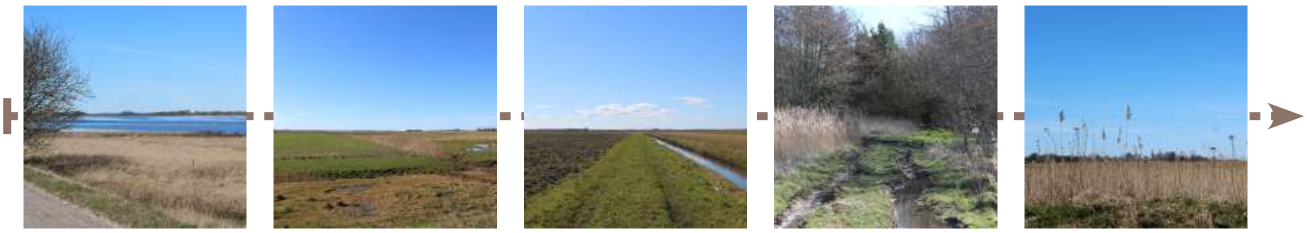
Ill. 5 Map of the routes

Serial vision

With inspiration from Gordon Cullen's serial vision method [Cullen, Gordon, 1961], three routes were photographed and analysed upon arrival to the site. The different character and spatial experience for each route, is photographed and shown in the pictures. The images come in chronological order as one approaches closer to the site.

When taking the ferry to Egholm, it’s not just a short journey, but a transition from the hectic city life to a distinguished scenery only 5 minutes away. When arriving to the island one is immediately met with a characterization of low detached housing. When walking a short distance a restaurant is breaking out from the tree line. Going through the forest, is a mind clearing path. Here one is embraced with dense trees surrounding and lastly opening up to the flat site.

When walking along the South-Western hiking route towards the site, the area is characterized of an open undisturbed landscape, having the water on the right and a subtle change from reeds to creeks on the left. The openness is breaking by clusters of trees, as one moves closer to the site. When walking past the dense stripe of trees that hinter the views, reaching the South-East corner of the site, one is met with a clearing where a 180 degree panorama is possible over the entire site.



When continuing past the restaurant following the main road, different scenery is present, first a wetland with reeds is noticeable, changing into farmed land, with distinguished creeks separating them. When walking in the edge of the forest, this gives an idyllic atmosphere.

Sense of place

“ It’s a beautiful day in February and the time is around twelve in the noon. My gaze is caught by the horizon where the lively water meets the calm blue sky, almost blending into each other. It is almost like looking into a canvas where there are several strokes of colors in the shades of blue; small and light strokes on the top that becomes larger and even harsh in the bottom. But in the middle of the canvas, is this image disturbed by a green spot emerging from the blue; the Island - it seems far away.

Illuminated by the rays from the sun, giving the hummock an idyllic light and the sky a sacred glow.

It feels like a nostalgic still image painting back from the romanticisme, an idyllic place where you want to withdraw and respite from the everyday life.

As I am dreaming away to this idyllic place, I hear the hum of the ferry starting its engine and i’m captivated of how the waves are dancing rhythmical along to the frequency of the engine - almost like a well written symphony, the movements are calming, and suddenly time slows and I’m distanced from the stress of city life. And before i realise it we are boarding on the shore of the island.

As I’m walking towards the site the first thing i notice are the small wooden cottage colony, and the restaurant not set far from there. This reminds me most of summer, freedom and sun. I recall the countless times me and my family spend our yearly summervecation in a wooden cottage somewhere in Denmark, it certainly brings back a piece of childhood. I recall the mood set by the bushes, trees and fences placed between the road and the sidewalk. This contributes to a down-to-earth expression, as these create a sense of peace and add character to the area. The houses all have the same height and i wonder if gaining some height and looking over the roofs they would form like a wavy blanket, covering and embracing the landscape and protecting everyone underneath.

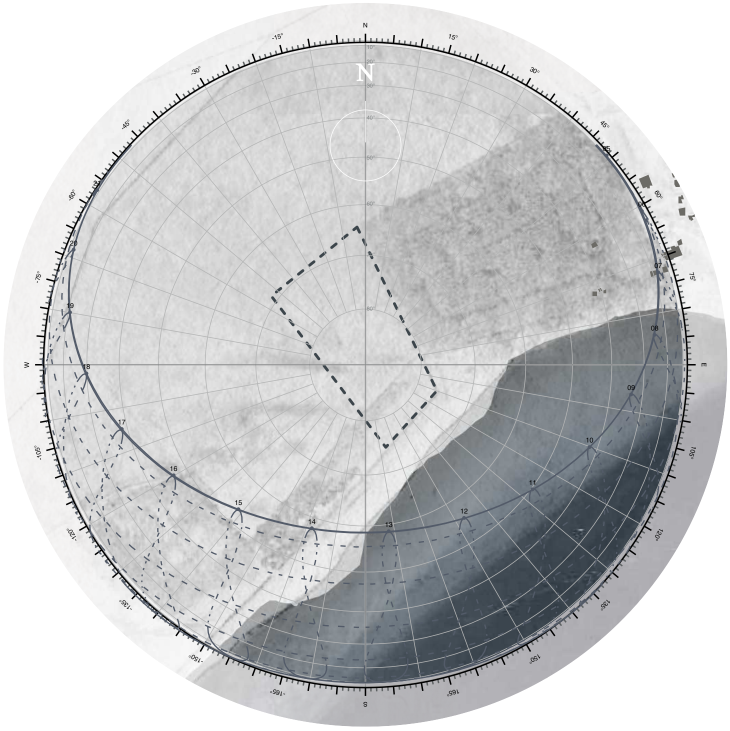
When I close my eyes to sense the place without the visual sense, the gust of wind breaks the silence, the sound of the rippling water is calming and faint cries of seagulls is dominating. I'm wondering what the atmosphere will be like in the summertime once the bushes and trees has blossomed. I get the picture that in every garden a Danish flag flutter in the air, like a small celebration of freedom and the openness one find these places.

I close my eyes for a minute and take in a deep breath of fresh air. The air here is incredibly rich, crisp and tasteless, I try to recall the last time i felt such appreciation, and i cannot, this is one of the many qualities we surely miss when living in the city.

While walking along the red route to the site, on the natural tracks, the first thing that comes to my mind is the quietness and a feeling of openness. The path seem infint and the fields and landscape merges into the sky in the long distant horizon.

I walk away the path as the nature leads me the forest.The trees are naked and reset my sense as I walk through, focusing my mind on this exact moment with the embracing and sheltering forest. It sooner allows me to get a view to what comes next. I arrive on the site and the first thing that comes to my mind when I walk along the water, is that the stream is so natural and undisturbed. The nature is allowed to just unfold - unfold without any limitations.

Crossing the road I'm finally approaching the site, and here is set the foundation to a new prosperous orphanage. ”



Ill. 6 Sun path

Microclimate

In order to achieve an energy conscious design, qualities and challenges related to the microclimate is identified. This supports the notion that human thermal comfort in building design is achieved by understating the basic principles of bioclimatic design, by ensuring a well-integrated building in its local context, and to make optimal use of passive means such as sun and wind.

SUN

To study the movement of the sun a 3D model was used. The information gathered from the analysis shows the yearly sun path and sun angle in relation to the site and area.

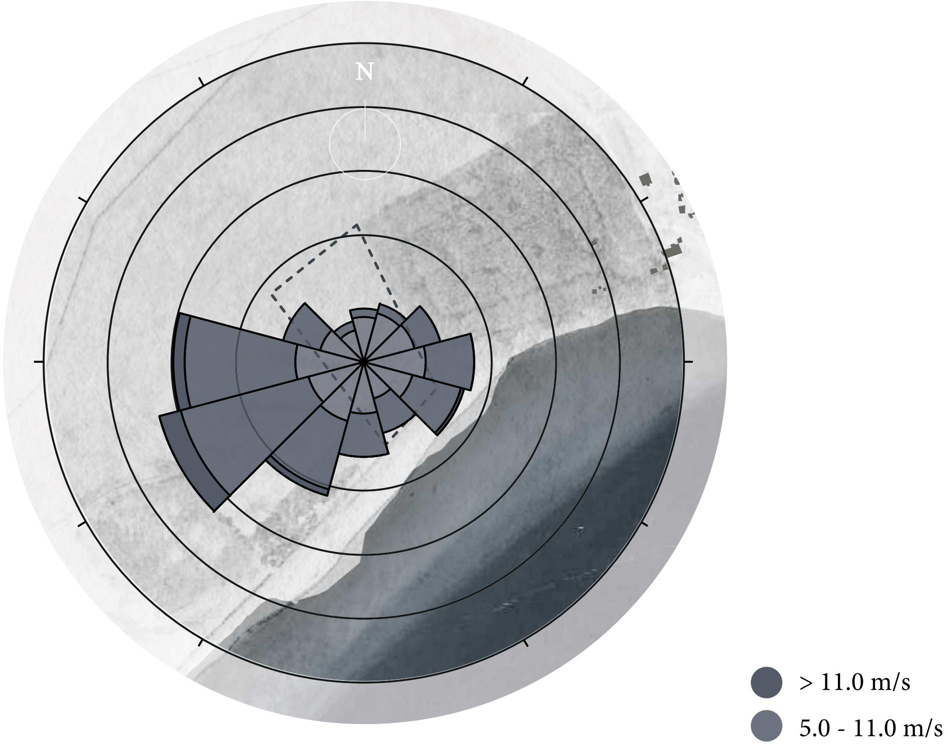
The data displayed in the diagram reveal that during the summer solstice, the sun is at its highest at 12:22, with an angle of 56.39, providing 17 hours and 54 minutes of daylight June the 21st. And at the equinox of Autumn and spring, the 20th of March and the 23rd of September, there is 12 hours and 21 minutes of daylight, the sun being at its highest at 12:13. The last solstice is winter on the 22nd of December having 6 hours and 42 minutes of daylight, with the sun highest at 12:18 in an angle of 15.39.

SHADOWS

There is no significant impact on shadowing issues since there are no buildings placed close to the site. However, there is a forest right next to the site, towards North-East, which will create some shading in the early mornings during the summer, and a line of trees towards West, which will create some shading in the late evening.

CONCLUSION

This is crucial information that needs to be considered in the further design, the amount of daylight varies throughout the year and is dependent on the season. Utilizing natural daylight reduce cost of artificial lightning, and is more beneficial as it possess the ability to vary and animate a room throughout a day. In terms of placement and orientation of a building the solar path also needs to be considered. The utilizing of passive solar heat needs to be exploited during the winter and avoided in the summertime, where cooling is need at its highest. This is also important for placement of solar panels and the outdoor recreational areas.



Ill. 7 Wind rose

WIND

The wind rose is based on data gathered from the area around Aalborg Airport, and is based on a standard normal period which is an average of climatic data of 30 years, from 1961-1990, [John Cappelen, Bent Jørgensen, 1999].

The site location on Egholm is a good representation of the similar wind conditions out at the airport, due to similar conditions experienced in the flat and open space. As it can be seen from the wind rose, the most dominant directions are West during the summer and South-West during the winter. The average wind speed in Aalborg in 4,4 m/s. [DMI, 2016].

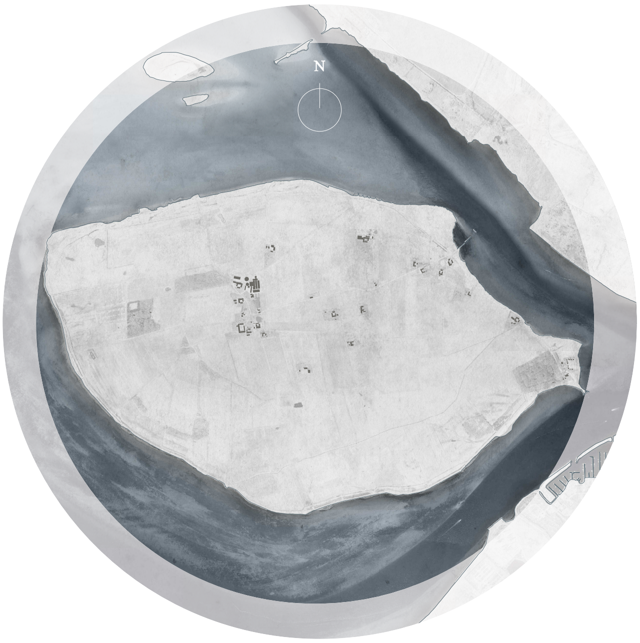
There is no surrounding buildings that could work as a shield for the wind, but towards West there is a line of trees.

CONCLUSION

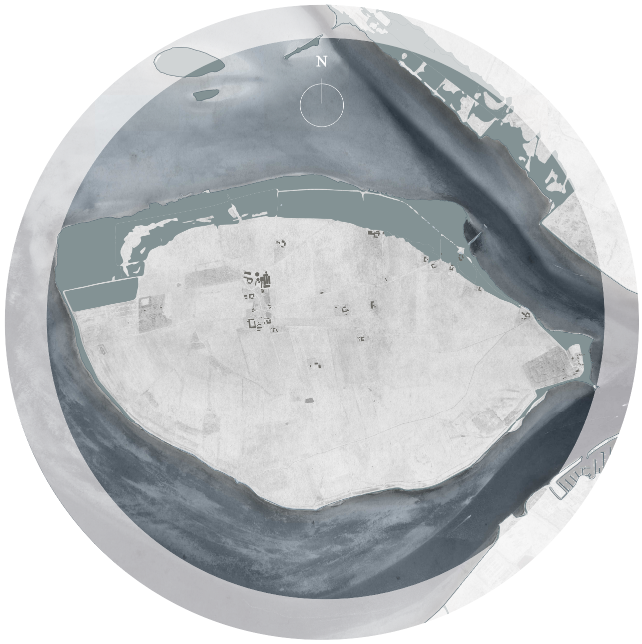
This is crucial information when designing outdoor areas, since these might need to be sheltered from the wind. A courtyard or wind protected gardens should be considered. However, knowing the predominant wind directions can be beneficial for the use of natural ventilation.

Water level

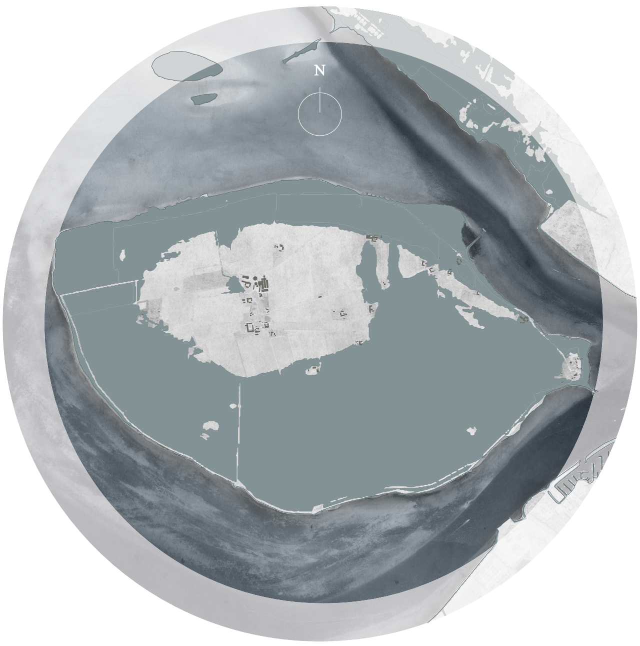
The site on Egholm has an increased possibility of flooding during storm surges, due to close proximity to the Limfjord. The flooding will emerge and come from the South, with a water level rise of 1.4m the entire site will be covered with water, due to the height of the existing dikes surrounding and protecting the island. DMI estimates that within 20 years the water will rise 1.4 meters as average threatening and exposing Egholms existence, as the highest point on the island is 1.5m [DMI, 2019].



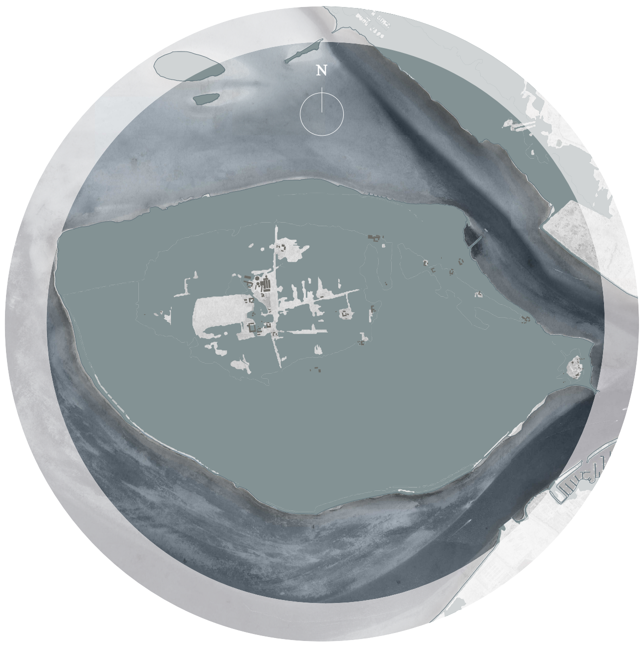
Ill. 8 Current water level (0m)



Ill. 9 Water level at 1.1 m



Ill. 10 Water level at 1.4 m



Ill. 11 Water level at 1.8 m

Part conclusion

The site analysis provided information about the location and the size of the site and it also revealed the challenges and potentials for the design by mapping analysis using James Corner method. Distanced from the center of the city, the site is accessible by a ferry, foot or bike. Due to the lacking functions in the area, public transit is available from close-by that can transport commuters to the city.

The most common typology in the context consist of open low and dense one storey detached gable houses of brick. The small scale and uniform building heights create a monotonous image that characterizes the typical suburb. It is desired that the design of the new orphanage should relate to the surroundings, by replicating architectural expression found in the context.

Having little to none public accessible parks or areas in the near context, gives no ample opportunities for recreational activities, like gardening, play, leisure or recreational use. A new building should accommodate the users needs for this.

The micro-climate strongly supports the site for energy efficient design. It is well lit by sun and not hindered by large shadows even in the worst time of the year. However, the wind is still a challenge that needs to be considered with the form and design.

Theme analysis

Climate changes

Global warming is causing climate changes and as the planet's temperature is rising, the climate varies. Global warming is caused by the greenhouse effect. The greenhouse effect is a natural process where the atmosphere retains some of the sun's heat, but the problem is, that the daily human activities are maximizing the greenhouse effect, causing the planet's temperature to increase, which results in melting of the ice caps at the poles, and therefore the sea level is rising, flooding and coastal threats are consequences of this. Some of the factors that has a significant influence on the Co_2-emission is the building sector, where increased energy demand and production are having a negative effect on the climate. Therefore the building sector should work more sustainable and future proof with the buildings in comparison to the climate changes [Acciona, 2019].

There is a big uncertainty as a result of different results from different climate models, different scenarios and different analyse methods. Therefore there is a vary of how bad the climate will change, and it is not possible to know which one is more correct. In this project the results from DMI, who use scenarios from FN's climate panel and their own simulations, will be taken into account.

There are four kinds of climate changes that we are experiencing in varying degrees around the world right now in result of the global warming; temperature, precipitation, rise of the sea-level and extreme weather conditions. In Denmark we are not that much affected by the climate changes as they are in other parts of the world, in fact, we are placed as no. 1 on a list showing how much the different countries are vulnerable to the changes and how well they will be able to handle the threats. But there are still going to be changes in our climate, and therefore it will be investigated further to see how the project can be more robust compared to the climate changes and how it can have a less negative effect on the climate [Videnskab.dk, 2019].

DMI (Danmarks Meteorologiske Institut) has tried to put down scenarios about how the climate is going to change in Denmark towards 2100. They use knowledge from FN's climate panel (IPCC) and own simulations. The calculations is based on two scenarios for greenhouse gas emissions in the future - high emission (RCP8.5) and low emission (RCP2.6) [DMI, 2019].

TEMPERATURE

The table shows the two scenarios for the change in the temperature, and it shows that the temperature will have an annual increase of 3.7 degrees (+/- 1 degree) in the period 2005-2100. Therefore it shows that the weather in Denmark will be more warm in the future [DMI, 2019].

Season	Avg. temp. 2018	Avg. temp. 1961-1990 / 2006-2015	Max temp. 2018	Min temp. 2018
Annual	9,5	7,7 / 8,9	33,6	-12,9
Winter	1,9	0,5 / 1,7	12,1	-10,5
Spring	7,9	6,2 / 7,5	29,3	-12,9
Summer	17,7	15,2 / 16,1	33,6	3,4
Fall	10,1	8,8 / 9,9	27,0	-7,1

Ill. 12 Temperature in Denmark.

Temp. [C°]	RCP2.6	RCP8.5
Annual	1.2 (+/- 0.5)	3.7 (+/- 1.0)
Winter	1.2 (+/- 0.7)	3.7 (+/- 0.9)
Spring	1.2 (+/- 0.5)	3.2 (+/- 0.8)
Summer	1.2 (+/- 0.8)	4.0 (+/- 1.5)
Fall	1.2 (+/- 0.6)	4.0 (+/- 1.1)

Ill. 13 Increased temperature from 2005-2100

CONCLUSION

Because of the increased temperature, the growing season will last longer, and the agricultural production will increase. It will be possible to cultivate brand new crops, but at the same time there will also be a bigger need of irrigation because of the dry periods together with drainage in the periods with increased rain [Analyse af IPPC, 2014].

The design has to be flexible compared to the temperature. It has to be possible to have a good indoor climate even though the temperature will increase in the future. Also outdoor areas will be more warm, so it would be a good idea to design some shaded outdoor areas. The increased temperature in the cold periods will have a positive impact on the heat demand, because there will be less need of heating.

Strategies:

- Natural ventilation
- Passive solar protection (which makes it possible to shade in summer period, but not in winter period)

The strategies will be integrated in the design. Also the temperature change will be tested in Bsim, to make sure, a good indoor environment are obtained even though the temperature is going to rise.

PRECIPITATION

There will be a big change in the amount and degree of precipitation. The rain will increase in winter, spring and fall, but in the summer period, the amount of rain will decrease a lot. We have just experienced a summer period last year (summer 2018), with high temperatures and no rain, which resulted in very dry nature and therefore no open fire were allowed. This kind of summer, compared to the scenarios, will be seen more in the future. Opposite, in the winter, spring and fall, there will be more rain and the intensity of the rain will increase in form of more powerful cloudbursts. This will result in very much rain in a short amount of time, and this rain needs to be absorbed in a way, otherwise it will turn into flood [DMI, 2019].

Precipitation [%]	RCP2.6	RCP8.5
Annual	1.5 (+/- 4.6)	6.9 (+/- 6.1)
Winter	3.1 (+/- 7.9)	18.0 (+/- 12.0)
Spring	3.7 (+/- 11.1)	10.7 (+/- 12.6)
Summer	-0.5 (+/- 9.6)	-16.6 (+/- 21.0)
Fall	0.8 (+/- 7.2)	10.2 (+/- 10.9)

Ill. 14 Changes in precipitation from 2005-2100

CONCLUSION

In Denmark, we use almost only water abstraction from groundwater, and because of the increased rain in winter and the more dry summer period, which affect the groundwater recharge in each direction, there is a significant uncertainty of how the climate changes will affect the water resources in Denmark [DMI, 2019].

As a affect of the changes of precipitation, there will be problems with dry nature in the summer period, but also problems with overload of rainwater which can result in flood the rest of the year. Therefore there should be integrated some strategies on the site, to cover for those problems.

Strategies:
- Rainwater harvesting
- Green roofs
- Delay basin
- A floating building

Green roofs or a rainwater harvesting system should be integrated in the design to cover the problems. There are going to be many residents resulting in a lot of water use in the building, therefore a rain water harvesting system (from the roof) could be used for e.g. toilet flush, washing machines and watering plants.

WATER-LEVEL

The estimation of the two different scenarios is that the water rising around Denmark will be between 0.3 and 0.6 meters in this century. But there is still a chance, that the water will rise even more [DMI, 2019].

Mean sea level [m]	RCP2.6	RCP8.5
Global mean	0.40 (0.26-0.54)	0.62 (0.45-0.81)
Denmark	0.34 (0.1-0.6)	0.61 (0.3-0.9)

Ill. 15 Changes in the mean sea-level from 2005-2100

CONCLUSION

The sea level will rise, which makes Egholm very exposed because it is a flat island. Also there is a bigger risk of storm surges as the sea level rises. Therefore a solution of this problem has to be designed.

The site and the most of the island is going to be flooded if the water rises 1.2 meters, but a water rise below 1.2 meters will not affect the site. Therefore the site is not in risk of being flooded if the scenarios are right, but because of huge uncertainty (there are cases where investigations shows that the water risks to rise even more), a strategy to stop the sea to flood the island, should be designed.

Strategies:
- A dike
- Build further into the land
- Build higher in the landscape
- Design for disassembly

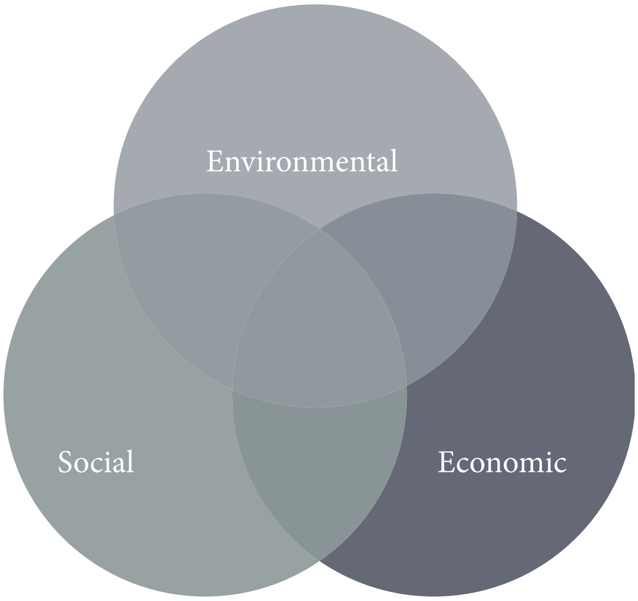
The building is going to be raised in the landscape and design for disassembly is going to be used as construction.

LIMITING THE CLIMATE CHANGES

While focusing on climate adaptation in this project, it is also important to have focus on limiting the climate changes by deriving less CO_2.

Strategies:
- Amount of materials
- Choice of materials (compared in LCA)
- Energy demand
- Passive solutions
- Active solutions

The outer wall are going to be investigated in LCA to chose the most sustainable solution. Also passive and active solutions are going to be integrated in the design, using e.g. Bsim and Be18 as a guide.



Ill. 16 The three main pillars of sustainability

Sustainability

Sustainability is a broad concept, but what does it really cover? In order to use sustainability as a design parameter and motive force for the design method it is necessary to establish our understanding and definition of what sustainability is.

Sustainability can be perceived and defined in many ways. The most frequently quoted definition of sustainability is from the Brundtland report; *"sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* [Brundtland, 1987]. This was the foundation in establishing the three thematic pillars for sustainable development from which interdependent elements are represented. The pillars are of environment, economy and society. These pillars are used to report and measure the success of sustainability efforts.

A HOLISTIC APPROACH

In order to create a new building design it is necessary to be aware of the three main pillars of sustainability, where sustainable buildings must be economically viable, while also incorporated adaptation to climate changes, energy and resource efficiency, environmental, architectural quality and social security. It should be noted that sustainability is achieved when all three pillars are implemented together and, importantly, with the same intensity.

THE THREE PILLARS

Environmental sustainable principles should benefit from the local climate and topography, and aim to reduce the use of fossil fuels and emissions of carbon dioxide. Thus, working with sustainable architecture in term of the buildings physics and renewable technologies.

These technical principles of sustainability are addressed through measures and calculations, thus easy to acknowledge.

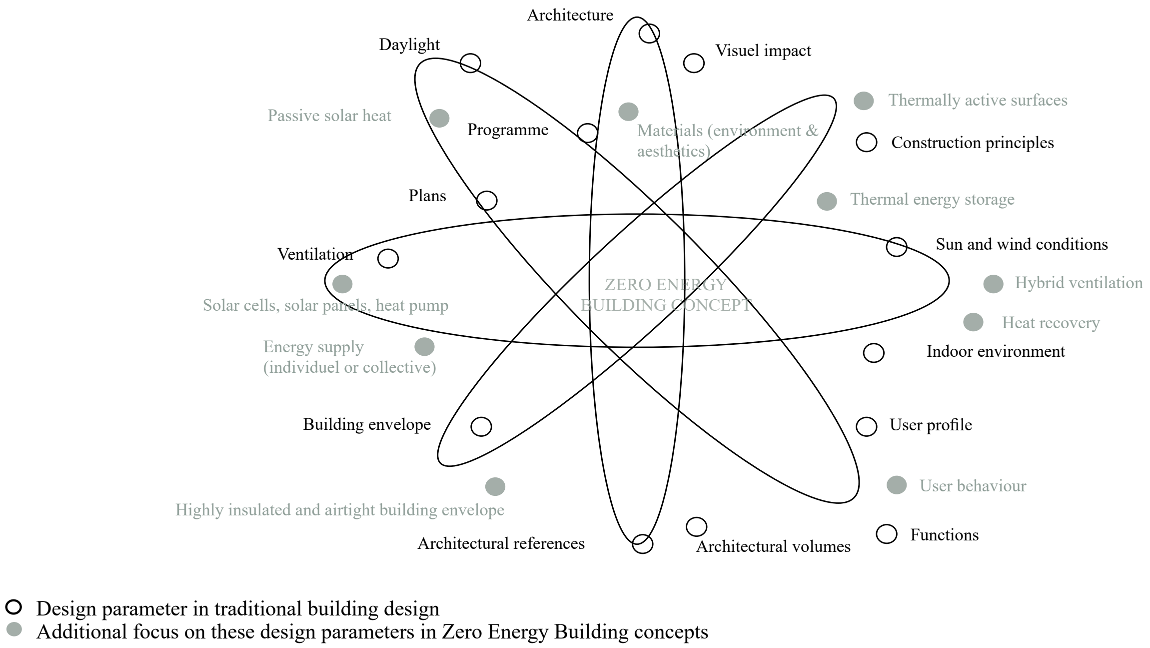
Social sustainability emphasizes the human factor as an essential requirement for the realization of a sustainable society. In the urban environment, social sustainability has to do with inclusion, diversity and safe surroundings, in order to create good life conditions.

The aim is to create architecture that promotes sustainable action and human well-being. These conditions, however, are much harder to measure and verify [Dansk Arkitektur Center, 2014].

It is useful in working with the sustainability concept to understand and work with the economy in terms of the costs for both the building and the production behind in order to be economically feasible.

CONCLUSION

Sustainability for this project will strive to achieve a balanced level of sustainability through the method of design for disassembly, as well as strategies from ZEB buildings, in the use of passive and active solutions.



Ill. 17 Overall strategy for designing ZEB

Zero energy building

With 40% of the global CO_2-emission coming from the building sector, we as architects and engineers have a great responsibility. But the possibility to change the energy consumption can be locked in the design, therefore a strong understanding of the integration of the three aspects in architecture with the trinity of aesthetics, functions and techniques is essential.

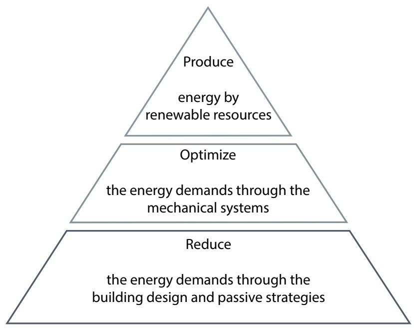
A ZEB is a building that should be designed to prevent unnecessary energy demand and that it is covered by energy the building itself can produce using renewable technologies.

When a ZEB is connected to the main energy grid, it is called Net ZEB, which means that it can balance the non-renewable primary energies used during the year, by self producing green energy.

Zero Energy Buildings does not only involve reduced energy need or producing energy that covers the energy demand, it also involves a very good indoor environment and respect for the user (e.g. temperature, air quality, daylight). Therefore, both passive and active solutions must be taken into considerations when designing a ZEB building [Anne Kirkegaard Bejder, Mary-Ann Knudstrup, Rasmus Lund Jensen, Ivan Katic, 2014]. The building should be connected to the collective heat supply grid if possible, also called a Net ZEB. There are four types of Net ZEB's; site, source, cost and emission. The aim in this project is to obtain a Net Zero Source Energy Building, where the building must produce at least as much energy, by renewable sources, as it uses in a year, when accounted for at the source.

Passive strategies need to strategically consider the location of the building, taking into account the macro and micro climates, building materials and environmental conditions. The approaches in utilizing passive strategies differ throughout the year, in cold winter months it is necessary to increase solar heat gain, and keep the heat inside while reducing transmission losses through utilization of well insulated external elements. The summer months, should look to prevent overheating and utilize natural ventilation.

When the passive strategies are applied the active strategies can be considered into the design. They produce renewable energy, and includes technologies such as solar thermal collectors, photovoltaic cells, and heat pumps [Annex 1].

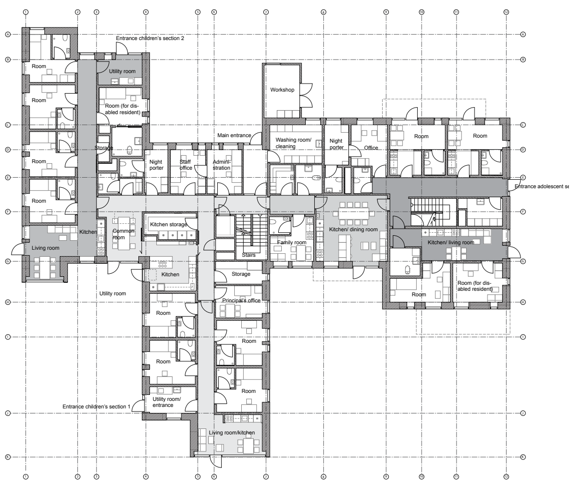


Ill. 18 ZEB triangle

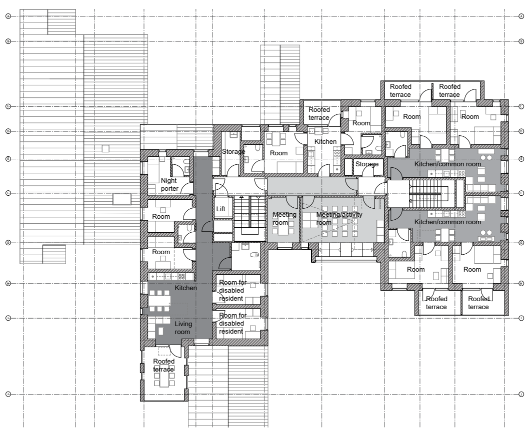
Case studies

The purpose of a case study is to do a qualitative analysis of a specific context and extension details and concrete knowledge within a desired field [denstoredanske.dk]. A case study of Villaen has been made with the purpose to gain insight into floor plans for an orphanage, and which functions and facilities, that is essential for the house. Furthermore, it is desired to extract knowledge of how the home can be designed in relation to both children and staff.

Ill. 19 Villaen



Ill. 20 Ground floor



Ill. 21 1st floor

VILLAEN

Villaen, Kerteminde, Denmark
Architect: CEBRA
Year: 2014
Area: 1500 m²

Villaen is a 24-hour care centre for marginalized children and teenagers who struggle with behavioural, social and mental health problems. The tile and wood cladded building plays with familiar elements and shapes to create a homely environment in a modern building that focuses on the residents' special needs. Villaen combines the traditional home's safe environment with new pedagogical ideas and conceptions of what a modern children's home is and which needs it should fulfil.

The vision is to establish a care centre that encourages social relations while at the same time accommodation the children's individual needs. It is a home that prepares the children for their future path in life in the best possible way. The architecture supports the staff's daily work with the children, by reflecting a practice-oriented pedagogic approach.

Villaen takes the familiar basic shape that is a typical sign for a Danish home, which is the rectangular pitched-roof building with a chimney. The basic geometric shape is modified by the dormer profiles, which grow in and out of the building and adds spatial variation and flexibility.

The smaller children's units are oriented towards the garden instead of the street, and has direct access to the playground. The staff is placed in connection with the main entrance to give an overview of arriving visitors and deliveries. The teenager's unit is the most extrovert section which is oriented towards the street, so they are encouraged to use the city.

The institutional functions (e.g. administration, staff rooms and storage) are mostly located in the basement and 1. floor so they are not that visible in the everyday life, to minimise the institutional feeling. [Archdaily, 2019]

A case study of Frederiksvej Kindergarten in Frederiksberg has been made with the purpose to gain insight into the design and roof construction of this concept. Even though it is a kindergarten, it is a place, which manage to create a homelike feeling by appearing as a playful village.

Ill. 22 Frederiksvej Kindergarten

Ill. 23 Gutter solution

Ill. 24 Section

FREDERIKSVEJ KINDERGARTEN

Frederiksvej Kindergarten, Frederiksberg, Denmark
Architect: Cobe
Year: 2015
Area: 1700 m²

Frederiksvej Kindergarten is a day-care institution in Frederiksberg, located in a residential area.

One of the questions that the architects asked themselves was “how do children see a house?”. The aim of the project was to create a small village that break away from the traditional, large-scale institution. Therefore, the project consists of 11 small houses joint together with different orientation, which makes the building appear like a playful village.

The two central kindergarten buildings have a white exterior while the other nine are covered in black. To strengthen the idea of the house shape and make the material connections simple, the building’s outer walls blend in with the roof. The minimalistic architecture of the individual volumes becomes more playful by the irregularity of their arrangements.

The roofs vary in both pitch and height. The roofline is kept uncluttered by means of hidden drains and precise material connections. The interiors are completely white, since the idea is that the users will be colourful enough [Detail, 2016].

Case studies

A case study of Lisbjerg Bakke and Circle House has been made with the purpose to gain insight into design for disassembly constructions in Danish architecture. These two projects are using new technologies of the design for disassembly principles and they are investigating new ways of construction, to have the best opportunity to disassemble and reuse building materials in the future.

Ill. 25 Lisbjerg Bakke, Århus

Ill. 26 Wood cassette fixed to the skeleton construction

Ill. 27 Joint. Column and beam connection in Lisbjerg Bakke

LISBJERG BAKKE

Lisbjerg Bakke, Århus, Denmark
Architect: Vandkunsten
Year: 2018
Area: 4100 m²

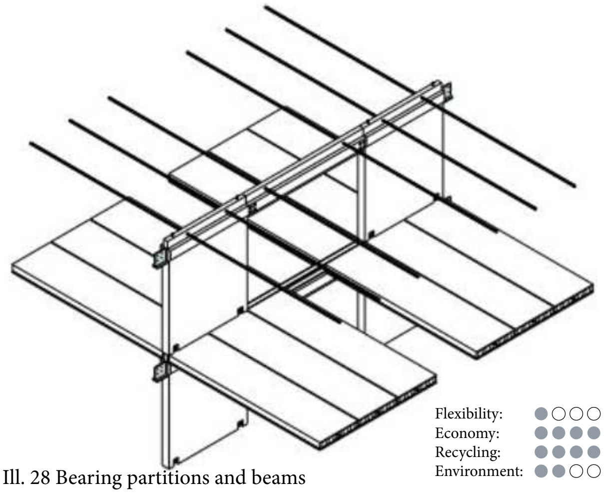
Lisbjerg Bakke consists of 40 apartments distributed in 6 blocks in 3-4 floors. The vision of the developer is that the building must be a sustainable solution for the future of housing. Therefore, the focus of the building is the skeleton construction with wood cassettes which futureproofs the building.

The project is listed with Wood Stock, which is a column and beam construction in glulam, developed by Vandkundsten and MOE. Besides almost only using wood in the construction, concrete and steel is used where it's needed to keep the proportions of the wood construction and to isolate the sound, since it is a multi-storey building.

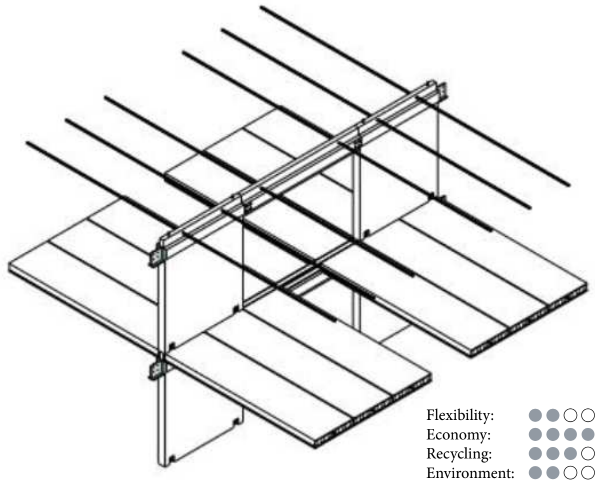
The construction also consists of wood cassettes on the facades and the roof, which makes it possible to prefabricate. The wood cassettes is produced on a factory where it is protected against wind and bad weather. Then the cassettes are transported to the site where they are placed and fixed to the skeleton construction [Ill. 26]. In this project, there is 27 different cassettes.

The building technique provides high planning flexibility and supports future dismantling and recycling of the building materials [ARKFO, 2017].

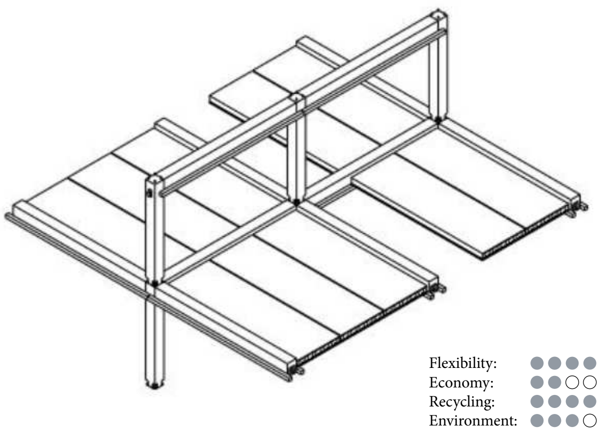
Circle house is a scalable demonstration project, which is going to bring new knowledge about building projects using the circular economy principles, which means that the building among other qualities can be disassembled and reused almost without losing any value.



Ill. 28 Bearing partitions and beams



Ill. 29 Extended system



Ill. 30 Column and beam system

CIRCLE HOUSE

Circle House, Århus, Denmark
Architect: 3XN, Leander Group, Vandkunsten
Year: 2020
Area: Ongoing project

The project consists of 60 apartments in Lisbjerg, Århus. The project is expected to be finish in April 2020. The vision of the project is the future of circular buildings and the concept is based on design for disassembly principles.

The starting point of the project is the concrete elements, which is the building system that is typically used for constructions in general. In order to make the building system more circular, they have reduced the number of different types of elements, which is also in general dimensions to ensure that they can be reused in other buildings in the future. The elements are clamped together using stainless steel joints, instead of casting them together, which gives the possibility to be disassembled and reused in other buildings. Therefore, the concrete elements can have a longer life span than usual [Circle House, 2018].

Furthermore, they have developed the principles of the construction further in relation to design for disassembly and how the system can be more flexible as well as enable a greater variation in the types of apartments, that resulted in three versions. The three systems were assessed in terms of four parameters; flexibility, economics, recycling potential and environmental impact:

Bearing partitions and beams [Ill. 28]. 7 elements. Creates less flexibility, but is easier to recycle.

Extended system [Ill. 29]. 11 elements. Same system, but it creates more flexibility compared to directions, different heights, etc because of more elements to choose from.

Column and beam system [Ill. 30]. 3 elements. Even more flexible system, but a more expensive solution because of the need of more elements and joints. At the same time, there is less use of concrete and more opportunities to adapt the system to the specific context. Because of the several floors, there will be challenges compared to stability, and therefore there has to be used a secondary system as a stabilizing element [IDEKATALOG, 2018].

Building resilience

The more frequent extreme weather and climate events like rising temperatures, increased flooding or storms, brings numerous directly and indirectly linkable consequences to the built environment and sets new challenges for architecture. Whenever such disasters have occurred, sustainability and building resilience become a discussion topic among architects, builders and constructors. And we need to remind ourselves that while green buildings certainly are important, DGNB or other certifications are useless if the building is damaged or uninhabitable due to a natural disaster. This is where initiative like building resilience comes to show.

Currently, architecture focuses on sustainability and mitigating climate changes by having energy efficient buildings. However, set buildings need to be extended to be both strengthened and capable to withstand future climate changes. To design for both present and future occurrences a resilience scenario is needed.

The UN Intergovernmental Panel on Climate Change estimates that the majority of global warming over the past 50 years is more than 90% likely due to man-made greenhouse gases [UN environment, 2017]. During the coming decades Denmark will get higher temperatures, the water level in the oceans will increase, and new patterns in temperature, precipitation and wind will give rise to more extreme weather. Some of these changes can already be noted.

Since 40% of the greenhouse gases are emitted from the building sector there has been a pressure to move towards sustainable low energy architecture, that could help mitigate the inevitable climate changes [UN environment, 2017]. Adaptive measures need to be incorporated in the field of architecture to alleviate the impact like defence strategies such as passive solutions are becoming more frequent to new buildings.

Resilient building strategies are the best way to respond to the changing climate of today and tomorrow. Buildings must be designed to survive the day-to-day pressures of increased heat, cold, drought, and rainfall; protect the occupants, and offer shelter during emergencies. Sustainable design strategies create more resilient buildings. However, only truly focused purposeful resilient design strategies will create the adaptation needed.

CONCLUSION

Resilience in the context of the built environment means incorporating into the design of a building, aspects and features that allow the building to carry out its intended functions, now and in the foreseeable future.

Part conclusion

The theme analysis defines what a sustainable approach should be when designing a building, both according to sustainability and zero energy in general. Therefore, a sustainable approach should be implemented already from the beginning together with the passive and active solutions. The inevitable climate changes needs to be addressed as a part of future proofing the building, here strategies for building resilience is taken into considerations.

The case studies has given inspiration for the architectural expression, construction and information that illustrate different plan solutions for an orphanage.

User analysis

User group

To gain a deeper understanding of what is needed of a new orphanage, and what the users requires, a user profile is made based on the literature, study trip, interview and statistics. This resulted in two main user profiles - one for the residents and one for the employed staff.

The children and young people all carry baggage from home in the form of violence, abuse, crime and, as a result hereof, great mental and social problems. They can be on the orphanage from the very young and up to 17 years of age and stay there for several years or just briefly. Some expect to stay on the orphanage, others are on their way to a foster family. It mainly depends on the action plan that is being made in cooperation with the municipality, where they have co-determination on how long their stay should last, [Annex 2].

No matter how bad it has been at home and how much the parents have failed, there is an everlasting desire for the family of the children and the young people who react very differently to their life situation. Some become outgoing and turn their frustrations against the people and the world that surrounds them. Others turn it inward. Generally, they have many negative and low expectations of the world and the adults as a result of many disappointments. It is therefore important that the adults show that they do not fail, have patience, and do listen to the children to unfold themselves and their potential.

CHILDREN

When children are placed in an orphanage it is often frightening, and intimidating in the beginning. Making new relations, and all the new impressions one has to familiarize with. Therefore it is important that their needs are prioritized when the orphanage is designed. Development and learning are the educational perspective and this needs to be expressed and emphasized in the design. Through their senses the children must develop their curiosity, motor skills and not at least their social skills. There must be room for individual immersion and social play through interactions between children, but also between children and adults. The orphanage must teach the children the basic skills required later on in their adult life. Another important factor is the broad age group among the children. It's interesting as their needs changes according to their age, but also because there is a possibility for the children to learn and inspire each other across ages [Løkkehusbørnehjem, 2019].

The physical surroundings have a significant impact on how children perceive the built environment as being intimidating or friendly. Children perceive everything considerably bigger than adults, so the building scale is an important factor, also relate-able to window sizes and placement, and furnitures, all have to be in an appropriate scale [Boernpaahospital.dk, 1987].

KEY CRITERIAS
- Play areas
- Placement of windows, view to outside
- Awareness of the building scale

TIMELINE

Waking up	Common breakfast	Off to kindergarten/school	Home Homework/free-time	Dinner	Homework/free-time	Off to bed
06.30	07.00	07.30	16.30	18.00	18.30	21.00

TEENAGERS

The majority of the placed children is adolescent from the age of 12-17 [Anbragte børn og unge, DST]. This group suffers from massive problems according to a special report prepared by SUS for TrygFonden, is the following applicable to the children placed in Denmark:

- 43 pct. of the 11-year-old children were placed as a result of neglect.
- 41 pct. was placed as a result of parenting abuse of alcohol or drugs.
- 37 pct. was placed as a result of behavioural problems.
- 30 pct. was placed as a result of parenting mental problems and/or mental illness.
- 29 pct. was placed due (significant) school problems.

Since the numbers add up to more than 100%, it appears that several of the children have more than one reason to be placed outside the home. It is children who have experienced many shifts, many failures and who are struggling with their own physical or mental problems. Children who have grown up with many adults and many breakouts. Several have not experienced living in other homes other than a foster family or an institution. It is children with challenges, intellectually, physically, psychologically, and behaviourally. Therefore is an orphanage first and foremost not a place of work but a home where marginalised children and adolescent live because they can't live with their parents. The building needs to reflect a homelike atmosphere, and create a safe and stable environment [Hørt, 2017].

KEY CRITERIAS
- Homelike atmosphere
- Privacy
- Common spaces

TIMELINE

Waking up	Common breakfast	Off to school	Home Homework/free-time	Cooking/ Dinner	Homework/free-time	Off to bed
06.30	07.00	07.30	16.30	18.00	19.00	22.00

COMMON SECRETARY

The common secretary functions as the face for the orphanage, being the first person visitors interact with, when either entering, talking or calling the orphanage. The main task for the secretary is functioning as an organizer for the orphanage, scheduling appointments and helping the residents and other staff members with practical tasks. It's important for the secretary to be close to the entrance while still being centrally located for a convenient distances to other staff members. While still should be the greeting and welcoming first impression, the office still needs a decent amount of privacy for immersive work [Løkkehusbørnehjem, 2019].

KEY CRITERIAS
- Centrally located
- Archive/storage space
- Signage/ way finding

TIMELINE

07.15	08.00	09.30	10.00	12.00	12.30	16.30
Off to work	Scheduling day	Administration work	Phone consultations	Lunch break	Administration work	Off from work

PEDAGOGUE

The orphanage should not only set the boundaries for the children - it must also function as a good work environment for the pedagogues. This means that the physical and measurable criterias such as daylight, thermal and acoustic needs must be taken into account. But the focus should also be on the qualitative criterias such as promoting social interactions. Good staff rooms needs to be designed and it's important that the room program for the building is arranged logically and optimized for the best work conditions. This could for instance be that the common room used for serving meals is placed in extension of the kitchen. The pedagogues function as the parenting role in the children and adolescents life, and this means that at least one needs to be accessible day around, so there is a need of a private room for the overnight person [Løkkehusbørnehjem, 2019]. Apart from taking care of the children and adolescent, the work schedule for a pedagogue is shown on the timeline below.

KEY CRITERIAS
- A room for a night watch
- Changing rooms and private areas

TIMELINE

06.30	06.45	07.15	10.00	12.00	12.30	16.30
Off to work	Wake up the children	Common breakfast	Phone consultations	Lunch break	Administration work	Off from work

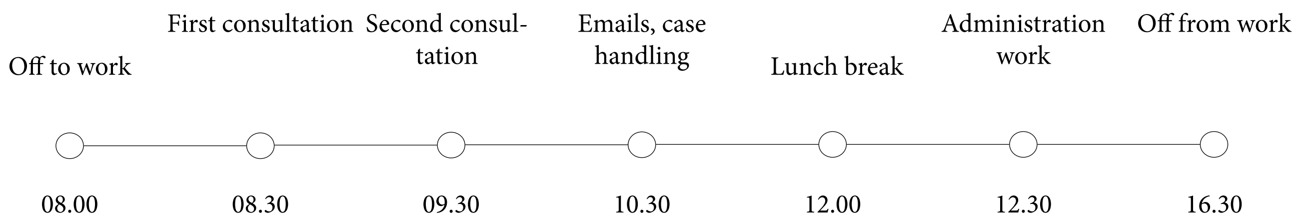
PSYCHOLOGIST

A part time psychologist is providing consultations and tools to help people through struggled times of their life. Having an orphanage with children an adolescent suffering from neglect and other traumas, the primary task would be consultation sessions in either an office or a more intimate space.

Each treatment is fitted to the patient, where different techniques or tools is dependent on the traumas and whether it'll be a child or an adolescent. To achieve a confidentiality and loyalty from the patient, it is important to create a judgemental safe space [PsykologeriDenmark, 2018]. It is important to design the room with privacy where a calming atmosphere is created, this can be done through the use of natural light, and the tactile and materiality of the surfaces of the interior. As some sessions can become private and emotionally, an adjacent bathroom would be a option.

KEY CRITERIAS
- Space for consultation in the office
- Calming atmosphere
- Access to larger rooms, for group sessions

TIMELINE

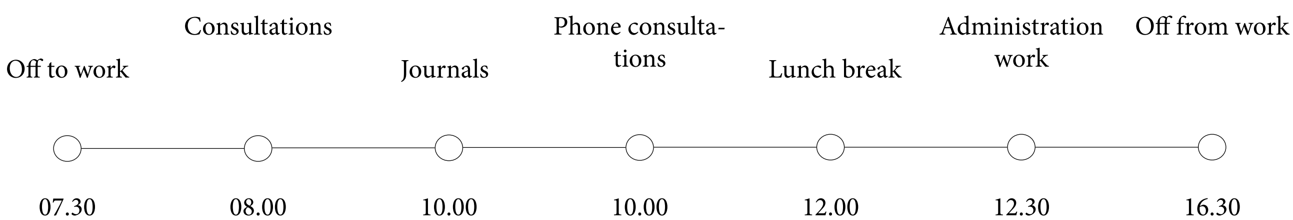


NURSE

The job of the part time nurse is to work in close relation with the psychologist, helping the children and adolescent. As the report SUS from [TrygFonden, 2013] states many of the habitants of orphanages suffers from severe social and mental problems and the nurse would attend that the children and adolescent could get and take the appropriated prescription. As the nurse would work in close relation to the psychologist, the office should be placed closely, and as the age group varies the rooms should accommodate the need of all.

KEY CRITERIAS
- Optimal thermal and atmospheric comfort, not compromising the hygiene
- Storage space for medical equipment
- Needs to fit a varied age group

TIMELINE



Design parameters

In the correlation to the further design process, different design criteria have been developed according to the initial problem statement of the project and key parameters that clarify the potentials and challenges regarding the micro climate, the users etc. These criteria focus on different scales in the home features, which cover different fields in relation to the environmental and social sustainability.

The criteria are the starting point for the sketching and designing phases in which they set a range of topics that must be developed in the future design proposals. Furthermore, a series of issues that must be solved by the use of different technologies and design strategies. As a consequence, design criteria can be denied as explicit goals that each design proposal must achieve in order to be successful in terms of the social and environmental sustainability approach. In the end, the criteria will be the tools to evaluate the feasibility or not of the different project alternatives.

SITE QUALITIES
- Integrate nature

Integrate the beautiful nature surrounding the building.

- View

Create a visual contact to the nature outside.

- Adapt to the nature

The building must adapt to the nature by e.g. placement and material choice.

USER
- Disable friendly design

The building must be disable friendly

- Implementation of private/social zones

Also the different areas should be split into zones compared to ages and social/private zoning.

- The building must relate to a human scale

Association to a home instead of an institution.

- Outdoor areas

Several different outdoor areas, which match the needs of the users - has to be placed close to the user group.

FUTUREPROOFING THE BUILDING
- Design for disassembly

Possibilities for reuse and recycling.

- Adaptable and flexible layout and construction

A building designed with good layout that allow removal or modification of any part, while at the same time its skeleton can remain untouched

- Raising ground level

Future proofing the building from the rising sea level by raising ground level 1,5 above sea level

- Increased precipitation

Prevent the increased precipitation in the future by material choice and rainwater harvesting.

- Future indoor climate

The building has to be able to adapt to the increased temperatures in the future.

SUSTAINABILITY, INDOOR CLIMATE AND ENERGY
- Sustainable materials

Material selection with technical, aesthetic and environmental reasoning (low CO_2 imprint).

- Energy frame

The energy frame much not exceed 20 kWh/m2 per year (BR20 requirements).

- Net Zero Energy Building

The building has to achieve the ZEB definition of 0 kWh/m2 by implementing photovoltaic panels.

- Good daylight conditions

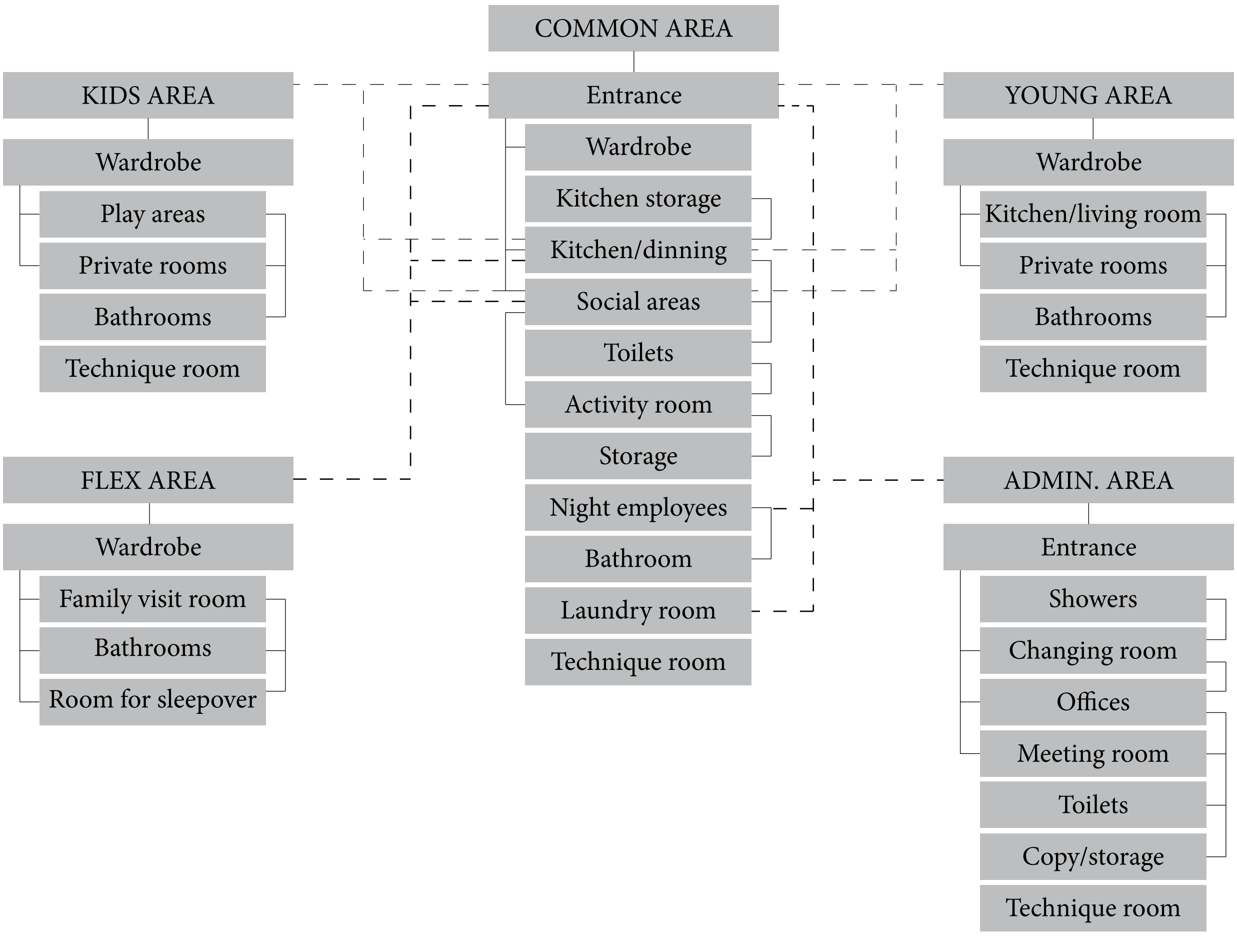
Which will have a positive effect on the users and to minimize the need of artificial lighting.

- Indoor climate

Focus on thermal and atmospheric comfort compared to BR18 requirements: max 100 hours >27 degrees and 25 hours >28 degrees. CO_2 level: max 1000 ppm.

Function diagram

The function diagram is based on the results from the case studies, study trip and interview as well as the user profile. It is split up in five main areas, which is created based on the users of the orphanage. The five main areas is; the arrival/common area, the administration area, the kids area, the young area and the flex area. All functions must be connected through the common room, promoting social interactions.



Ill. 31 Function diagram

Room program

The room program is based on the results from the case studies and the user profile as well as the function diagram and the plan distribution process.

The room program details the different sections of the orphanage, by stating the functions, the quantity and the approximate sizes as well as explaining the wanted qualities for each space.

According to BR18, the temperature must not exceed 100 hours above 27 degrees and 25 hours above 28 degrees during the year.

According to BR18, the CO_2 level must not exceed 1000 ppm.

According to BR18, the window area must be equivalent of min. 10% of the floor area compared to good daylight quality.

Administration // facilities	QTY	CAP	UNIT AREA	TOTAL AREA	NOTES	RELATION
Meeting room/activity room	01	10	48,3 m2	48,3 m2	Cozy and homely instead of office feeling	Shared
Copy/storrage	01	01	6,7 m2	6,7 m2		Shared
Technique	01	01	4,5 m2	4,5 m2		-
Changing room + Showers	01 02	02 02	7,3 m2 3,4 m2	7,3 m2 6,8 m2		Shared
Staff offices - Open office - Single office	03 01 02	 04 01	 20,8 m2 9,9-12,1 m2	 20,8 m2 22 m2	Freely accesible for residents. Calm view	Private
			Total	116,4 m2		

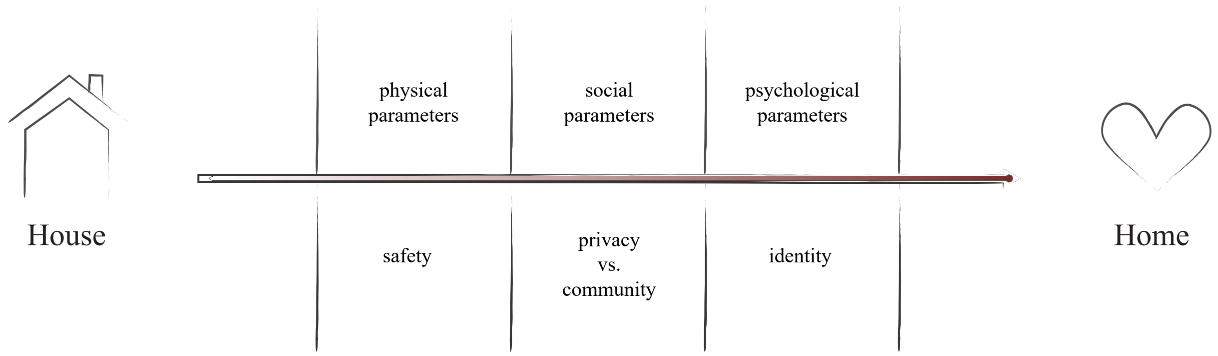
Young // facilities	QTY	CAP	UNIT AREA	TOTAL AREA	NOTES	RELATION
Ground floor					16-23 years	
Wardrobe	01	02	34,4 m2	34,4 m2	Like an entrance in a home	Shared
Shared kitchen-dining-living area	01	04	86,5 m2	86,5 m2	Room for friends, direct acc. out. View	Shared
Rooms	04	01	20,4-30,8 m2	95 m2	Private. Decorate - personalize. Calm view	Private
Showers // toilets	02	2	7,15 m2	14,3 m2		Shared
Technique	01	01	8,4 m2	8,4 m2		-
First floor					16-23 years	
Wardrobe	01	02	7,9 m2	7,9 m2	Like an entrance in a home	Private
Shared kitchen-dining-living area	01	03	63,1 m2	63,1 m2	Room for friends, direct acc. out. View	Private
Rooms	03	01	15,7-21,7 m2	58,6m2	Private. Decorate - personalize. Calm view	Private
Showers // toilets	02	01	7,15 m2	14,3 m2		Shared
Technique	01	01	6,1 m2	6,1 m2		-
			Total	388,6 m2		

Flex // facilities	QTY	CAP	UNIT AREA	TOTAL AREA	NOTES	RELATION
Family visit apartment					Family visits and sleepovers	
Toilet	01	01	6,2 m2	6,2 m2		-
Room	01	04	22,9 m2	22,9 m2	Room for sleepovers	Shared
Social area	01	04	19,2 m2	19,2 m2	Room for private gatherings. Calm view.	Shared
			Total	48,3 m2		

Kids // facilities	QTY	CAP	UNIT AREA	TOTAL AREA	NOTES	RELATION
Ground floor					0-11 years	
Wardrobe	01	02	15,4 m2	15,4 m2		Shared
Play area	01	04	61,5 m2	61,5 m2	Room for friends and play	Shared
Technique	01	01	4,2 m2	4,2 m2		-
Toilets	02	01	5,8 m2	11,6 m2		Shared
Rooms	04	01	12,5-15,8 m2	59 m2	Private. Decorate - personalize. Play.	Private
First floor					12-15 years	
Wardrobe	01	02	14,1 m2	14,1 m2	Like an entrance in a home	Shared
Social area	01	03	57,2 m2	57,2 m2	Room for friends.	Shared
Technique	01	01	2,4 m2	2,4 m2		-
Toilets	02	01	5,8 m2	11,6 m2		Shared
Rooms	03	01	15,3-14,2 m2	43,7 m2	Private. Decorate - personalize. Calm view.	Private
			Total	280,7 m2		

Common // facilities	QTY	CAP	UNIT AREA	TOTAL AREA	NOTES	RELATION
Main entrance	01	02	17,6 m2	17,6 m2	Entrance and wardrobe	Shared
Laundry // cleaning room	01	02	10,1 m2	10,1 m2		Shared
Social area	01	20	41,9 m2	41,9 m2	Social areas with diff. functions and view	Shared
Toilets	01	04	31 m2	31 m2		Shared
Kitchen // dining area + Kitchen storrage	01 01	25 01	73,1 m2 7,3 m2	73,1 m2 7,3 m2	Kitchen in close connection with dinning	Shared
Social area 1. floor	01	6	42,8 m2	42,8 m2	Social areas with diff. functions and view	Shared
Play area	01	10	56,7 m2	56,7 m2	Social areas with diff. functions and view	Shared
Night porters + Toilet // Shower	01 01	02 01	19 m2 6,2 m2	19 m2 6,2 m2	Room for 2 people	Private
			Total	305,7 m2		

Total	1139,7 m2
Hallway - Common area	66,8 m2
Hallway - Young	56,5 m2
Hallway - Administration	47,4 m2
Hallway - Kids	31,9 m2
Hallway - Total m2	202,6 m2
Total m2 Net area	1544,9 m2
Total m2 Gross area	1620,2 m2



Ill. 32 Home qualities

From a house to a home

In the following, an analysis and a merging of the concept home has been made in correlation with the designing of a home for children. This will explain the definition of a home, and how a building becomes a home based on studies in architecture and anthropology.

THE PHENOMENOLOGICAL PERCEPTION OF A HOME

The primary function of a home is to provide shelter for weather and wind and to create security, comfort, and other basic necessities. The residence serves a functional purpose as a base or a hub for the people living in it.

ADAPTING TO HOME

A house is a temporary stage while the home becomes a bond between an object and a human being, [Mark Vacher, 2004]. It takes time to set the boundaries for a home, to get the feeling of a house becoming one's home. The individual perception and the physical framework of a home must be fused together. Here one must adapt to the new surroundings. This is done by the body and the senses coming together in a new place. At the same time, the house needs to adapt to the user's needs, where the functions of the rooms are adapted to the individual. This process extends over time when the body and the house familiarizes to each other. Only then the house will become a home. The theory of this is described by Finnish architect Juhani Pallasma: *"…a 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"* [Pallasma,1995].

CONCLUSION

Through the project, it is desired to pass on the process from house to home. The orphanage must adapt to the individuals and the common needs through the room program, while the residents also have to adapt to the design of the house, and utilize the spaces and architectural qualities that is created. As a user of the building one have to perceive and associate spaces as one's own, like having a favourite corner, a niche of a room, or a special spot in the garden. Creating memories and stories and forge an emotional bond is important and the building must accommodate theses niches and make room for the individuals.

Part conclusion

Alongside the theme analysis, the user analysis led to define the design criterias in an architectural context in correlation to terms of both functional and indoor environmental aspects.

One of the most important factors for the users is to have a home feeling, which is a feeling that should be investigated further on and be implemented in the design.

After investigating the needed functions for an orphanage, the function diagram and room program was made, which gives a more clear vision of what the orphanage should contain.

Presentation

This chapter presents and explains the final proposal for the project. This is done through renderings, floor plans, sections, elevations and various diagrams. The presentation starts from an urban overview and goes closer into detail. It presents the technical aspects of the project with the architectural.

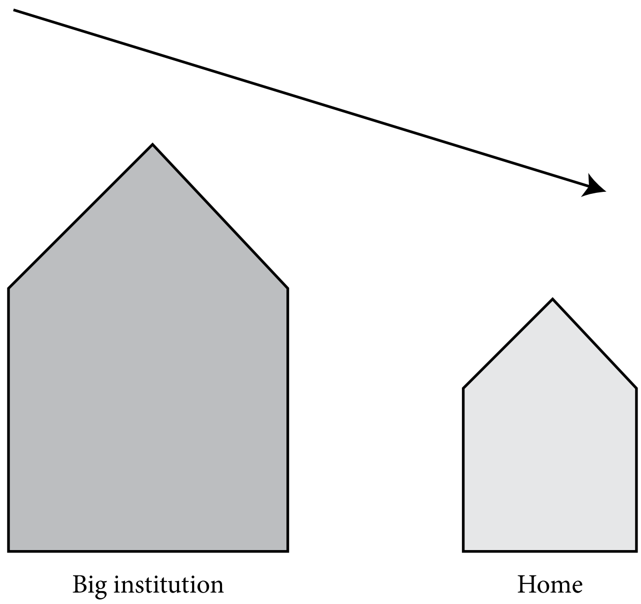
The attached drawing folder contains all drawing material in larger scale.

Concept

The overall concept is to create a building that breaks the scale of a large institution to become more like a “home” while at the same time have a great focus on users and the qualities of the site, which is expressed by the surrounding nature and views.

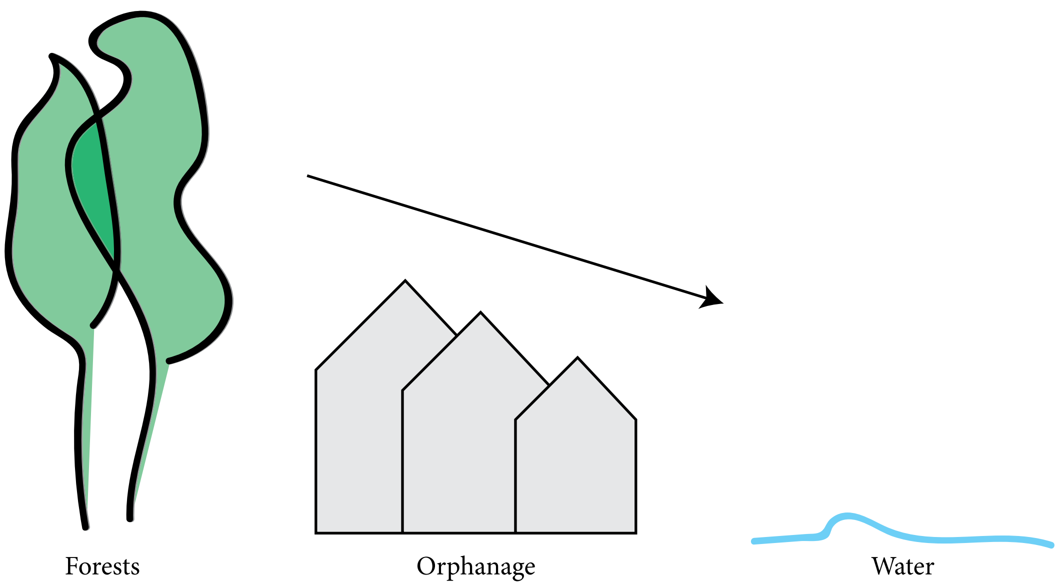
The residence should have a feeling of living in a home like everyone else. Therefore, the concept takes it’s starting point of a traditional village, which is joined together creating a home under one roof.

In addition, the building proportions follows the proportions of the nearby context by having peak points towards the forests and gradually size down towards the water and landscape.



Ill. 33 Concept diagram

The overall concept is to break the scale of the big institution, creating a more home-like atmosphere.



Ill. 34 Concept diagram

The next step is to adapt the building to the values of the site. In this case, the building must adapt to the proportions of the existing nature surrounding the site.

Entrance

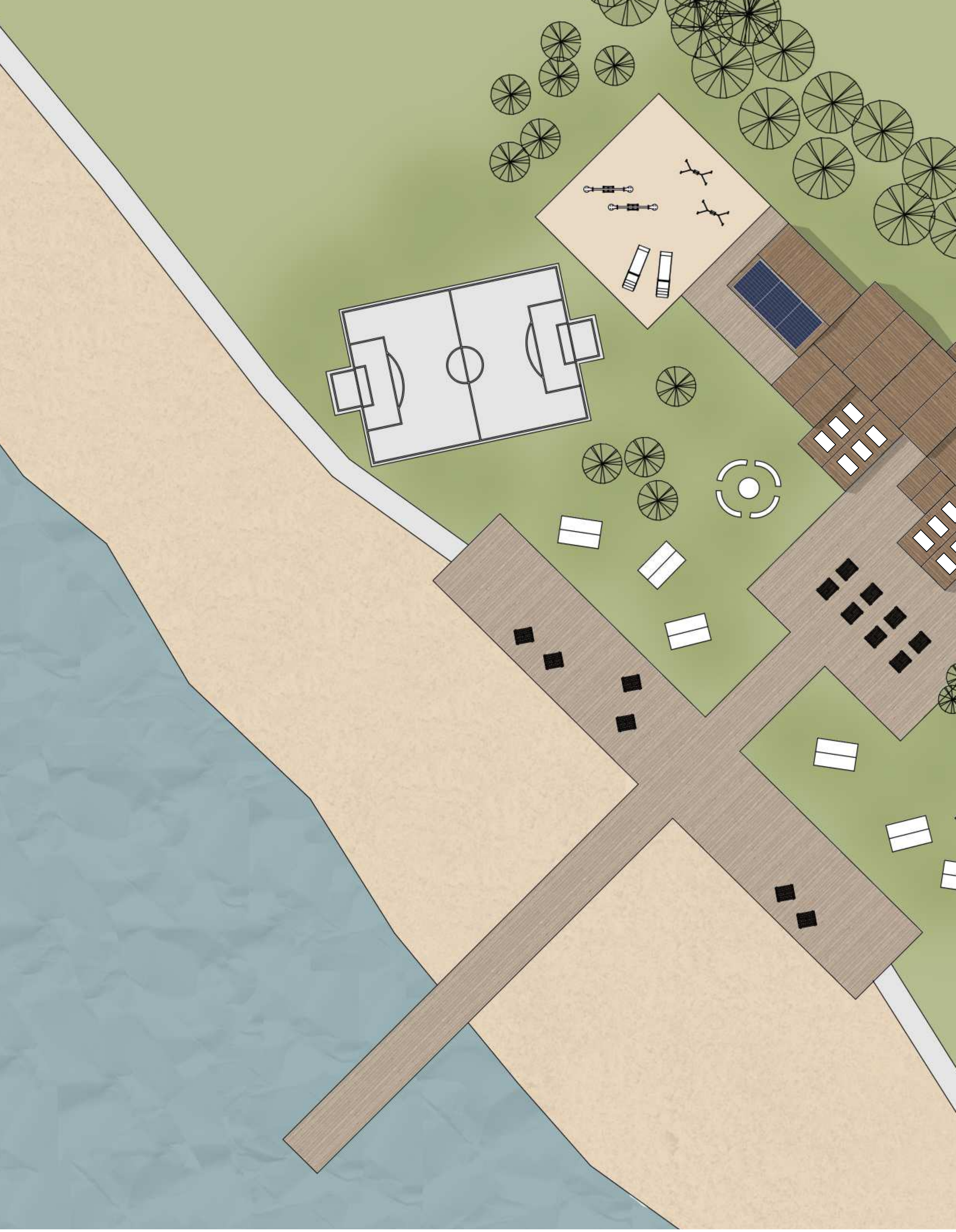
Already when you are about to enter the building, you are met with an atmosphere of home. Here, the various pitched roofs clearly illustrates the illusion of a small village, joined together under one roof in a peaceful area, only surrounded by nature.

Ill. 35

Outdoor area

The common outdoor area creates great opportunities for social interactions between age groups. Here there are both space for barbecues or relaxation in the sun in close connection to the water. The joined buildings create great spaces in between, where semi-social areas occurs.

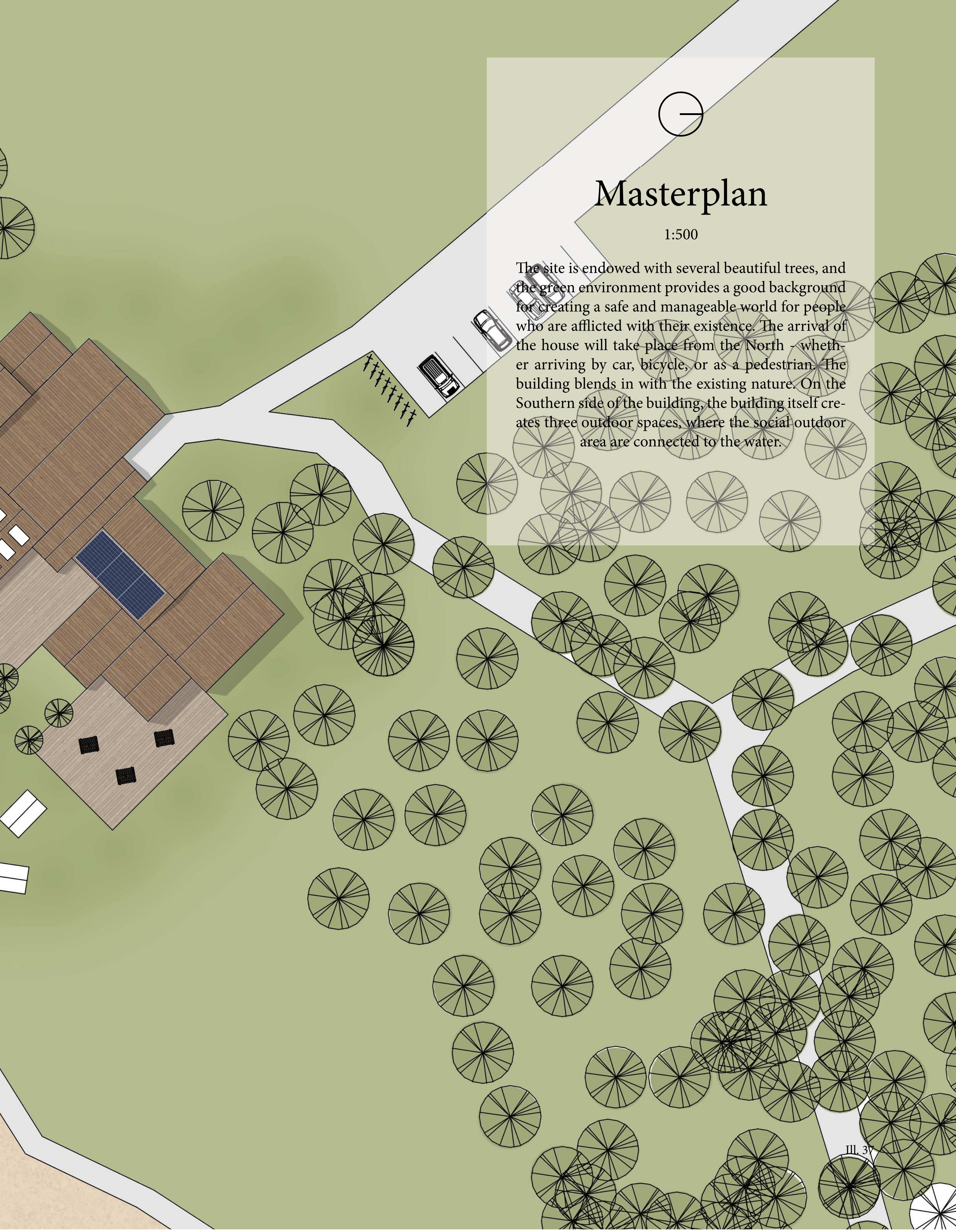
Ill. 36



Masterplan

1:500

The site is endowed with several beautiful trees, and the green environment provides a good background for creating a safe and manageable world for people who are afflicted with their existence. The arrival of the house will take place from the North - whether arriving by car, bicycle, or as a pedestrian. The building blends in with the existing nature. On the Southern side of the building, the building itself creates three outdoor spaces, where the social outdoor area are connected to the water.



Ill. 37

Social area

The social areas in the orphanage has an atmosphere of life and play. The kitchen area is lowered with few steps and has high ceilings to have a more defined social area and to distance it from the walk through hallway. The big window area in the kitchen with a view to the water creates a calm and light atmosphere.

Ill. 38

Plan

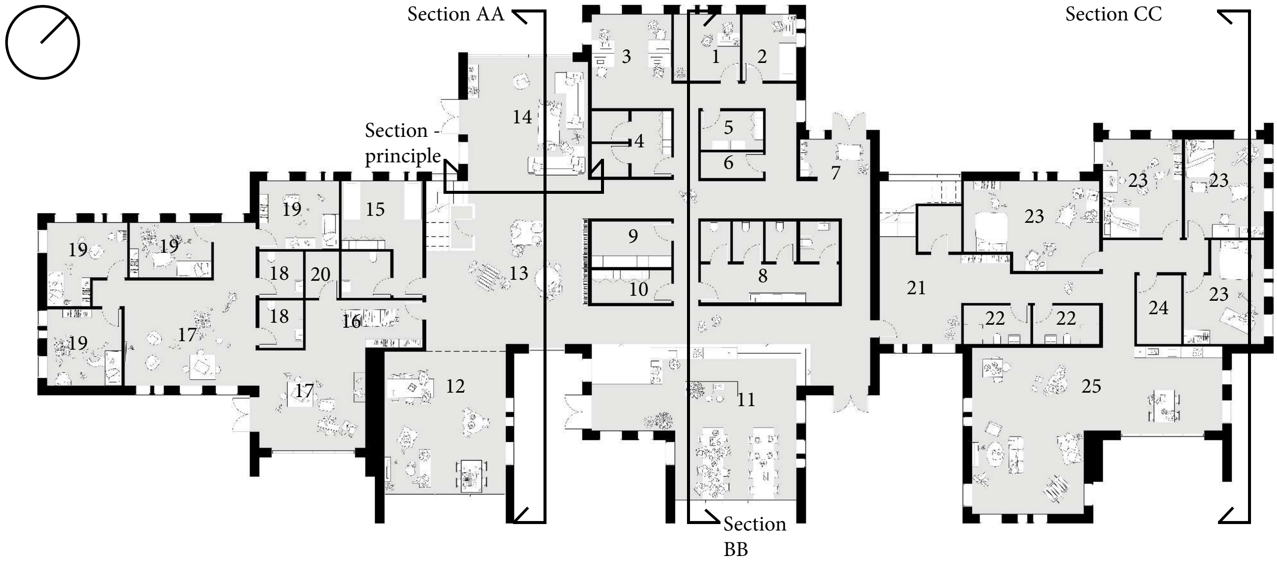
The vision has been to create a building that, with a clear architectural statement, marks a difference from traditional orphanages, and in a shaded manner form the framework for the activities that the house must accommodate.

The new orphanage must be able to fulfil two important tasks; it must at one and the same time be a modern children's home's face, and create the safe environment for the vulnerable children and young people, between the public and the domestic.

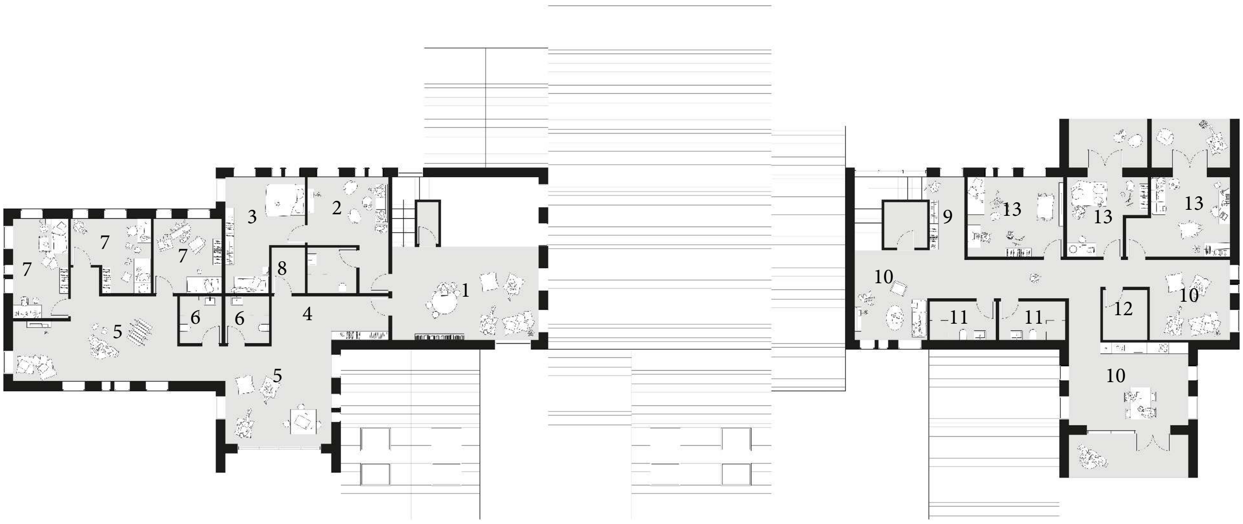
The shape is based on the archetypal house - what most of us associate with a home, a traditional saddle roof house. In plan, the house takes shape after the plot and the distinctive qualities of the place.

The building is designed based on having a good indoor comfort, both visually, atmospheric and thermal. The plan shows the distribution of rooms and areas in the institution. Overall, the building is divided into five zones, common, office, youth, children and flex where it has been a great focus to create a flow and flexibility in the plans together with the values of the site.

The lovely and quiet atmosphere of the nature and water is freely accessible to the residents, as it is embracing the building.



Ill. 39 Ground floor, 1:400



Ill. 40 First floor, 1:400

GROUND FLOOR
1. Office, 9,9m2
2. Office 12,1m2
3. Shared office, 20,8m2
4. Changing room with showers, 14,1m2
5. Copy room/storage, 6,7m2
6. Technique room, 4,5 m2
7. Main entrance, 17,6m2
8. Toilets, 31m2
9. Laundry room, 10,1m2
10. Kitchen storage, 7,3m2
11. Kitchen and dinning area, 73,1m2
12. Meeting room/activity room, 48,3m2
13. Play area, 56,7m2
14. Social area, 41,9m2
15. Night porter room with toilet, 25,2m2
16. Entrance - kids, 15,4m2
17. Play areas, 61,5m2
18. Toilets 11,6m2
19. Rooms, 12,5-15,8m2
20. Technique room, 4,2m2
21. Entrance - young, 34,4m2
22. Toilets, 14,3m2
23. Rooms, 20,4-30,8m2
24. Technique room, 8,4m2
25. Kitchen, dining, living area, 86,5m2

FIRST FLOOR
1. Social area, 42,8m2
2. Family visit area with toilet, 25,4m2
3. Family visit sleepover room, 22,9m2
4. Entrance - kids, 14,1m2
5. Social areas, 57,2m2
6. Toilets, 11,6m2
7. Rooms, 14,2-15,3m2
8. Technique room, 4,2m2
9. Entrance - young, 7,9m2
10. Kitchen, dinning, living area, 63,1m2
11. Toilets, 14,3m2
12. Technique room, 6,1m2
13. Rooms, 15,7-21,7m2

Elevations

The orphanage is a building with a focus on the human scale. From arrival you are met by a small one-floor house shaped unit. The house shapes are clear by the brick cladding, creating an illusion of an archetypal house. Various houses are to be seen from all angles of the building, creating the illusion of a village joined together creating a home under one roof.

From South-West and North-West, the proportions of the forest is clear where the building connects the two forests. From North-East, the building is graduating down towards the water and landscape. Towards South-West, the house shape appears for the kids area.

The wood cladding creates a warmer and embracing atmosphere in between the units.

In addition, a clear vision of private and social areas from outside is created by the choise of windows.

Ill. 41 North-West facade, 1:500

Ill. 42 South-East facade, 1:500

Ill. 43 North-East facade, 1:500

Ill. 44 South-West facade, 1:500

Sections

Section AA shows the difference in height, where the common kitchen area are lowered and with high ceilings, compared to the administration area and the hallway, creating a clear division of the walk through hallway and the social area.

Section BB shows the double high social room, where there is a visual contact of the two floors. This room invites to social interactions, and is created in smaller rooms combined, to have different activities at one time.

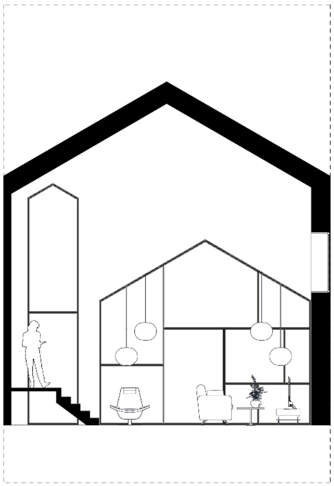
Section CC shows a cut in the young department, where the room on ground floor is bigger, since there is more need of space in those rooms than on first floor, where the rooms are created with high ceilings and a loft.

The section principle is a cut through the double high social room, and it illustrates the interior house shape that is occurring here.

Ill. 45 Section AA, 1:500

Ill. 46 Section BB, 1:500

Ill. 47 Section CC, 1:500



Ill. 48 Section - principle

Common area

Here the atmosphere is life and play. The interior house shape is occurring, which strengthens the homely atmosphere. The big window area is creating a beautiful and calm view towards a green scenery.

Ill. 49

Ill. 50

Rooms

The rooms must create the framework for the users life. It should be a safe and private environment, with room for visits by friends and sleepovers. It should be a place, that they can decorate by them self, to create a diversity from other rooms in the orphanage, and to personalise their own room to feel more home. They can chose the colour of the wall, they can decorate with furnitures etc, to make the room their own personal room and style. It should also be a place with a good indoor environment, with a good amount of daylight and a view to calm scenery. The rooms in the orphanage is each having different qualities, both according to size, room height, loft, no loft, windows and view. This creates an opportunity for the residents to choose the room, which fits their needs and wishes.

Design for disassembly

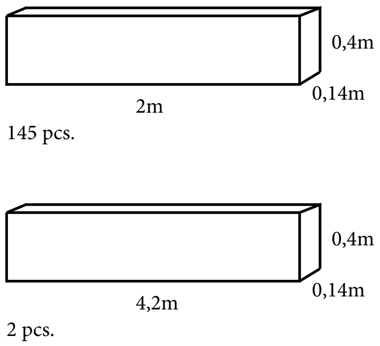
The construction consists of a column and beam system, which is formed by a grid. The material of the columns and beams are construction wood and are connected with steel connections and screws, which makes it easy to disassemble in the future for later reuse.

Through the process, the construction has been optimized by minimising the amount of elements and cassettes. Through investigations about the maximum spans, there has been chosen four widths of units with various lengths to minimize the amout of elements; 4,2m, 6,4m, 8,6m and 10,8m.

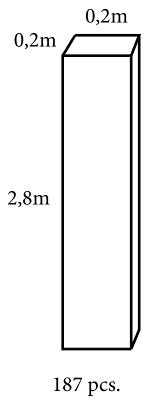
RESULT OF ELEMENTS

The construction is build up by a grid system, which is 2,2x2,2 meters, which means that there is 2 meters in between each column. Therefore, the beams are able to be the same size, which is 2m [Ill. 51]. Only in few cases where a column has to be removed, the beam has to be longer, here the biggest span is 4,2m which is acceptable compared to the investigations. Also all columns is the same dimension, which is 2,8m [Ill. 52]. The slab consists of concrete elements. There are three concrete elements used for the construction; 2x1m, 0,6x1m and 0,4x1m [Ill. 53]. For the floor slabs, it has been possible to only use one size of beams, which is 8,6m, with 0,4m distance, since all two floor units are 8,6m wide [Ill. 54].

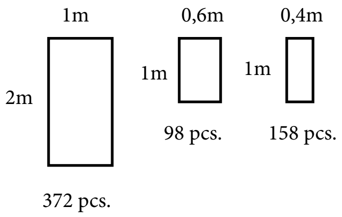
For the roof construction, when big spans is occurring, and high ceilings isnt needed, the trusses are used as roof construction. This gives a great possibility of a large span up to 12 meters with these two kinds of trusses [Palsgaard spær, 2019]. The spans of the trusses is reduced to three spans through the process and they have a distance of 1m compared to the investigations [Ill. 57]. For units with high ceilings, three lengths of ridge beams is used [Ill. 56]. Furthermore, three lengths of rafters is used with 1m distance [Ill. 55].



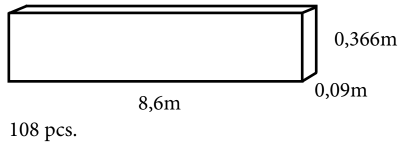
Ill. 51 Facade beams



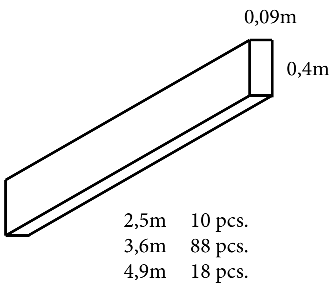
Ill. 52 Columns



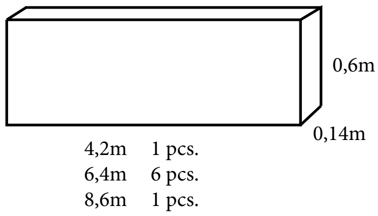
Ill. 53 Concrete elements



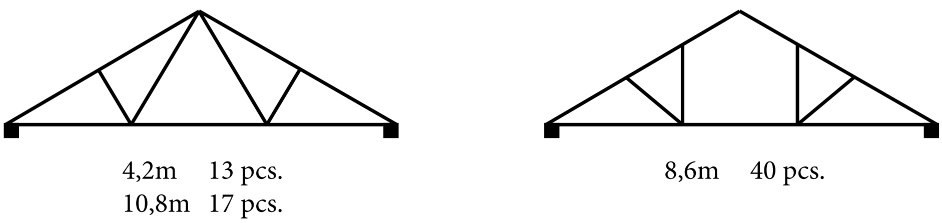
Ill. 54 Floor slab beams



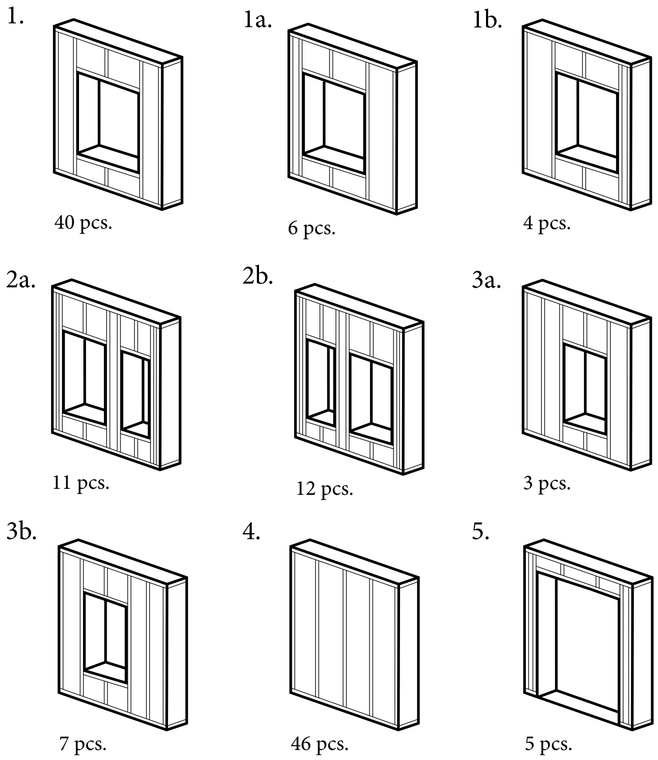
Ill. 55 Rafters



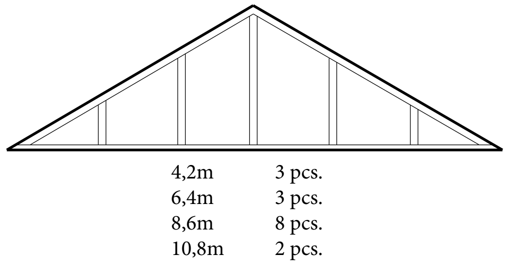
Ill. 56 Ridge beams



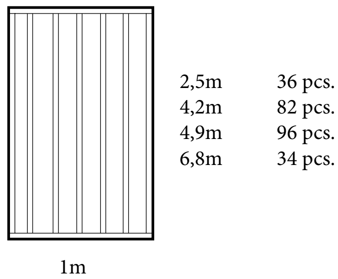
Ill. 57 Trusses



Ill. 58 Facade cassettes



Ill. 59 Triangular cassettes



Ill. 60 Roof cassettes

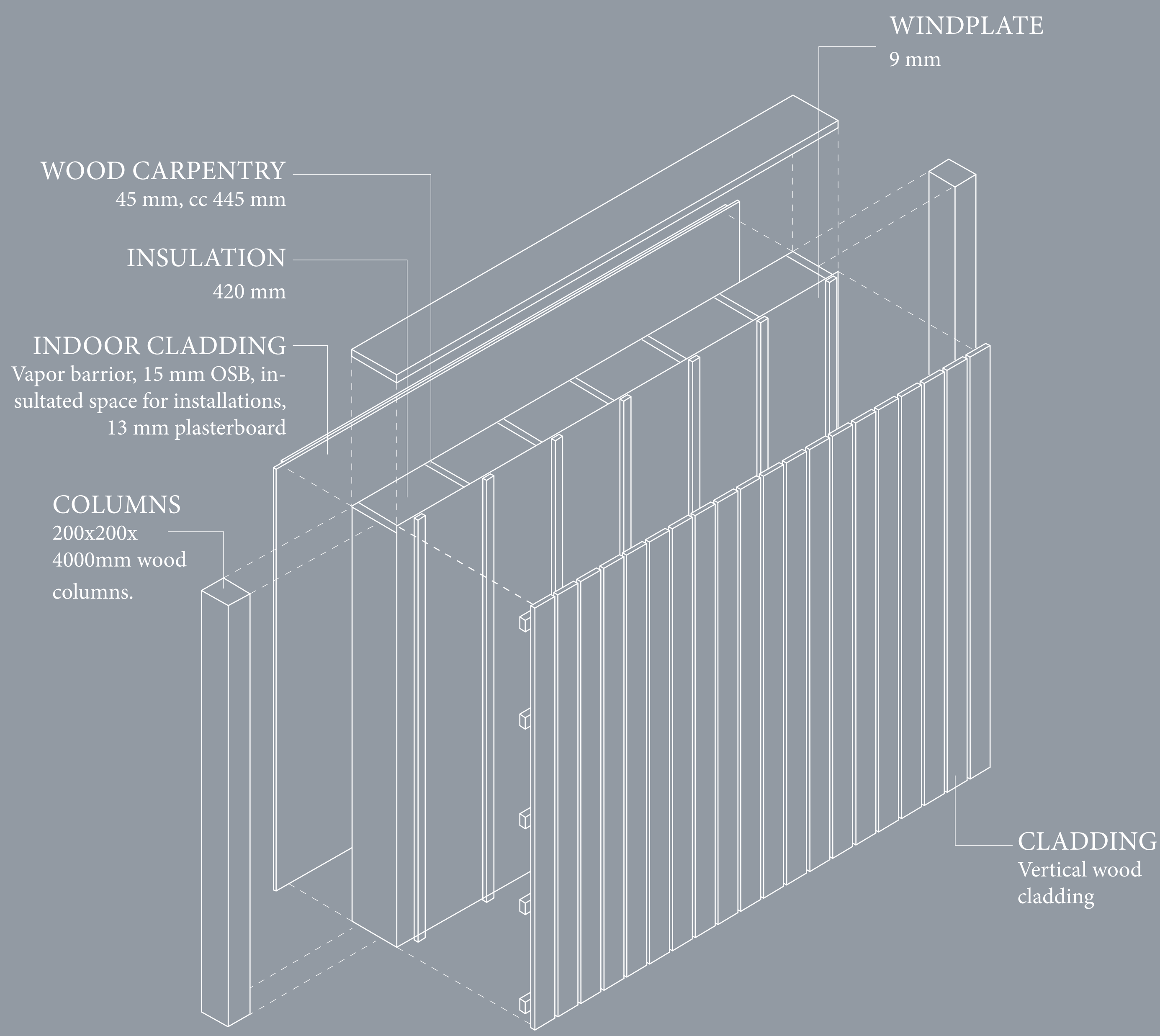
Cassettes

The construction consists of cassettes, which make the production process more easy, because it is possible to prefabricate the cassettes, and easy to transport to the site and connect to the construction on site. 9 types of cassettes is being used in the construction [Ill. 58], which means the cassette is used more than one time in the envelope. The cassettes is placed in between the columns which results in the same dimension of all cassettes, which is 2x2,4 meters. The cassettes is being placed in between the columns, after the columns are placed on the site, and then the space around the columns and beams is insulated and then the cladding is added.

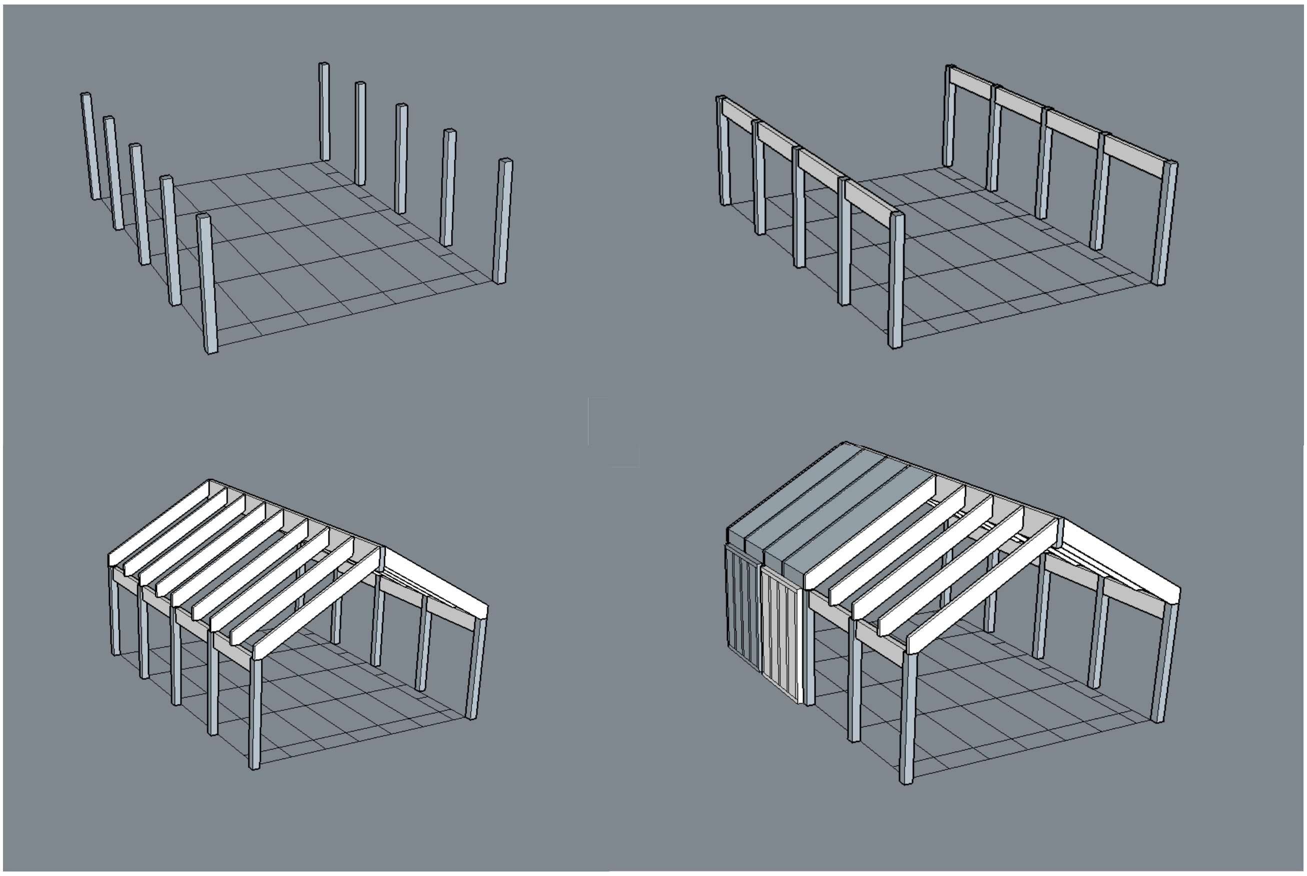
The triangular cassettes and the roof cassettes is also done as a minimum, where only four types is used [Ill. 59 and 60], since the dimensions of the units has been considered through the process.

The construction makes the building very flexible, and it is therefore easy to adjust/change the interior walls in the future, if it is necessary e.g. because of changes of the functions in the building, which makes the building very robust and the lifetime becomes longer. As an example, it could be used as a hotel in the future when the water rises that it is not a good spot for an orphanage anymore, but maybe an attractive spot for a hotel surrounded by water.

In this case, there has been some places in the envelope which compromises with the construction. These places has to be done at the site since it is not possible to use the cassettes, if these kind of qualities is wanted in the building. One case is in the social units where a full glass facade is wanted. Another case is the staircases where a high window is wanted through the two floors and in the double high social room, where the interior house shape is occurring. The last case is in the residential units where bigger window areas are wanted. It it considered, that these qualities is big so therefore these places has to be done at site.



Ill. 61 Cassette with wood cladding



Ill. 62 Construction principle

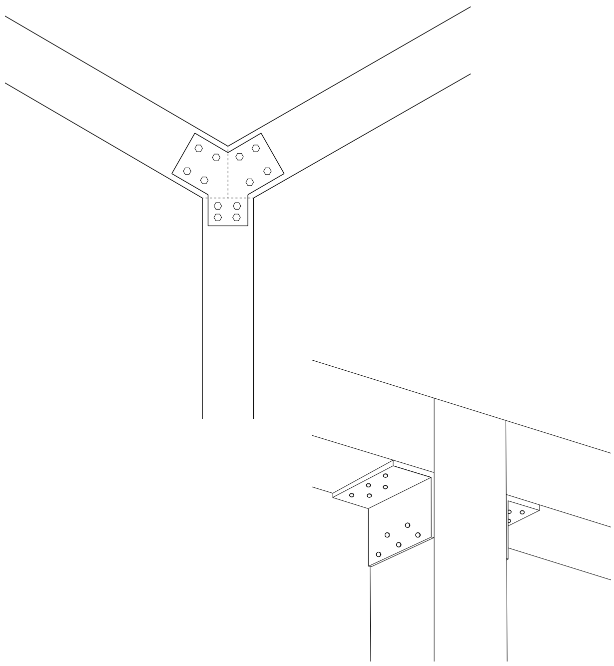
CONSTRUCTION

The buildings constructural principle is shown as an example of one unit [Ill 62].

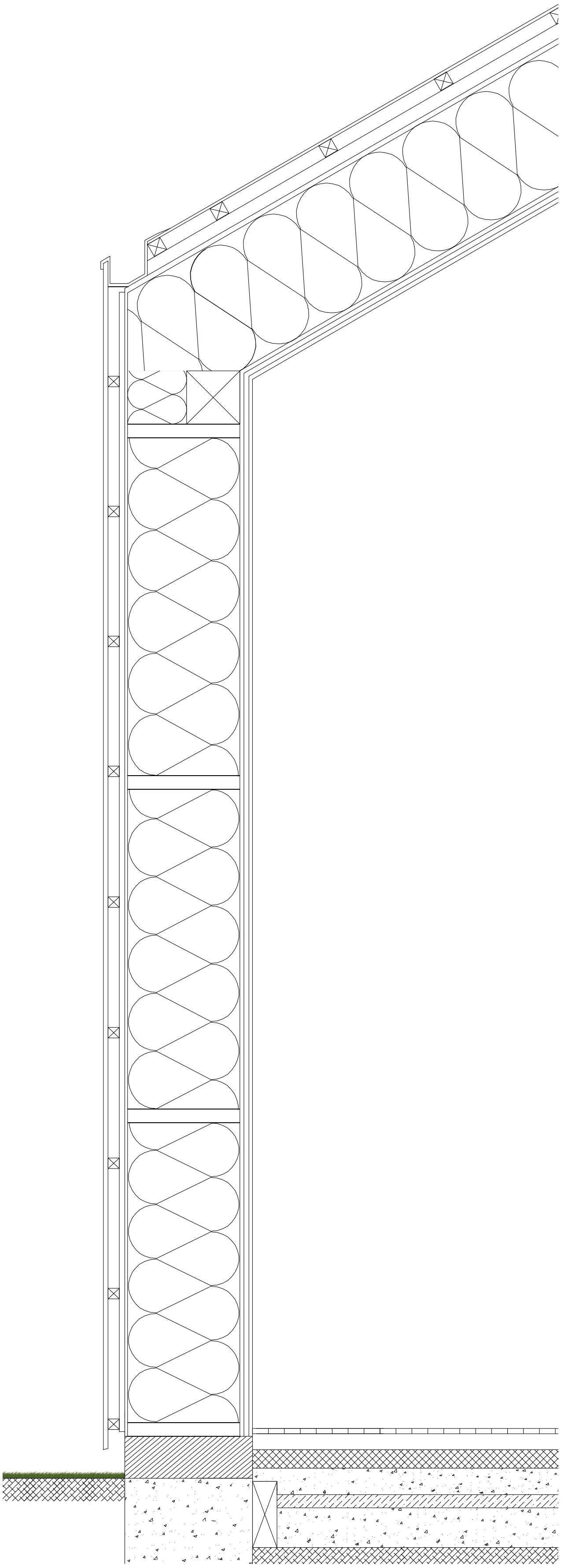
The first step is placing the concrete elements and the columns. Next step is placing the facade beams. Then the roof construction is placed, making the skeleton construction ready for placing the roof and facade cassettes. The final step is insulating the columns and placing the cladding of the building.

JOINTS

The joints has been investigated through the process to minimize the amount of element sizes. With this solution, where the facade beams is connected to the column with steel joints, the facade beams can be one size only. Also, by connecting the roofs on one column when it's possible, minimizes the amount of columns needed in the whole construction [Ill. 63].



Ill. 63 Joints principle drawings

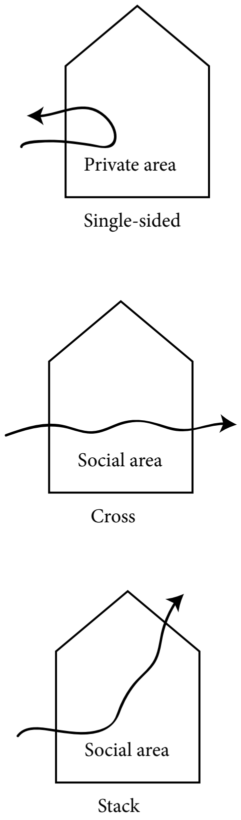


ROOF
30 mm wood cladding
20 mm ventilation gap with mounting lists
9 mm wind plate
420 mm insulation
Vapor barrior
15 mm OSB plate
13 mm plasterboard

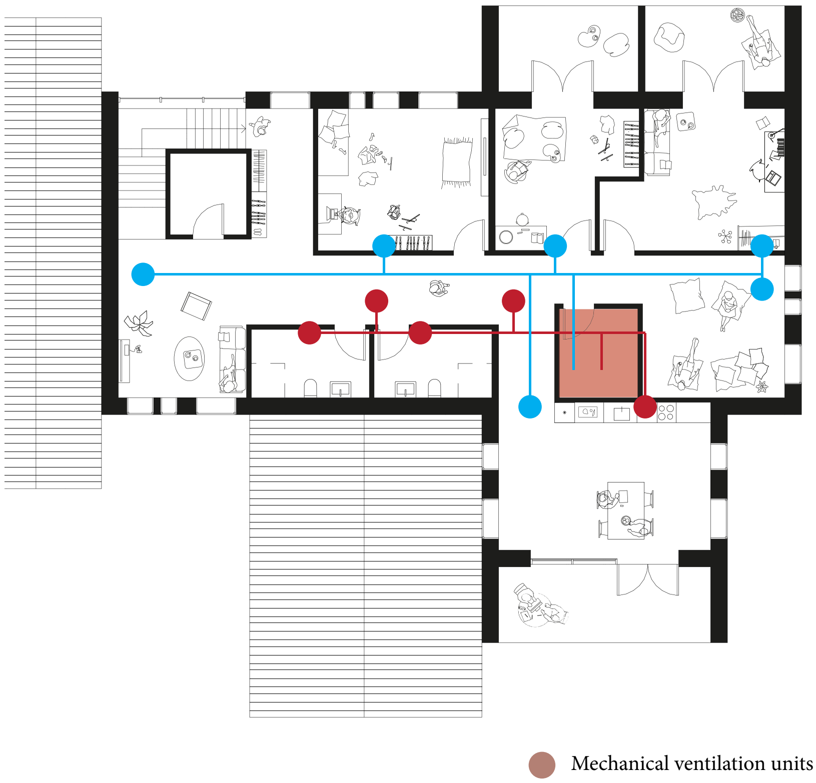
WALL
30 mm vertical wood cladding
20 mm ventilation gap with mounting lists.
9 mm wind plate
420 mm insulation / 45 mm wood construction cc
445 mm
Vapor barrior
15 mm OSB plate
20 mm space for installations
13 mm plasterboard

FLOOR
20 mm wooden floor panels
60 mm wooden straps
70 mm rigid insulation between straps
100 mm concrete slab
Vapor barrior
50 mm sand bliding
Concrete blockwork
150 mm concrete

Ill. 64 Detail drawing 1:25



Ill. 65 Natural ventilation strategy



Ill. 66 Placement of mechanical ventilation units in the building

Hybrid ventilation

Hybrid ventilation is the ventilation strategy used in the orphanage, which means that the natural ventilation is used in the months where the weather allows it and mechanical ventilation is used when it's too cold to open the window, to avoid heat loss.

NEEDED AIRFLOW
The needed airflow has been calculated compared to both sensory and CO2, to ensure a good indoor air quality [Annex 3].

NATURAL VENTILATION
During the design phase, the ventilation system plays an important role as a passive strategy, to minimize the energy demand for ventilating the building and as a cooling strategy. Therefore, natural ventilation is occurring in all rooms, except for the practical rooms, such as toilets. In the private rooms where only few people will be, the ventilation strategy has been single sided ventilation. In social rooms which are bigger rooms and more people will use, cross ventilation or stack ventilation is used as strategy.

During the process, the windows has been investigated compared to natural ventilation. One case is calculated, where only single sided ventilation is an option [Annex 4].

MECHANICAL VENTILATION
In order to lower the energy consumption, a mechanical ventilation system with a heat recovery system is going to be used to ventilate the building in the heating season to limit heat losses. To minimize the length of the pipe distribution, which will save energy on the ventilation system, three central ventilation units are placed in the building. They each serves a ventilation zone; the social and administration area, the young area and the kids and flex area.

A DCV system is chosen for all three ventilation units, which is a more expensive system to install, but the system use sensors that automatically adjusts the ventilation rate in each room, so it only ventilates the rooms that are used and compared to the need of ventilation in each room. This results in a lower energy consumption [DCV system, 2019].

The pipe distribution of the second floor in the young department is shown to illustrate how it works when high ceilings is occuring in some rooms. The supply air and extraction diffusers are placed in the ceilings in most cases, but in the rooms with heigh ceilings, they are placed in the walls. The ventilation unit is placed on ground floor in a continued shaft leading to this first floor.

Rooms	M2	Total glass area	BR18 requirements
Social kitchen and dining area	73,1m2	34,11	7,31
Social area	41,9m2	23,77	4,19
Night porters	19m2	3,59	1,9
Social play area	56,7m2	8,91	5,67
Social area 1. floor	42,8m2	9,45	4,28
Activity room/meeting room	48,3m2	27,8	4,83
Office 1	12,1m2	3,59	1,21
Office 2	9,9m2	3,59	0,9
Open office	20,8m2	5,16	2,08
Young groundfloor/			
Kitchen/living area	86,5m2	29,51	8,65
Room 1	20,4	3,59	2,04
Room 2	21,9	5,31	2,19
Room 3	21,9	5,16	2,19
Room 4	30,8	3,59	3,08
Young 1. Floor:			
Kitchen area	27,7	16,54	2,77
Living area 1	17,7	3,59	1,77
Living area 2	17,7	3,59	1,77
Room 1	21,2	3,59	2,12
Room 2	15,7	3,78	1,57
Room 3	21,7	3,78	2,17
Family visit:			
Social area	19,2	3,59	1,92
Room	22,9	5,31	2,29
Kids ground floor:			
Play area 1	33,0	11,88	3,3
Play area 2	28,5	5,31	2,85
Room 1	15,1	3,59	1,51
Room 2	12,5	1,87	1,25
Room 3	15,6	5,31	1,56
Room 4	15,8	3,59	1,58
Kids 1. Floor:			
Social area 1	29,9	17,19	2,99
Social area 2	27,3	5,31	2,73
Room 1	15,3	5,31	1,53
Room 2	14,2	2,87	1,42
Room 3	14,2	2,87	1,42

Ill. 67 Window area in each room

Daylight and windows

The daylight has been a major part in the design due to the many qualities of well-being. Most of the day is being spend indoors, and therefore it is important to secure good daylight conditions. The building regulations states that the daylight is enough if the window area equivalent of min. 10% of the floor area [Bygningsreglementet, 2019]. This has been investigated in each room of the building, to ensure a good daylight quality in the rooms [Ill. 67]. Furthermore, the daylight factor has been investigated further through the process in Velux in the critical rooms which is the deep rooms occurring in the orphanage to improve the daylight quality. Therefore, all window areas are more than 10% of the floor area, based on the study of the daylight factor where it is preferable to reach 2% daylight factor in min. 50% of the room. The study showed a need of more than 10% to reach this, because many of the rooms is deep rooms with only one facade [Annex 5].

Furthermore, the window design has been processed through the design phase where the mullions has been investigated compared to natural ventilation. The result is that the whole window has to be openable when 20 degree opening is wanted because of safety feeling [Annex 4].

Instead, the mullions has been used in the full glass facades in the social areas to enhance a playful expression here, since these are not openable.

Besides the daylight and natural ventilation that has characterised the design, the desire for a visual contact to the beautiful nature surrounding the building has also been a great design criteria. Therefore, the windows are placed in 500 mm height, so everyone is able to have a view to the outside. A social and private zoning has also characterised the choice of windows, since the residents has to feel private in their own rooms. Therefore, the rooms are placed towards peaceful areas and there are used smaller windows in the private rooms instead of big window areas to the floor. For the social areas, the focus has been to have a connection to the outside. Therefore, big curtain walls is used starting from the floor. This has led to further investigations about the indoor climate.

Indoor climate

In order to achieve the BR18 requirements for thermal indoor climate, there must be max 100 hours above 27 degrees and max 25 hours above 28 degrees during the year [Bygningsreglementet, 2019]. To document this, a critical room was tested in Bsim for overheating. The room was tested both compared to the climate as we see now, and to the future (2050 and 2080) with future predicted weather files. When looking at the results for the future one must be sceptical as the climate changes is difficult if not possible to predict in a specific area. The used weather files are assumptions based and used to gain an insight into how the building would perform under different circumstances. There are more yearly peaks, meaning that the summer months are generally warmer.

The critical room were defined as a social room in the young department with an orientation towards South-East. This is one of the worst-case scenarios since the South-East sun will go directly into the room, and since it is a small room with a big window area wanted to get the view towards the water. This will result in a great exposure of solar radiation. In this room, there is no shading from the surroundings.

The temperature is set to 21 degrees done by heating from radiators, which is the normal living room temperature. The max people load is in the weekend with an average of 4 people from 8-23. In the weekdays, there will still be 4 people but only in the early morning and in the evening. Therefore the temperature is tested on a Saturday in 2080 where the room will be used the most, and the outdoor temperature will be high compared to 2020 [Ill. 71]. The temperature is at it's highest in the morning time, since the orientation is towards South-East. The temperature peaks when there is being cooked in the room, which is a result from the equipment. The shading system towards South-East is constant. All windows has a g-value on 0,54 and a light transmission on 0,72. The air change rate is based on calculations [Annex 3]. The mechanical ventilation system has a 0,85 heat recovery with no heating or cooling system. The natural ventilation has been used in summer months, which will result in less mechanical ventilation and save energy. Therefore, all rooms in the building are designed so that it is possible to ventilate naturally.

In the future, the span of the summer- and winter period will change since the temperature will rise. These new inputs is used for the future predicted simulations.

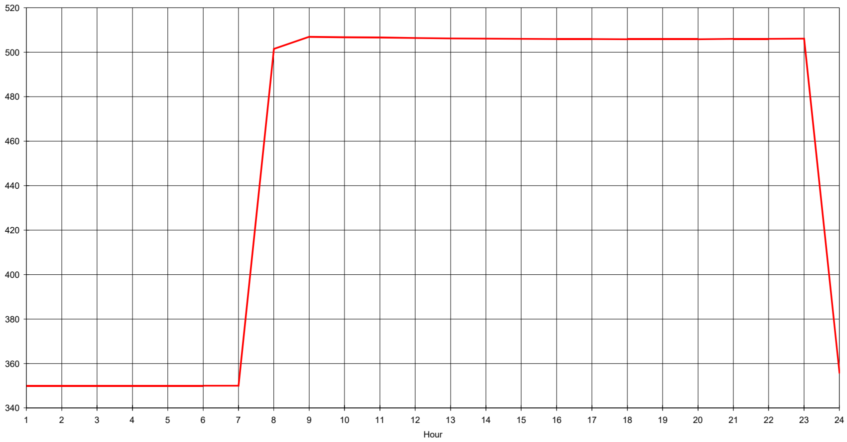
When looking at the temperatures during the year, the results are meeting the requirements [Ill. 70]. This is done mainly by extruding the building further in form of solar shading as an integrated part of the building, and minimizing the area of the window towards South-East. The process of implementation of solar shading is to be seen in the process [Page 104].

For other social areas where the window areas are big, the extrusion of the building is done with 1,5m, which also creates a shielded outdoor space and a framed view. The g-value is lowered to 0,35, since the rooms are very exposed of solar radiation. The room has bigger dimensions and better opportunities for ventilation because of the roof windows. All windows towards the Northern direction has a g-value of 0,54.

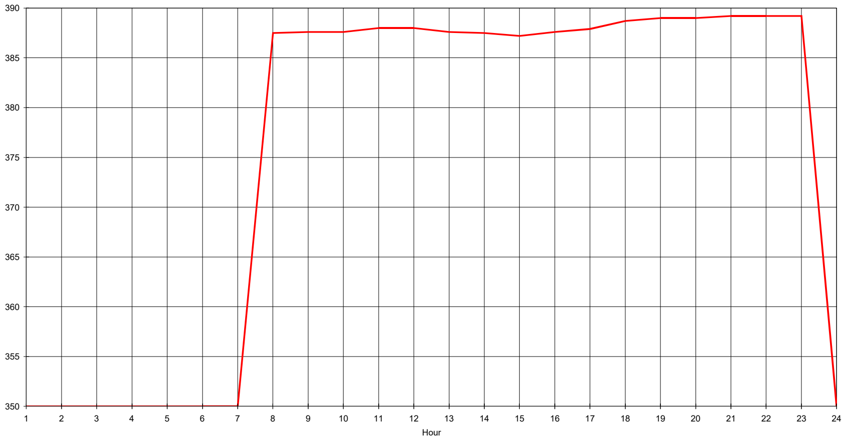
CO2

The building requirements state that the CO2 concentration shouldn't be more than 1000 ppm [Bygningsreglementet, 2019]. To document this, the CO2 level is tested on a Saturday since the people load is highest [Ill. 68 and 69]. The air change rate is based on calculations [Annex 3]. The room has a max load of 4 people. The natural ventilation system is set to the temperature of 21 degrees.

When looking at the CO2 concentration it is varying from 420 to 472 ppm in 2020, 420 to 600 ppm in 2050, and 420 to 660 ppm in 2080.



Ill. 68 CO2 - Mechanical venlitation on a Saturday 2080



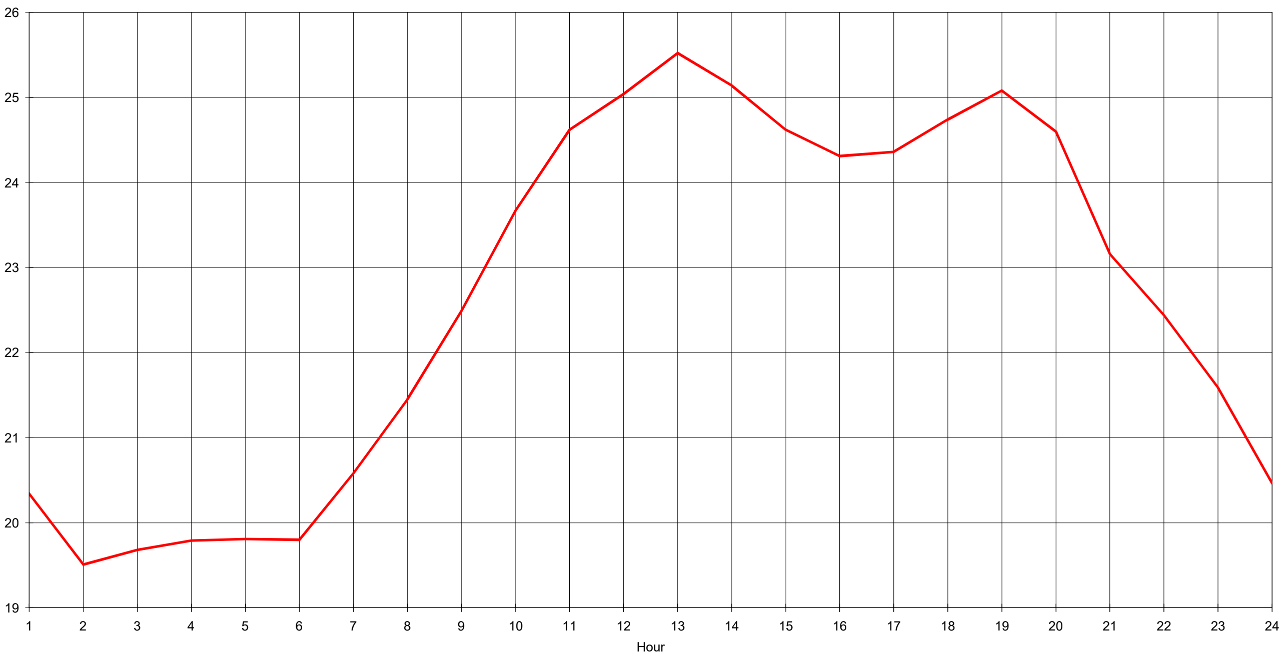
Ill. 69 CO2 - natural ventilation on a Saturday 2080

2020	Hours
>27	29
>28	6

2050	Hours
>27	27
>28	5

2080	Hours
>27	66
>28	22

Ill. 70 Overheating



Ill. 71 Temperatures each hour on a Saturday. 2080.

Energy frame

Be18 is a simulation software to assist in the design of a building and comply with the requirements of the Danish building regulations. The program works by calculating a buildings energy frame on a yearly basis pr. square meter. The energy frame includes how much energy is used for ventilation, cooling, heating, DHW and lightning etc. Reaching the 2020 demands means that the energy performance can't exceed 20kWh/m^2 without implementation of renewable energy sources such as solar collectors or photovoltaic (PV) panels etc.

The energy frame shows that the orphanage will be able to meet the requirements for the 2020 demands without the use of PV panels, and that it meets the zero energy building definition of 0kWh/m^2 while implementing PV panels [Annex 6].

There is used passive strategies through the process to save energy and to optimise the indoor climate. The passive strategies optimises the indoor climate and insures a low energy use for heating, cooling and lighting.

The building is optimised according to heat loss mainly by optimising the U-values. In addition, it is noticeable that the line losses has become a critical point for this building, since there is used extrusions, and also the amount of windows has a lot influence, so these are minimized through the process.

Another implementation is the g-value, which is the amount of solar heat that enters the room through the window. The higher g-value, the more heat is added to the room. Therefore, the windows towards North-West and North-East has a higher g-value than the windows towards South-East and South-West, since it affects the indoor climate and energy in a positive way.

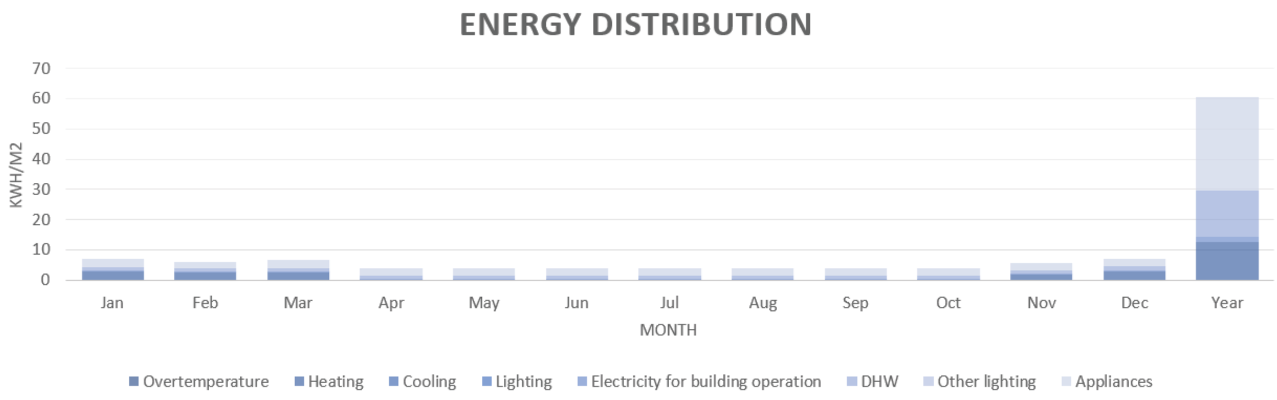
The rooms are also placed according to optimal orientation, where all small private rooms are placed towards North-West/North-East, and the social areas, which is bigger areas with more envelope, are placed towards South-East.

To avoid overheating, and therefore the need of cooling, a integrated shading element is used on the most critical rooms towards South-East. On the other windows, a flexible solar shading system is added. The shading system is outdoor lamellas with a shading factor of 0,1 (outdoor 30 degree lamella), and in the future the lamellas can be adjusted for the future needs, instead of having to change the wholes system.

The ventilation are made as a hybrid ventilation system where the natural ventilation will be used in the summer period to save energy.

The needed area for PV panels is calculated to be 172,4m2 [Annex 7]. To get the most efficient orientation of the PV panels, two units is turned 90 degrees, to get free orientation towards South-East, without shading from other units. The roofs has a 30 degree angle since it is the most efficient angle for this orientation.

The energy performance and the breakdown for each category can be seen in the graph [Ill. 72]. When working with a residential building, the lighting is not included in the energy consumption.



kWh/m2	January	February	March	April	May	June	July	August	September	October	November	December	Year
Overtemperature	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating	2,9	2,4	2,5	0	0	0	0	0	0	0	1,8	3,0	12,6
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity for building operation	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	1,8
DHW	1,3	1,2	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	15,3
Other lighting	0	0	0	0	0	0	0	0	0	0	0	0	0
Appliances	2,6	2,4	2,6	2,5	2,6	2,5	2,6	2,6	2,5	2,6	2,5	2,6	30,7

Ill. 72 Energy distribution

Vision

The vision for the project is to design a 24-hour care centre for marginalized children and teenagers that encourages and promote social interactions and a sense of being a part of a community while at the same time accommodating the children's individual needs – a place they can call home. The design of the orphanage needs to stimulate the senses for children who struggle with behavioural, social and mental health problems, while at the same time securing a good working environment for the staff.

Design process

This chapter details the design process of the building using The Integrated Design Process, combining both architectural and technical aspects into the process. The presentation of the process has been divided into different sections, in order to explain the process more clearly, even though they were running concurrently and affecting each other.

Plan layout

When developing the plan layout of the building, there are important factors:

- A conceptual idea (building form)
- The functionality and zoning
- Orientation of the building and the functions
- The building field (nearby context)
- Construction

There are also challenges when designing the plan layout. One is the construction, which is very strict. Another is to avoid long corridors, which creates an institutional feeling. Another one is to create social spaces without creating a walk through space.

PLACEMENT OF DEPARTMENTS
Private and social zoning is a very important factor in this project, since the residents has to be able to feel private even though many people are living under one roof. In addition, the division between ages are wide, because people living here is 0-23 years old. Therefore, the functions is divided into departments compared to ages. It creates five areas: common, administration, young, kids and flex (family visit).

There are three main settings surrounding the site. These are the forest appearing on two sides, the view to Limfjorden and the parking/access. Here the orientation of the different departments takes its starting point together with the path of the sun where it is based on the user profile compared to the daily schedule of the residents. The diagram shows the preferable orientation for the areas, both according to function, view and sun path [Ill. 74].

ADMINISTRATION
The administration needs a good working light, preferable northern light, as it doesn't glare in a computer screen. In addition, here the entrance area should be placed, in connection with the administration, the parking and the existing path. The orientation is creating a clear and undisturbed view to the green landscape which has a decreasing effect on stress.

COMMON AREA
The common area should be placed in the heart of the building, to create a common meeting point for the residents and there should be opportunities for different views in different directions.

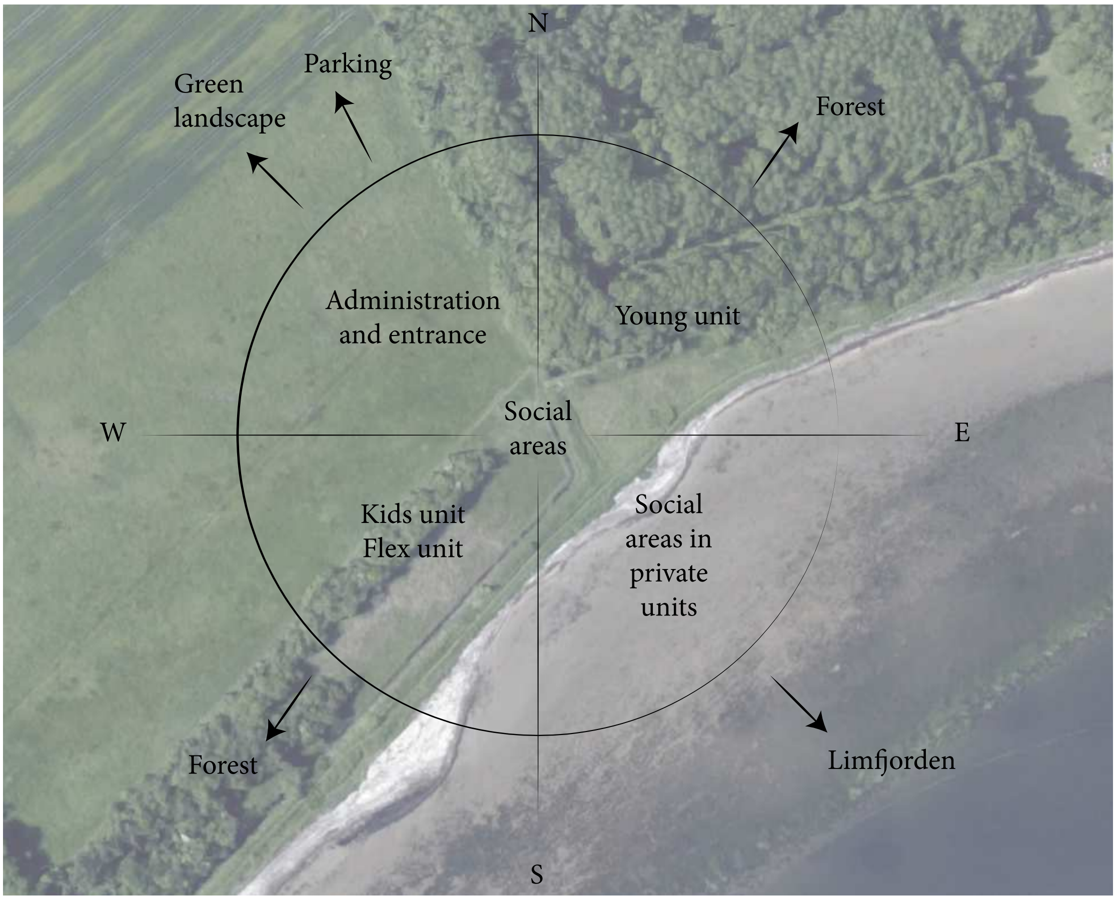
YOUNG
The youth should be placed towards East/South-East for optimal use of morning sun, while still having a view to calm scenery. They use their area a lot, e.g. be with friends, therefore they are placed with the good view towards the water and the city - thereby they also achieves a visual connection to the city.

FLEX
The flex area is going to be used of family visits. Therefore it should be placed with an orientation towards West, to get the afternoon sun, which is when the rooms is going to be used the most, and it creates a great calm view towards the forest.

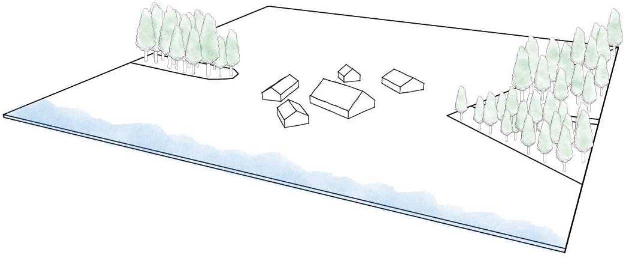
KIDS
The kids has to be placed in a corner of the building which is going to be shielded from the other areas, because it is a user group which creates more noise than the others. They are also not appreciating the view as much as other residents are and are more active. Therefore, they should be placed towards South-West, so the noise will not affect the peaceful surroundings towards the water. Here, they also get the evening sun, because they will use the rooms mostly in the evenings, and use the outdoor areas in daytime.

In addition, the rooms should be placed towards North/West and North-East, since it creates a calm view towards the green scenery and it creates less exposure of solar radiation. The semi-private social areas should be placed towards the great view towards the water.

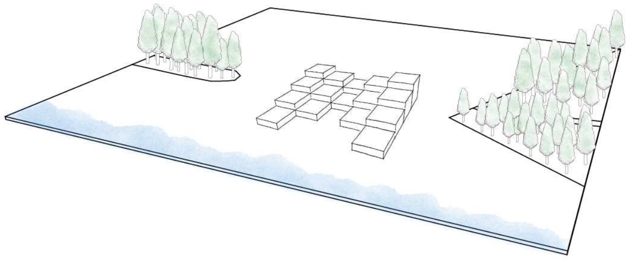
Ill. 73 Orientation towards Fjordparken



Ill. 74 Placement of departments

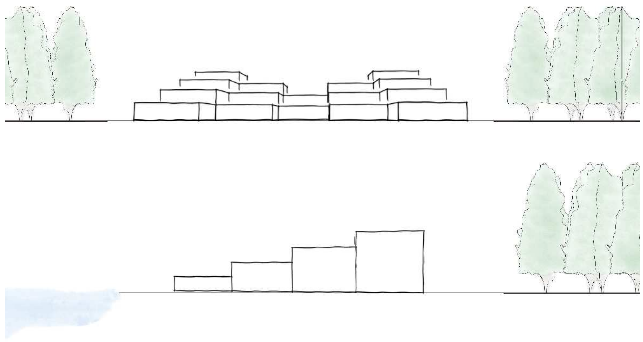


Ill. 75 Concept 1



Ill. 76 Concept 2

Ill. 77 Concept 1 - looking at the wide context



Ill. 78 Concept 2 - graduating building

Concept development

At the beginning of the integrated design process of this project, a study was made concerning building size and building field. Two concepts were developed by looking at the wide context by zooming out from the site looking at the whole island, and by the nearby context zooming closely to the site. The concepts that have been taken into consideration in the beginning of the design phase are the following two principles.

The first option is that the volume of the building is characterized by zooming out from the site and looking at the architecture that are characterized on the whole island. The whole island is characterized by small buildings that is spread out on the island and letting the nature embracing the buildings. It is like a village, where small buildings is spread out creating a community. The definition of a village is a group of houses and associated buildings, larger than a hamlet and smaller than a town, situated in a rural area. Therefore, this can be characterized as a village-like community spread out on the whole island [Ill. 75].

The second option is looking more close to the nearby context where the volume of the building is to be characterized by the high forests in each side of the site and the water in front. The initial idea was to create a shape with peak points towards the forests, where the building connects the two forests and facing the land towards the water [Ill 76].

CONCLUSION

The concept to work further on is a combination of the two concepts. To create a village like feeling by breaking down the scale of the building but at the same time create a shape that relates to the nearby context by having peak points towards the forests and gradually size down towards the water. In this way, the concept both relates to the vision for the users and to the existing context.

The building is going to be placed in the middle of the two forests, which creates an opening to the beautiful view towards the water and the city while at the same time having views towards forests and fields. When placing the building close to the water, the future climate changes should be in mind in the further development.

VOLUME DEVELOPMENT

The volume study takes it starting point from the architecture on the island where small gable houses are to be seen all around. Also from the analyse phase (design criterias) where it was found that the association to a home and not an institution makes more sence to break down the scale.

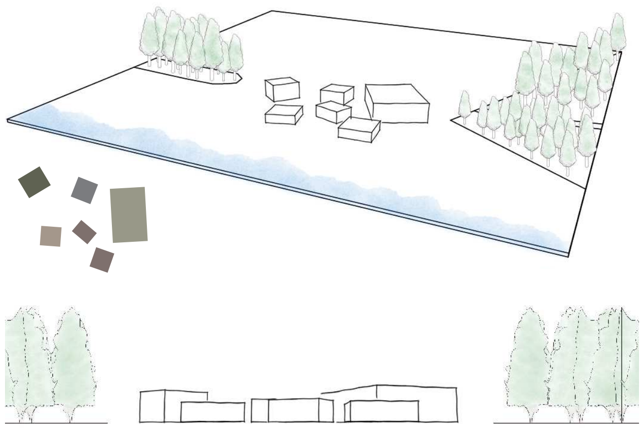
The first step was to determine the needed footprint of the building according to the room program and the division of areas according to the function diagram.

First step. Here the buildings are seperated as a mimic of the overall context of the island. And graduated compared to the nearby context. This solution makes complications for the staff to keep an eye on the residents, and the residents has to walk outside to get to the social area [Ill. 79].

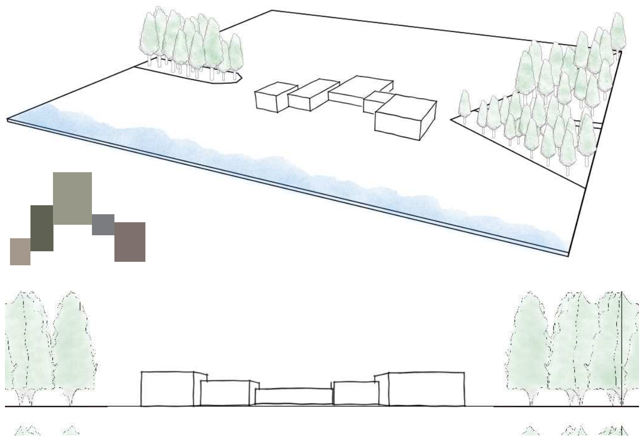
In the second phase, the small units are joint together to create a community under one roof. The scale is still broken into smaller units. The units is graduated compared to the trees, but it is creating challenges to graduate compared to the water in this case. Creates a great outdoor area towards the water [Ill. 80].

In the third step the houses are joined together making the building more compact. Here the small units are joint together making it a community under one roof. The scale is broken in smaller units and it creates a shape that relates to the nearby context by graduation compared to the two forests on each side and to the water in front. Creating a small compressed image of a village and a more dynamic facade expression. In addition, it creates more seperated outdoor areas [Ill. 81].

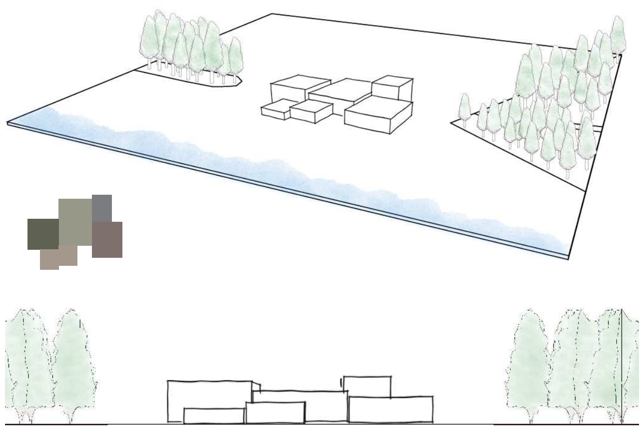
Starting from these initial ideas, some layouts has been developed in the following pages.



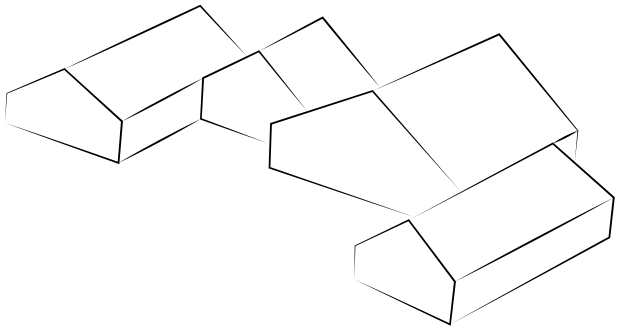
Ill. 79 First option



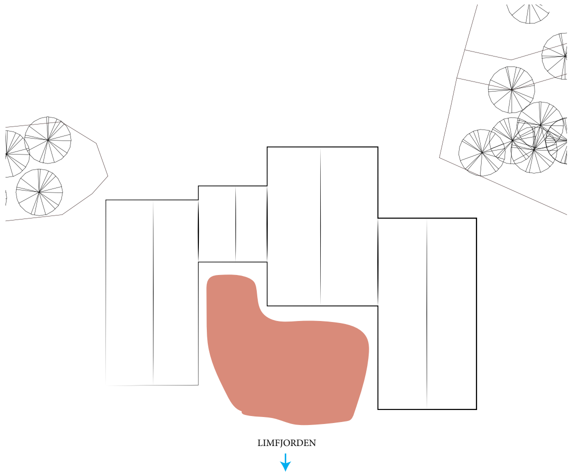
Ill. 80 Second option



Ill. 81 Third option



Ill. 82 Volume



Ill. 83 Outdoor area

Plan solution 1

In the first step of a plan distribution, a one-floor building was tested. The plan solution and form takes its offset by the concept of a village, where the institution was split into four areas creating smaller units. The units is then placed in connection with each other, to create a community under one roof. To meet the conceptual idea of a village, the units is placed with the gable sides towards the water, to get the shapes of small houses from Aalborg, which creates the illusion of small homes/a village [Ill. 82].

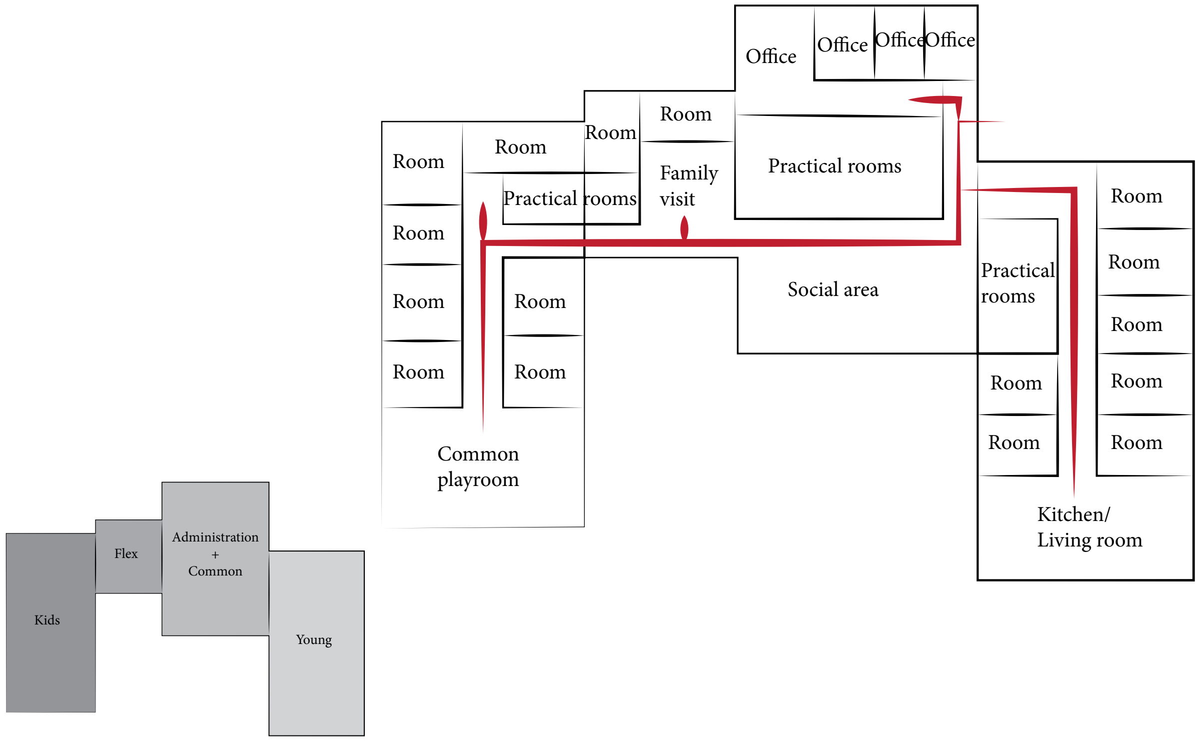
When connecting the units, the shape takes its offset from the idea of creating a connection between the two forests and reach out for the guests/residents from the entrance side towards North, creating a u-shaped building with a big outdoor area towards the beautiful view towards the water and a shield from the worst wind from West [Ill. 83]. The challenge of this is, that it is going to be hard to divide the outdoor areas compared to the very different areas there is going to be without disturbing the other residence. Here it would have been preferred to have a split between the kids, social and young outdoor area because of the difference in age and needed functions.

When looking at the plan solution, one of the qualities by only having one floor is that it is very disable friendly and it creates a great overview for the staff making the functions very accessible. On the other hand, it creates a very large ground floor, which creates an issue of a long distance from one end to another, creating long corridors and departments crossing each other [Ill. 84]. Also in the private units, long corridors with many doors will appear, because of the many rooms that has to be entered. As another solution of this problem, the clusters can be split into even smaller units [Ill. 85]. This will also split up the social areas, which is preferable and easier to furnish instead of a big open room, which is not divided into smaller areas. Another issue is the need of the big envelope to create enough rooms with daylight, and this will create a lot of "dead" space in the middle of the building in this case, which is only going to be used for practical rooms such as toilets, storage and hallways because of the minimal amount of daylight.

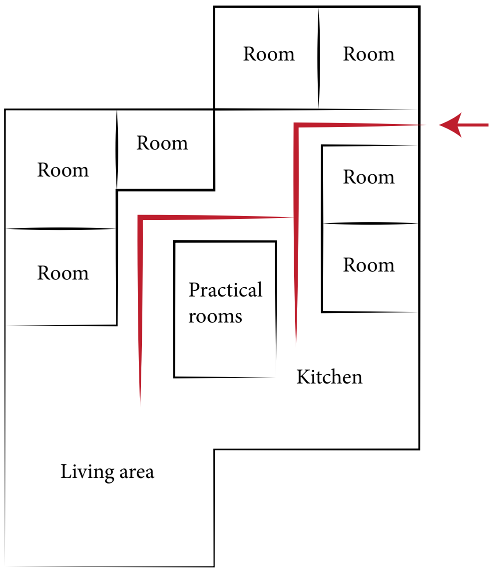
Another thing, which is hard to create in this solution, is rooms where there is windows on to sides, creating more daylight - that reaches the middle of the unit and opportunity for cross ventilation. The mechanical ventilation system will in this case also create a long pipe distribution, which can be solved by splitting the mechanical ventilation into smaller zones. Then there has to be installed technical rooms in each unit. In addition, the construction is challenging in this solution since there is big spans when only having one unit. Therefore, there has to be bearing columns inside the building, which is not preferred in this project.

When looking back at the volume, when having only one floor, it is a challenge to graduate in proportions compared to the forest and the water, which makes the building volume having less relation to the nearby context [Ill. 86 and 87].

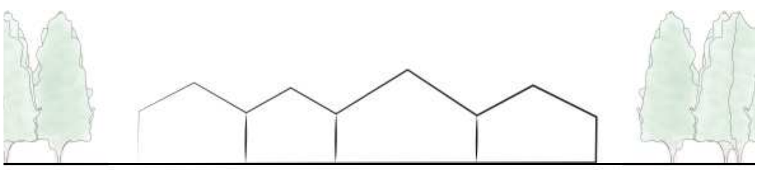
It can be concluded that by dividing the units into smaller units, it will create greater indoor spaces, and therefore it has to be tested as a solution. Since the building already is taking up much of the space, it will be tested if two floors has more qualities than one floor.



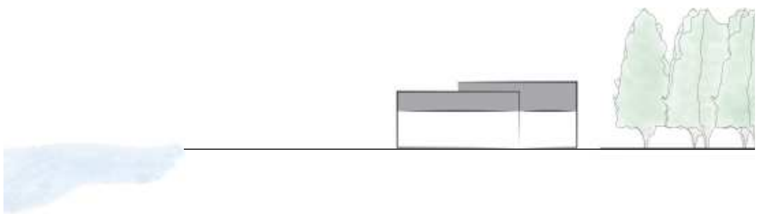
Ill. 84 Plan solution 1 with flow - long corridors



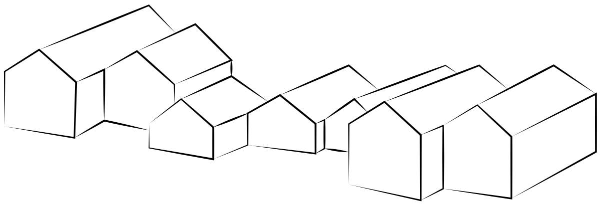
Ill. 85 One unit split in two



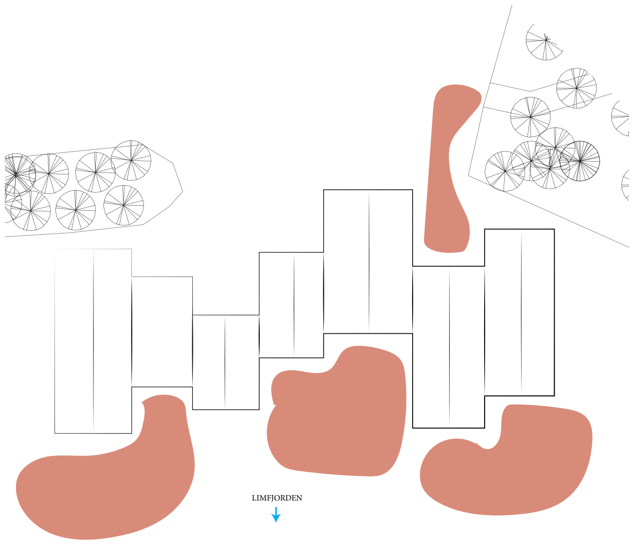
Ill. 86 Facade seen from Aalborg



Ill. 87 Volume comparison with context



Ill. 88 Volume



Ill. 89 Outdoor area

Plan solution 2

In next step of the plan distribution, two floors is tested to see the qualities and challenges of this solution. The plan solution and form still takes its offset by the concept of a village, where the gable sides is oriented towards Aalborg to create the illusion of a village [Ill. 88].

Now the units is divided into smaller units to create more usable spaces and to try to avoid "dead" spaces and long corridors. The placements of the units is creating more separated outdoor spaces, which means that the outdoor areas can be divided so e.g. the young people can be outside without having kids playing all around them. The building "grabs" the guest from North, in close connection to the existing path [Ill. 89].

The plan creates great quite spaces for the rooms, where they are facing the forests in both sides. When looking at the facade from Aalborg, the building is now having related proportions from the forests, where the building is highest at by the trees and lowest in between the, which makes a great mimic of the existing nature [Ill. 95].

It has also been investigated what the choice of roof does to the image of a village by changing the roof to a flat roof in the "institutional" part of the building and have gable roofs on the "homes", which gives a clear vision of what is private and what is common areas [Ill. 96]. The flat roof can also give an opportunity for direct outdoor space from first floor. As a conclusion, it gives a clearer image of a village when having gable roofs on all units.

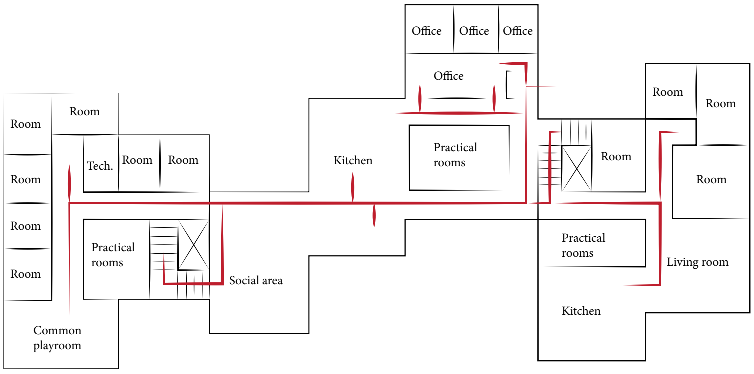
When looking at the plan solution, it gives less clear overview for the staff to have 2 floors, but in this case, the kids area is still in ground floor and they are the once which needs most overview from staff.

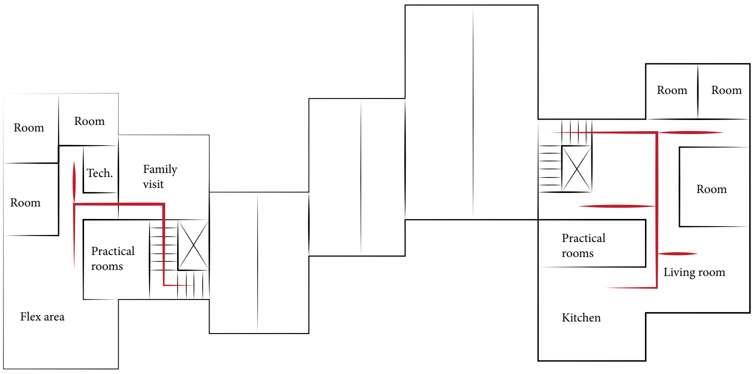
When dividing the units into smaller units, it creates a better flow to avoid long corridors with many doors [Ill. 90]. It also creates the opportunity to have cross ventilation in the social areas which is bigger rooms with more people gathering. In the private rooms, single sided ventilation is going to be used because of the small room sizes and the small amount of users [Ill. 94]. In the big social areas there is going to be daylight from both sides, which also creates two very different views [Ill. 97].

Another thing is that in social rooms, it is preferred to have high ceilings and in the private rooms low ceilings - in this case it is not possible to have high ceilings in the semi-social areas in the private units because of the first floors [Ill. 92].

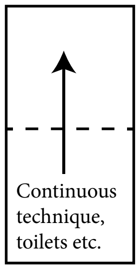
To avoid long pipe distribution, there is now a ventilation unit to each zone - and the technical and practical rooms are placed above each other to create a shaft where the technical stuff continuous [Ill. 91].

The orientation of the roofs are in this case not able to be towards South, which is the most preferable direction if installed solar cells on the roof. Therefore, the orientation and placement needs to be further investigated.

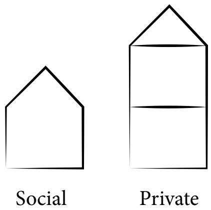




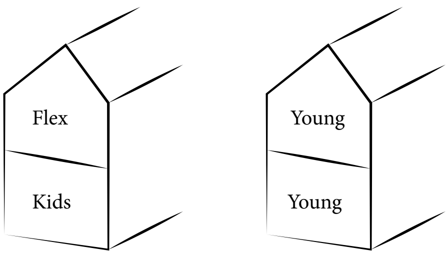
Ill. 90 Plan solution 2 and flow



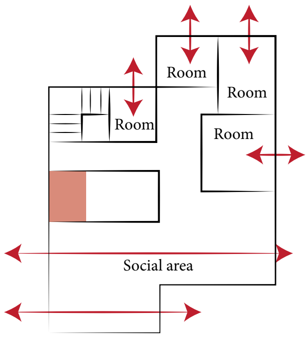
Ill. 91 Continuous technique, toilets etc. to first floor



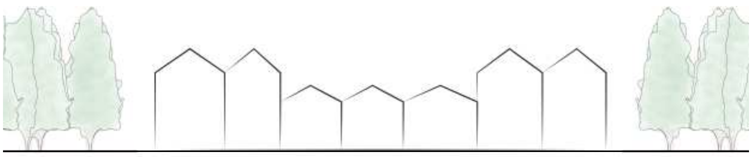
Ill. 92 High ceilings in social rooms, low in private rooms



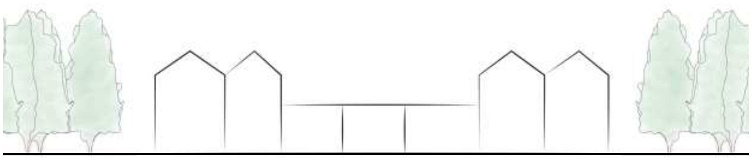
Ill. 93 Departments divided in two floors



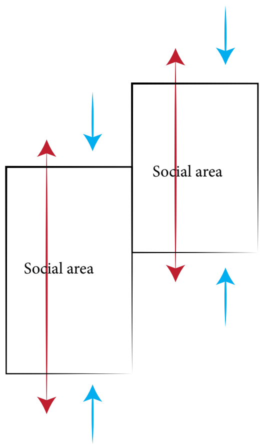
Ill. 94 Ventilation



Ill. 95 Facade seen from Aalborg



Ill. 96 Flat roof institution, gable houses ”homes”



Ill. 97 Social areas - cross ventilation and daylight

Optimization of plan

The plan distribution and shape was investigated further through a long sketching phase. It was investigated with several aspects in mind such as;

- spatial experiences
- volume
- architectural expression
- constructive principles
- energy consumption
- indoor climate
- ventilation strategies
- daylight and windows
- user needs
- the flow through the building
- the placement of the departments and rooms
- outdoor areas
- orientation of the building
- materials
- passive and active solutions

where aesthetic and technical aspects was a parallel process to each other, which will be described on the following pages where the overall shape is taking form. The aspects is done parallel to each other.

Through the process, the overall shape is also taking inspiration from other projects, where the illusion of a village is occurring [Ill. 98-100].

The user profile concludes the most important factors for the different users in the orphanage. For the kids it is play areas, for developing their social skills. In addition, the building scale and placement of windows has a great influence on their perception of the building. For the teenagers, privacy in their own rooms are an important factor. In addition, a social space should be available for developing their social skills, when they want to be social.

The majority of placed children is in the age of 12-17 years, which means that this age group needs most space in the orphanage.

For the staff, it can be concluded that there is a need of two private offices for the nurse and the phycologist in close connection with each other. In addition, a common office for the secretary and the rest of the staff has to be available. The administration has to be close to the entrance, and it has to be a place where the kids feels welcome to enter, and not a part of the building where they are not allowed. Also access to a bigger room for group sessions is needed. Some other important factors is that the dinning space and the kitchen should be located close to each other. In addition, a night porter room and a changing area is needed.

The most important factor for the residences is the homelike atmosphere - it is important that the orphanage first and foremost is not a place of work, but a home for the residence.

Ill. 98 Villaen, Kerteminde

Ill. 99 Vonsild skole

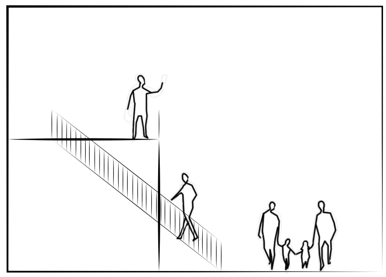
Ill. 100 Frederiksvej Kindergarten

Spatial experiences

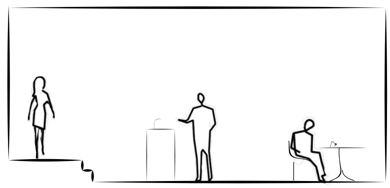
During the design process, the spatial experience has been taken into account. The scale and proportion of the buildings and spaces are significant factors, as they have an impact on the human's perception of spatiality and their sensual experiences. In this case, there has been worked with diversity in different ceiling heights and room sizes compared to the private and social zones and users, where the private areas has low ceilings or high ceilings with a loft (which create more space in the room for other stuff) compared to the user, and the social areas has high ceilings since it is rooms with high people load. In addition, the rooms has been developed more difference so that all rooms are not the exact same as the neighbor rooms.

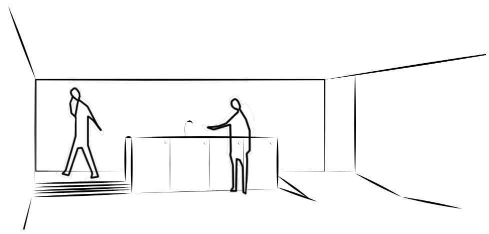
As a parallel part of the plan distribution process, some interior design solutions has also been progressed, where double-height social rooms and architectural furnitures has been developed. The double-height room makes it possible to have a visual contact diagonally through the floors and therefore the staff is able to have a visual contact on several floors at the same time [Ill. 101]. In addition, a split between the hallway and the social area has been worked with, by lowering the social area with few steps to create a visual division of hallway and social area [Ill. 102]. Also a diversion of the social areas has been developed since it creates greater small interior spaces with less people on the same spot, than one big room with all the functions and peoples gathered in one spot.

The architectural furnitures works as storage instead of storage rooms, which makes it more accessible for the residence. This creates an overall more accessible storage in the whole building. The integrated walls is done with shelves and lockers and creates a furniture to sit in some cases [Ill 103].

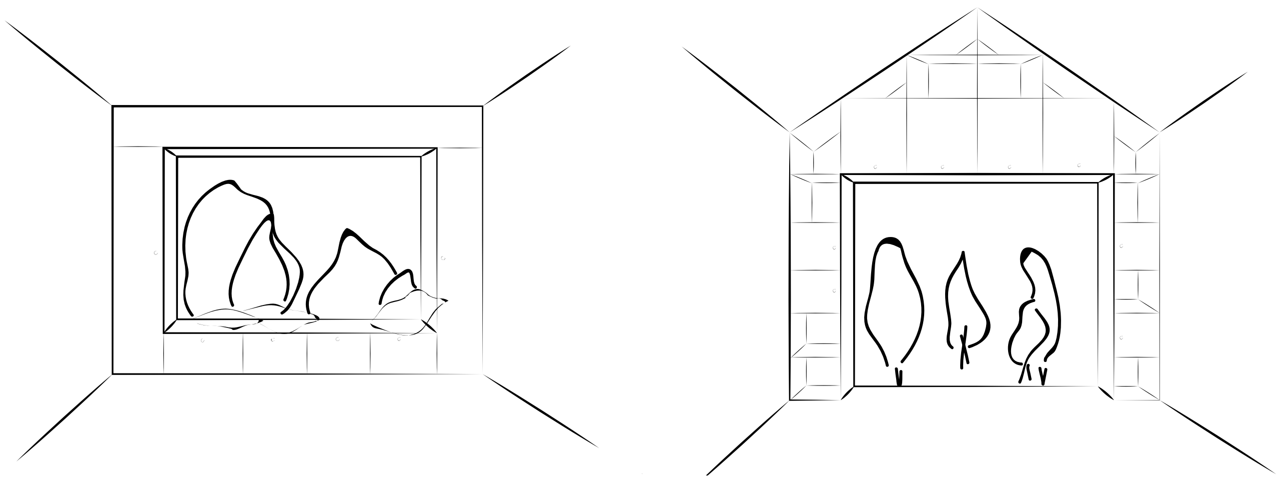


Ill. 101 Double heigh social room

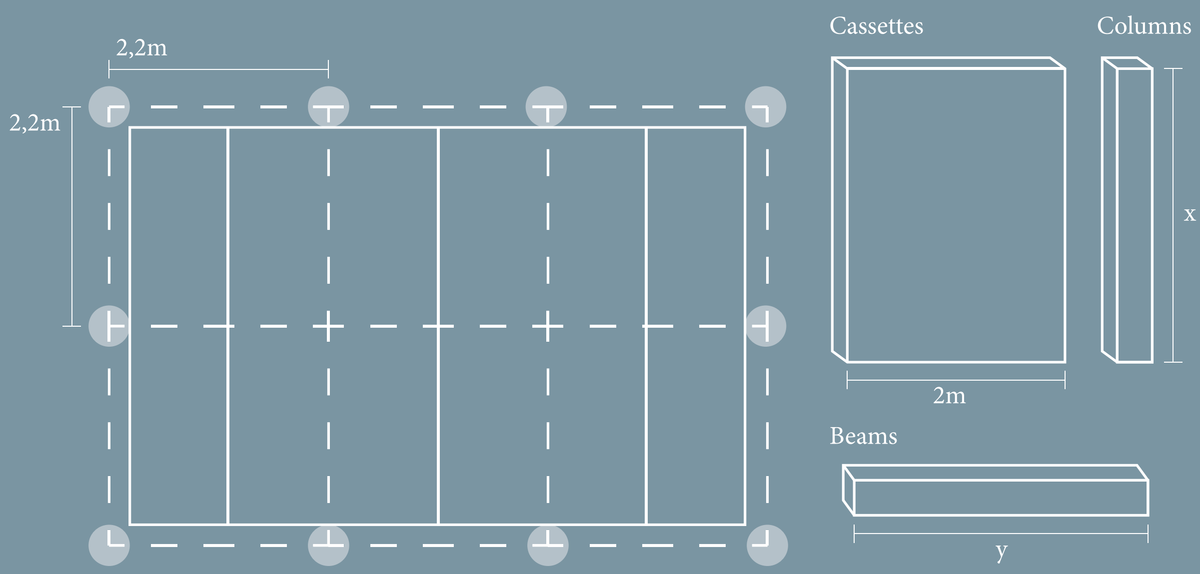




Ill. 102 Split between hallway and social room



Ill. 103 Architectural furnitures



Ill. 104 Grid structure and elements

Design for disassembly

In order to be able to develop the plan distribution in the further process, it is important to choose and understand the construction, since it is a major part of the design process, when working with design for disassembly. Two methods has already been investigated through case studies [Page 34-35].

In order to choose the better solution for this project, the two types of constructions are investigated further and compared to environment, disassembly, reuse and flexibility.

To rate the environmental impact, results from LCA calculations are used. To be able to compare the constructions, they both has bricks as cladding and they both have the same u-value, which is 0,09 W/m2K [Annex 8]. The LCA results showed that the wood construction have the smallest CO2 impact on the environment [Ill. 107].

The ability to be disassembled and reused are found from literature, where Vandkunsten has compared the two construction strategies [Circle house, 2018]. Both systems are easy to disassemble because they are assembled with steel connections, but the wood construction is easier to reuse than concrete.

The wood construction is a column and beam construction with cassettes as facade elements. Therefore, it becomes a very flexible system, where all elements can be prefabricated and transported to the site, which is a good quality in this case since it is on an island [ARKFO, 2017].

Overall, the wood construction has the highest score compared to the concrete construction [Ill. 105-106]. Therefore, the wood construction is being used in the further development. This results in a grid structure [Ill. 104], which has to be integrated in the plan distribution through the process to create less elements and therefore make it more reusable in the future.

GRID STUCTURE

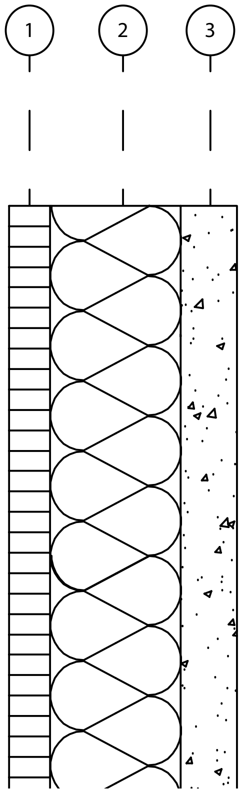
When using a wood construction where the elements should be reused, it is a good solution to choose to work with a small amount of elements, so it is easier to prefabricate and reuse, than if the elements was varying in sizes. It also makes the production process easier. Therefore, a grid structure should be used in the dimensions compared to the wanted sizes of the elements.

The grid structure is going to fit to the size of the cassettes and the concrete elements for the floor. In this case, it has been chosen to work with a grid of 2,2x2,2 meters, which means that one column is going to be placed for every 2 meters. In between the columns, the cassettes are placed with the dimension of 2 meters. This result in a construction that can be prefabricated, which therefore is easier to transport to the island. It also results in a construction, which easily can be disassembled and reused in the future [Ill. 104].

In the further process, the grid structure has to be integrated in the plan distribution with few elements to choose from, and the joints of the construction has to be investigated further.

1. 108 mm bricks
2. 345 mm insulation
3. 150 mm reinforced concrete elements

= 603 mm

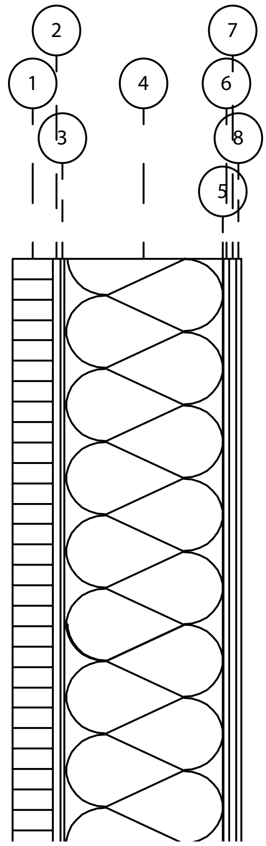


U-value:
0,09 W/m²K
Environment:
●●○○
Disassembly:
●●●●
Recycle:
●●●○
Flexibility:
●○○○

Ill. 105 Concrete construction

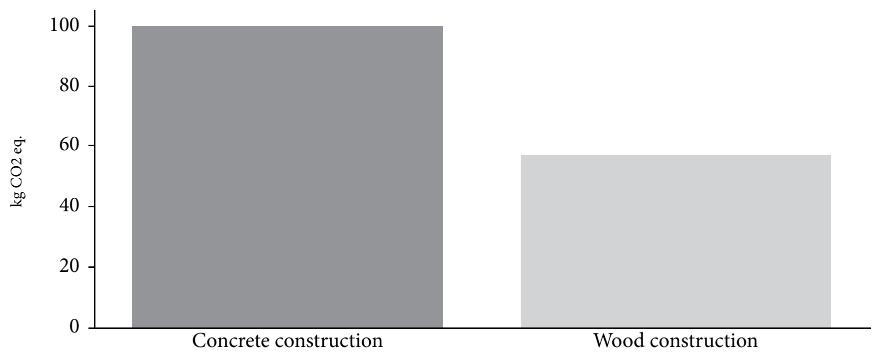
1. 108 mm bricks
2. 20 mm ventilation gap
3. 9 mm wind plate
4. 420 mm insulation / 45 mm wood construction cc 445 mm
5. Vapor barrior
6. 15 mm OSB plate
7. 20 mm insulated space for installations
8. 13 mm plasterboard

= 657 mm



U-value:
0,09 W/m²K
Environment:
●●●○
Disassembly:
●●●●
Recycle:
●●●●
Flexibility:
●●●●

Ill. 106 Wood construction



Ill. 107 Construction comparison from LCA. 1m2 is tested of each.

Ventilation strategy

HYBRID VENTILATION

A hybrid ventilation system is a good and sustainable way to obtain a good indoor climate, where the natural ventilation can be used, when the weather allows it.

NATURAL VENTILATION

As a parallel process, the natural ventilation strategy has been investigated. Natural ventilation is the most sustainable way to ventilate the building in the summer months and leads to a reduced energy consumption compared to mechanical ventilation. Natural ventilation can be divided into single sided ventilation, whether it will be one or two openings, cross ventilation and stack ventilation. By utilizing naturally occurring airflows [Annex 3], thermal buoyancy, difference in temperature and wind pressure to ventilate, energy can be saved and thermal comfort increased.

In rooms with max dimensions of 2,5 times the room height, the single-sided ventilation can be used. Otherwise, cross ventilation can be used, if the max dimensions is 5 times the room height. This has to be in mind when doing the plan distribution. The most dominating wind is occurring from West and South-West, and this also has to be in mind through the process.

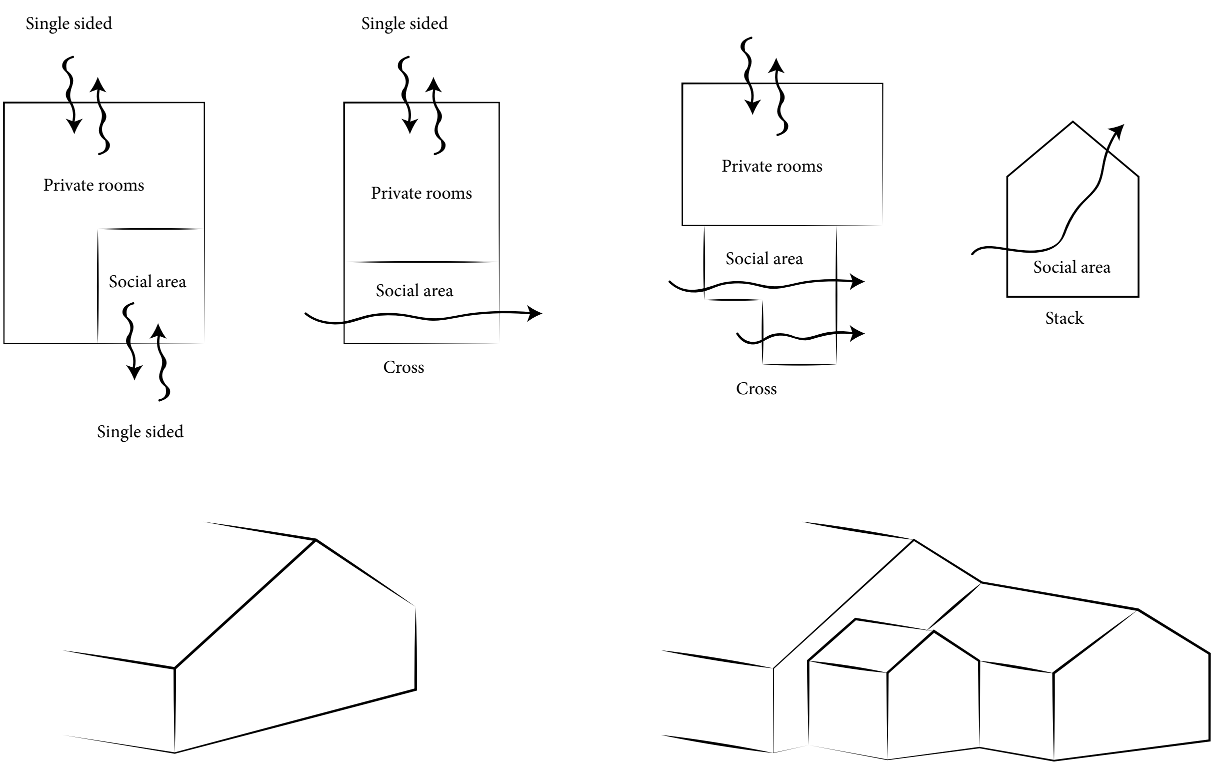
As a conclusion, the social areas which will be bigger rooms and where there will be more people at the same time, it is preferred to use cross ventilation. In the small private rooms, there is going to be used single sided ventilation because of the size and small amount of people.

In rooms with high ceiling heights, stack ventilation can be a good choice where the natural ventilation can be optimized with a roof window where the room can be ventilated very fast due to the so-called chimney effect, where thermal forces heats up the cold air and leads it out of the roof window [Indeklimaportalen, 2019]. In some cases if the room is shielded from the building itself, stack ventilation is preferred.

This result in smaller units as social areas, attached to the private units, which also creates a more dynamic facade expression and strengthens the illusion of a small village [Ill. 108].

MECHANICAL VENTILATION

In the plan distribution process of the building, one of the focus points for mechanical ventilation was to minimize the pipe distribution since the building is very wide and there is two floors in both ends. This results in 3 ventilation zones, which each has its own ventilation unit and technical shafts where the mechanical ventilation unit can serve the second floors.



Ill. 108 Volume development compared to ventilation strategies

Construction

As a part of the process, the possibilities of spans has been investigated, since it is wanted to have a flexible construction which requires that the only bearing part of the building is the envelope of the units and therefore nonbearing internal walls in each unit, which futureproofs the building for future redesign.

It is found that with trusses - depending on which kind is chosen, it is possible to have a span of max 28 m [Palsgaard spær, 2019].

Some guidelines of spans has been found, which is used through the design process [Flexwood, 2009]. These tables set the boundaries for the max span for facade beams and floor slabs, rafters and ridge beams. Based on this knowledge, the amount of different spans of units has been minimized through the process, which results in less amount of different elements. In the end of the process, four spans is chosen for units with various lengths; 4,2m, 6,4m, 8,6m and 10,8m. These spans are chosen based on the investigations through the process.

When looking at the process of the volume, this also result in a clearer facade expression, where the rooftops are following each other instead of reaching different heights.

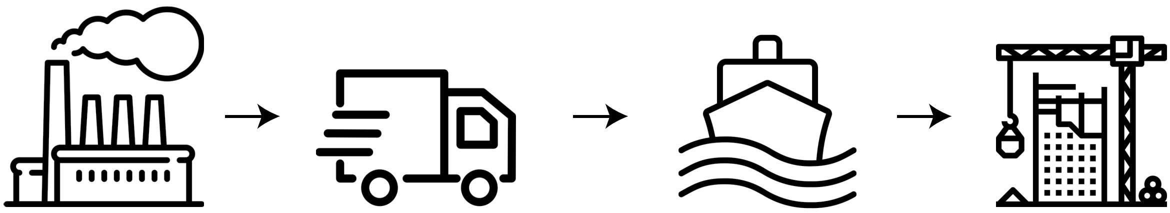
PREFABRICATION

The elements is going to be assembled in a factory, which is a more controlled environment that allows a more accurate construction, where it also is protected from the weather conditions, which leads to a significant shorter construction time.

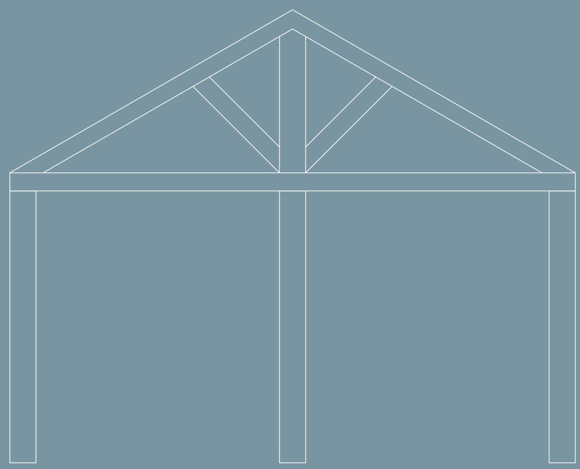
Prefabrication is also a more energy efficient and sustainable construction method. A traditionally construction method requires extra materials that leads to increased waste. When prefabricating, the extra materials can be recycled on the factory. Another quality of modular constructions is, that it easily can be disassembled in the future.

Prefabrication of the elements also reduces the site disruption, since many of the components already are completed in the factory [Constructionworld, 2019].

After the components are prefabricated on the factory, it is transported to the site by the ferry and later on assembled on the site. Therefore, the elements has to be in relatively small sizes since it has to fit on the ferry [Ill. 109].



Ill. 109 Prefabrication



Ill. 110 Example of roof construction

Roof design

Various roof shapes were tested in relation to both the aesthetic expression of the building compared to the context and surrounding nature and in relation to the opportunity to prevent the problems caused by the increased precipitation in the future and the possibility to install photovoltaic panels on the roof.

To create the illusion of a home and a village, the pitched roof is the most obvious choice, which creates this illusion. At the same time, the angle of the roof is a better choice when thinking of the increased precipitation where rainwater harvesting can be used if the material allows it.

The pitched roof [Ill. 111] is used in the context on the island and it is the well-known house shape, which kids always connects with a house. This strengthens the clear statement of "a home" while still creating qualities for the increased precipitation and the photovoltaic panels.

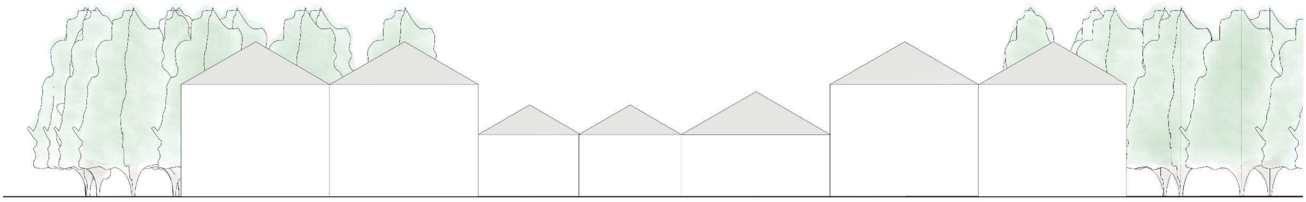
The pitched roof can be further developed to imitate the forests in the surroundings [Ill. 112], where it is highest towards the forests and lower towards the middle of the building, but this solution is creating problems when looking at the construction and the possibility for lofts. It also creates a less clear statement of a house shape than a pitched roof with the same angles. Therefore, the pitched roof is the choice for the roof shape, since it's giving the wanted expression of a village while at the same time creating qualities for the precipitation and the photovoltaic panels.

PHOTOVOLTAIC PANELS

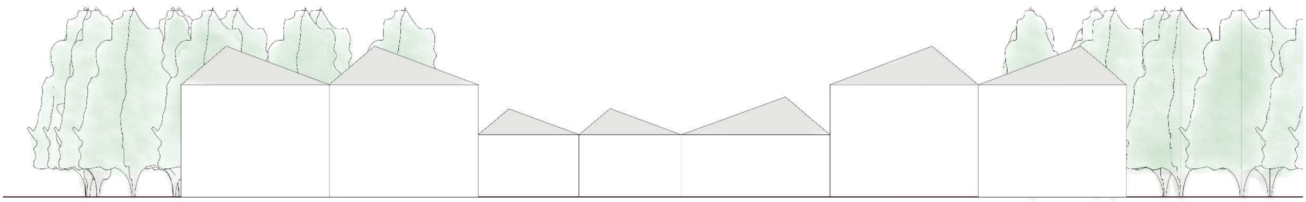
The placement of the photovoltaic panels also creates many options. It can e.g. be used as an aesthetic feature such as shutters or placement on the facade or it can be more hidden on the roofs or placed in the surroundings. For this project it's a goal to place it somewhere, where it is more hidden from the sight of the residents, Some options that has been considered is where it is integrated in blinds and fenches of the terraces or on roofs. The blinds makes it only possible to collect energy when they are in use, therefore it is not an efficient choice. The fences are not creating enough m2 compared to the needs. On the roofs on the highest buildings, the photovoltaic panels will be invisible from ground, therefore they are going to be placed on some of the roofs compared to the needed m2 panels.

Since the orientation of the roofs can only be either towards South-East or South-West it has been investigated which direction and angle is the most optimal for placing the panels on the roof. It is found that the direction towards South-East is more efficient than South-West [PV beregningsark]. In this case, it has to be investigated if the joined roofs are creating shading on the PV panels.

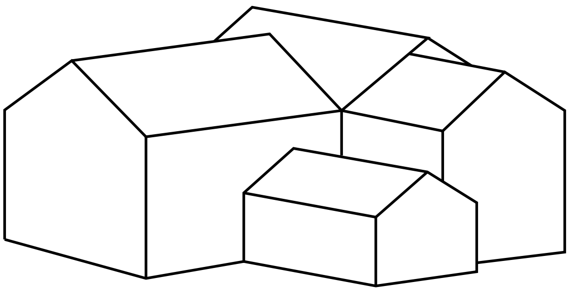
As a parallel iteration, the different directions has been tested as a volume, where it was found that the roofs needs to have the direction towards South-West/North-West to create the wanted house shape visible from Aalborg. Instead, it is found that if some of the units (compared to needed area of solar cells) is turned 90 degrees, it will have a positive effect on the building expression, creating more diversity and creating the house shape towards the kids outdoor area, while still creating the wanted house shape towards Aalborg [Ill. 113]. It also creates a better expression of a village joined together, since they are placed in different directions. Afterwards the plan distribution has been adjusted with this new aspect. The most efficient angle of the roof is in this case 30 degrees, which also will create less visibility from the ground than if it was more.



Ill. 111 Pitched roof with 30 degree angle



Ill. 112 Pitched roof with 20 and 40 degree slope in relation to the surrounding trees



Ill. 113 If some units is turned 90 degrees for most efficient photovoltaic panels in this case.

Indoor climate optimization

Since there is concerns about some of the rooms according to overheating, one is tested in Bsim in order to optimize the indoor climate. The Building Regulation states that the thermal indoor climate must contain max 100 hours above 27 degrees and max 25 hours above 28 degrees per year [Bygningsreglementet, 2019].

The room, which is tested, is the social area on level 1 in the young department. It is chosen to be a critical room because of its small size combined with the big window placement towards South-East, which results in great exposure of solar radiation. The size of the room is 6,3 m x 4,4 m and in addition to the big window area towards South-East, there is two windows towards North-East and also two windows towards South-West to be able to cross ventilate the room. The room is both simulated compared to the climate as we see it now and to the future (2050 and 2080).

As a starting point, since the wish is to have a great view towards the water - a window area of 100% towards South-East is tested [Ill. 114].

Afterwards, since the daylight factor [Annex 5] is more than enough compared to the requirements, it is a possibility to change the area of the window to minimize the temperature, but in this case, the quality of view was decreased magnificantly. In addition, the big window area from test 1, was tested again, but now with the implementation of solar shading where the envelope is extruded further from the building. This still created overheating problems, which had to be fixed. The room is then tested with the implementation of 30 degree outdoor lamellas on the other windows (shading factor 0,1).

Then the window area was changed to 45% window area towards South-East, which still creates a good daylight factor and a great view towards the water together with a relation to the outside. Now the requirements is met for 2020.

To investigate if the room meets the requirements in the future, there is used future predicted weather files in Bsim. Here the simulation showed overheating because of the increased outdoor temperatures in the future, and therefore it further had to be investigated. The inputs were changed compared to the new climate which results in a longer summer period which is from June-September and the building envelope was extruded further to create more solar shading and as a result, it creates a possibility of use as a terrace and therefore an opportunity for direct access to outdoor areas on the 1. floor. The daylight was then tested compared to the new solar shading system [Annex 5], which still showed a good daylight factor in the room.

SOLAR SHADING

As a parallel iteration to the thermal indoor climate, it was discovered, that there is a need of solar shading. There are many options to choose from, when choosing a solar shading system. One of the significant factors of this project is visual comfort, where the ability to have a great view and connection to the surrounding nature is i focus while at the same time have a great natural light as it has a positive effect on human well-being. Therefore the shading system should shade when it is needed but not take view when it's not activated. It should also still create visual comfort when it's activated. Some options is considered because they match the wanted qualities [Ill. 115-117].

As a part of the building design process, the extrusion was investigated parallel to the indoor climate simulation in Bsim. This solution made it possible to have a larger window area, while still obtaining a good thermal indoor environment, and as a result creating a greater view towards the water and therefore a greater relation to the outside, which was the goal in the social areas. This also created the opportunity for direct access to outdoor areas on 1. floor. The terraces and solar shading is then an integrated part of the overall building design. In addition, this keeps out the sun in summer and letting in the sun in winter.

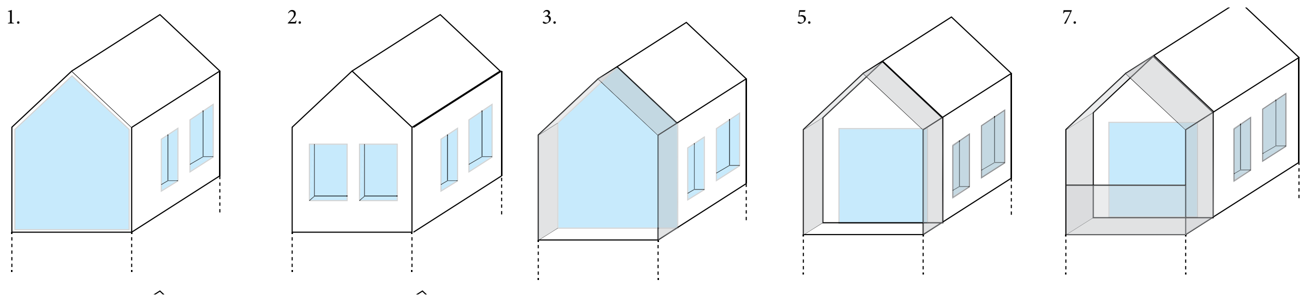
Another significant factor is to be able to adapt to the future climate changes. Automatic outdoor lamellas is chosen for the other windows in the building both because of the possibility of view and the aesthetic reasons, where they are hidden behind the cladding when it's not in use, and also because of the ability to change the degrees of the blinds compared to the needed shading, which therefore results in a system that still can be used in the future, when the climate changes.

TERRACE DESIGN

When designing the terraces there are important factors to have in mind. An extrovert terrace will not be an integrated part of the building design while it makes the user very exposed - both visually and in terms of weather. As an integrated part of the solar shading, the user will be less exposed and it becomes a natural part of the design.

Another facade expression is now created and the spaces underneath the terraces can either be used as more space for the ground floor if it is needed or as a shielded outdoor space in connection with the ground floor.

	Description	Simulation results
Test 1	Starting point. 100% window towards South-East.	2020: >27=1022 hours, >28=740 hours.
Test 2	Smaller window area towards South-East (14%).	2020: >27=119 hours, >28=47 hours.
Test 3	The window area from test 1, now with roof and sides (2m).	2020: >27=208 hours, >28=74 hours.
Test 4	Test 3 - now with solar shading added on the small windows.	2020: >27=174 hours, >28=60 hours.
Test 5	Smaller window area towards South-East (45%).	2020: >27=61 hours, >28=13 hours. 2050: >27=112 hours, >28=52 hours. 2080: >27=268 hours, >28=135 hours.
Test 6	Changes in inputs compared to the new climate.	2050: >27=29 hours, >28=4 hours. 2080: >27=81 hours, >28=27 hours.
Test 7	More roof and sides (now 2,5 m) = terrace.	2020: >27=29 hours, >28=6 hours. 2050: >27=27 hours, >28=5 hours. 2080: >27=66 hours, >28=22 hours.



Ill. 114 Bsim simulation results

Ill. 115 Lamellas (outdoor). Will be visible on the facade.

Ill. 116 Solar shading above the windows. Will be visible on the facade.

Ill. 117 Lamellas (outdoor). Hidden when not used.

Daylight and windows

The window design had a great influence on the design process, since there is many factors involved in the choice of windows. Daylight is an important factor when thinking of human well-being. The site gives great opportunities for daylight where only the trees will create some shading.

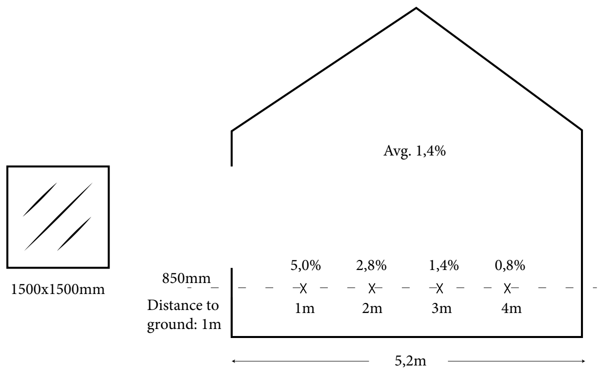
The site has beautiful surroundings, which is one of the greatest qualities of the location, and therefore the view and making a visual contact with the nature outside, will be one of the main goals. In addition, a clear division of social and private zones is a factor when choosing the window design, because the residents has to be able to feel private in their own rooms. Another thing, which has to be in mind, is if the windows has to have a function, e.g. a desk or a place to sit, or if it should just function as a window. In addition, the placement and height of the window compared to the users also has a great impact of the quality of view. Therefore, simulations and studies has been made to create an understanding of the windows.

The building regulations states that the requirement for daylight is enough if the window area is the equivalent of min. 10% of the floor area or in addition if there is min. 2% daylight factor in min. half of the room [Bygningsreglementet, 2019]. To get a better understanding of how light enters the room, it has been investigated what influence the size and placement of the windows have on the daylight factor in different points of the room. A room in the building has been chosen to investigate, which is a room in the young department towards North, which has a dimension of 5,2m x 4,2m. It is a room, which is deep, and there is only envelope on one side. Therefore, the daylight has to reach far into the room. Several investigations are made, where the window shape is tested compared to how the daylight enters the room.

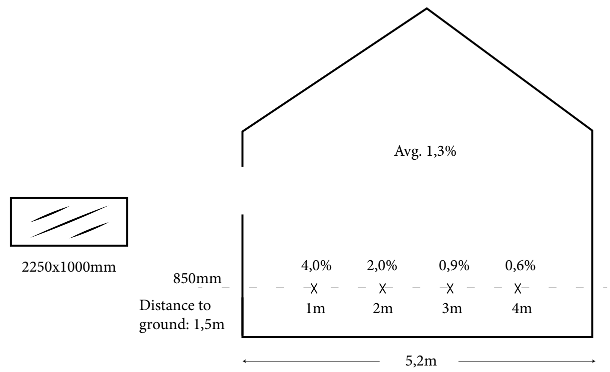
From the study, it can be concluded that the daylight factor is better further inside the room if you have a window placed highly [Ill. 118-120]. In addition, it can be concluded that a tall window creates better daylight factor further inside the room than a wide window, but at the same time, the wide window creates a better daylight average than a tall window [Ill. 121-122]. A squared window is in between, where it creates a good daylight average while at the same time gets the light further inside the building.

The placement of the window in the envelope creates different opportunities, where if the window is placed close to outside, it can be used as different functions because of the wide envelope and it also creates a greater view while if it is placed towards inside, it creates a more private feeling [Ill. 124-125].

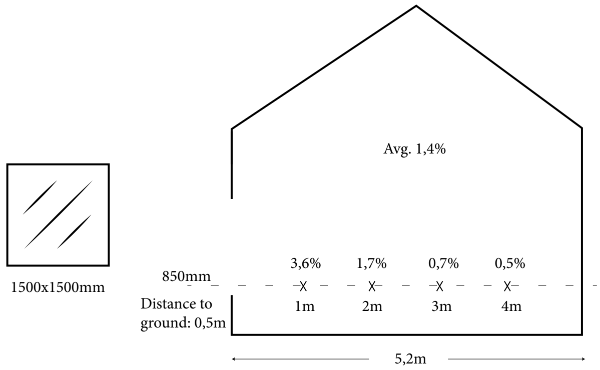
In addition to the functional and aesthetic reasons for the window choices, the indoor climate has been a parallel process when designing the windows, as the amount and direction of the windows has a big influence on the sun radiation and therefore the temperature in the building. Natural ventilation has been a parallel process too, where the needed air flow rate has to be fulfilled to have a good indoor climate by the amount of m2 opening and the placement of the windows compared to if it's either single-sided, cross or stack ventilation. In addition, the amount of windows has an impact on the energy consumption for the building, which has been a parallel process too.



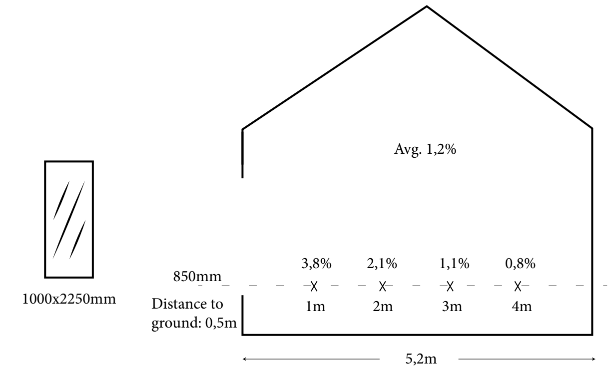
Ill. 118 1500x1500, 1m distance to ground



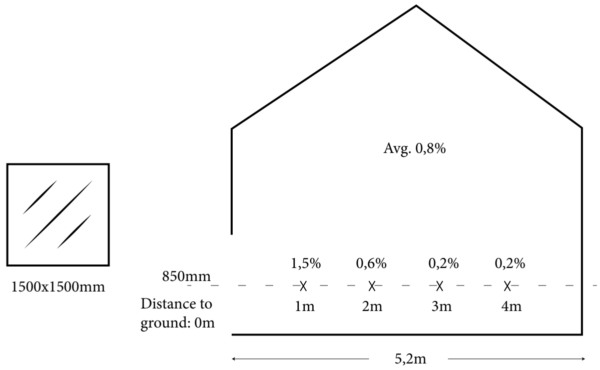
Ill. 121 2250x1000, 1,5m distance to ground



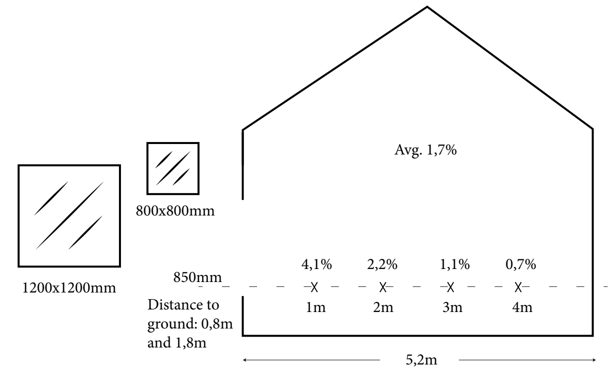
Ill. 119 1500x1500, 0,5m distance to ground



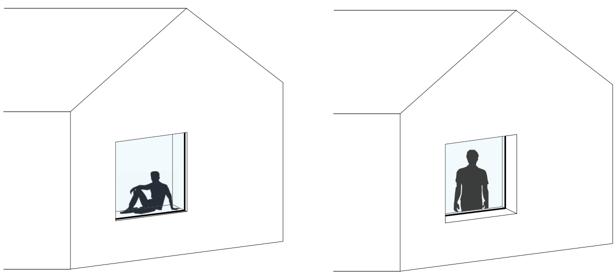
Ill. 122 1000x2250, 0,5m distance to ground



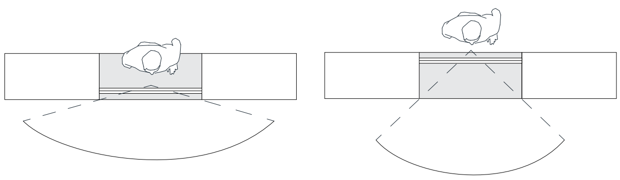
Ill. 120 1500x1500, 0m distance to ground



Ill. 123 1200x1200, 800x800, 0,8m and 1,8m distance to ground.



Ill. 124 Placement and function



Ill. 125 Placement and view

Ill. 126 Facade comparison from LCA. 1m2 is tested of each.

Materials

The materials for the facade is investigated through LCA to figure out the environmental impact of the materials [Ill. 126], through 3D renders to evaluate the aesthetic reasons [Page 110] and through literature to gain knowledge about the materials and their properties [Annex 9]. In this case, it is important that the choice of materials is easy to disassemble in the future.

In order to achieve a reduction of the overall climate impact of the building sector, it is essential that the materials are produced at low costs in relation to the environment. The level of sustainability for materials involve the lifetime, production, recyclability and economy.

Bricks and wood are the two main materials chosen to be tested for the facade, because of the relation to the context and concept. Bricks is the main material used as cladding on buildings on the island and are the well-known house material. Wood is the main material used for cladding on the holiday houses on the island while it at the same time will have a big relation to the surrounding nature. The materials are investigated in a combination of the chosen construction [Ill. 127-128] and with the same u-value, which is 0,09 W/m2K [Annex 8] to have the best possible way to compare the materials in LCA to figure out the environmental impact [Ill. 126].

Then the materials are assessed according to following aspects; disassembly, reuse, environmental impact and relation to nearby context [Ill. 127-128]. The evaluation is done by results from LCA and gained knowledge about the materials [IDEKATALOG, 2018].

RAINWATER HARVESTING

One of the conclusions from the analysis phase is, that the precipitation in Denmark is going to be more heavy and powerful. Therefore, water strategies has to be integrated, to avoid any possible floods in the future. Rainwater harvesting is a system, that collects the water from the roofs and stores the water in a tank underground, then to be reused in the building for e.g. washing machines and toilet flushes or for irrigation [Rainwater harvesting systems, 2012].

When working with rainwater harvesting, the material on the roof is a big factor, because some materials are unsuitable, if the water is going to be used for indoor functions. Some of the suitable materials is materials with a smooth surface such as slate, while some of the unsuitable materials are green roofs and copper roofs. When using e.g. green roofs, the water can still be collected for irrigation, but not for indoor use, since the water will be unclean and therefore it is not optimal to use for functions inside the building. Beside the ability to be used for irrigation, green roofs is also a great choice for delaying the rainwater, which is convenient when the amount and degree of precipitation will increase in the future [Brug af regnvand, 2002]. This has to be in mind while choosing the materials for the roofs.

CONCLUSION

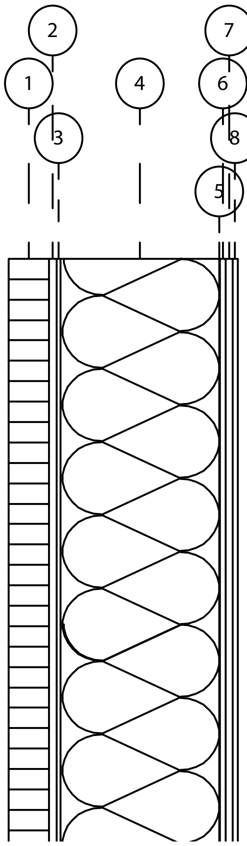
Wood had the highest score under the GWP, and if recycled it has a negative impact of CO_2. After examining several different types of wood [Annex 9], Cedar wood (Kæmpethuja) has been chosen to investigate further in 3D due to the good properties and it's light colour. It grows in Denmark, resulting in low transportation cost, and has a good natural durability while at the same time for the patina where it turns grey by time. The cladding is going to be mounted on mounting lists with screws, which makes the cladding easy to disassemble from the construction for later reuse.

Brick is creating the most CO2 imprint of the two, while at the same time being the most difficult material to disassemble for later reuse compared to wood cladding. Bricks is still investigated further through 3D, even though it is not the best compared to the investigations, but still to see the aesthetic expression of the building.

Both green roofs and wooden roofs is chosen to be investigated through 3D to see the aesthetic reasons since they both have great qualities compared to the increased precipitation in the future.

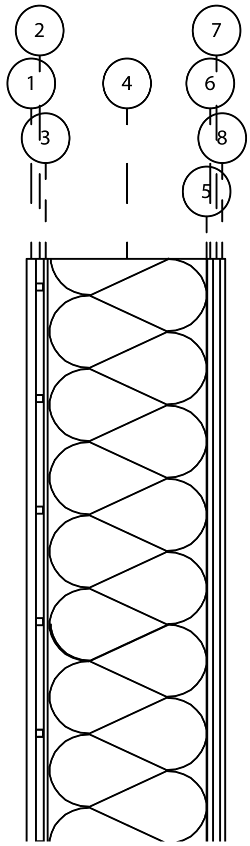
1. 108 mm bricks
2. 20 mm ventilation gap
3. 9 mm wind plate
4. 420 mm insulation / 45 mm wood construction cc 445 mm
5. Vapor barrior
6. 15 mm OSB plate
7. 20 mm insulated space for installations
8. 13 mm plasterboard

= 657 mm



Ill. 127 Brick cladding

U-value:
0,09 W/m^{2}K
Disassembly:
●●●○
Reuse:
●●●●
Environment:
●●○○
Context:
●●●○

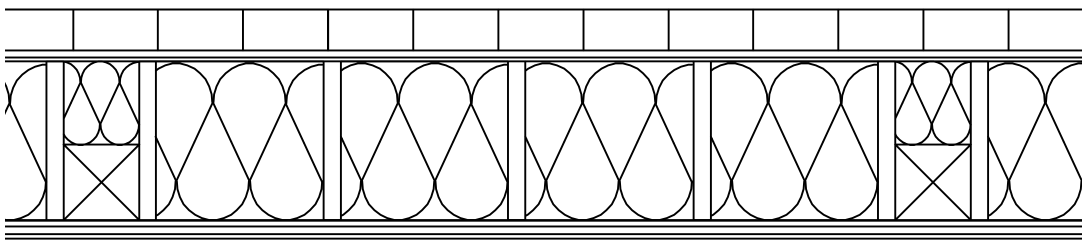


Ill. 128 Wood cladding

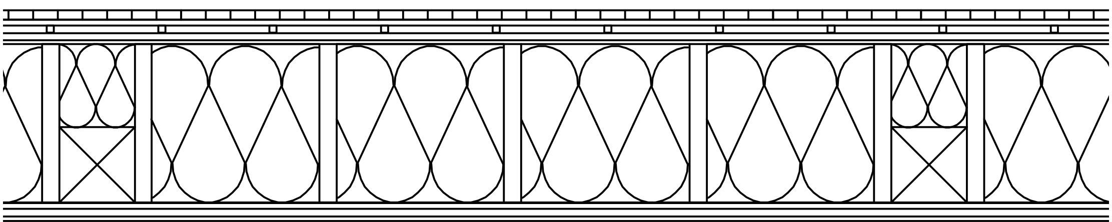
U-value:
0,09 W/m^{2}K
Disassembly:
●●●●
Reuse:
●●●○
Environment:
●●●●
Context:
●●●●

1. 30 mm vertical wood cladding
2. 20 mm ventilation gap with mounting lists.
3. 9 mm wind plate
4. 420 mm insulation / 45 mm wood construction cc 445 mm
5. Vapor barrior
6. 15 mm OSB plate
7. 20 mm insultated space for installations
8. 13 mm plasterboard

= 579 mm



Ill. 129 Brick cladding



Ill. 130 Wood cladding

Facades

MATERIALS

In addition, it is important that the choice of materials is underlining a home feeling and that it is warm and inviting. It is also important that it complements the nearby nature.

Several proposals of facade and roof cladding is investigated [Ill. 132-135]. One proposal of bricks is investigated because of the relation to the wide context, where it is a well-used material. In addition, it is a material, which we relate to a home. Other proposals is a wooden facade where the vertical cladding becomes a part of the vertical trees. Here it is investigated with green roofs and wooden roofs. Another proposal is a mix of wood and bricks, where the bricks is forming the house shape creating the archetypal illusion of a brick house, with wood ”wrapping” the building creating more warm outdoor spaces with a relation to the nature. In this case, the main material will be wood, which is the best choice compared to the previous investigation. As a conclusion, the illution of the light wood wrapping the building with bricks in front is chosen since it works well aesthetically with the choice of solar shading as the wood ”wrapping” will create the extrusion of the building, which strengthens the idea of having it as an integrated part of the building.

WINDOWS

To enhance a playful and dynamic facade, the windows has been processed. One proposal is with windows that vary in size and height, creating a dynamic facade. The windows in different heights creates many possibilities for indoor use, where e.g. some can be for sitting and others can create a shelf. A disadvantages is that the textured cladding and the very dynamic building envelope mixed with the playful windows can become complex to look at. In addition, the different heights and sizes will create problems for the cassettes, where the options of size and placements are many, and it will be difficult to minimize the amount of cassettes.

Since there are many deep rooms in the building, another proposal is made with vertical windows since it has been concluded that vertical windows has a great quality of getting the light further into the room. The vertical windows is varying in width but placed in same heights, which relates to the vertical forests. This creates a more systematic and calm look to the facade, which still is dynamic because of the extrusions of the building envelope. Here it is again noticeable to minimize the options, which will minimize the amount of cassettes, but in this case, it has been concluded that there will already be less options to choose from. This proposal is chosen to be further developed.

To enhance a more playful facade with this option, the window design is processed with different mullions. In this process, the choice of mullions is based on both the aesthetic reasons and natural ventilation qualities [Annex 4]. To enhance a more private feeling in the private rooms but still creating great daylight and view, the windows are being placed in a height of 500 mm and placed close to outside. This will create possibilities for functions, e.g. sitting possibilities in the window, and it will create view for all users.

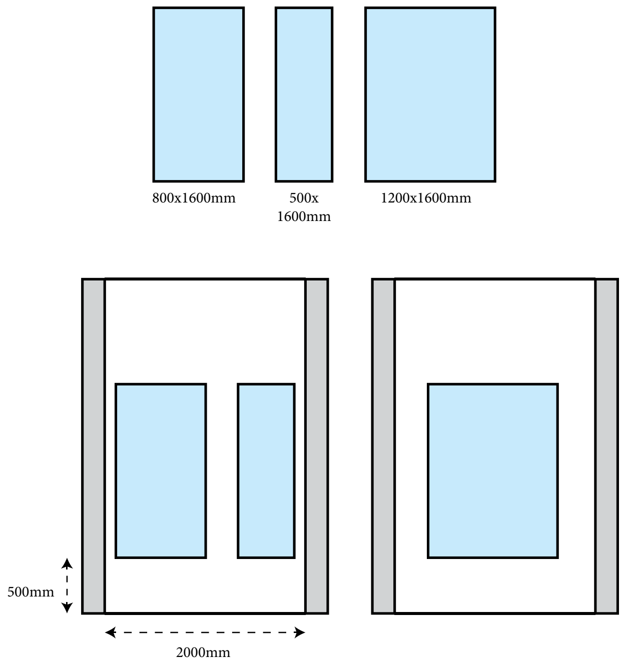
DAYLIGHT

Some critical rooms has been tested compared to the daylight factor [Annex 5]. These investigations is used to have assumption for the needed window areas compared to the room dimensions. The common areas are big and deep rooms which requires big window areas for optimal daylight factor, and therefore it is chosen to be big windows from floor to ceiling, which also creates a great view and a connection to the nature outside. Looking from outside, it will also create a clear vision of which places is private or social.

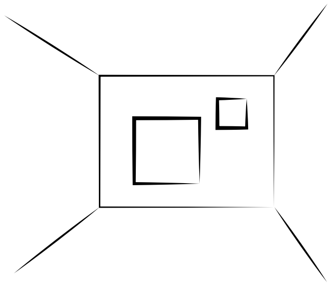
These choices are used in the further development of the windows, where the placements compared to the amount of cassettes is going to be developed.

CASSETTES

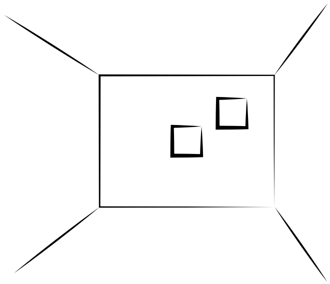
As a conclusion, three sizes of windows [Ill. XX] is chosen for the further development. The three sizes will minimize the amount of cassettes compared to more solutions to choose from, while still be able to create a dynamic expression of the facade. The sizes is chosen compared to the size of the cassettes, and since they have a great relation to each other, while at the same time create possibilities for different functions [Ill. 131]. After several attempts, the placement of the windows resulted in 9 different facade cassettes, which compared to the case study of Lisbjerg Bakke is not a lot since they have 27 different cassettes.



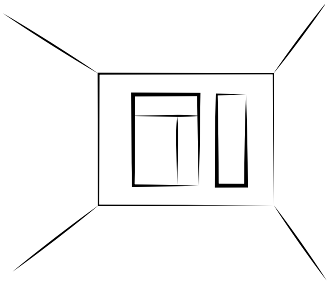
Ill. 131 Window sizes



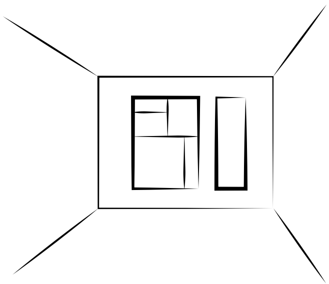
Ill. 132 Bricks and green roofs. Squared windows



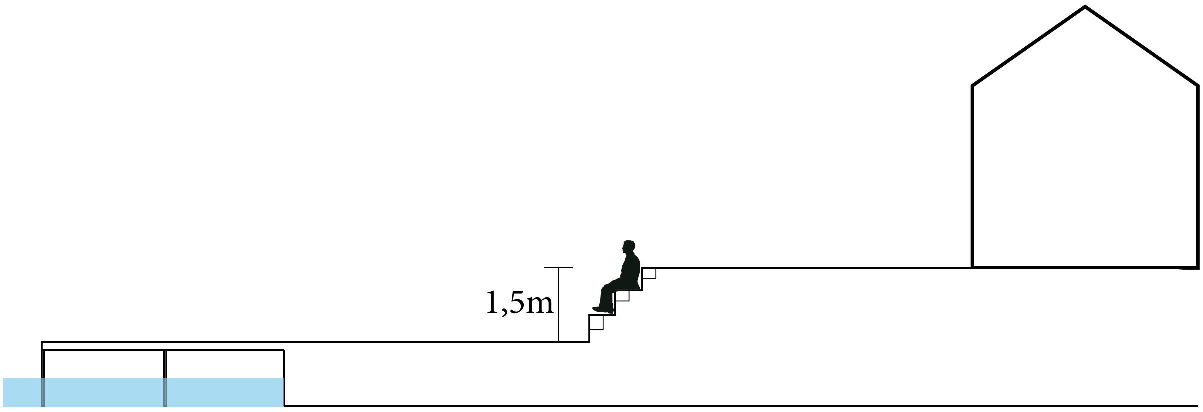
Ill. 133 Wood and green roofs. Squared windows



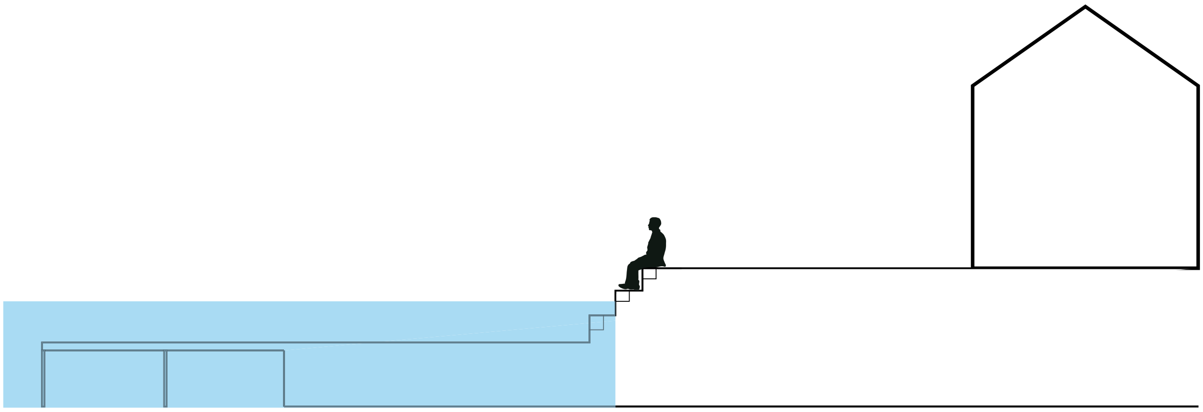
Ill. 134 All wood. Tall windows



Ill. 135 Wood and bricks. Tall windows



ILL. 136 Flood proofment - Raising the ground 1,5 m



Ill. 137 Future - when the water rises

Master plan development

The master plan has to refer to the user and their needs, which results in three different areas, which should be in relation to the residents living nearby. Therefore, the outdoor areas are split by the building, creating the three areas in relation to the units.

In addition, the orientation of the building has been a parallel process. The building is shading for the most dominant wind from West, and creates great outdoor spaces towards the water with great sun conditions, which is towards South-East. The building itself will shade from the worst solar exposure, which is a great quality especially in the future where more shaded spaces is wanted because of the increased temperatures.

CLIMATE CHANGES

When looking at the future climate, it is estimated that the water may rise up above the existing dikes surrounding the site on Egholm. To flood proof the building, different approaches can be taken into consideration, most effectively is to build above the water level. To avoid a hilly terrain, and make a smooth flatten landscape, more usable for recreational activities for the residents, it has been chosen to elevate slowly upwards to the building with a bathing pier with stairs, which also will integrate the water and the site [Ill. 136]. In the future, when the water rises, it will remove the pier, but then the terrace and stairs can be used as a place to sit and enjoy the close contact with the water [Ill. 137].

Ill. 138 Integration of the water

Ill. 139 Fun landscape in kids area

Ill. 140 Integrated hammock and plants

Placement of functions

The entrance area is placed towards North. It should consist of parking facilities - both for cars and bicycles, and there should be paths connecting the entrance of the building to both the parking facilities and the existing paths, which leads to the ferry.

The kids area will be located just outside the kids unit towards South-West. Here there should be a fun landscape - e.g. piano shapes [Ill. 139] and a mooncar track. It should also consist of a playground and a multi-purpose pitch. The area should be defined by trees.

The common area will have a location towards South-East close to the water. It should be integrated with the water by a bathing pier where they can have their small boats. The pier will be integrated with the site by stairs and a big terrace [Ill. 138] which is split in two of the building. Here all the residents can be together for a barbecue and relaxation in hammocks and sun beds. In addition, there should be placed a campfire and greenhouses nearby.

The young area should consist of a big terrace which can fit the young residents and their friends for a barbecue. In addition, there should be placed integrated hammocks [Ill. 140] and plants.

Epilogue

This chapter contains the closing statements about the project as well as a reflection of what could be alternated or improved.

Conclusion

Through the iterative steps of The Integrated Design Process, the project has led to the design proposal for a new sustainable orphanage on Egholm. The project has been targeted to comply with a design that lives up to the user requirements and criterias, as well as a building that relates to its contextual environment. The user's needs for private and social facilities are fulfilled by dividing between a common area that connects the departments, which are of a more private character assigned to the so-called user group. The load-bearing grid system allows for an open floor plan that is both flexible and allows for a social environment.

The building is designed to take into account the context through its typology and scale. Through the placement of units, there has been established both intimate courtyards and a division between the different outdoor areas. The facade has a light and dynamic expression due to the materials and the extrusions, which both has a great relation to the archetypal house and the surrounding nature.

Throughout the process, decision-making has been highly based on the integration of sustainable solutions, which still contribute to the architectural expression. Different passive and active strategies have been design drivers in the optimisation of the building to reach zero energy standards. Firstly, the energy demand has been minimised through a highly insulation building envelope, the integrated solar shading, the use of natural ventilation and mechanical ventilation with heat recovery. These decisions have been made as a balance between securing a low energy demand and providing a good quality of indoor environment. Secondly, PV panels have been integrated in order to cover the remaining energy demand. Beside the focus on different aspects of environmental sustainability, a key driver has also been socially sustainable solutions. The highly flexible plan layout can accommodate several different user types depending on different needs.

Reflection

The project and its design evolves from the user analysis, which was used actively to form a vision and the set design criteria. As a user analysis, an interview and a visit to the institution Hugin and Munin was done, which gave qualitative data.

When designing on a site with such a unique and defined sense of place as on Egholm, the creative thinking was somewhat either limited, or to wide. In the start the idea of building directly in contrast to the existing form language on Egholm, or relating to it gave initial conflicts. It was later decided to go for a more neutral visual expression, relating to the perception of a home, rather than building a visual distinguished landmark.

When working with an marginalised user group, it was somewhat difficult getting qualitative data about how and what theses users need. The group struck into difficulties scheduling appointments with existing orphanages, as they had an obligation for their residents. This ended up giving limited data of the needs and structure of an orphanage.

The structural system has clearly set some boundaries in the architectural exploration. This led to conpromises which can be discussed if it is the right choice or if it is a better solution to stick to the boundaries made by the structural system.

In terms of future proofing the building by robustness, other materials like concrete would have been more optimal. Were as the choice was to future proof in different approaches, by focusing on a more sustainable matter, where the design for disassembly and prefabrication has been a great focus for transportation to the site and the ability to disassemble and reuse in the future.

The grid and the spans has played an important role in the early stages of the design process, which has limited other possible layouts. If other space principles were involved, several variations could possibly be achieved in the floor plans. It has secured cohesion throughout the design process and has resulted in a holistic concept “The Village”.

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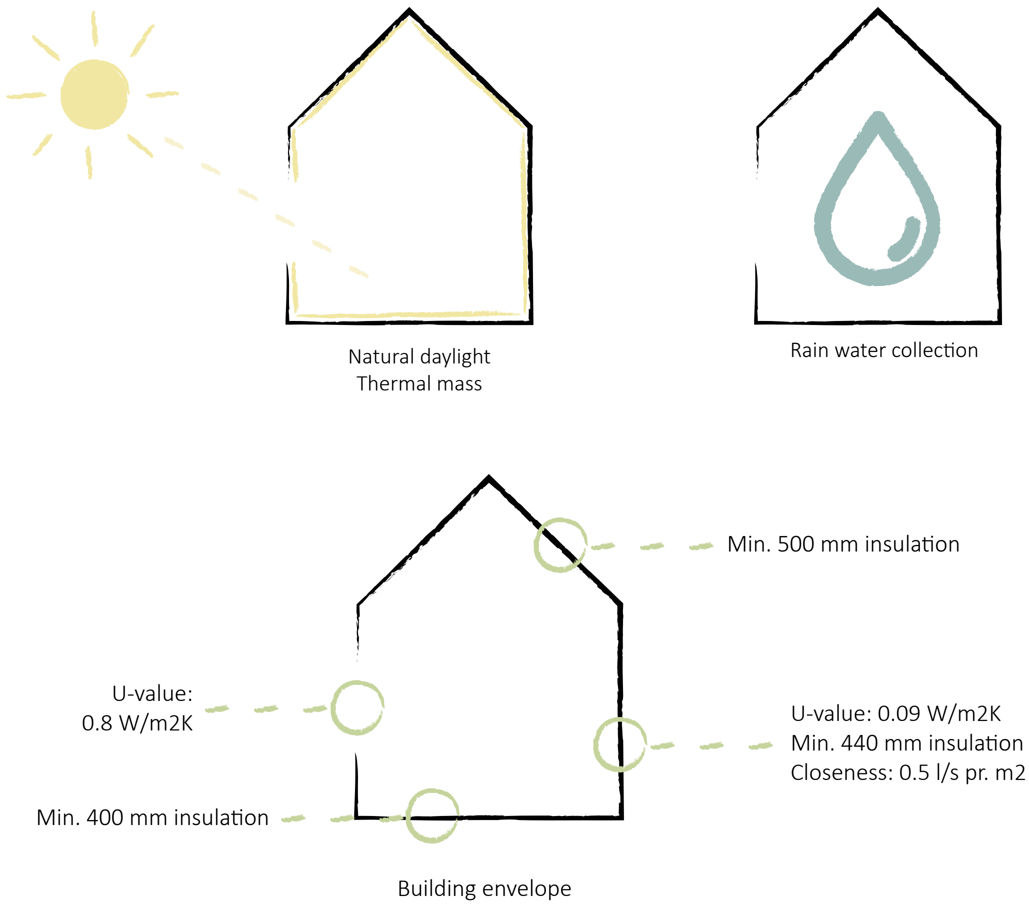
Illustrations

Illustration 1-18: Own production
Illustration 19-21: Available at: https://www.archdaily.com/570664/children-s-home-cebra
Illustration 22-24: Available at: https://www.archdaily.com/781669/frederiksvej-kindergarten-cobe
Illustration 25-27: Available at: https://adk.elsevierpure.com/en/publications/anvendt-byggeteknik-i-dansk-arkitektur-tr%C3%A6konstruktion-lisbjerg-b
Illustration 28-30: Available at: https://issuu.com/www.innobyg.dk/docs/idekatalog_web_version
Illustration 31-97: Own production
Illustration 98: Available at: https://www.archdaily.com/570664/children-s-home-cebra
Illustration 99: Available at: https://skala-ark.dk/c/projekter/vonsild-skole
Illustration 100: Available at: https://www.archdaily.com/781669/frederiksvej-kindergarten-cobe
Illustration 101-114: Own production
Illustration 115: Available at: https://www.duco.eu/en-gb-products/en-solar-shading/why-solar-shading
Illustration 116: Available at: https://www.archdaily.com/560667/studio-gang-reveals-14-story-residential-tower-planned-for-miami-design-district/54495345e58eceb567000232-studio-gang-reveals-14-story-residential-tower-planned-for-miami-design-district-photo
Illustration 117: Available at: https://www.verre-menuiserie.com/produit/9421-brise-soleil/54118-bso-z90-c80-page-1.html
Illustration 118-137: Own production
Illustration 138: Available at: https://www.designboom.com/architecture/adept-vestre-fjord-park-aalborg-denmark-11-08-2017/
Illustration 139: Available at: Arch2o – facebook 11. july
Illustration 140: Available at: https://www.pinterest.dk/pin/837599230679442087/

ANNEX

ANNEX 1
Sustainable strategies



Sustainable strategies used in the design

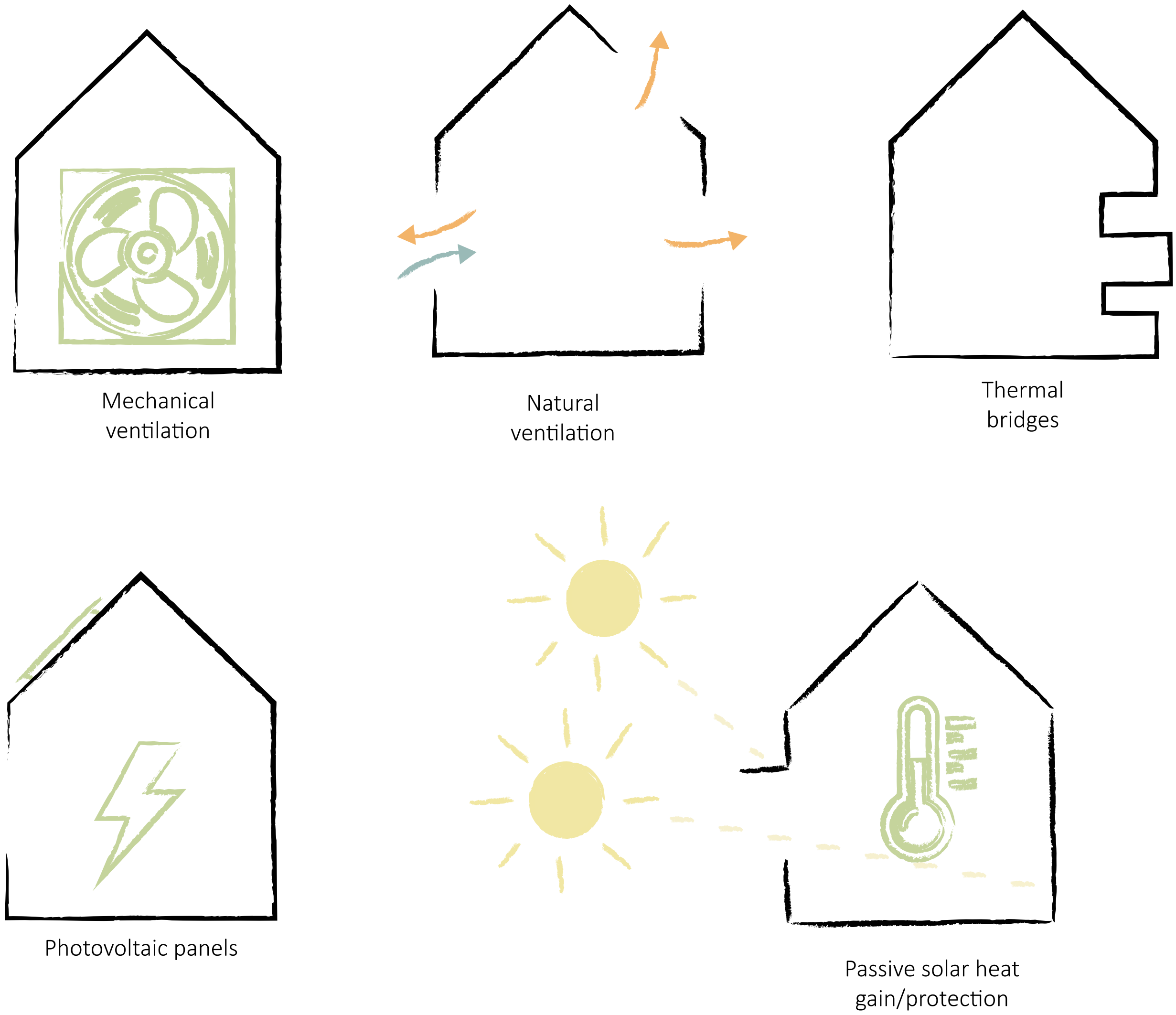
Both passive and active solutions have to be considered while designing a sustainable zero energy building. To reduce the need of active solutions, the building should be optimized by implementing the passive solutions first.

NATURAL DAYLIGHT
The implementation of the natural daylight is a passive solution, which minimizes the need of artificial light in the building, which results in a reduction of the energy consumption for lighting. Also natural daylight has a positive effect on human well-being. The aim in this project is to obtain an average daylight level above 2% in all rooms in the building. When designing the building, deep rooms should be avoided in the plan distribution so it is possible to meet the wanted average daylight level. Zoning should also be implemented, so the rooms are going to be placed right compared to the path of the sun and when the rooms are going to be used by the residents.

THERMAL MASS
Thermal mass can optimize the indoor climate by implementing e.g. concrete as a material, which absorbs the heat during the day and releases it during the night.

RAINWATER COLLECTION
Rainwater harvesting is when the rainwater is collected from e.g. the roof of the building, and later reused on-site. This is a sustainable solution to water plants etc. on-site.

BUILDING ENVELOPE
The heat loss from the building can be minimized by considering the thermal bridges, the u-values and the surface to volume ratio.



Sustainable strategies used in the design

HYBRID VENTILATION

Natural ventilation is the most sustainable way to ventilate the building in the summer months and leads to a reduced energy consumption compared to mechanical ventilation. Natural ventilation can be divided into single sided ventilation, whether it will be one or two openings, cross ventilation and stack ventilation. By utilizing naturally occurring air flows, thermal bouyancy, difference in temperature and wind pressure to ventilate, energy can be saved and thermal comfort increased. But natural ventilation can also have a negative influence on the indoor climate - in the winter season, it would let cold air into the building, which will affect the energy consumption used for heating up the building. Therefore, a hybrid ventilation system is a good and sustainable way to obtain a good indoor climate, where the natural ventilation can be used, when the weather allows it. To save energy on preheating the air, the mechanical ventilation system has to have a heat recovery system, which utilize the heat from the exhausted air to heat up the new air.

PHOTOVOLTAIC PANELS

When implementing photovoltaic panels, there are some factors that influences the effectiveness of the panels; the type, the slope and the orientation.

SOLAR HEAT GAIN/PROTECTION

When using solar heat gain as a passive solution, the window orientation and the building layout are big factors. Windows towards south creates the most solar heat gain, but at the same time, overheating should be taken into consideration. Again, zoning should be implemented in this solution, so the rooms which needs a higher temperature should be placed towards South - and opposite. In this solution, the season should also be in mind, so it is possible to use the sun, when it's most needed - in the winter season, and still be able to avoid it when the temperature is highest in the summer season. This can be done by implementing e.g. an overhang or trees or in a more user controlled way, with a solar shading system.

ANNEX 2
Interview

To gain more knowledge about how to run a place like an orphanage and about the needs of functions and staff in an orphanage, a study trip was arranged to Villaen, Kerteminde and to Hugin and Munin, Viborg. In Kerteminde, I wasnt allowed to enter the building to get an interview, but at Hugin and Munin, they were ready to help with an interview which resulted in a better understanding of the running of a special place like an orphanage.

Beboere og ansatte:

1. **Hvor mange beboere har i? Aldersgruppe?**

14 beboere. 18-68 år

2. **Hvilke problemer kan være grunden til at de kommer her og bor?**

Behandlingsdom, udviklingshæmmet, misbrugt, familie kan ikke tage sig af dem/misbruger dem…

Skolen ser fx at der er sket den unge noget → siger det til kommunen → sendes til dem.
De vælger selv om de vil bo på dette bosted.

3. **Hvor mange har i ansat?**

3 x personale pr. 9 beboere.
Kommunen vurderer når de fylder 18 om hvor mange timer de skal have støtte til.

Hos dem har de 26 ansatte (hvor 8 af dem er timelønnede/vikarer)
Der er 5 admin - som er ledelse men de har også timer "på gulvet".
Der er 3 pædagoger ovre ved beboerne om dagen.

4. **Hvad laver de forskellige ansatte?**

De 3 pædagoger er ved beboerne. to af dem tager hjem kl 23 og den sidste bliver der og sover (nattevagt)
Derudover er der også en kok og en pædagog hver dag i 3 timer som laver morgenmad og middagsmad hvor beboerne kan få dagstilbud om at hjælpe dem så de bliver sat igang.

De holder ikke som sådan øje med dem der bor der, de holder øje med tegn (ift. om de er kede af det og har brug for en krammer og et spil for at få tankerne på noget andet så de ikke laver skade på dem selv)

5. **Hvor mange og hvem er på arbejde af gangen?**

5 admin + 3 pædagoger.
+ kok med en pædagog i 3 timer

Bygningen:

1. **Hvordan er det at bo/arbejde her? Hvordan er det et godt hjem/arbejdsplads?**

Det er godt. beboerne kan godt lide det og siger kun positive ting om stedet. De kan godt lide at lejlighederne er forskellige så de selv kan vælge den lejlighed der passer til dem.

Det er også en god arbejdsplads fordi admin fx spiser med beboerne, så der ikke laves "forskel". Beboerne er også mennesker, så det giver mere sammenhold at de fx. spiser sammen.

Beboerne har privatliv ift. at de ansatte banker på og de må ikke gå ind hvis de ikke vil have det (med mindre de har skrevet under på det ift. farer).

De laver et samtykke med beboeren når de kommer ift. hvilke regler der skal være og hvad de ansatte må. der laves også en handlingsplan for at få beboeren til at blive klar til at klare sig selv.

De bestemmer selv hvordan de vil indrette deres lejligheder og om de vil have deres egne ting med eller om de vil købe nye.

De betaler 2500 for kost og logi, for at give dem en virkelighedsfornemmelse. resten af pengene styrer de selv.

De kan gå og komme som de vil, og de kan også blive kørt rundt hvis de ønsker det.

Der er fx en beboer der har fået lov til at have hendes hund, så der blev bygget et hundehus til den samt hun fik et rum hvor hun kan male. så de prøver så vidt muligt at opfylde beboernes ønsker.

Ugentlig maddag.
Aktiviteter i weekenden som de er med til at bestemme.
De skal selv gøre rent men kan spørge om hjælp til det hvis de ikke lige kan overskue det.

2. **Kvaliteter (ting der virker godt, og mindre godt)**

At det er forskellige lejligheder.
Antal ansatte ift. andre steder (da de er private er der flere hos dem).
Privatliv - de har eget toilet, men fælles køkken → hvis de har en hel lejlighed for dem selv har de tendens til at låse sig inde i stedet for at komme ud. De har delt afdelingerne op i 2 bygninger og så er der 4 personer pr. fælleskøkken/fælles stue, så der er ikke så meget larm ift. at der er mange mennesker på et sted. derved er det også mere behageligt for dem at komme ud fra deres værelser og være sociale.

Det gør ikke noget for dem at det er delt op så de er nødt til at gå ud for at komme hen til afdelingerne - du skal også ud af huset for at besøge din ven normalt. Tommy kan ikke lige store bygninger da det er for meget som en institution og ikke så intimt.

3. **Hvilke rum/funktioner er der behov for? Har de deres eget værelse, køkken, toilet eller deler de?**

De har ca 4500 m2 grund og omkring 2000 m2 bygning.

Der er lejligheder som er forskellige ift størrelse og form - de er alt fra 20 m2 til 45 m2. da nogle ønsker mindre lejligheder end andre. Der er soveværelse, toilet og stue i lejlighederne.

Så er en lejlighed aldrig magen til en andens.

Administrationsbygning med kontorer og mødelokaler
Fælles spiserum hvor de spiser morgenmad og frokost. både beboere og admin
Lejligheder med eget toilet
Fælleskøkken - 4 personer pr køkken
Fælles opholdsstuer. 4 personer pr. stue.

Tommy mener:
De kan dele toilet da det også er det de ville skulle gøre derhjemme.
Fælles køkken og stue.
God ide at opdele bygningerne så det bliver mere intimt frem for en institutions fornemmelse.

4. **Har de behov for meget privathed? Eller bruger de meget de sociale rum?**

De har behov for privathed i form af deres lejligheder, men det er også vigtigt at give dem et skub ud i de sociale rum, for at hele dem.

5. **Hvis i gør, hvordan får i det så til at føles som et hjem frem for en institution?**

Så meget medbestemmelse som muligt. De er ligeså meget mennesker som os. De har bare brug for hjælp til nogle ting i hverdagen, men derfor skal de selv kunne bestemme over deres liv. det er ikke et sted de er anbragt - de har selv valgt det og de kan flytte hvis de vil, de tvinges ikke til at være der.

Beboerne har medindflydelse og kan medbringe deres egne ting. Hvis de ikke vil have deres egne ting med (det kan være de relaterer til en dårlig periode), så køber de nye ting til dem.
Beboerne vælger selv hvilket ledigt rum de vil bo i når de kommer.

6. **Hvordan trives beboerne i bygningen? Er der noget de synes er ekstra godt? Er der nogle funktioner de mener der mangler?**

De trives godt. Lejlighederne er især et +.

Tommy ville gerne have fx et fitnesscenter, men på den anden side er det også godt for beboerne at komme ind til byen i fitnesscenter, da det er sådan det er i den rigtige verden. så derfor kan man sagtens ønske nogle flere smarte ting i bygningerne men det er ikke ens betydende med at det er godt for beboerne at de er der, da det kan låse dem fast på stedet.

7. **Har i nogle udearealer som de bruger?**

De har natur → som kan bruges til ude træning.
De griller udenfor. men udearealerne er ikke helt lavet endnu.

<u>Andet</u>:

1. **Er det et stort problem i Danmark?**

JA, det er et kæmpe problem i Danmark. Og der bliver behov for flere sengepladser med tiden.

2. **Hvor langt tid bor de i gennemsnit hos jer?**

½ år - evighed men så kort tid som muligt.
Men de er en 107 institution, hvilket vil sige at de er egnet til beboere der ikke skal bo der permanent men skal have en handlingsplan og komme i bedring så de kan leve selv resten af deres liv.

3. **Hvordan er forløbet - fra de kommer til de flytter igen?**

Handlingsplan. Den bliver lavet når de kommer og dermed er de selv med til at bestemme hvordan deres forløb skal være.
Dermed hjælper de dem til at kunne klare en normal hverdag. vækker dem hvis de har behov for det, arbejdstilbud på stedet, skole, husker dem på at de skal børste tænder, rengøring og andre normale ting man skal kunne i dagligdagen.

4. **Er der nogen der kræver særlig behandling/opmærksomhed?**

Ja psykologhjælp og lignende.
De holder øje med at de ikke tager deres eget liv ved at kigge efter tegn. de starter også ud med at spørge hvad der kan gøre dem sure og ked af det så de ved det.
De er i tæt samarbejde med psyk i viborg og sygeplejersker så de hurtigt kan få hjælp hvis der er behov for det.

5. **Hvordan er en typisk dag for beboerne? Arbejde/skole/fritidsinteresser?**

Skole, træne, praktik og sådan noget.
5 går pt derhjemme da de er for medicineret til at arbejde.
De har aktiviteter i weekenderne - svømme, golf, fisketur eller hvad de ellers har lyst til.
Daglig tur med indkøb.
Støttetimer!!

Så tæt på en normal hverdag som muligt. De vækker dem hvis de har svært ved selv at stå op og ellers klarer de det selv. Så tager de i skole eller på arbejde eller på et arbejdstilbud på stedet. og så er der aftensmad.

6. **Hvordan er en typisk dag for de ansatte? Holder i meget øje med beboerne eller er i mest i administrationen eller hvad laver i?**

Hvis de fx kun har 4 timers støtte, så skal de selv bestemme hvornår de står op og sådan noget.
De holder ikke som sådan øje med beboerne, men de er hele tiden omkring dem så de altid kan få hjælp.

7. **Modtager de nogen form for behandling? Psykolog hjælp eller?**

De har egen psykolog, sociolog og sygeplejerske.
Samarbejde med psyk i viborg og politiet.

8. **Har i fælles arrangementer? I så fald hvordan dyrker i et fælleskab? Synes i det er vigtigt?**

I weekenden - ture sammen. De bestemmer hvad de skal i løbet af ugen.

Andet i synes der er værd at vide?

Beboerne har mulighed for arbejdstilbud på stedet.

ANNEX 3
Airflow calculation
SENSORY

	Room	Floor area	Ceiling height	Room volume	Persons	Pollution per person	Pollution building	Total pollution	Air quality in the room	Outdoor airquality	Airflow	Airflow	Airflow	Air change
Sensory	Catagory A - 15% discontent, DS/CEN/CR 1752 1. udgave. p. 23					Kids: 1,2 20% smokers: 2 DS/CEN/CR 1752 p. 26	non-low pollution:0,2 DS/CEN/CR 1752 p. 27		Category A: 1 DS/CEN/CR 1752 p. 23	Excelent: 0 DS/CEN/CR 1752 p. 27	((1 olf)/ (1 l/s)) = 10 decipol			
Unit		m^2	m	m^3	Amount	olf	olf/m^2	olf	decipol	decipol	l/s	**l/s pr. m^2**	m^3/h	h^-1
Designation				Vr				q	c	ci	Vl		Vl	n
Calculation				m^2*m				Total pollution			10*q/(c-ci)		Vl/0,277778	Vl/Vr
	Common area													
	Main entrance	10,5	3	31,5	2	2	0,2	6,1	1	0	61,00	5,81	219,60	6,97
	Wardrobe	16,5	3	49,5	2	2	0,2	7,3	1	0	73,00	4,42	262,80	5,31
	Kitchen/dinning area	91	3	273	25	2	0,2	68,2	1	0	682,00	7,49	2455,18	8,99
	Social area	115,5	3	346,5	20	2	0,2	63,1	1	0	631,00	5,46	2271,58	6,56
	Toilets	27,5	3	82,5	3	2	0,2	11,5	1	0	115,00	4,18	414,00	5,02
	Technique room	12	3	36	1	2	0,2	4,4	1	0	44,00	3,67	158,40	4,40
	Laundry room	20	3	60	1	2	0,2	6	1	0	60,00	3,00	216,00	3,60
	Night porters	26	3	78	2	2	0,2	9,2	1	0	92,00	3,54	331,20	4,25
	Toilet/Shower	8	3	24	1	2	0,2	3,6	1	0	36,00	4,50	129,60	5,40
	Activity room	33,5	3	100,5	10	2	0,2	26,7	1	0	267,00	7,97	961,19	9,56
	Hallways and niches	182,5	3	547,5	5	2	0,2	46,5	1	0	465,00	2,55	1673,99	3,06
	Administration													
	Office 1	11	3,5	38,5	1	2	0,2	4,2	1	0	42,00	3,82	151,20	3,93
	Office 2	11	3,5	38,5	1	2	0,2	4,2	1	0	42,00	3,82	151,20	3,93
	Open office	46	5	230	5	2	0,2	19,2	1	0	192,00	4,17	691,19	3,01
	Meeting room	11	3,5	38,5	6	2	0,2	14,2	1	0	142,00	12,91	511,20	13,28
	Kitchen storage	15	3,5	52,5	1	2	0,2	5	1	0	50,00	3,33	180,00	3,43
	Toilets	9	3,5	31,5	2	2	0,2	5,8	1	0	58,00	6,44	208,80	6,63
	Showers	5	3,5	17,5	2	2	0,2	5	1	0	50,00	10,00	180,00	10,29
	Changing room	5,5	3,5	19,25	2	2	0,2	5,1	1	0	51,00	9,27	183,60	9,54
	Copy room	4	3,5	14	1	2	0,2	2,8	1	0	28,00	7,00	100,80	7,20
	Teqnique room	6,5	3,5	22,75	1	2	0,2	3,3	1	0	33,00	5,08	118,80	5,22
	Hallway	8	3,5	28	2	2	0,2	5,6	1	0	56,00	7,00	201,60	7,20
	Young 1													
	Wardrobe	20	3,5	70	2	2	0,2	8	1	0	80,00	4,00	288,00	4,11
	Hallway	12,5	3,5	43,75	2	2	0,2	6,5	1	0	65,00	5,20	234,00	5,35
	Kitchen/living area	47,5	6	285	4	2	0,2	17,5	1	0	175,00	3,68	629,99	2,21
	Toilet/showers	14	3,5	49	2	2	0,2	6,8	1	0	68,00	4,86	244,80	5,00
	Technique	6,5	3,5	22,75	1	2	0,2	3,3	1	0	33,00	5,08	118,80	5,22
	Toilets	15	3,5	52,5	2	2	0,2	7	1	0	70,00	4,67	252,00	4,80
	Room 1	21,5	6	129	1	2	0,2	6,3	1	0	63,00	2,93	226,80	1,76
	Room 2	24,5	3,5	85,75	1	2	0,2	6,9	1	0	69,00	2,82	248,40	2,90
	Room 3	20	3,5	70	1	2	0,2	6	1	0	60,00	3,00	216,00	3,09
	Room 4	19,5	6	117	1	2	0,2	5,9	1	0	59,00	3,03	212,40	1,82
	Young 2													
	Wardrobe	11	3,5	38,5	2	2	0,2	6,2	1	0	62,00	5,64	223,20	5,80
	Hallway	8	3,5	28	2	2	0,2	5,6	1	0	56,00	7,00	201,60	7,20
	Kitchen/living area	41,5	6	249	3	2	0,2	14,3	1	0	143,00	3,45	514,80	2,07
	Toilet/showers	10,5	3,5	36,75	2	2	0,2	6,1	1	0	61,00	5,81	219,60	5,98
	Room 1	18,5	6	111	1	2	0,2	5,7	1	0	57,00	3,08	205,20	1,85
	Room 2	18,5	6	111	1	2	0,2	5,7	1	0	57,00	3,08	205,20	1,85
	Room 3	16,5	3,5	57,75	1	2	0,2	5,3	1	0	53,00	3,21	190,80	3,30
	Family visit apartment													
	Toilet/shower	7	3,5	24,5	1	2	0,2	3,4	1	0	34,00	4,86	122,40	5,00
	Kitchen/living area	43	5	215	4	2	0,2	16,6	1	0	166,00	3,86	597,60	2,78
	Flex													
	Wardrobe	5,5	3,5	19,25	2	2	0,2	5,1	1	0	51,00	9,27	183,60	9,54
	Technique	5,5	3,5	19,25	1	2	0,2	3,1	1	0	31,00	5,64	111,60	5,80
	Toilet/shower	5,5	3,5	19,25	1	2	0,2	3,1	1	0	31,00	5,64	111,60	5,80
	Kitchen/living area	47,5	5	237,5	2	2	0,2	13,5	1	0	135,00	2,84	486,00	2,05
	Room 1	18	3,5	63	1	2	0,2	5,6	1	0	56,00	3,11	201,60	3,20
	Room 2	18	3,5	63	1	2	0,2	5,6	1	0	56,00	3,11	201,60	3,20
	Kids 1													
	Wardrobe	9	3,5	31,5	2	1,2	0,2	4,2	1	0	42,00	4,67	151,20	4,80
	Toilets/showers	16	3,5	56	2	1,2	0,2	5,6	1	0	56,00	3,50	201,60	3,60
	Living area	20	5	100	4	1,2	0,2	8,8	1	0	88,00	4,40	316,80	3,17
	Room 1	14,5	3,5	50,75	1	1,2	0,2	4,1	1	0	41,00	2,83	147,60	2,91
	Room 2	14,5	3,5	50,75	1	1,2	0,2	4,1	1	0	41,00	2,83	147,60	2,91
	Room 3	14	5	70	1	1,2	0,2	4	1	0	40,00	2,86	144,00	2,06
	Room 4	14	5	70	1	1,2	0,2	4	1	0	40,00	2,86	144,00	2,06
	Technique	6	3,5	21	1	1,2	0,2	2,4	1	0	24,00	4,00	86,40	4,11
	Hallway	16	3,5	56	2	1,2	0,2	5,6	1	0	56,00	3,50	201,60	3,60
	Kids 2													
	Wardrobe	13,5	3,5	47,25	2	1,2	0,2	5,1	1	0	51,00	3,78	183,60	3,89
	Toilets/showers	15,5	3,5	54,25	2	1,2	0,2	5,5	1	0	55,00	3,55	198,00	3,65
	Living area	30	5	150	3	1,2	0,2	9,6	1	0	96,00	3,20	345,60	2,30
	Room 1	12,5	3,5	43,75	1	1,2	0,2	3,7	1	0	37,00	2,96	133,20	3,04
	Room 2	12,5	3,5	43,75	1	1,2	0,2	3,7	1	0	37,00	2,96	133,20	3,04
	Room 3	12,5	3,5	43,75	1	1,2	0,2	3,7	1	0	37,00	2,96	133,20	3,04
	Storage	19,5	3,5	68,25	1	1,2	0,2	5,1	1	0	51,00	2,62	183,60	2,69
	Hallway	8	3,5	28	2	1,2	0,2	4	1	0	40,00	5,00	144,00	5,14

CO2	Room	Floor area	Room height	Room volume	Persons	DS/CEN/CR 1752 p. 26 Pollution per person	DS/CEN/CR 1752 p. 53 Activity	Total pollution	DS/CEN/CR 1752 p. 24 CO2 max in the room	DS/CEN/CR 1752 p. 24 CO2 outdoor air	Airflow	Airflow	Air change
Unit		m^2	m	m^3	Amount		MET	m3/h	m^3/m^3	m^3/m^3	m^3/h	l/s pr m^2	h^-1
Designation				Vr				q	c	ci	Vl	Vl	n
Calculation				m^2*m				pers*(forurening*MET)/1000	*10^-6		q/(c-ci)	m^3/h:3600*1000	Vl/Vr
	Common area												
	Main entrance	10,5	3	31,5	2	19	1	0,038	0,00085	0,00035	76,00	2,01	2,41
	Wardrobe	16,5	3	49,5	2	19	1	0,038	0,00085	0,00035	76,00	1,28	1,54
	Kitchen/dinning area	91	3	273	25	19	2	0,95	0,00085	0,00035	1900,00	5,80	6,96
	Social area	115,5	3	346,5	20	19	1	0,38	0,00085	0,00035	760,00	1,83	2,19
	Toilets	27,5	3	82,5	3	19	1	0,057	0,00085	0,00035	114,00	1,15	1,38
	Technique	12	3	36	1	19	1	0,019	0,00085	0,00035	38,00	0,88	1,06
	Laundry room	20	3	60	1	19	1	0,019	0,00085	0,00035	38,00	0,53	0,63
	Night porters	26	3	78	2	19	0,8	0,0304	0,00085	0,00035	60,80	0,65	0,78
	Toilet/Shower	8	3	24	1	19	1	0,019	0,00085	0,00035	38,00	1,32	1,58
	Activity room	33,5	3	100,5	10	19	1,2	0,228	0,00085	0,00035	456,00	3,78	4,54
	Hallways and niches	182,5	3	547,5	5	19	1	0,095	0,00085	0,00035	190,00	0,29	0,35
	Administration												
	Office 1	11	3,5	38,5	1	19	1,2	0,0228	0,00085	0,00035	45,60	1,15	1,18
	Office 2	11	3,5	38,5	1	19	1,2	0,0228	0,00085	0,00035	45,60	1,15	1,18
	Open office	46	5	230	5	19	1,2	0,114	0,00085	0,00035	228,00	1,38	0,99
	Meeting room	11	3,5	38,5	6	19	1,2	0,1368	0,00085	0,00035	273,60	6,91	7,11
	Kitchen storage	15	3,5	52,5	1	19	2	0,038	0,00085	0,00035	76,00	1,41	1,45
	Toilets	9	3,5	31,5	2	19	1	0,038	0,00085	0,00035	76,00	2,35	2,41
	Showers	5	3,5	17,5	2	19	1,2	0,0456	0,00085	0,00035	91,20	5,07	5,21
	Changing room	5,5	3,5	19,25	2	19	1,2	0,0456	0,00085	0,00035	91,20	4,61	4,74
	Copy room	4	3,5	14	1	19	1	0,019	0,00085	0,00035	38,00	2,64	2,71
	Technique	6,5	3,5	22,75	1	19	1	0,019	0,00085	0,00035	38,00	1,62	1,67
	Hallway	8	3,5	28	2	19	1,2	0,0456	0,00085	0,00035	91,20	3,17	3,26
	Young 1												
	Wardrobe	20	3,5	70	2	19	1,2	0,0456	0,00085	0,00035	91,20	1,27	1,30
	Hallway	12,5	3,5	43,75	2	19	1,2	0,0456	0,00085	0,00035	91,20	2,03	2,08
	Kitchen/living area	47,5	6	285	4	19	2	0,152	0,00085	0,00035	304,00	1,78	1,07
	Technique	14	3,5	49	1	19	1	0,019	0,00085	0,00035	38,00	0,75	0,78
	Toilet/showers	14	3,5	49	2	19	1,2	0,0456	0,00085	0,00035	91,20	1,81	1,86
	Toilets	15	3,5	52,5	2	19	1	0,038	0,00085	0,00035	76,00	1,41	1,45
	Room 1	21,5	6	129	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,39	0,24
	Room 2	24,5	3,5	85,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,34	0,35
	Room 3	20	3,5	70	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,42	0,43
	Room 4	19,5	6	117	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,43	0,26
	Young 2												
	Wardrobe	11	3,5	38,5	2	19	1,2	0,0456	0,00085	0,00035	91,20	2,30	2,37
	Hallway	8	3,5	28	2	19	1,2	0,0456	0,00085	0,00035	91,20	3,17	3,26
	Kitchen/living area	41,5	6	249	3	19	2	0,114	0,00085	0,00035	228,00	1,53	0,92
	Toilet/showers	10,5	3,5	36,75	2	19	1,2	0,0456	0,00085	0,00035	91,20	2,41	2,48
	Room 1	18,5	6	111	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,46	0,27
	Room 2	18,5	6	111	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,46	0,27
	Room 3	16,5	3,5	57,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,51	0,53
	Family visit apartment												
	Toilet/shower	7	3,5	24,5	1	19	1,2	0,0228	0,00085	0,00035	45,60	1,81	1,86
	Kitchen/living area	43	5	215	4	19	2	0,152	0,00085	0,00035	304,00	1,96	1,41
	Flex												
	Wardrobe	5,5	3,5	19,25	2	19	1,2	0,0456	0,00085	0,00035	91,20	4,61	4,74
	Technique	5,5	3,5	19,25	1	19	1	0,019	0,00085	0,00035	38,00	1,92	1,97
	Toilet/shower	5,5	3,5	19,25	1	19	1,2	0,0228	0,00085	0,00035	45,60	2,30	2,37
	Kitchen/living area	47,5	5	237,5	2	19	2	0,076	0,00085	0,00035	152,00	0,89	0,64
	Room 1	18	3,5	63	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,47	0,48
	Room 2	18	3,5	63	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,47	0,48
	Kids 1												
	Wardrobe	9	3,5	31,5	2	19	1,2	0,0456	0,00085	0,00035	91,20	2,81	2,90
	Toilets/showers	16	3,5	56	2	19	1,2	0,0456	0,00085	0,00035	91,20	1,58	1,63
	Living area	20	5	100	4	19	1	0,076	0,00085	0,00035	152,00	2,11	1,52
	Room 1	14,5	3,5	50,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,58	0,60
	Room 2	14,5	3,5	50,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,58	0,60
	Room 3	14	5	70	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,60	0,43
	Room 4	14	5	70	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,60	0,43
	Technique	6	3,5	21	1	19	1	0,019	0,00085	0,00035	38,00	1,76	1,81
	Hallway	16	3,5	56	2	19	1,2	0,0456	0,00085	0,00035	91,20	1,58	1,63
	Kids 2												
	Wardrobe	13,5	3,5	47,25	2	19	1,2	0,0456	0,00085	0,00035	91,20	1,88	1,93
	Toilets/showers	15,5	3,5	54,25	2	19	1,2	0,0456	0,00085	0,00035	91,20	1,63	1,68
	Storage	19,5	3,5	68,25	1	19	1	0,019	0,00085	0,00035	38,00	0,54	0,56
	Living area	30	5	150	3	19	1	0,057	0,00085	0,00035	114,00	1,06	0,76
	Room 1	12,5	3,5	43,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,68	0,69
	Room 2	12,5	3,5	43,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,68	0,69
	Room 3	12,5	3,5	43,75	1	19	0,8	0,0152	0,00085	0,00035	30,40	0,68	0,69
	Hallway	8	3,5	28	2	19	1,2	0,0456	0,00085	0,00035	91,20	3,17	3,26

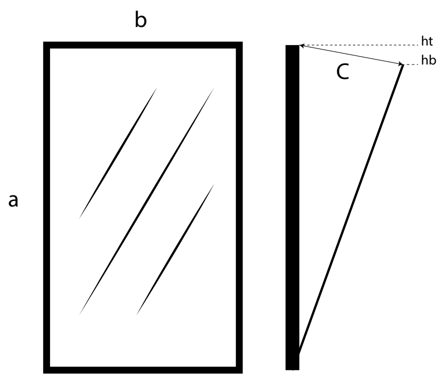
ANNEX 4
Natural ventilation calculation

Here the needed m2 of opening is calculated for the tested room, to gain knowledge about the needed window opening size to ventilate the room and thereby determine the mullions.

INFORMATION ABOUT THE ROOM:

A room is tested in the young department on groundfloor.
Size: 30,8m2, 2,8 ceiling height.
Window opening tested: attached to the bottom, 20 degree opening in the top. Different areas are tested compared to the window arrangement.
Needed air change in the room: 3,41/h

Effective area of the opening:



Effective area = bxc

THERMAL BUOYANCY AND WIND PRESSURE:

$$V_{eff} = \frac{q}{\frac{A}{2}} = \sqrt{C_1 V_{ref}^2 + C_2 (H_t - H_b)(T_i - T_u) + C_3}$$

Where:
q is the total air flow rate [m3/s]
A is the effective area of the opening [m2]
C1 is a dimensionless coefficient depending on the wind [-] = 0,001
C2 is a constant depending on the thermal buoyancy [-] = 0,0035
C3 is a constant depending on wind turbulence [-] = 0,01
Vref is the wind speed at a reference height [m/s] = 6*0,57=3,42m/s
Ht is the height of the top of the opening above the floor [m]
Hb is the height of the bottom of the opening above the floor [m]
Ti is the indoor temperature [K]
Tu is the outdoor temperature [K]

$$q = \frac{A}{2} \sqrt{0{,}001 * V_{ref}^2 + 0{,}0035 (H_t - H_b)(T_i - T_u) + 0{,}01}$$

IF THE DIFFERENCE IN THE INDOOR AND OUTDOOR TEMPERATURE IS 2 DEGREES
Indoor temp = 22 degrees = 295 K
Outdoor temp = 20 degrees = 293 K

Window iteration 1: window area: 1x1m
Effective opening area: 1x0,6=0,6m2

Calculated airflow rate for the window:

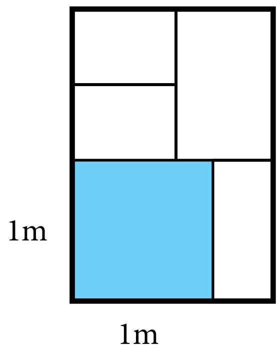
$$q = \frac{0,6}{2}\sqrt{0,001 * 3,42^2 + 0,0035(1,5 - 0,9)(295K - 293K) + 0,01} = 0,048m^3/s$$

$$0,048m^3/s * 3600 = 172,8m^3/h$$

Calculated air change for the window:

$$\frac{172,8m^3/h}{30,8m^2 * 2,8m} = 2,0/h$$

= Not enough.



Window iteration 2: window area: 1,4x1m
Effective opening area: 1x0,85=0,85m2

Calculated airflow rate for the window:

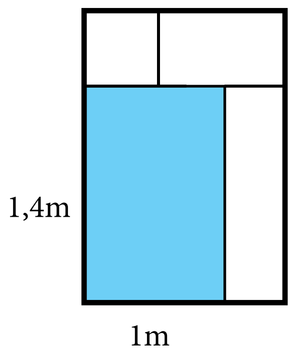
$$q = \frac{0,85}{2}\sqrt{0,001 * 3,42^2 + 0,0035(1,9 - 1,05)(295K - 293K) + 0,01} = 0,07m^3/s$$

$$0,07m^3/s * 3600 = 252m^3/h$$

Calculated air change for the window:

$$\frac{252m^3/h}{30,8m^2 * 2,8m} = 2,9/h$$

= Not enough.



Window iteration 3: window area: 1,6x1,2m
Effective opening area: 1,2x0,96=1,15m2

Calculated airflow rate for the window:

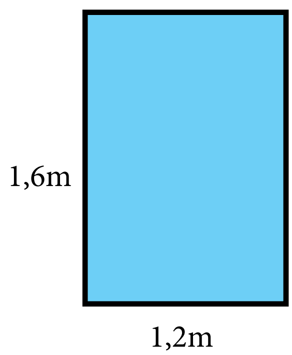
$$q = \frac{1,15}{2}\sqrt{0,001 * 3,42^2 + 0,0035(2,1 - 1,14)(295K - 293K) + 0,01} = 0,097m^3/s$$

$$0,097m^3/s * 3600 = 349,2m^3/h$$

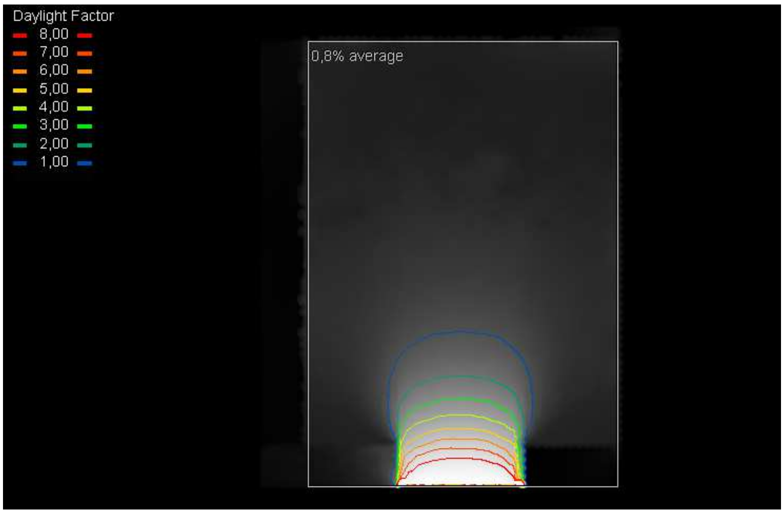
Calculated air change for the window:

$$\frac{349,2m^3/h}{30,8m^2 * 2,8m} = 4,04/h$$

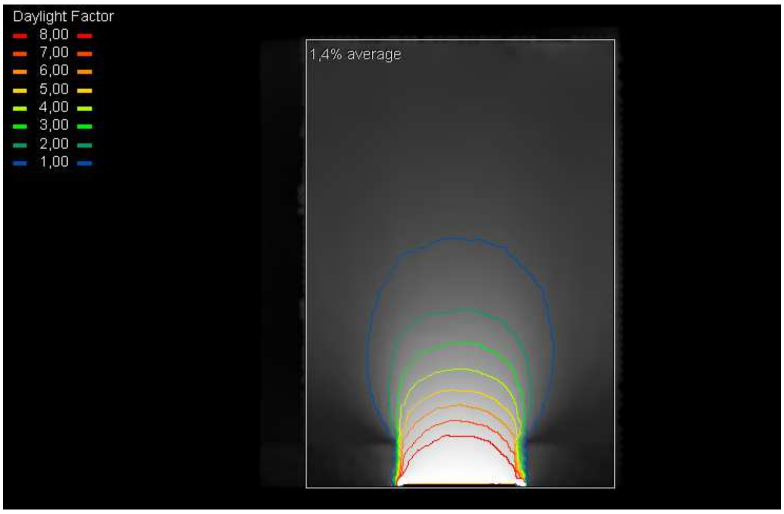
= Enough to ventilate the room



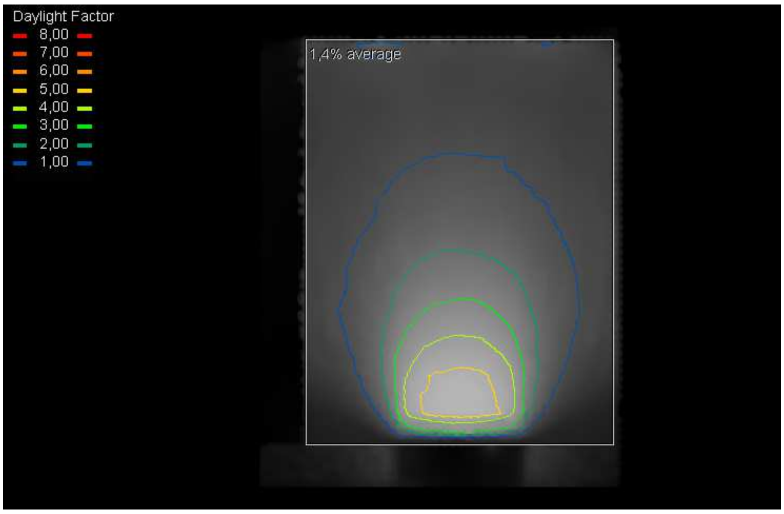
ANNEX 5
Window study



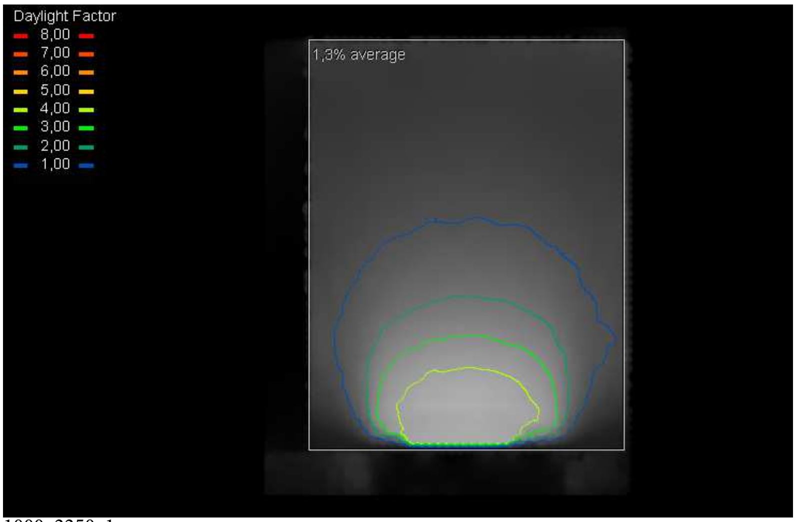
1500x1500, 0m



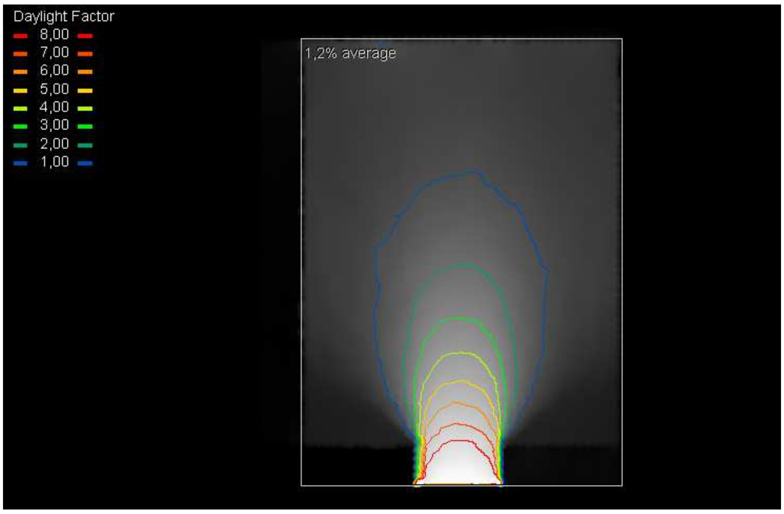
1500x1500, 0,5m



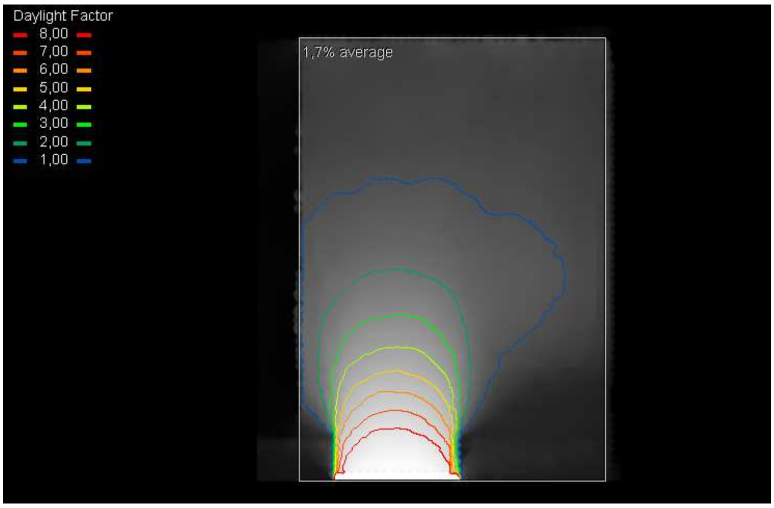
1500x1500, 1m



1000x2250, 1m



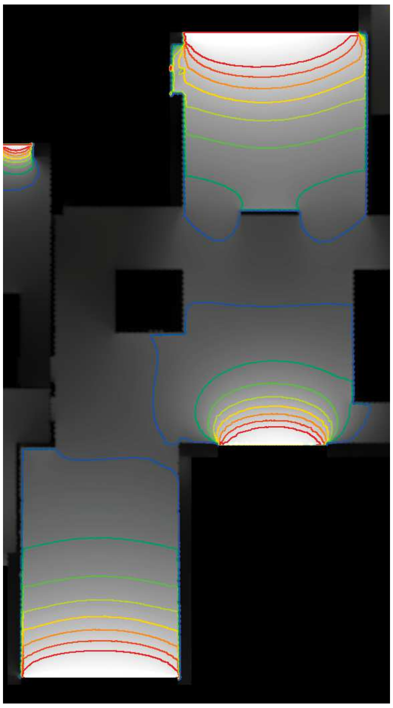
2250x1000, 0,5m

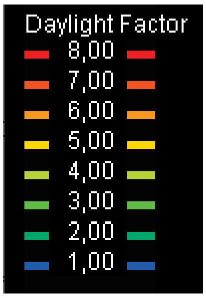


1500x1500, 0,8m + 800x800, 1,8m

Velux simulations

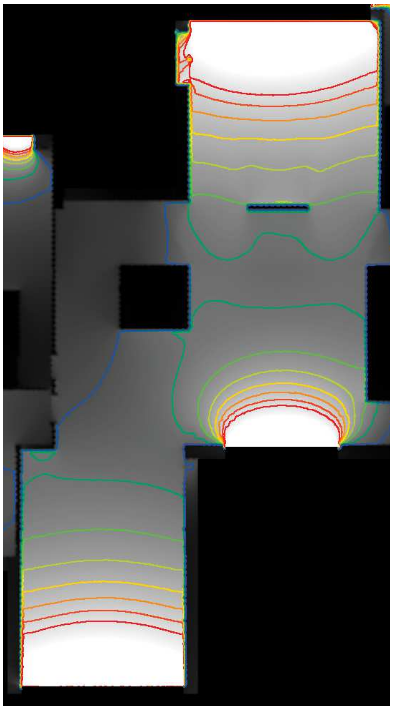
Here the output of the daylight simulations from Velux is listed. The simulations is made to be used as a base for the window placement in the rest of the building, where the amount of needed m2 window area can be used as an assumption for the further window process.

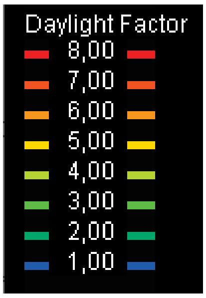




The social area was a challenge because of the rooms dimensions.

Area of windows: 62,7m2
Area of room: 198,2m2
Percent: 62,7/198,2*100=31,6%
Result: There is min. 2% daylight factor in 50% of the rooms towards South-East and North-West, but there is only 2% daylight factor in around 20% of the middle of the building. (eller 40% i opholdszonen).

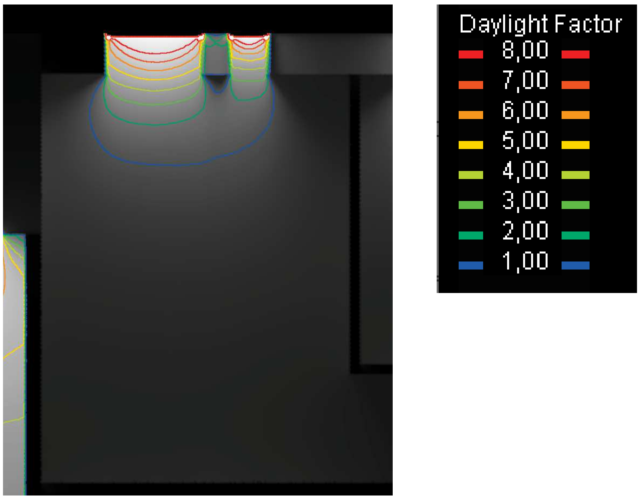




Double height room is done, so the light can enter from above in the middle of the room.

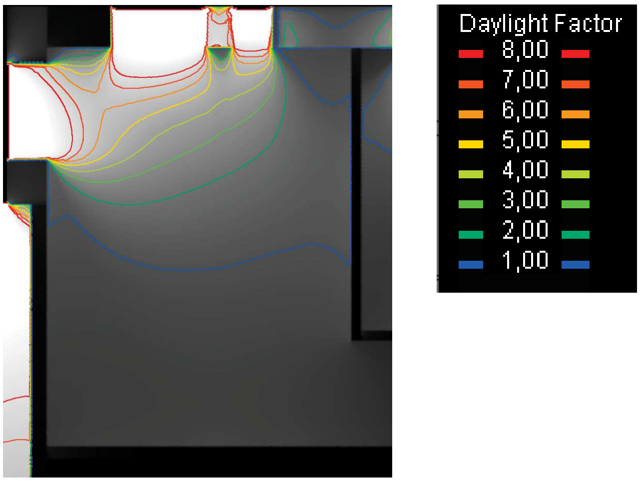
Area of windows: 75m2
Area of room: 198,2m2
Percent: 75/198,2*100=37,8%
Result: now 50% of the middle of the room also has a daylight factor of 2%.

For further improvement, roof windows is added and a tall window at the staircase area.



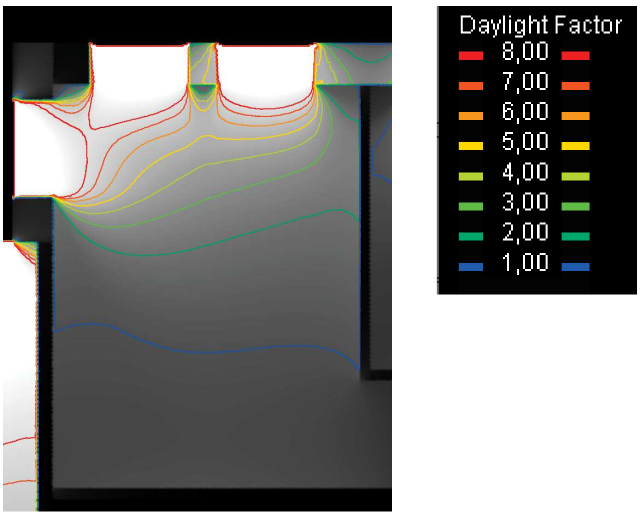
The office area was a challenge because of the rooms dimensions, and the small envelope for windows.

Area of windows: 2,72m2
Area of room: 21,1m2
Percent: 2,72/21,1*100=12,9%
Result: only about 10% of the room is 2%.



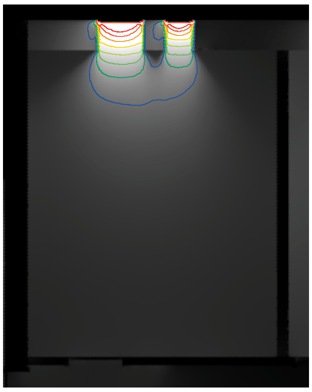
Window added towards South-West and the g-value is increased.

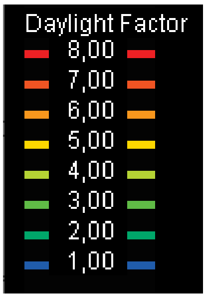
Area of windows: 4,64m2
Area of room: 21,1m2
Percent: 4,64/21,1*100=21,9%
Result: nearly 50% of the room now has a daylight factor at 2%.



Bigger window area added towards North-West.

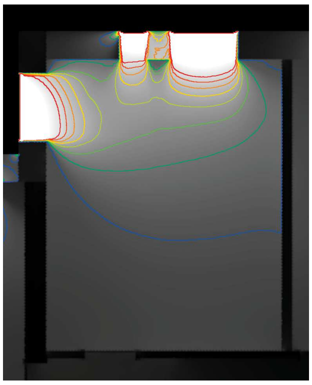
Area of windows: 5,76m2
Area of room: 21,1m2
Percent: 5,76/21,1*100=27,3%
Result: 50% of the room now has a daylight factor at 2%.

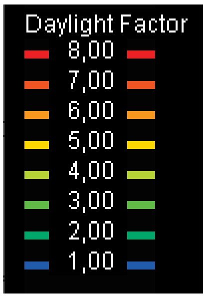




A room was a challenge because of the rooms dimensions, and the small envelope for windows.

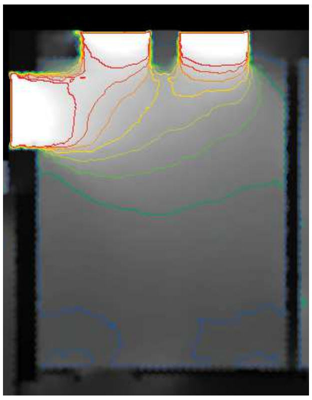
Area of windows: 2,72m2
Area of room: 21,8m2
Percent: 2,72/21,8*100=12,4%
Result: There isn't a daylight factor of at least 2%, for at least 50% of the room.

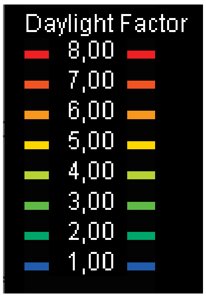




A window is added towards South-West and the g-value is increased.

Area of windows: 4,64m2
Area of room: 21,8m2
Percent: 4,64/21,8*100=21,3%
Result: nearly 50% of the room has 2% daylight factor.



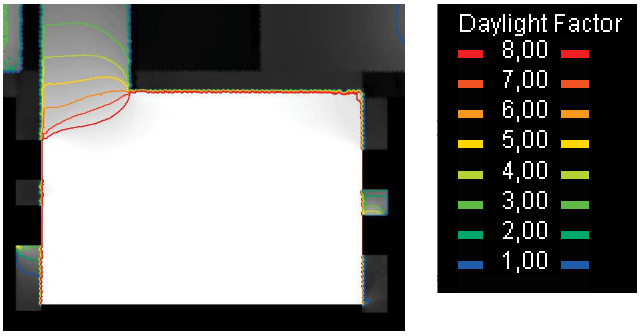


The window area is increased towards North-West.

Area of windows: 5,76
Area of room: 21,8m2
Percent: 5,76/21,8*100=26,4%
Result: now 50% of the room has 2% daylight factor.

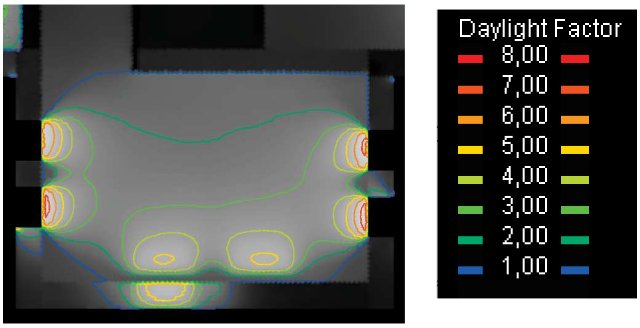
Daylight test for Bsim simulation process

The indoor climate process was done parallel with the daylight simulation, to make sure that the daylight in the room still obtains a good indoor environment. In addition, the indoor climate process results in an integrated shading system, which also is going to affect the daylight.



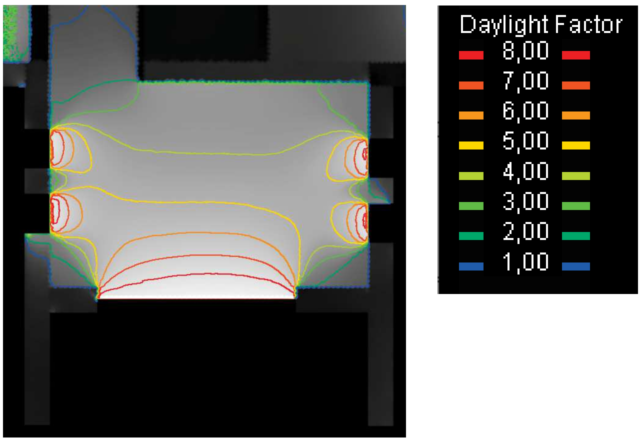
The room was tested for daylight in the different cases as a parrallel iteration to the indoor climate simulations.

Area of windows: 31,62m2
Area of room: 26,4m2
Percent: 31,62/26,4*100=119,7%
Result: There is a daylight factor of 8% in the whole room.



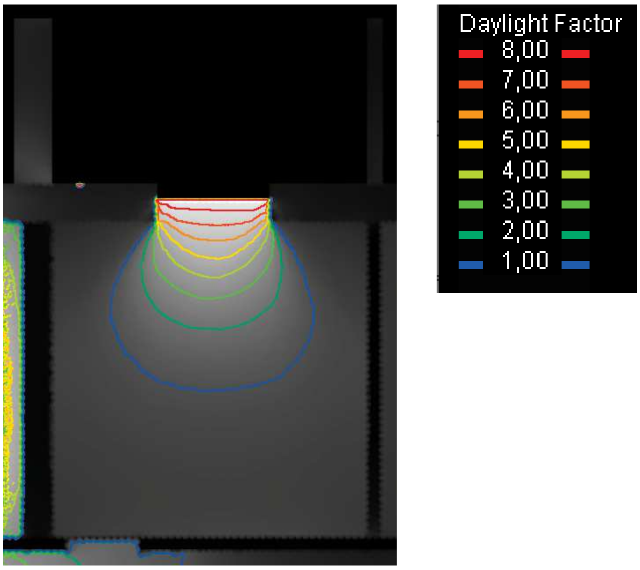
Then it is tested with a 33% window area.

Area of windows: 8,96m2
Area of room: 26,4m2
Percent: 8,96/26,4*100=33,9%
Result: there is a daylight factor of 2% in more than 50% of the room.



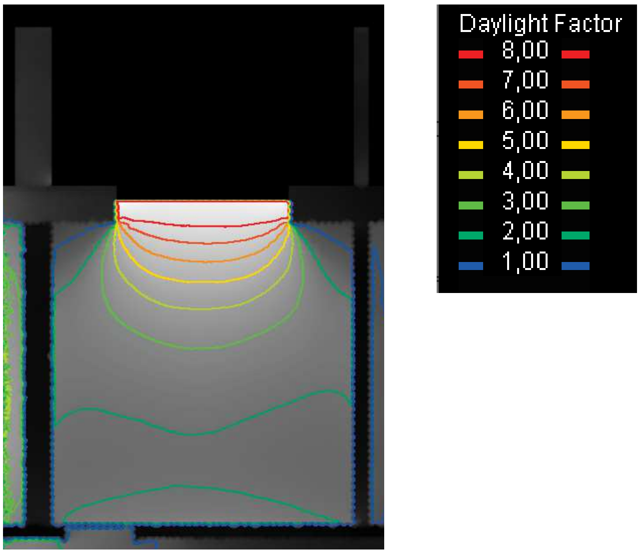
Then it is tested with a 40% window area with an attached terrace which will create shading.

Area of windows: 17,12m2
Area of room: 26,4m2
Percent: 17,12/26,4*100=64,8%
Result: more than 50% of the room has a daylight factor of 2%



Another room was now a challenge because of the rooms dimensions, and the small envelope for windows, and the attached terrace which will create shading.

Area of windows: 3,15m2
Area of room: 17,6m2
Percent: 3,15/17,6*100=17,9%
Result: there is not enough daylight in the room.



The window area and the g-value is both increased.

Area of windows: 5,04m2
Area of room: 17,6m2
Percent: 5,04/17,6*100=28,6%
Result: there is more than 50% of the room with a 2% daylight factor.

ANNEX 6
Be18 results

Nøgletal, kWh/m² år

Renoveringsklasse 2

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
112,2	0,0	112,2
Samlet energibehov		32,3

Renoveringsklasse 1

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
53,6	0,0	53,6
Samlet energibehov		32,3

Energiramme BR 2015 / 2018

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
30,7	0,0	30,7
Samlet energibehov		26,7

Energiramme Byggeri 2020

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
20,0	0,0	20,0
Samlet energibehov		19,9

Bidrag til energibehovet

Varme	28,0
El til bygningsdrift	1,8
Overtemp. i rum	0,0

Netto behov

Rumopvarmning	12,6
Varmt brugsvand	15,3
Køling	0,0

Udvalgte elbehov

Belysning	0,0
Opvarmning af rum	0,0
Opvarmning af vbv	0,1
Varmepumpe	0,0
Ventilatorer	1,6
Pumper	0,1
Køling	0,0
Totalt elforbrug	32,4

Varmetab fra installationer

Rumopvarmning	0,0
Varmt brugsvand	2,2

Ydelse fra særlige kilder

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

Be18 results without PV

Nøgletal, kWh/m² år

Renoveringsklasse 2

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
112,2	0,0	112,2
Samlet energibehov		7,3

Renoveringsklasse 1

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
53,6	0,0	53,6
Samlet energibehov		7,3

Energiramme BR 2015 / 2018

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
30,7	0,0	30,7
Samlet energibehov		1,7

Energiramme Byggeri 2020

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
20,0	0,0	20,0
Samlet energibehov		-1,4

Bidrag til energibehovet

Varme	28,0
El til bygningsdrift	-8,2
Overtemp. i rum	0,0

Netto behov

Rumopvarmning	12,6
Varmt brugsvand	15,3
Køling	0,0

Udvalgte elbehov

Belysning	0,0
Opvarmning af rum	0,0
Opvarmning af vbv	0,1
Varmepumpe	0,0
Ventilatorer	1,6
Pumper	0,1
Køling	0,0
Totalt elforbrug	32,4

Varmetab fra installationer

Rumopvarmning	0,0
Varmt brugsvand	2,2

Ydelse fra særlige kilder

Solvarme	0,0
Varmepumpe	0,0
Solceller	11,9
Vindmøller	0,0

Be18 results with PV

ANNEX 7
PV calculation

The needed area of photovoltaic panels is calculated.

$$Annual\ service\ [kWh] = C * D * E$$

A = Area of the modules

B = module efficiency [%] = 18

C = Installed effect = A*B/100

D = Assessment of system factor = 0,85

E = Insolation [kWh/m2] = 30 degrees towards South-East = 1100

Compared to BE18 results, the wanted annual service is:

Heat: $28{,}0 * 0{,}6 = 16{,}8 kWh/m^2/year$

El. for operation: $1{,}8 * 1{,}8 = 3{,}24 kWh/m^2/year$

Total energy contribution in Br2020: $16{,}8 + 3{,}24 = 20{,}04 kWh/m^2/year$

Total energy contribution for the whole building: $20{,}04 kWh/m^2/year * 1448{,}4 m^2 = 29025{,}9 kWh/year$

$$29025{,}9 = \frac{A * 18}{100} * 0{,}85 * 1100$$

$$A = 172{,}4 m2$$

Area of roofs towards South-East = 192m2

ANNEX 8
U-value

The u-value is calculated for the construction choice and for the chosen construction with facade cladding.

CONCRETE CONSTRUCTION

Homogeneous wall construction

$$\frac{d}{\lambda} = R_{Material\ layer} \qquad R = R_{si} + \sum \frac{d}{\lambda} + R_{se} \qquad U = \frac{1}{R}$$

$$R_{Bricks} = \frac{0{,}108}{0{,}610} = 0{,}18 \qquad R_{Insulation} = \frac{0{,}345}{0{,}034} = 10{,}15 \qquad R_{Concrete} = \frac{0{,}150}{0{,}260} = 0{,}58$$

$$R = 0{,}13 + (0{,}18 + 10{,}15 + 0{,}58) + 0{,}04 = 11{,}08 \qquad U = \frac{1}{11{,}08} = 0{,}09$$

WOOD CONSTRUCTION

Inhomogeneous wall construction

$$\frac{d}{\lambda} = R_{Material\ layer} \qquad \lambda = \frac{A_1 * \lambda_1 + (A_2 - A_1) * \lambda_2}{A_2} \qquad R = R_{si} + \sum \frac{d}{\lambda} + R_{se} \qquad U = \frac{1}{R}$$

$$R_{Bricks} = \frac{0{,}108}{0{,}610} = 0{,}18 \qquad R_{Windplate} = \frac{0{,}009}{0{,}17} = 0{,}05 \qquad \lambda = \frac{45 * 0{,}14 + (445 - 45) * 0{,}034}{445} = 0{,}04$$

$$R_{Insulation} = \frac{0{,}420}{0{,}04} = 10{,}5 \qquad R_{Vapor\ barrier} = \frac{0{,}002}{0{,}17} = 0{,}01 \qquad R_{OSB\ plate} = \frac{0{,}015}{0{,}12} = 0{,}13$$

$$R_{Plasterboard} = \frac{0{,}013}{0{,}25} = 0{,}05 \qquad R = 0{,}13 + (0{,}18 + 0{,}05 + 10{,}5 + 0{,}01 + 0{,}13 + 0{,}05) + 0{,}04 = 11{,}09$$

$$U = \frac{1}{11{,}09} = 0{,}09$$

d = Material thickness [m]

λ = Thermal conductivity [W/mK]

R_{si} = Indoor transmission [m²K/W]

R_{se} = Outdoor transmission [m²K/W]

A = Length of the layer [mm]

U = U-value [W/m²K]

WOOD FACADE

Inhomogeneous wall construction

$$\frac{d}{\lambda} = R_{Material\ layer} \qquad \lambda = \frac{A_1 * \lambda_1 + (A_2 - A_1) * \lambda_2}{A_2} \qquad R = R_{si} + \sum \frac{d}{\lambda} + R_{se} \qquad U = \frac{1}{R}$$

$$R_{Wood} = \frac{0{,}030}{0{,}14} = 0{,}21 \qquad R_{Windplate} = \frac{0{,}009}{0{,}17} = 0{,}05 \qquad \lambda = \frac{45 * 0{,}14 + (445 - 45) * 0{,}034}{445} = 0{,}04$$

$$R_{Insulation} = \frac{0{,}420}{0{,}04} = 10{,}5 \qquad R_{Vapor\ barrier} = \frac{0{,}002}{0{,}17} = 0{,}01 \qquad R_{OSB\ plate} = \frac{0{,}015}{0{,}12} = 0{,}13$$

$$R_{Plasterboard} = \frac{0{,}013}{0{,}25} = 0{,}05 \qquad R = 0{,}13 + (0{,}21 + 0{,}05 + 10{,}5 + 0{,}01 + 0{,}13 + 0{,}05) + 0{,}04 = 11{,}12$$

$$U = \frac{1}{11{,}12} = 0{,}09$$

ANNEX 9
Materials

The materials has been investigated to gain knowledge about the pros and cons. All materials can be recycled but have various degrees of environmental impact over reproduction. For example, concrete and bricks are environmentally easier to recycle, whereas iron, steel and glass require a high energy consumption. A number of the materials, including steel, glass and concrete, require more energy to produce compared to brick and wood. The materials can be sustainable solutions, but it depends on the way the material is used and how the building interacts with it.

A number of materials are being reviewed in order to illustrate the advantages and disadvantages, as well as their sustainable qualities. The analysis focuses on typically used building materials, and their different characteristic qualities.

	Pros	Cons
Concrete	• Concrete has a long durability, which is a sustainable quality. • Concrete can be reused by that it can be crushed and used as road filling or gravel (casting mix). If the origin of the material is known, the composition and thereby strength be determined. It can then be determined whether the concrete has enough strength to work as a load-bearing building part. • For easy reuse, as mounting system can be used, where steel connections is used in stead of casting the concrete on site [IDEKATALOG, 2018].	• The amount of energy for the production of cement, and hence concrete, is large. Concrete accounts for 4-5% of the world's total CO2 emissions. It's used great energy amounts on construction sites to dry the concrete, which is expensive and environmentally harmful.
Glass	• Glass is an easily accessible material and has long durability. • Glass can be recycled directly by recycling or remelting. This reduces accumulation of building waste [velfac.dk, 2019].	• High energy consumption is required due to the demanding production form.
Brick	• The brick is durable and can be recycled. In this way reduction of building waste is reduced, so the brick is an excellent, sustainable solution. • Recycled bricks have a low energy consumption for production. • For more easy recycling process, lime mortar can be used. Then it is more easy to seperate the bricks.	• 24% of the brick is mortar, which is not reusable. • There is an environmental impact in the form of energy consumption during excavation of clay, when transporting them.

Steel	• Iron and steel are the most recycled materials and are the easiest to recycle. This reduces the accumulation of building waste. • Not much material is required in relation to the overall design.	• Steel has challenges in relation to the overall sustainability assessment, as it requires a large amount of energy production and recycling. • Energy is used to melt steel for recycling. In addition, there are expenses in relation to fire protection of steel structures.
Wood	• Wood is generally a cheap and easy available material, but this depends on the specific choice of wood type and its maintenance. • Wood absorbs CO2 from the atmosphere as it grows, thereby helping to clean the air. • Wood can be abolished by fire, which reduces accumulation of building waste.	• Wood durability is partially poor and untreated wood lasts 10-20 years [mst.dk, 2019].
Spruce	• Spruce is traditionally used in Denmark for facade cladding. • The most common tree species in Denmark today. Grows fast.	• White yellowish colour. • Good moisture repellent properties - high service life (up to 60 years). [trae.dk, 2019]
Pine	• Pine is suitable for facade cladding. • High durability and moisture resistant. • Grows in Denmark.	• White yellowish colour. [danskeboligarkitekter.dk, 2019]
Oak	• Oak is an exclusive and expensive facade material. • One of the species with the highst durability and moisture resistance.	• Grows in Denmark. • Grey yellowish colour which turns brownish. [danskeboligarkitekter.dk, 2019]
Siberian Larch	• Siberian Larch is used for facades in Denmark, but it is a slow-growing species. • One of the species with the highst durability and moisture resistance.	• Larch is not naturally occurring in Denmark. • Yellowish colour. [danskeboligarkitekter.dk, 2019]
Cedar	• Cedar wood is an expensive but often used facade material. • High durability and moisture resistant.	• Grows in Denmark (Kæmpethuja). • White yellowish colour. Turs to a grey colour. [danskeboligarkitekter.dk, 2019]
Green roof	• Thermal qualities: cooling in summer and 'warm' in winter. [Klimatilpasning.dk, 2019] • Reduces the amount of water to the drainage system.	• Roof lifespan increases. [Aalborg.dk, 2019]