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LCA and adaptability studies of an Attefalls house for Norway and Sweden

Master´s thesis

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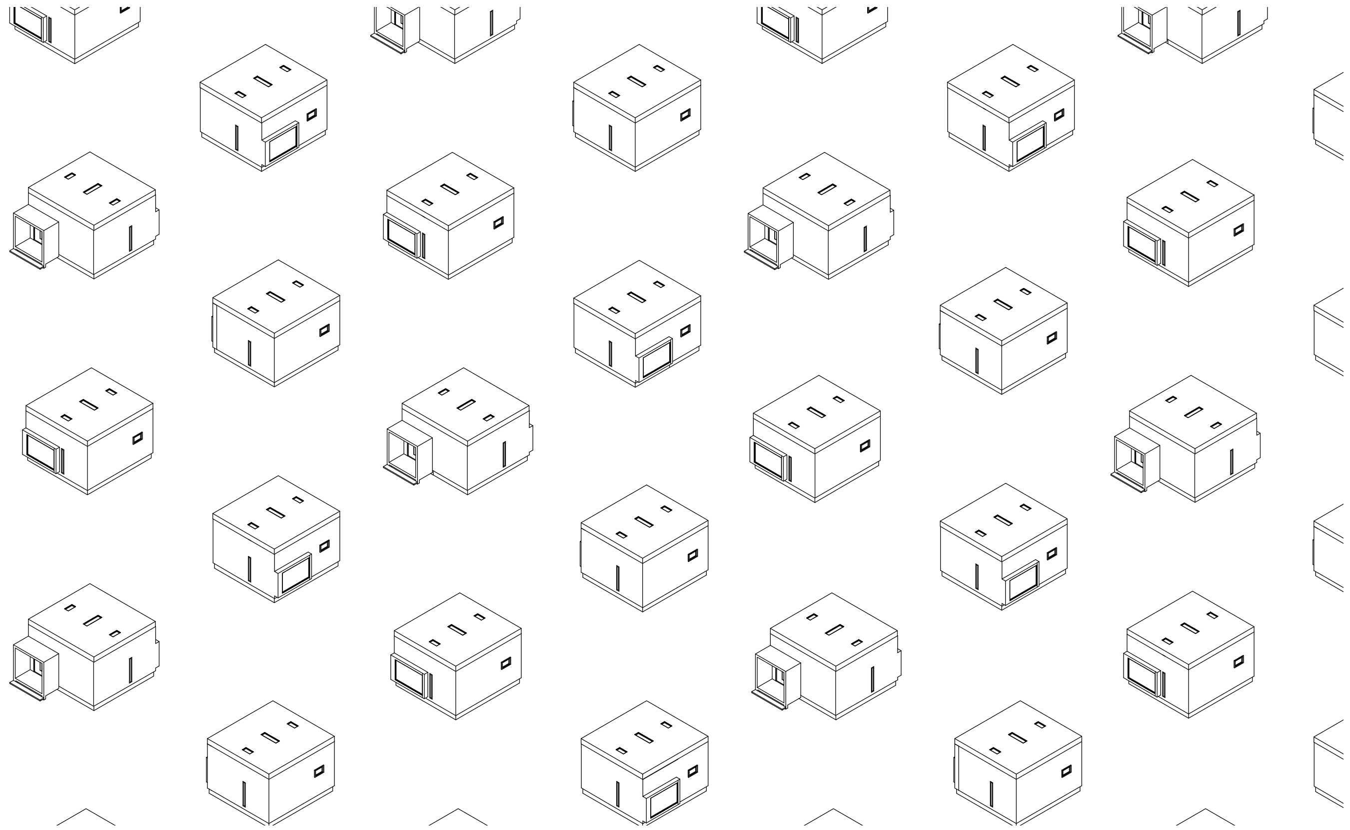

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LCA AND ADAPTABILITY STUDIES OF AN ATTEFALLS HOUSE FOR NORWAY AND SWEDEN

ABSTRACT

This project involves discovering approaches for a project within a zone other than a site. The goal was to propose an adaptable Attefalls house concept, minimizing the environmental impact that a building can generate. This has been done by testing the adaptable concept in three different sites in Norway and Sweden. The climate data from the sites was analysed and compared, to help during design process of the adaptable concept. The adaptable strategies were tested with simulation tools.

Life Cycle Assessment calculations were done during design process and at the end, to minimize the embodied emissions, replacement of materials, and operation of the building. Simulation tools were also used to provide the building operation results.

ACKNOWLEDGEMENTS

Firstly, we would like to express our sincere gratitude to our supervisors Professor Inger Andresen and Anne Grete Hestnes for the continuous support during this whole process, and immense knowledge. They guided us through the hole process of this Master thesis. We could not have imagined having better mentors. To the Norwegian University of Science and Technology, for give us, international students, this opportunity.

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ABBREVIATION

VA - View Access
ASE - Annual Solar Exposure
LCA - Life Cycle Assessment
EPW - Energy Plus Weather File
EPD - Environmental Product Declaration
PV - Photovoltaic
Cfc - Continental Climate (Temperate without dry season, cold summer)
Dfc - Cold continental Climate (without dry season, cold summer)
ET - Polar Tundra
FSC - Forest Stewardship Council
PVA - Portion of space with more than 3% view in percentage
PASE - Portion of space with more than 250 hours of annual solar exposure above 1000 lux in percentage
PVMS - Portion of space with view, but minimum sun in percentage
LEED - Leadership in Energy and Environmental Design
AM - Ante Meridiem (past midday)
SC - Scale
BBR - Boverkets Byggregler (Swedish building requirements)
WFC – Wood frame constriction
MWC – Massive wood construction
SC – Slim construction
PPM – Parts per million
kWh – Kilo watt hours
PPD – Predicted percentage dissatisfied
PMV – Predicted mean vote
GHG – Greenhouse gas
TEK - Byggteknisk forskrift 8 (Norwegian Building code)

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INTRODUCTION

STATISTICS

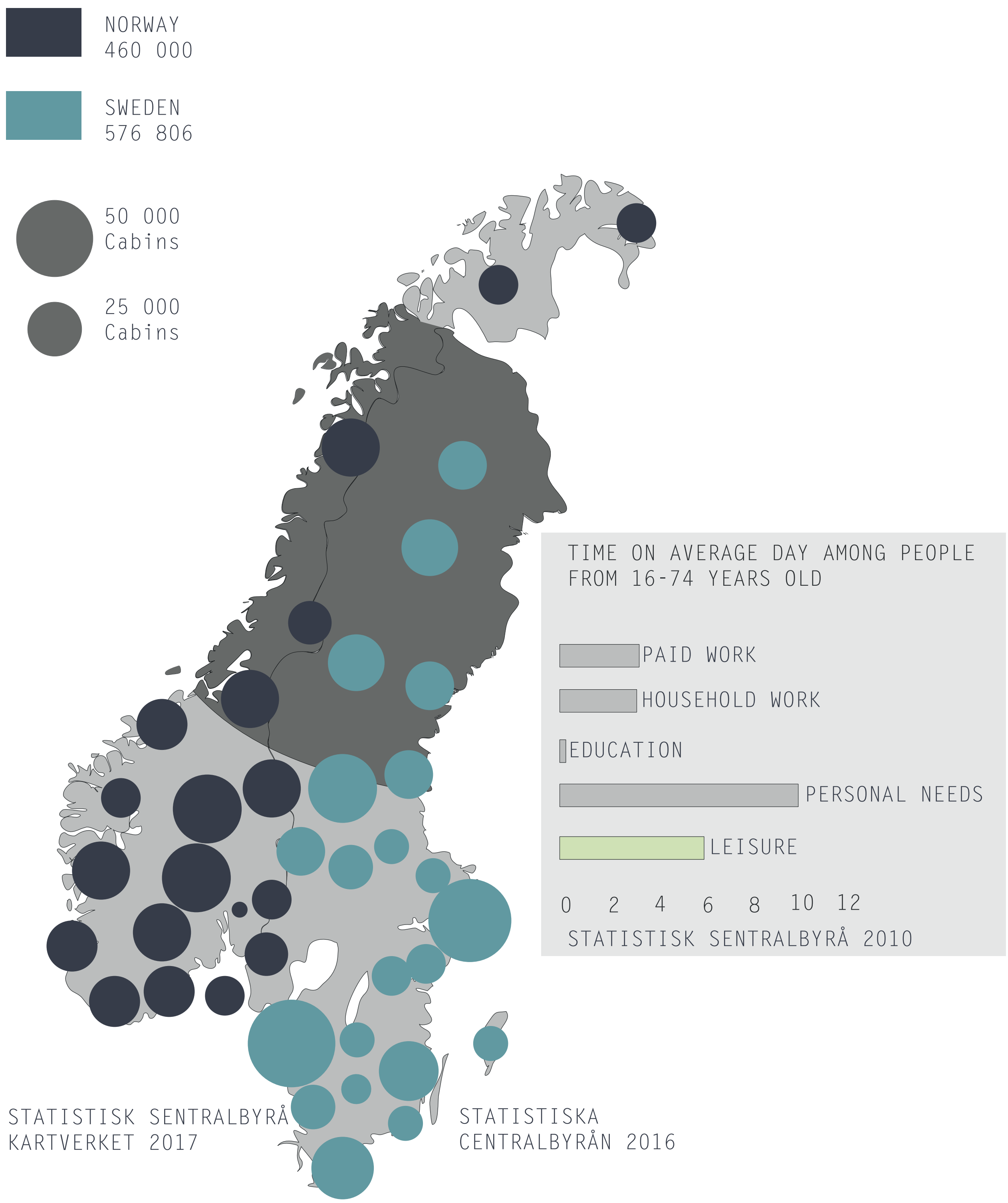


Figure 1: Concentration of cabins in Norway and Sweden and Time average spent [Statistics from Sentralbyrå and Centralbyrån]

According to the statistics on time spend on an average day among people from 16 to 74 years, Norwegians spend a great amount of time spent in leisure. Many chose to be closer to the nature. Swedes also enjoy to spend time in the nature and to have a second property away from the city life. The cabins, are numerous and are spread throughout both countries with bigger concentration in the south part, as we can see on the map.

Comparing the total of 1 million cabins to the population, in 2016, approximately 6% of the population in Sweden had a cabin. In 2017, approximately 8% of the population in Norway had a cabin. Cabins are so popular that in 2010, Norway's statistics on building material and housing, shows that in 45 municipalities there was more cabins than full-year housing.

This paper propose to offer a sustainable cabin for those who wish to be in contact with the nature, minimizing the environment impact caused by the construction materials and operation of the building. The proposal is a simple compact cabin living with adaptable concept, meaning that the building can be adapted to different sites. To do so the construction method, materials and climate were taken into consideration during the design development.

The choice of the zone for this proposal is the northern part of Sweden and central part of Norway, marked on the map. The criteria for the zone was to be were there is less concentration of cabins according to statistics and harsher climate.

In order to test our concept and to help during design process, we chose three different locations to analyse the climate data, simulate View Access (VA) opposed to Annual Solar Exposure (ASE) and to test view towards scenery on site, with focus on reducing embodied emission embodied emissions and operation phase.

| NORWAY

To legally build houses in Norway the regulations listed in the Norwegian building codes TEK17 needs to be followed.

In Norway the definitions for cabins are different depending on the size of the cabin. A cabin under 70 m2 does not need to follow all the regulations that a cabin with 70 - 150 m2 needs to follow.

The energy regulations in Unit 14 in TEK 17 needs to be followed when building a 70 – 150 m2 cabin, but when building a cabin smaller than 70 m2 only paragraph §14-1, §14-3 and §14-4 needs to be followed. The paragraphs are listed below.

§14-1: The building need to have defensible energy consumption.

§14-3: minimum dimensions of wood external wall shall be 150 mm, minimum U-value for roof shall be 0,18, minimum U-value for ground slab toward foundation or air shall be 0,18 and for windows and doors included frame minimum U-value shall be 1,2. The leakage rate at 50 Pa pressure difference (N50) air exchange per hour, shall be min 6.

§14-3 it is not allowed to heat the cabin with fossil fuel.

If a cabin smaller than 70 m2 is expanded to a building bigger then 70 m2, then the exceptions no longer applies.

(Byggteknisk forskrift ,2018)

| SWEDEN

To legally build houses in Sweden the regulations listed in the Swedish building regulations (BBR) needs to be followed. The regulations are different for different types of buildings based on the intended purpose of the building, there are for example stricter regulations for building a permanent residence than for a cabin.

The definition for a cabin is a building that is not intended to be a permanent residence and that are just used for a certain period of the year.

Cabins does not need to follow the energy requirements that are required from BBR in Sweden for newly produced single-family houses, and cabins does not need to be adapted for people that are physically disabled.

Apart from that, all the regulations regarding the construction and structure which ensures the buildings strength and moisture resistance are almost the same as for a permanent residence and needs to be followed. The difference lays in that a cabins lifetime is differently dimensioned, where as a permanent residence must be dimensioned for a lifetime of min. 50 years and a cabin only has to be dimensioned for 20-25 years.

If the cabin later is converted to a permanent residence, it needs to be reported in to the municipality. The exceptions from the BBR then no longer applies and the cabin needs to be upgraded accordingly to meet the regulations for a permanent residence.

If the cabin later will change to be a permanent resident that needs to be announce to the municipality and the exceptions no longer applies.

(Boverket, 2008)

(Bärtås, 2018)

WHAT IS ATTEFAULLS HOUSE

The Attefalls house is a building concept developed in Sweden by the Swedish building regulations, to make it easier to build a complementing residential in Sweden.

The Attefalls house is intended to be a complementary residential to an existing single or two-family house but the house can be built to fulfil different purposes such as for example an outhouse, garage, storage, greenhouse, sauna, guest-house etc.

The building regulations are less strict for an Attefalls house than for a permanent Residential building, but depending on which purpose the house will have, the house needs to be built according to different construction and building regulations from Boverket and BBR. The following regulations is independent of the building purpose and must always be followed when constructing an Attefalls house

- The Attefalls house needs to be a complementary house to an already existing single or two-family house.
- The Attefalls house must be built at the same site as the existing single or two-family house.
- The total gross floor area has the limit of 25 m2.
- The maximum height of the Attefalls house can not exceed 4 meters to the ridge.
- No building permit is required, but a written building request needs to be sent in to the building authorities if the request is approved, a notice of start-up is given, and the house can be constructed. If the request is rejected, the decision can be appealed.
- The Attefalls house can not be built closer than 4,5 meters from the property line without consent from the neighbours affected.
- In Sweden most shorelines are protected by the shoreline act according to the environmental legislation, therefore a special permit is required if the house is to be constructed within 100 meters from the shore.

(Boverket, 2008)

Images source: https://attefallsverket.se/attefallshus/classicserien/classic2c/

Figure 2: Examples of Attefalls house Classic 2C [Attefallsverket]

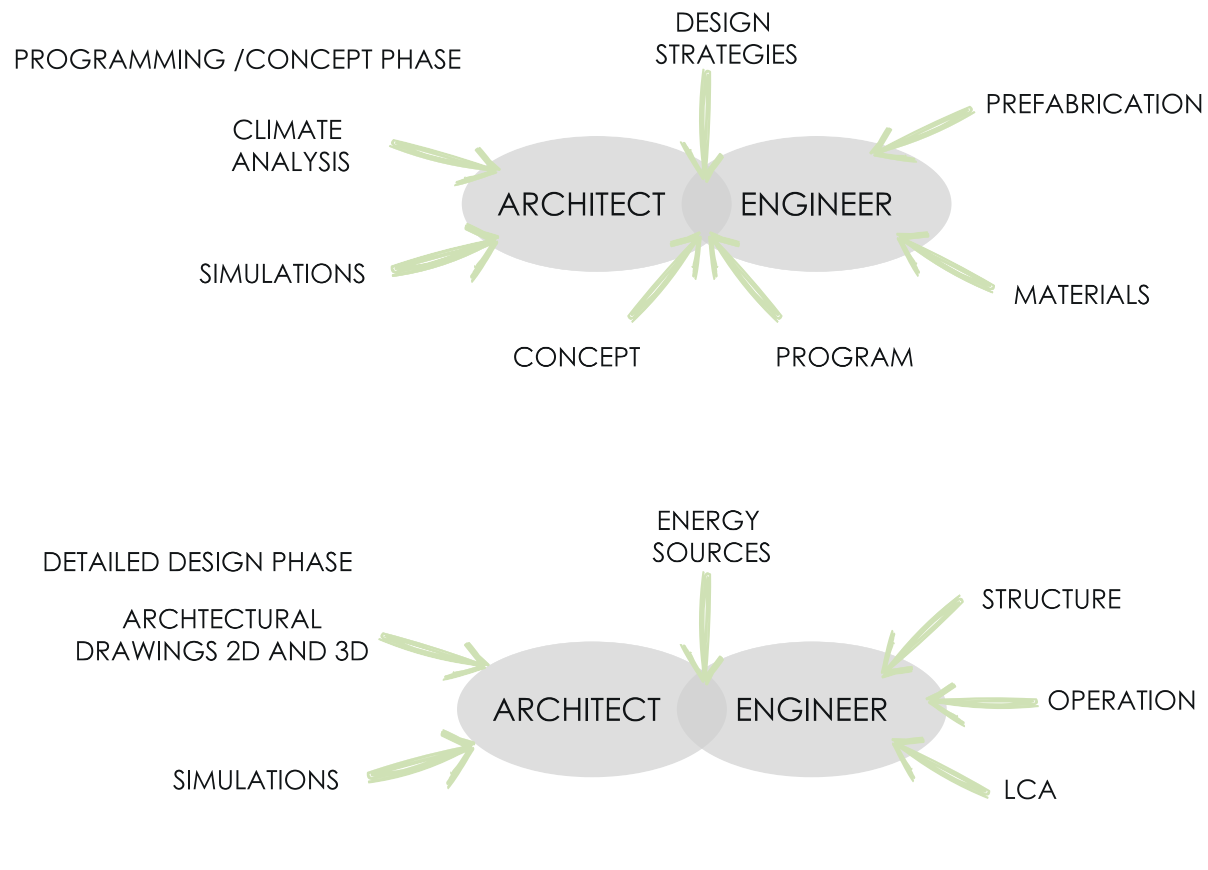


Figure 3: Integrated design team diagram

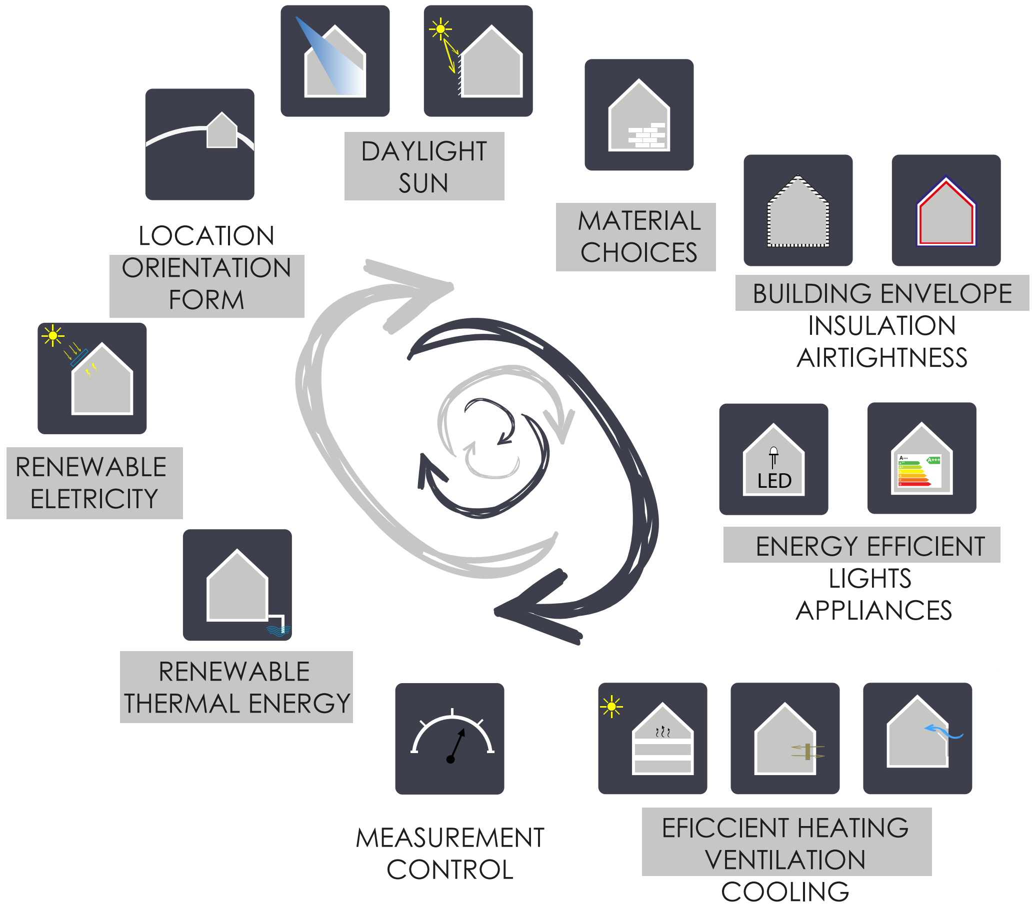


Figure 4: Boundary conditions [ZEB BOOK]

The integrated energy design team is composed by an architect and an engineer. During design stage, there was separate tasks and combined tasks. The climate analysis, simulations, case studies, and site analysis, were executed by the architect. The engineer was focused on researching about construction methods and materials locally sourced. Together, both the architect and the engineer, decided upon program, design strategies and concept.

During detailed phase, the architect focused on architectural drawings both 2D and 3D. The energy sources was a combine decision and the engineer was working with operational energy, Life Cycle Assessment (LCA) and structure of the project.

The decisions taken during the processes attempted to follow the boundary conditions suggested by the book Zero emission buildings[2] as demonstrated above and Attefalls house regulations.

The idea was to try to integrate into the design, the orientation, form, daylight sun, material choices, building envelope, energy efficiency, efficient heating, ventilation, renewable thermal energy and electricity. Measurement control was least relevant for this project, as well airtightness and cooling.

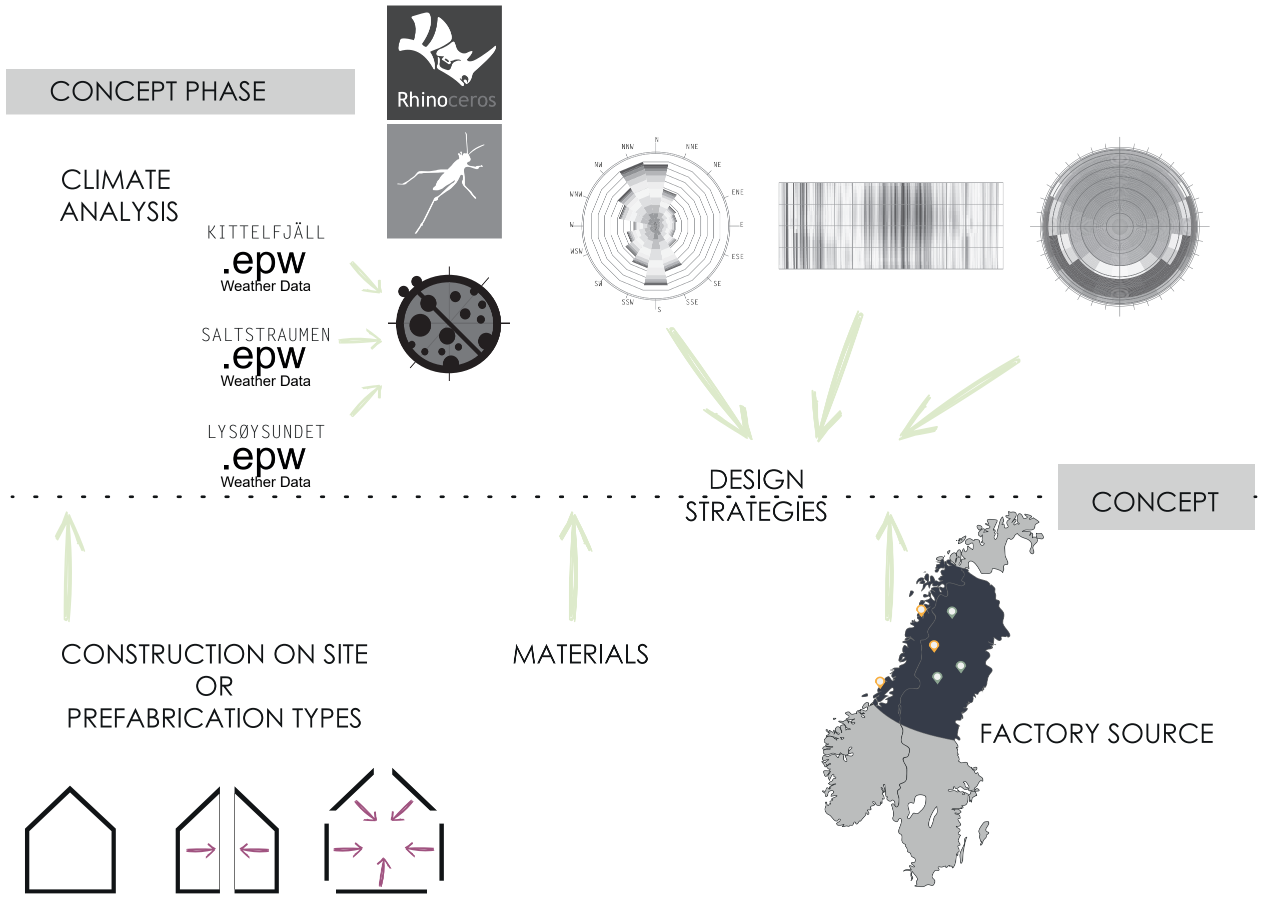


Figure 5: Method during concept phase

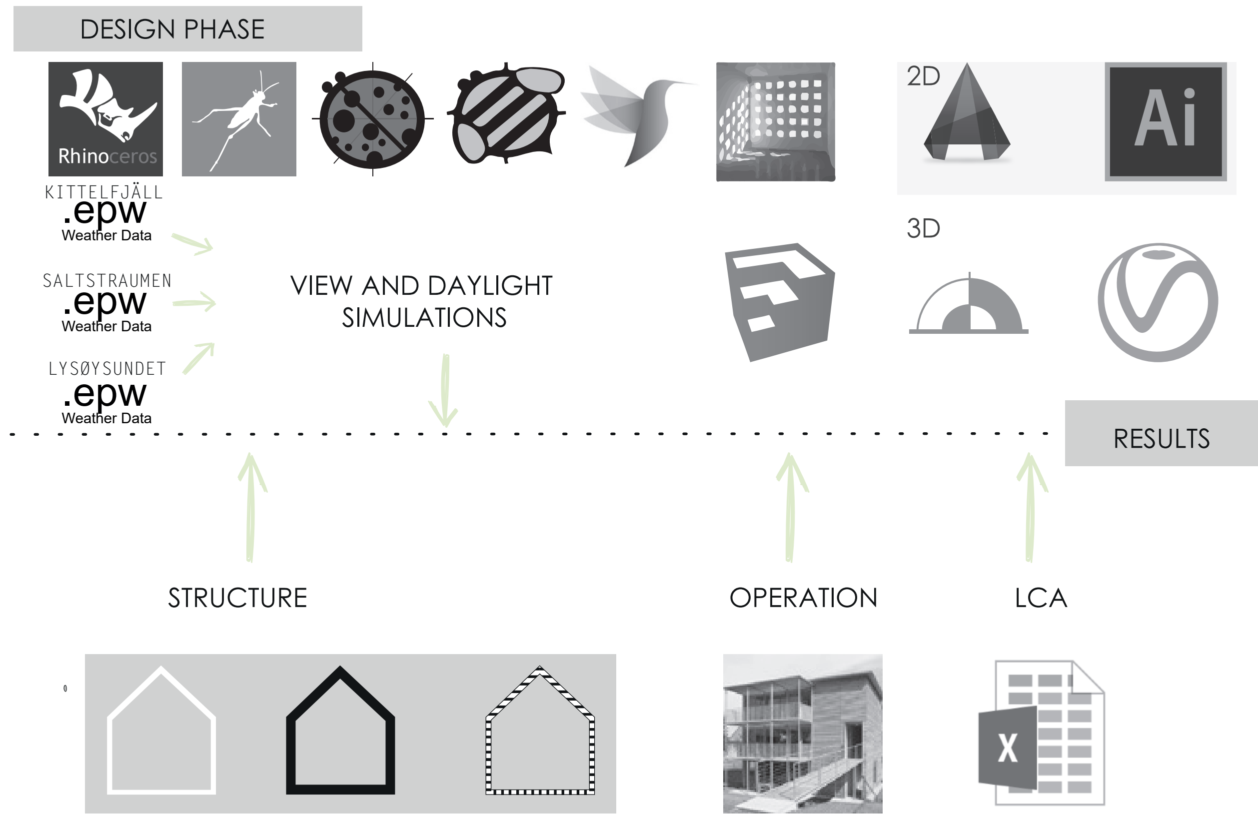


Figure 6: Method during design phase

The methods used for this research-based project during concept phase, was to collect Energy Plus Weather File (EPW) sourced by Meteonorm Version 7.x from 2005, and analyse the climate behaviour from Kittelfjäll, Saltstraumen and Lysøysund.

The climate data was extract by Rhino 5 and Grasshopper in combination with the Ladybug tools and Ecotect.

For the construction phase, it was conducted a research about construction on site, pre-fabrication and its types. The reason for that was to get an understanding on which option is a best fit for the project. Also, materials and prefabricated factories were searched during this stage.

During design phase, parametric simulations for VA, ASE, daylight and glare, were conducted using Rhino, Lands Design, Grasshopper, Ladybug, Honeybee, Colibri, Radiance and Design Explorer. AutoCAD and Illustrator were used for the architectural drawings in 2D. Rhino, Sketch-up and V-ray, were used for the architectural drawings in 3D.

To calculate operational energy consumption, the software used was SIMIEN. The LCA of the materials were calculated by using Environmental Product Declaration (EPD), based on proximity to the zone, lower emissions and design orientated. The embodied emissions and operation emissions were calculated in Excel.

BUILDING PROGRAM

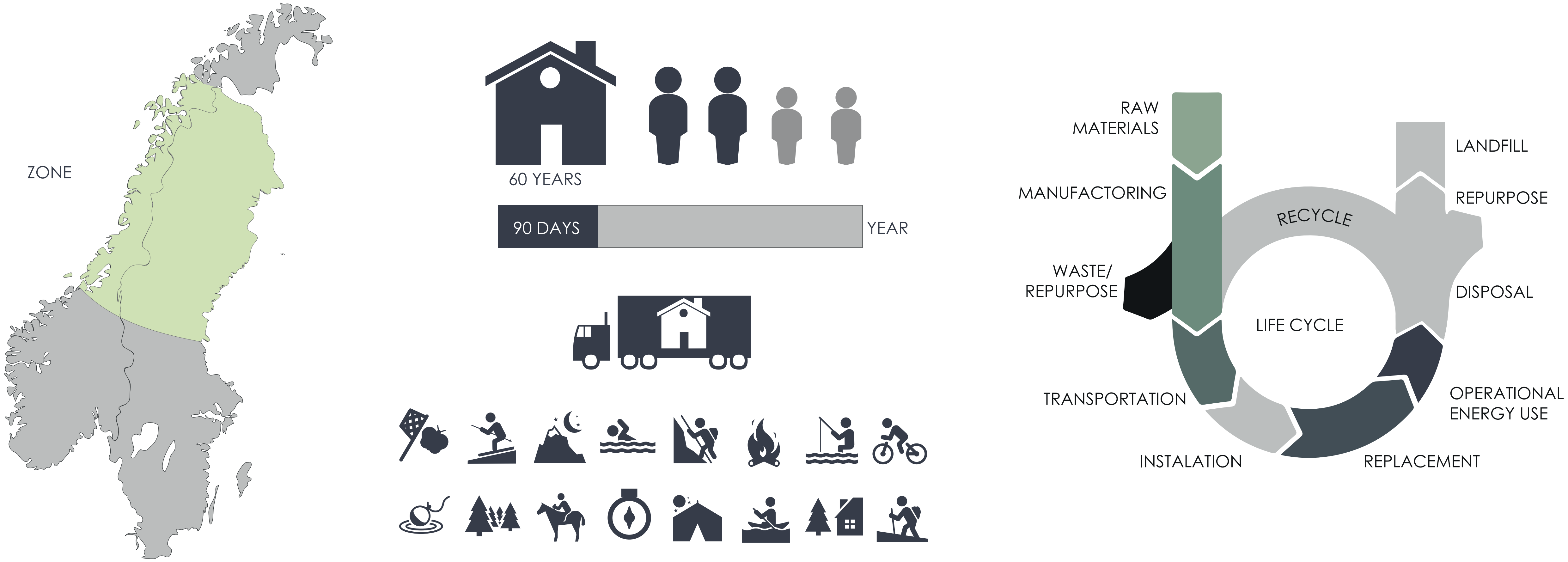


Figure 7: Project program

The program was determined for the zone marked above. The cabin was design to host from two up to four people. The occupancy of this cabin is of 90 days with a 60 years life time.

The cabin compact shape, needs to be of low maintenance to allow the users to spend most of their time enjoying the nature. The size restriction was based on the Attefalls house requirements. The cabin should to be easy to relocate to different locations with different nature setting.

To achieve the home feeling in the compact shape, the cabin must offer a warm and cosy atmosphere.

Being in contact with the nature is important as well as to reduce the environmental impacts. To achieve that, this project must reduce embodied emissions on the Life Cycle of the building. The reduction is also occur during replacement and operational energy use of the cabin.

CLIMATE ANALYSIS

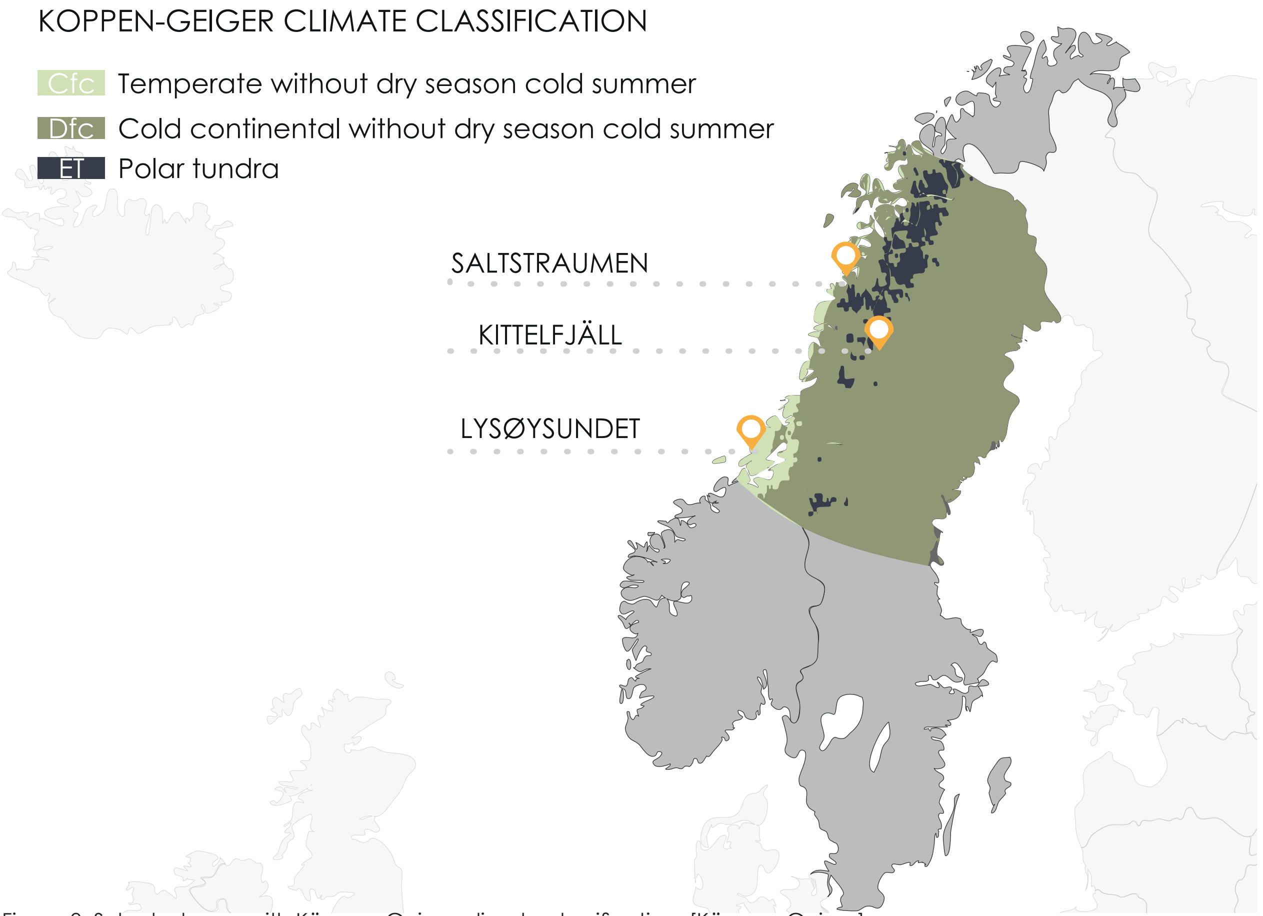


Figure 8: Selected zone with Köppen-Geiger climate classification [Köppen-Geiger]

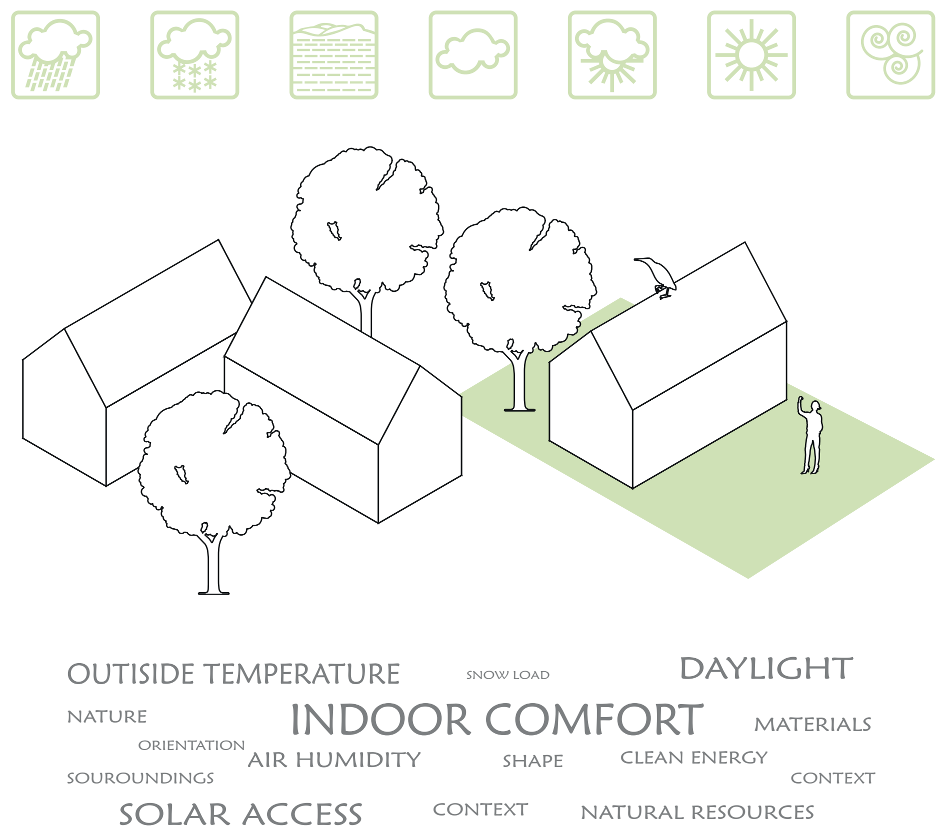


Figure 9: Climate design drivers

| KOPPEN-GEIGER WITHIN THE ZONE

The zone of the project has manly three of the Köppen-Geiger classified zones, as shown above. Cfc is classified as temperate without dry season and cold summer, as shown in light green, Dfc is classified with cold continental without dry season and cold summer, marked in dark green, and ET is classified as polar tundra, marked in dark blue, with extreme temperatures, relative wet and dry seasons.

Both Saltstraumen and Kittelfjäll are located on Dfc, but close to ET as well, and Lysøysund is located on Cfc.

| CLIMATE DESIGN DRIVER

The locations are exposed to different climate zones. The climate information is crucial to design a sustainable building. Since the project does not have a definite site, climate analysis started with comparing the climate data from Kittelfjäll, Saltstraumen and Lysøysund, with the goal of creating a project that adapts to different climate, scenery and topography scenarios.

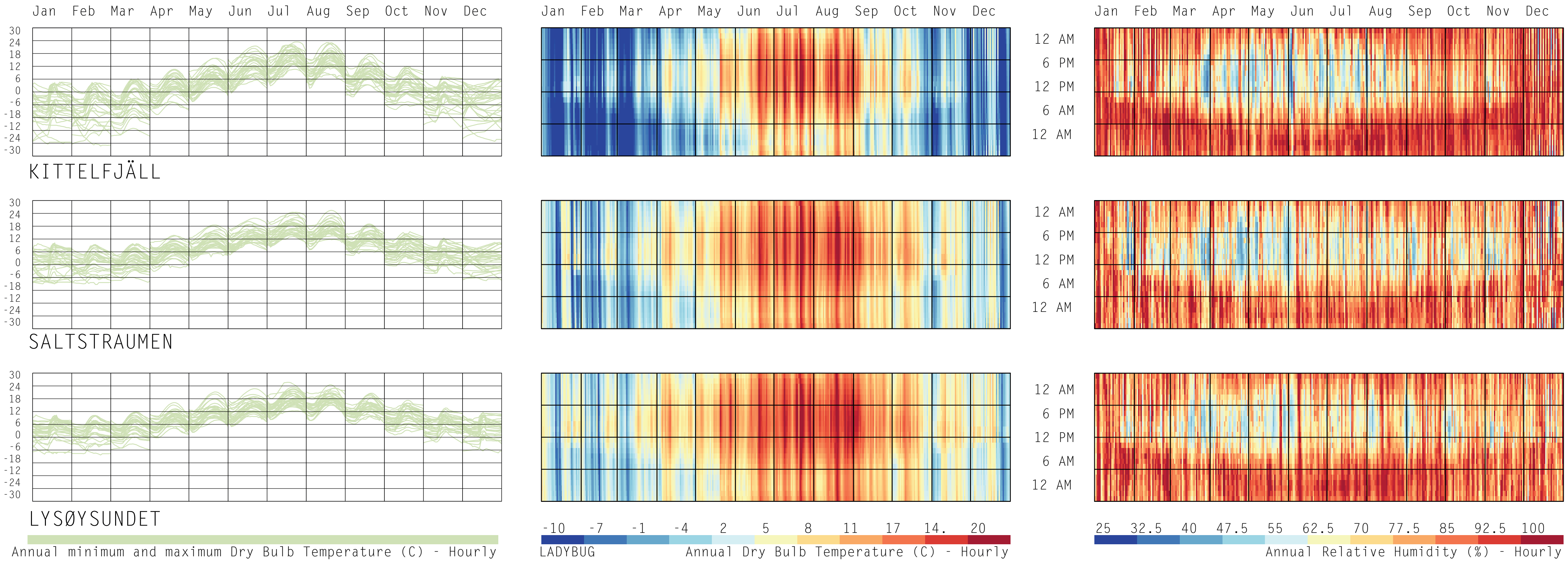


Figure 10: Temperature and relative humidity comparative [Ladybug tools and Meteonorm 2005]

The air temperatures on the sites varies from a minimum of -26 ° C to -9 ° C and maximum of 21 ° C to 24 ° C. Kittelfjäll has the coldest temperature among the sites, during the winter. In the summer, the air temperature has a similar range as the other sites.

Using the colour map to compare the temperatures with same low-bound and high-bound air temperature, we can see that Kittelfjäll has colder temperatures throughout the year.

Heat and cooling demands can be directly influenced by the outside air temperature. Based on this data we can assume that the heating demand would be higher in Kittelfjäll compared to the other three locations, considering that all of them would have the same building envelope.

The indoor comfort is also influenced by the relative humidity. In all the three locations the results are similar on the colour map. The driest periods are concentrated during the day time and we can also observe that evenings and early mornings are the periods with most relative humidity.

This project intent to use natural ventilation, which will also affect the air humidity. This means that whenever the air is to dry indoors, or too warm, the users can open the windows for the comfort to be re-established.

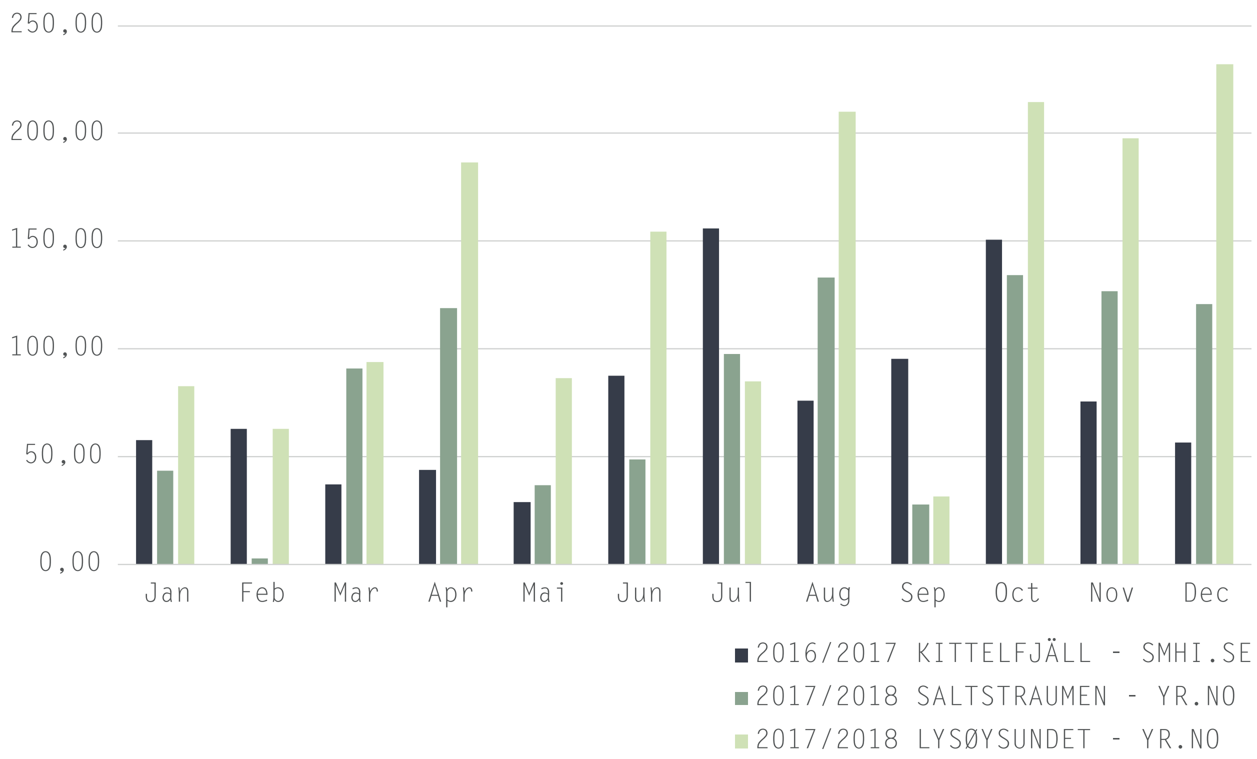


Figure 11: Precipitation comparative [SMHI.SE and YR.NO]

| PRECIPITATION

Lysøysund has the highest precipitation average. In second place is Saltstraumen, followed by Kittelfjäll. The precipitation readings had different source and year.

One of the project's challenges is to adapt to all kinds of scenarios, including those affected by the precipitation. Things such as cloudy days and snow loads, can obstruct the PV's reducing energy production. In each case the energy productivity might be different.

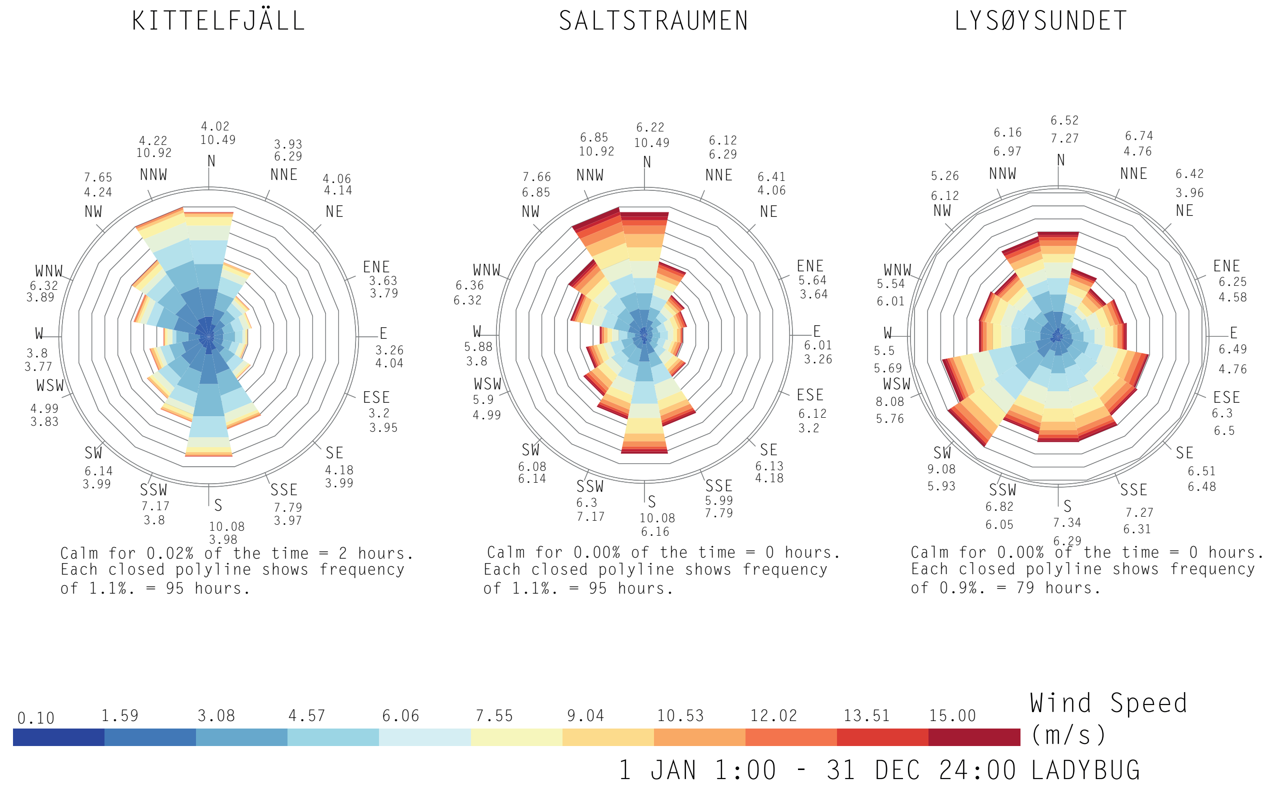


Figure 12: Prevailing wind comparative [Ladybug tools and Meteonorm 2005]

| WIND

This climate data was generated by Meteonorm 2005, and it is uncertain if the wind data is accurate.

The prevailing wind for Kittelfjäll and Saltstraumen are similar in this data. For these locations, the summer wind blows from south. During winter the prevailing wind blows from north and north west. In Lysøysund the summer wind blows from north and north west and during winter in south west.

Context such as trees, neighbouring buildings, ant topography can affect drastically on wind direction and speed. The intention is to use cross natural ventilation that could work for all sites.

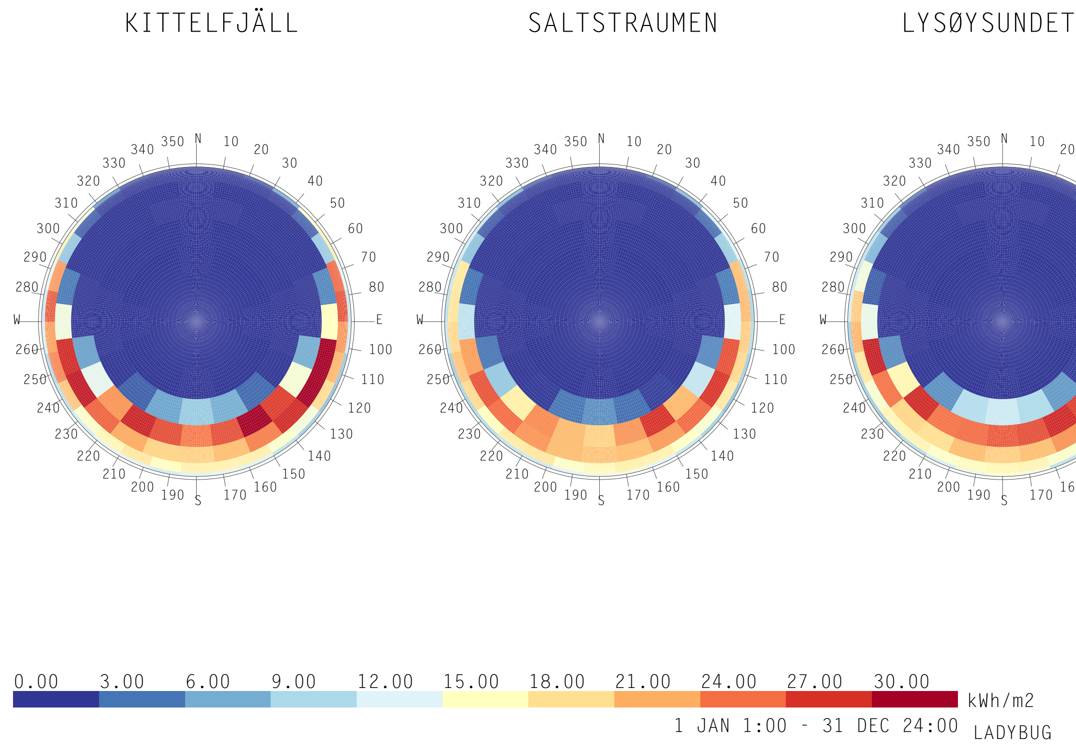


Figure 13: Direct solar radiation comparative[Ladybug tools and Meteonorm 2005]

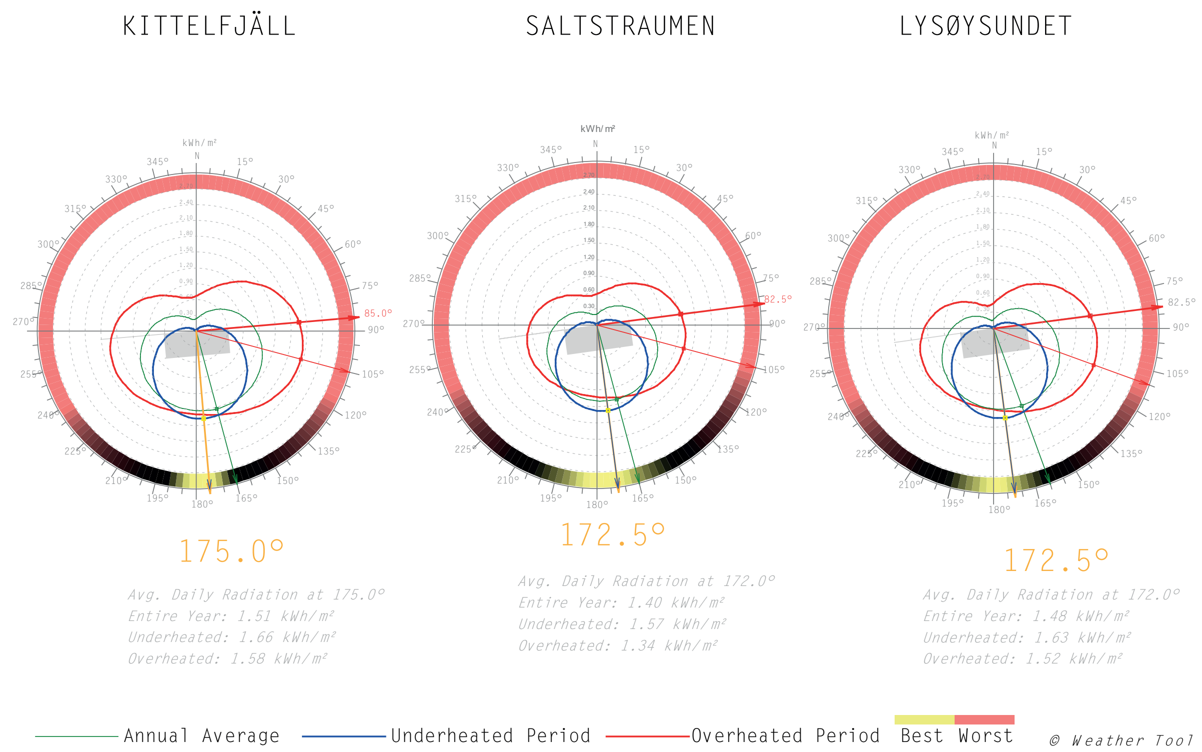


Figure 14: Optimum orientation comparative [Ecotect and Meteonorm 2005]

| DIRECT RADIATION

The direct solar radiation on the sky dome is slightly different in all cases. The highest solar radiation for Kittelfjäll is in the south east and south west, during summer months. Saltstraumen shows the highest at a 155°. In Lysøysund the highest is at 109° between summer and autumn. All locations present similar and uniform radiation levels from autumn towards winter.

This information helps us to understand in were the solar radiation is stronger on the sky level.

| OPTIMUM ORIENTATION

The optimum orientation is almost the same for the three locations, only Kittelfjäll has a 2.5° difference from the others.

The optimum orientation suggest the best orientation for the PV's. For this project they should be installed on same orientation to provide better energy production. In case the PV are position on optimum orientation, based on the direct radiation, we can assume that the difference in energy production must be small, although it is important to further investigate the PV production for each case.

CONSTRUCTION OPTIONS

This research was made in order to find information about prefabricated wood constructions and if it is possible to reduce the energy use by prefabrication buildings or not.

This research is based on published reports about prefabrication with topic: prefabrication method, prefabricated design, greenhouse gas emissions between off-site prefabrication and conventional construction methods, Life-cycle energy analysis of prefabricated building components and so on.

The published research reports have been looking into different materials, where steel -, concrete-, and wood constructions are mostly researched. The locations of the research projects are made in China, Hong Kong, Australia, United Kingdom, Estonia, USA and Scandinavia.

| PREFABRICATED BUILDINGS

Every year a huge amount of demolition waste is generated by the construction industry all over the world. In order to reduce and minimize the construction waste both the architects, engineers and constructors need to collaborate through all the phases in a housing project; choice of construction method, material selection, transport distances, design process and also the end of life phase has to be carefully chosen and planned for. The most efficient way to reduce and to minimize the construction waste is already in the design phase and the way to look at reusing and recycling of construction materials.

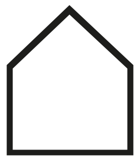
In a study looking into the percentage of waste from public house projects and percentage of waste from private residential buildings, it shows that the percentage of waste is higher in the private residential buildings.

There are several potential solutions for reducing construction waste: by balance cut and fill in excavation, modular design system, prefabricate: external wall panels, kitchen, bathroom, internal wall system, door set, false ceiling and pre-cast: floor slab, staircase, ramp and wall claddings. It is necessary to understand the input of the design decisions with respect to construction waste and the potential to save construction materials. (A.N. Baldwin, 2007)

There are different ways on how to prefabricate buildings. The constructions methods can be divided into three categories: volumetric modular building, comprehensive prefabrication and semi-prefabrication. Volumetric modular building is when an entire building is produced in a factory. Comprehensive prefabrication when all building elements or modules are independently manufactured in the factory and then fixed together on site. Semi-prefabrication is when some elements of the building are cast in situ on site while the remainder adopts factory-built components or units.

Trade	Material	Percentage wastage public housing projects	Percentage wastage private residential buildings
Concrete	Concrete	3–5%	4–5%
Formwork	Timber board	5%	15%
Reinforcement	Steel bars	3–5%	1–8%
Masonry	Brick and block	6%	4–8%
Dry wall	Fine aggregate	5%	6–10%
Wall screeding	Ready-mix cement	7%	4–20%
Floor screeding	Ready-mix cement	1%	4–20%
Wall plastering	Plaster	2%	4–20%
Ceiling plastering	Plaster	2%	4–20%
Floor tiling	Tiles	6%	4–10%
Wall tiling	Tiles	8%	4–10%
Installation of bathroom fitting	Sanitary fitting	2%	1–5%
Installation of kitchen joinery	Kitchen joinery	1%	1–5%

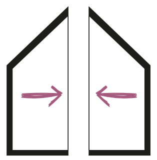
Figure 15: Percentages wastage from public housing projects and private residential buildings [Chao Mao, 2012]



VOLUME

Volumetric modular building refers to an entire building produced in a factory.

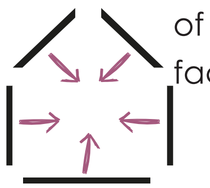
MODULES OT ELEMENTS



In comprehensive pre-fabrication, all building elements or modules are independently manufactured in the factory and then fixed together on-site.

ELEMENTS

Semi-prefabrication is a construction method where some elements of the building are cast in situ on-site while the remainder adopts factory-built components or units.



(Chao Mao, 2012)

Figure 16: Prefabricated types [Chao Mao, 2012]

In a study at the Chongqing and Hong Kong Polytechnic University of a semi-prefabricated construction process looking into embodied emissions of building materials, transportation of; building materials, construction waste and soil and prefabricated components, operation of equipment, and construction techniques. It was shown that semi-prefabrication method produces less greenhouse gas (GHG) emissions/m2 compare to a conventional construction, it also showed that the building materials stood for the biggest portion of the emissions. It was concluded in the study that the CO2 emissions from the construction phase could be reduced by as much as 30 % only by a careful selection of materials with low environmental impact.

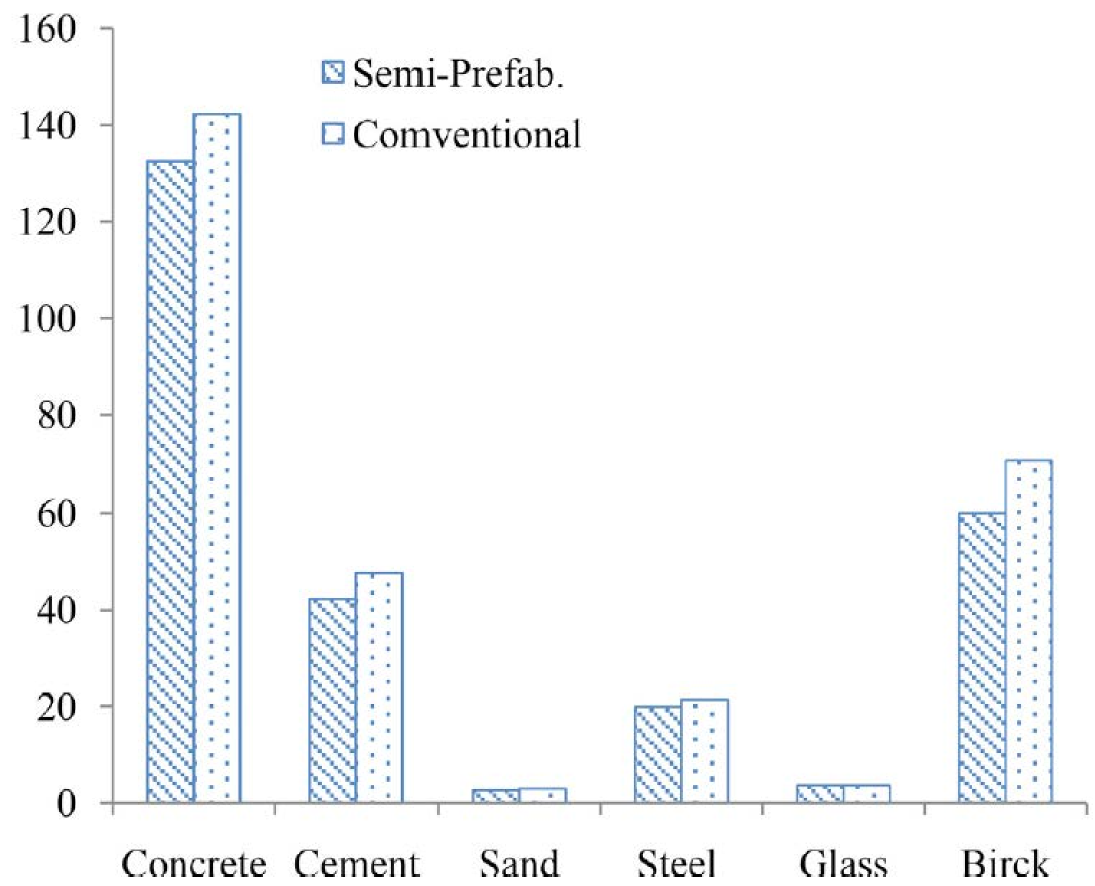


Figure 17: GHG emission from different materials in semi-prefab construction method and conventional construction metho [Chao Mao, 2012]

Another study made at the Chongqing Hong Kong Polytechnic University showed that there is a significant potential of saving energy by reducing waste and recycle materials in the construction process. The study showed that by choosing prefabricate modules it makes it easier to recycle waste and the recycling process alone could achieve 16%-24% energy reduction. It was also shown that waste reduction and high-quality control could save 4%-14% of the total life-cycle energy consumption. (Jingke Hong, 2015) The energy savings from waste reduction and maintenance account for 4%-14% of the total embodied energy consumption. (Jingke Hong, 2015)

The study also looked into the building material timber, it was shown that waste from timber by conventional construction was between 4%-23% and by prefabrication between 0,6%-12%. (Jingke Hong, 2015) The waste that is produced from prefabricated modules made by wood, can be collected and can be converted into wood chips, bark and chips can then be sold to; paper companies, biofuel companies, district heating plants and chipboard industry. (Agneta Falk, 2014)

When building a house with prefabricated modules the construction time is often reduced. By making prefabrication in a factory it lowers the risk of theft and damage at the construction site. This will reduce the transport of new unexpected materials that needs to be ordered because of damage or if it is missing. (Jeffrey Molavi, 2016) In general, the quality of prefabricated modules can be better because it is easier to control the modules during the process and before they leave the factory. Most of the damage occurring in the construction phase is moisture-related due to precipitation, this is something that can be avoided in the factory. The safety for the workers during the construction phase is often higher in the factory since each site is unique with new conditions and new risks on every new site.

Construction of most of the building elements in a factory will lower the noise from a site construction as well as reduce the time the neighbors will be exposed to it. (Agneta Falk, 2014) The construction site will also be cleaner if prefabricated modules is used since there is less materials on the site. (Svensson, 2008)

Prefabricating modules generally saves energy and reduces the emissions, but it needs a more detailed preparatory work. It demands a more accurate planning and a high detail level on the construction drawings before production, since all the construction elements are prefabricated, the accuracy must be at a very high level in order to avoid construction faults on the site. It is also an inflexible method with regards to late changes, since a substantial and detailed planning is done before the construction of the modules and the opportunity for changes during the construction process at the site is very limited. It can result in less flexible floor planning, since the measurements of the modules are fixed. (Johanna Elfström, 2013)

Transport limitations is something that needs to be considered when prefabricating modules. There can be regulations for transportation on roads with regards to the weight and dimensions of the load, it can also be heavy lifting at the construction site, which can require cranes. This can limit the design options for the prefabricated modules. (Agneta Falk, 2014) When the prefabricated modules will be put together on site the work on the site needs to be performed accordingly to avoid challenges regarding the jointing assembly of the modules. If the modules are not jointed together properly it can result in more thermal bridges, heat losses and an increased material demand. (Svensson, 2008)

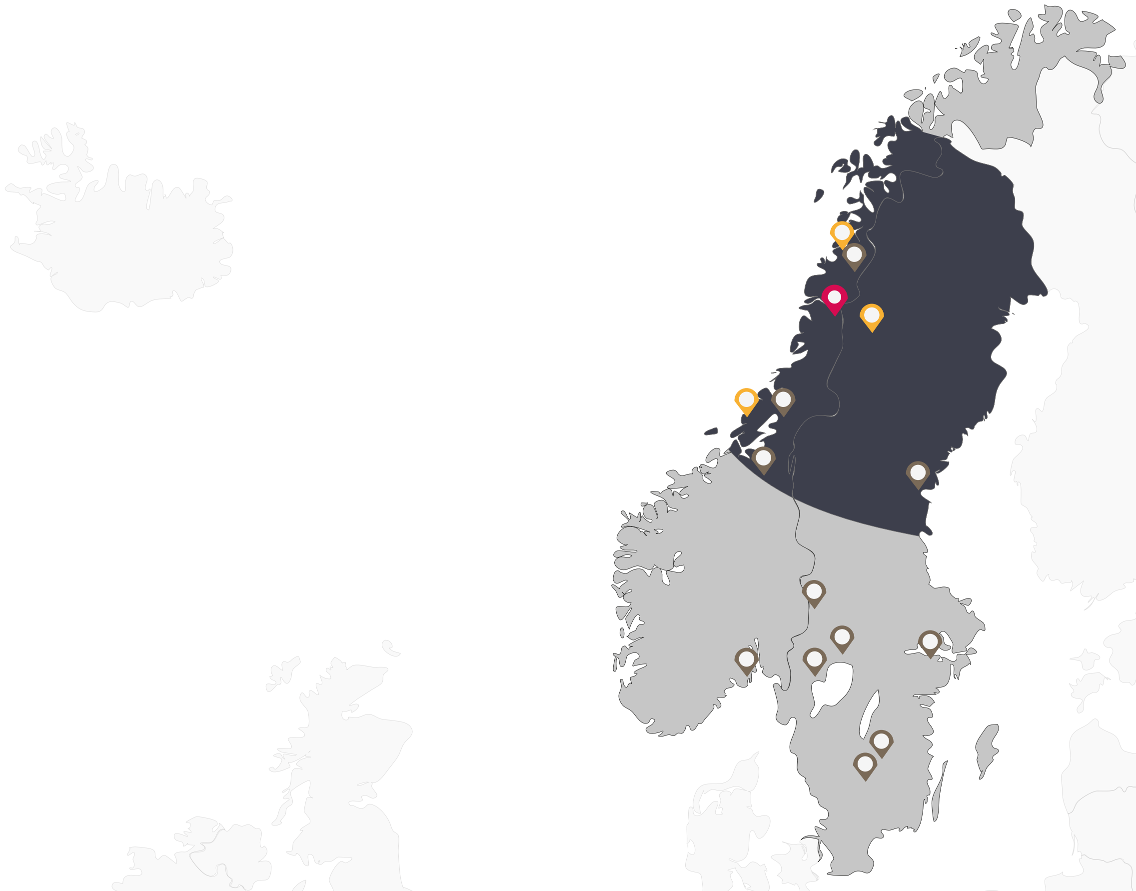


Figure 18: Factory locations in Sweden and Norway, red is the chosen factory, orange it the sites.

There are several prefabrication factories in both Norway and Sweden that makes wood frame construction elements from the size of cabins to permanent residential buildings. In Norway the prefabrication factories are located in: Rusånes, Steinkjer, Selbu, Larvik and Mo I Rana. In Sweden the factories are located in: Strängnäs, Vrigstad, Sundsvall, Kil, Sandsjöfors, Torsby and Säffle.

The prefabricated factory that was chosen for prefabrication of the modules is located in Mo i Rana. The reason for choosing the prefabrication factory in Mo i Rana is because that factory is located in the centre of the zone. By choosing a factory in the centre of the zone, the transport distance from the factory to the site where the cabin will be built is minimized, by reducing the transport distance the CO2 emissions is also reduced.

CASE STUDIES

KODA KODASEMA	TREK-IN MOODBUILDERS & KRISTEL H.	BACKCOUNTRY HUT LECKIE STUDIO
		
2015	2012	2016
ESTONIA	NETHERLANDS	CANADA
26m2 / 50m2	21m2 / 35m2	18-90m2
1 DAY	1 DAY	1 WEEK
380.000 NOK	400.000 NOK	430.000 NOK
NO FOUNDATION	CONCRETE FOOTING/ PILE	CONCRETE PILE FOUNDATION
VOLUME	MODULE	ELEMENTS
WOOD, GLASS STEEL, CONCRETE	FSC CERTIFIED WOOD, GLASS, STEEL	STEEL, WOOD, GLASS

Figure 19: Case studies comparative [Kodasema, Achidaily, Thebackcountryhutcompany websites]
Images sources: https://http://www.kodasema.com/; https://www.archdaily.com/566419; http://www.thebackcountry-hutcompany.com/

As reference for this project, the prefabrication designs above were analysed. The selection was based on different prefabrication types and wood architecture designs. Above we compared them based on year, country, size, how long it takes to build, cost, foundation, prefabrication types and main materials.

These references helped in the concept and design phases, as well as the choice for the prefabrication type, based on the building program.

Figure 20: Koda [Kodasema] Images sources: https://http://www.kodasema.com/

| KODASEMA KODA

This project was design to be easy to built and possible to relocate, with multiple purposes. This cubical structure can be set up as an apartment, office, stand for marketing, hotel, even an Airbnb investment.

The design is by the office KODASSEMA, in Estonia. The target group is spread throughout Europe, with demo houses in United Kingdom and Netherlands.

The transportation is by truck and in one single piece. They also prepare foundation when needed, as well as connection to water, sewerage and electricity. The hole process should take about one day.

Figure 21: Trek-in [Archidaily] Images sources: https://www.archdaily.com/566419

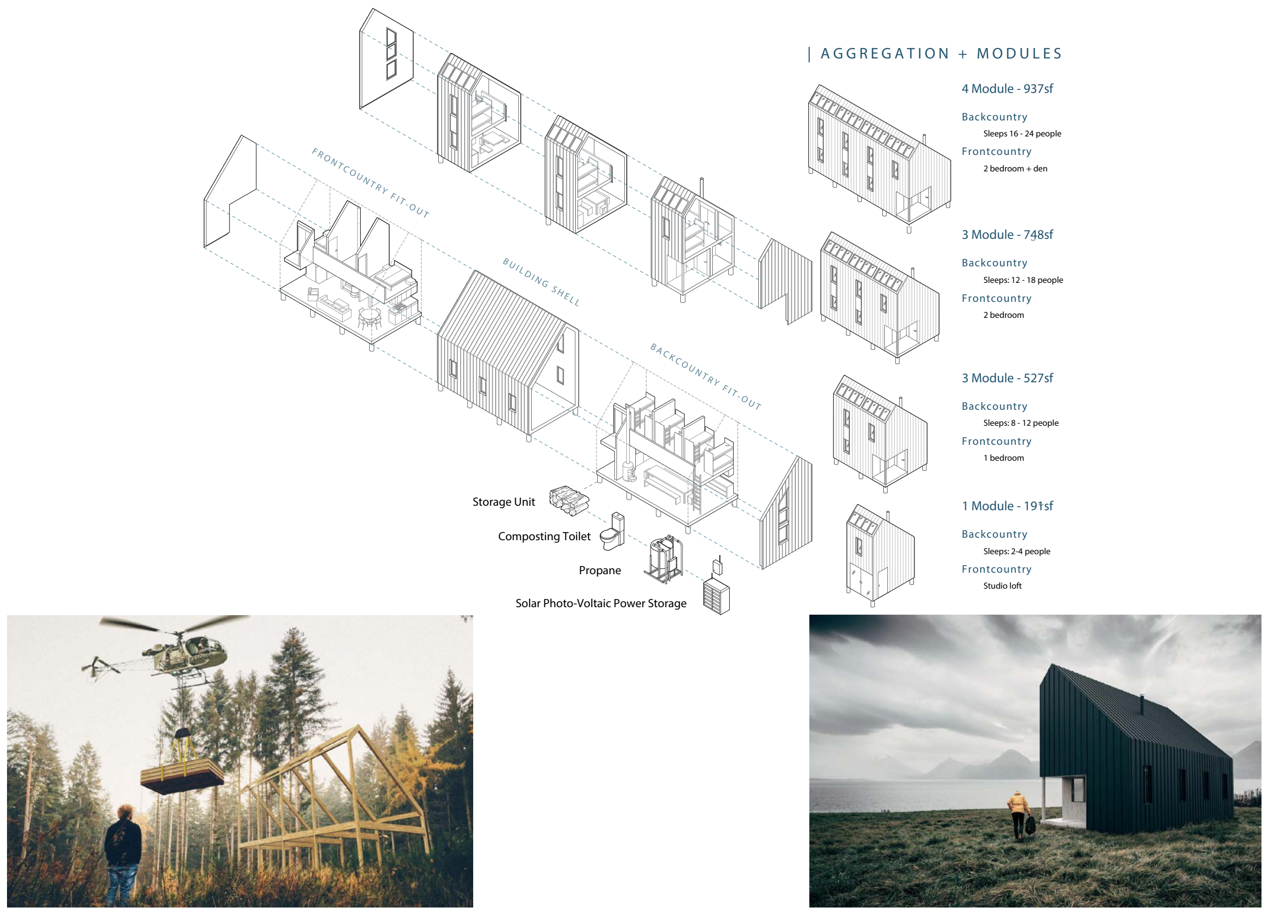


Figure 22: Backcountry [Thebackcountryhutcompany] Images sources: http://www.thebackcountryhutcompany.com/

| TREK-IN MOODBUILDERS AND KRISTEL HERMANS

Trek-in is a project that started as a design for a WoodChallenge competition by the Eindhoven University of Technology. The idea was to provide a sustainable hikers cabin, with fully equipped bathroom and kitchen. The official prototype was presented at the Dutch Design Week in 2012.

This cabin is prefabricated into two module pieces, that can be assembled in one day. They also have a smaller project, the Trek-in Junior, which is one single prefabricated volume with 21m2.

| BACKCOUNTRY HUT LECKIE STUDIO

Inspired by Ikea's assemble your-self-products, this project started with the proposal to offer a build your-self-project. It has modular structures that can be expanded from one module to up to four modules, depending on the building program. The construction process works as a collective 'barn-raising' process and it can take approximately one week to be complete.

The transportation can be done even by helicopter, for properties off grid with hard access. The materials used are; engineered wood products, Forest Stewardship Council (FSC) certified lumber and 100% recyclable components adopting zero-waste philosophy.

DESIGN DEVELOPMENT

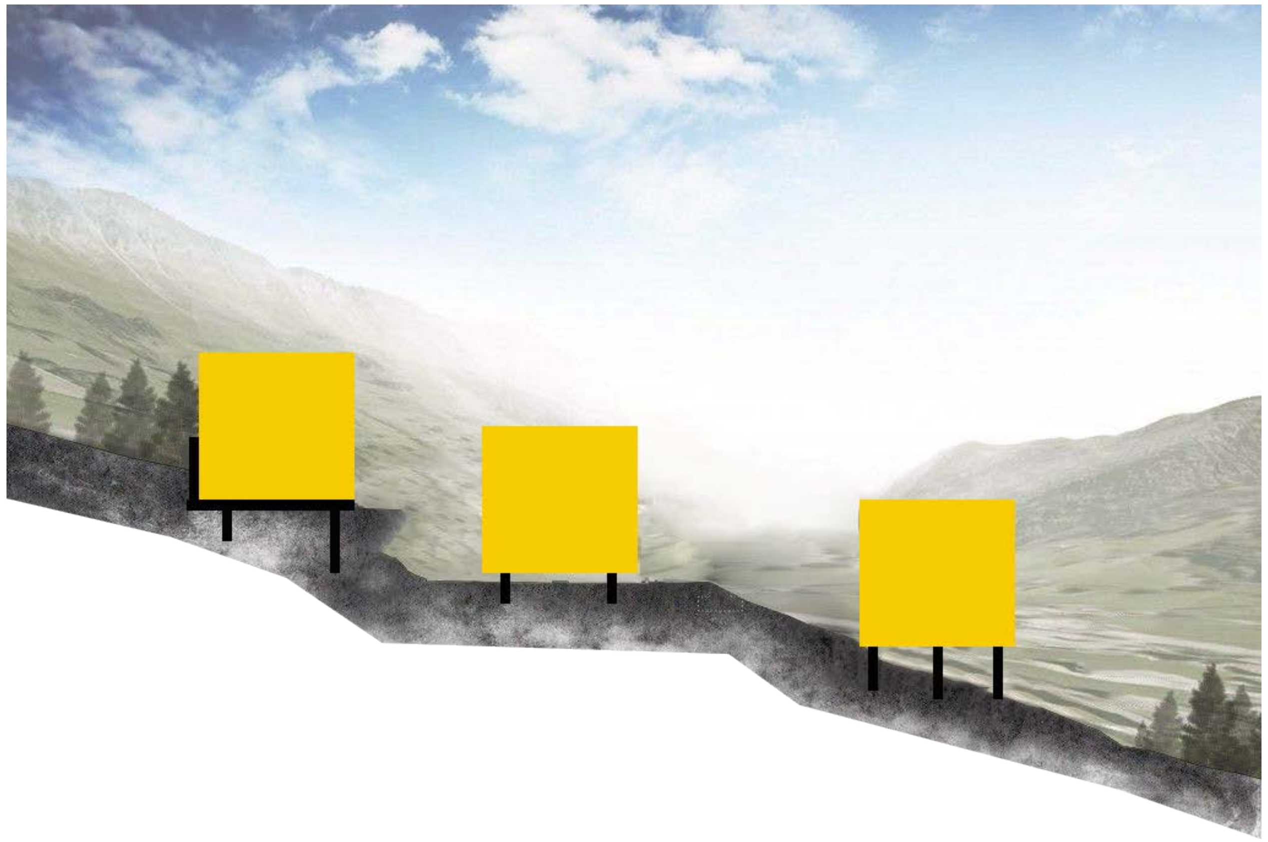


Figure 23: Topography scenarios Image source: http://conorcoghlan.com/blog/?tag=architecture-2

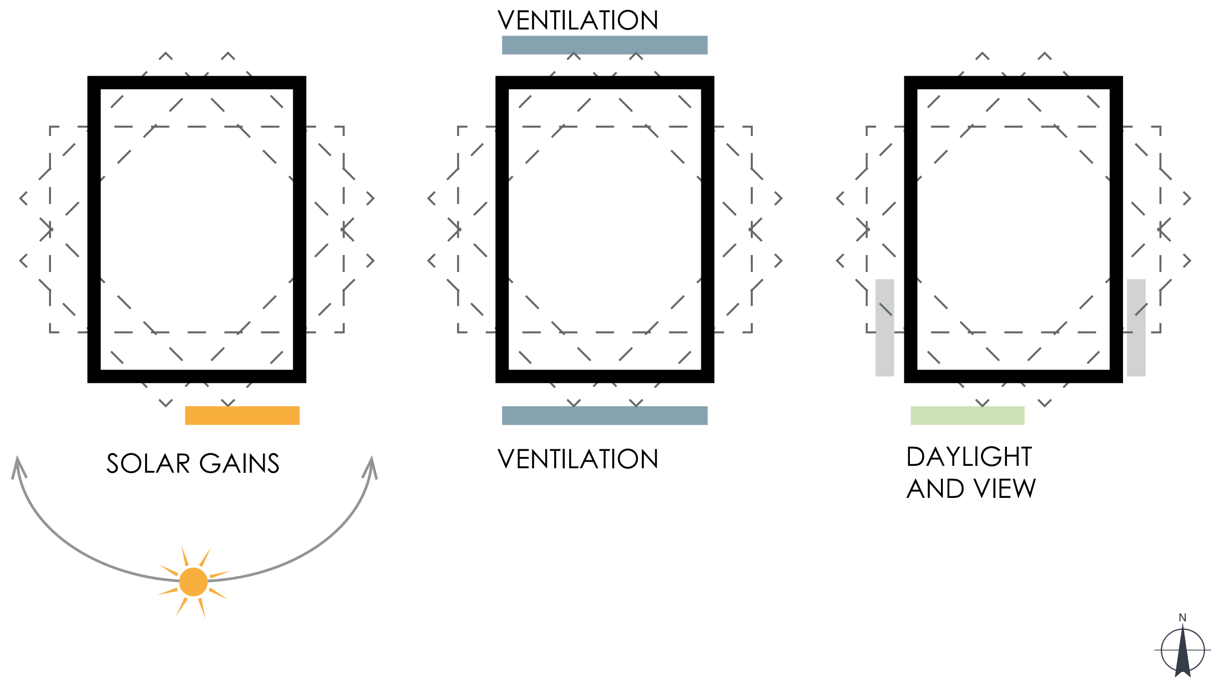


Figure 24: Adaptability strategies

| CONSTRAINTS

Without a definite site, it is hard to predict how to integrate building with environment, landscape, local architecture, local culture, building orientation, solar access, wind conditions, precipitation, natural resources, noise level, air quality and how should the foundation support the building in different terrains. All these aspects should be taken into consideration for the adaptable design project.

Another restrain on the program is the Attefallshus regulations. How to fit a sustainable project and still feel spacious in a compact volume.

| ADAPTABILITY STRATEGIES

The adaptable strategies starts with the attempt to maximise the 100 m^3, for indoor comfort. Since the orientation of a holiday home is normally based on view, the project needs to consider different view access orientation and still have good energy performance.

For energy production, the PV should always be at optimum orientation or at south. The cabin should be able to have view towards a scenery and be consider for different orientations. The natural ventilation is to be with cross effect, with opening on opposite façades.

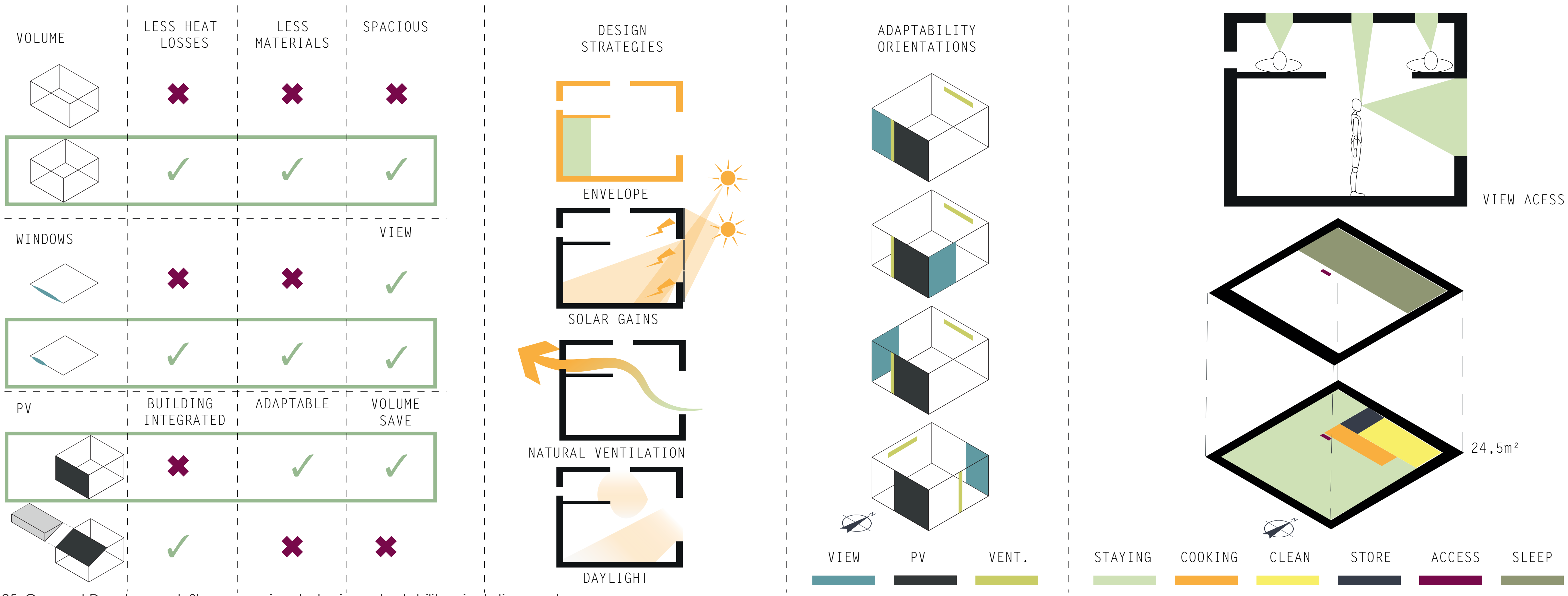


Figure 25: Concept Development, Shape, passive strategies, adaptability orientations and space use

| PROCESS

In the beginning we compared building shape and evaluate which option would have less heat loss, less material and offer best layout distribution. In this case the cubic shape was the best option.

The simulations for VA and ASE helped to decide on glazing ratio and overhang considering indoor comfort.

With the compact shape, the criteria was to use as much space as possible. After Calla Dome simulations, and trying to fit the program inside the building, the PV's could be integrated on the facade and have a tilt of 30 °. In this scenario the building would lose indoor space. During the design process, the PV's became an additional accessory to the building.

The design strategies were to have an efficient envelope, good solar access, natural cross ventilation, natural daylight and solar gains.

The main window had to adapt for different orientation to provide VA. The PV's were considered to always be installed on the facade, for easier maintenance and avoid snow obstruction of the cells.

The building grid was base in thirty centimetres grid, half measure of many standard materials. The criteria for the layout was to concentrate electrical and plumbing in the same area, have flexible living space, fully equipped kitchen and bathroom and loft for sleeping.

Kittelfjäll is located in Vihelmina municipality, in the mountains. This place is popular for skiing holiday and hiking. During summer and autumn the common activities are fishing, hunting and canoeing. This area is popular during Easter when there is snow and the sun is shinning.

Saltstraumen is located in the Bødo municipality and has one of the strongest tidal currents in the world . It is a popular place for fishing, diving, and has spectacular views towards Børvasstindene mountains.

Lysøysund is village located in Bjugn municipality. The village is on the coastline, offering hiking, fishing and swimming in the nearby lakes.

The site analysis is based on context, wind directions in winter and summer, solar access and VA. The VA can be of a forest, sea, mountains, valleys, fjords, or something unique. Each of the three sites have a different view orientation.

The VA is important in this project, because the design strategies must consider the indoor comfort and minimize CO2 emissions, without compromising the VA on each site.

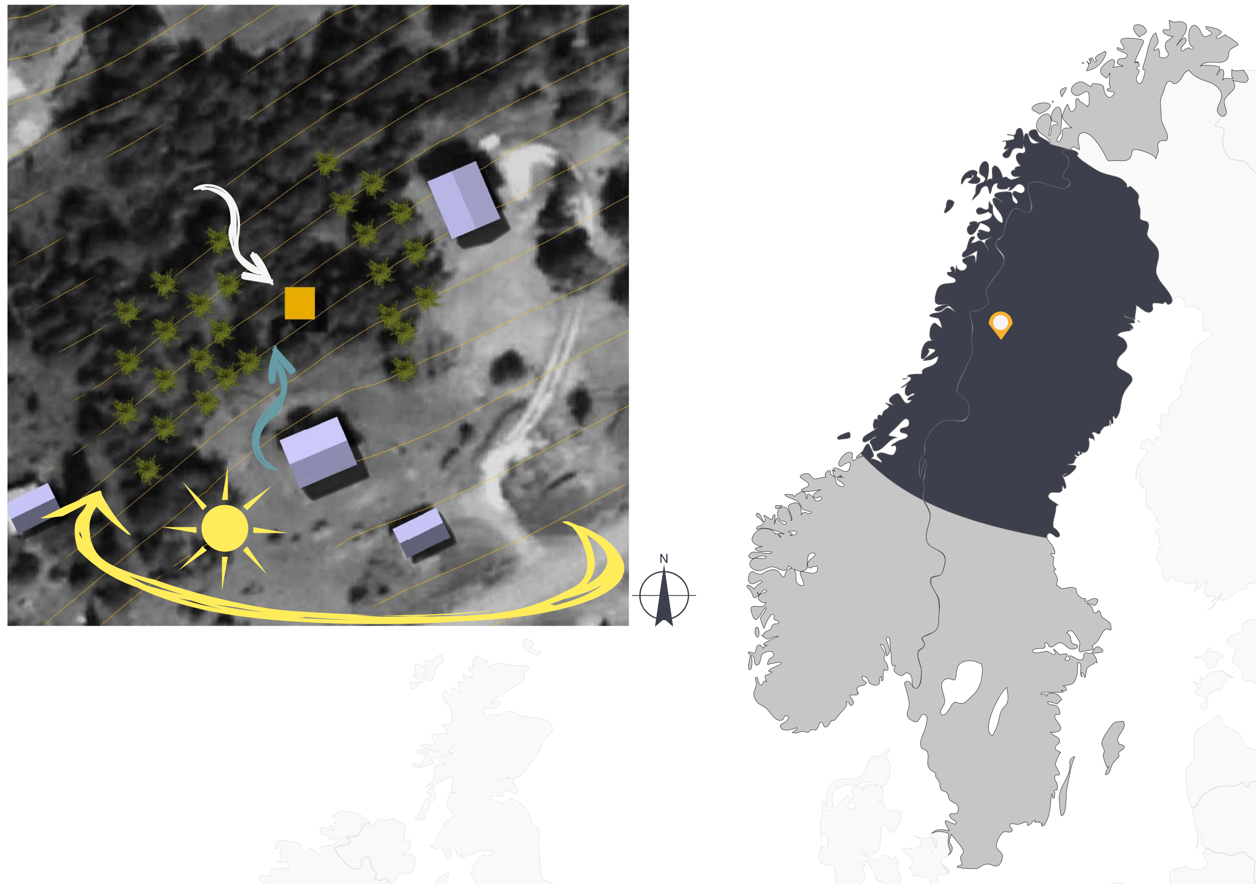


Figure 26: Kittelfjäll site analysis [Google Earth and Lands Design]

| KITTELFJÄLL

Kittelfjäll site is located nearby the ski resort AB Fjällaktiviteter I Västerbotten and the Kittelparken hotel.

On the western part of the property, there is a water stream surrounded by local forest. The view focus on this site is towards west, to take advantage of the beautiful view of the mountains. The prevailing wind during summer is from south and during winter it is from north west.

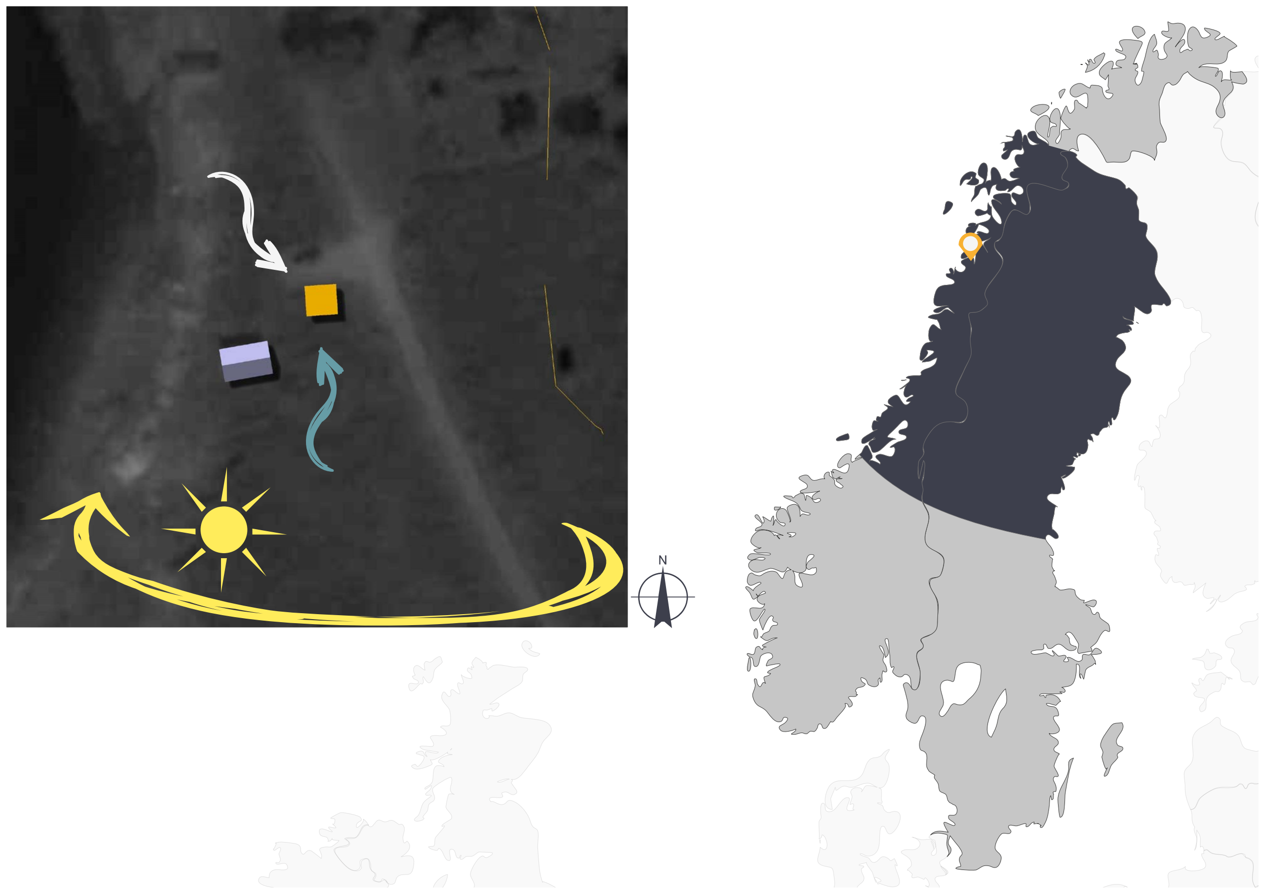


Figure 27: Saltstraumen site analysis [Google Earth and Lands Design]

| SALTSTRAUMEN

Saltstraumen site is located in the fjord close to the Saltstraumen's famous tidal current. The view focus on the site is towards Børvasstindene mountains in south direction.

The prevailing wind during summer months is from the south, in winter the prevailing wind it is in north west.

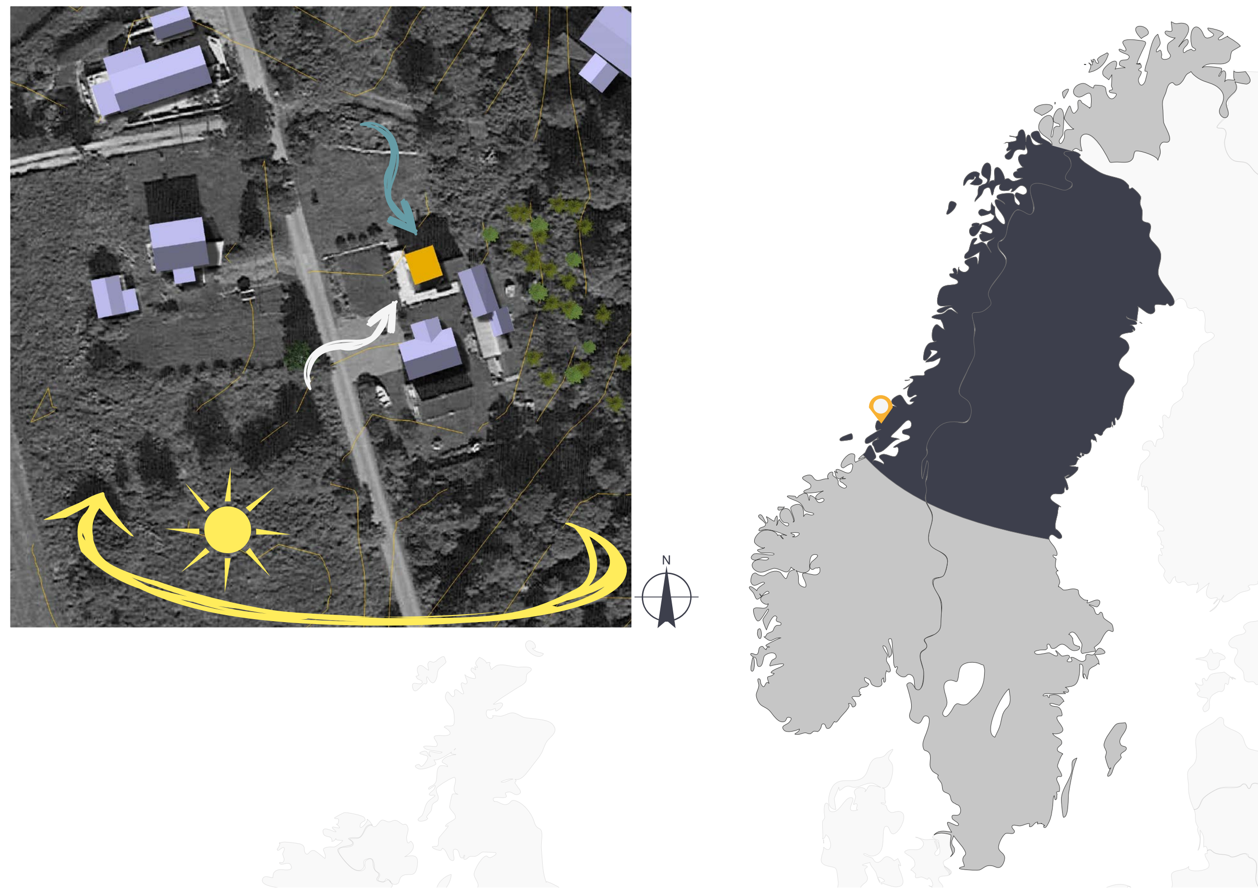


Figure 28: Lysøysund site analysis [Google Earth and Lands Design]

| LYSØYSUND

On this site the ocean view is towards north. The north side has the least solar radiation, which is a sensitive side for heat loss.

This scenario is the most delicate for the adaptability strategies, because in this case the building and the window must be rotated to get VA towards north.

The prevailing wind is from north during summer and in winter it is from south west.

SIMULATIONS

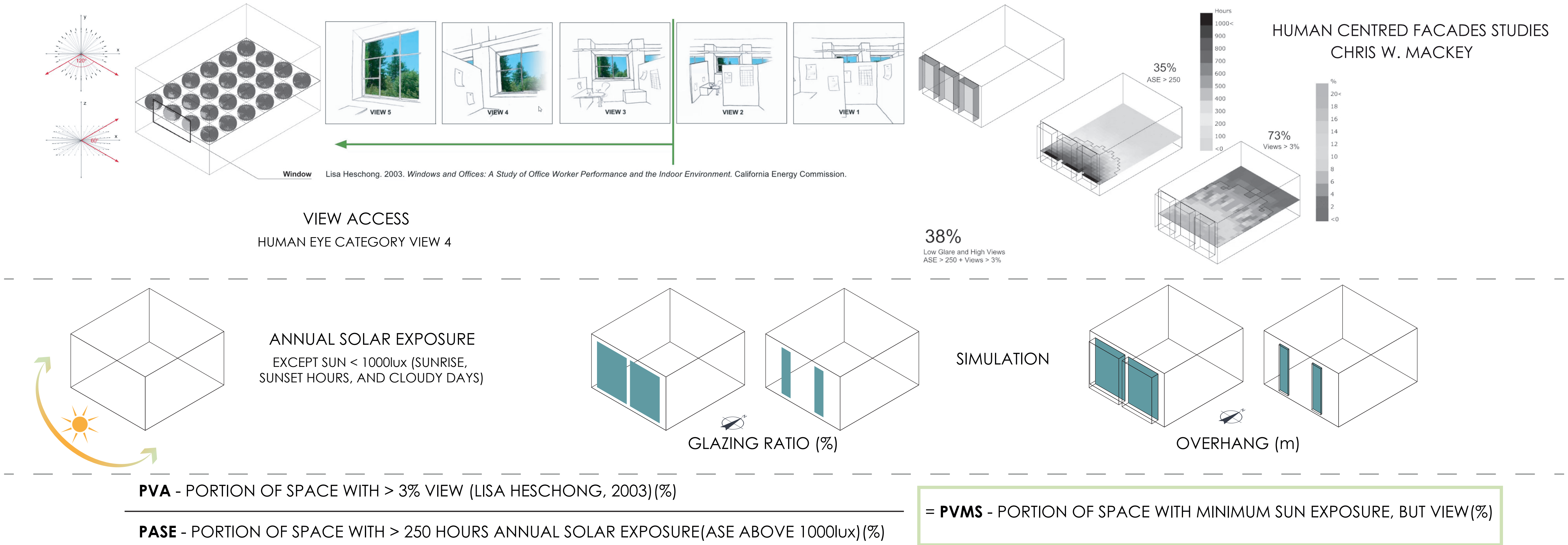


Figure 29: Early design work-flows for Human Centered Facades [Chris W. Mackey]

Image source: https://vimeo.com/ondemand/humanfacades

Human Centred Facade is a simulation developed by Chris Mackey, Master of Architecture and Master of Science in Building Technology from MIT. He is one of the coders of Ladybug tools for environmental analysis.

This simulation is an initiative to prove that fully glazed façades are most likely to provide less user comfort. For example, when the space has more solar exposure, there is a chance that the user might use blinds or curtains, which in our case would obstruct the view.

Although this simulation was designed mostly for office spaces, the idea was to use this tool to find a good glazing ratio, avoiding thermal losses and with more clear view hours without glare.

The simulation is based on VA and ASE. ASE is a parameter to measure solar exposure above 250 hours in a year, excluding sun lower than 1000lux. The sun is lower than 1000lux when it is setting, rising, or hidden by clouds, which is not considered uncomfortable hours.

The view access simulation is based on human eye, with a set of vectors on 60˚ for the monocular view and 120 ˚on the binocular view. These vectors read the percentage of the space that passes through the window opening. The analysis relates to the percentage of the space with views and the research *Windows and offices: A study of office worker performance and the indoor environment* (Lisa Heschong, 2003). This study shows that a good view inside an office space is categorized as view 3 on the example above. For our studies we want to test VA with at least category view 4.

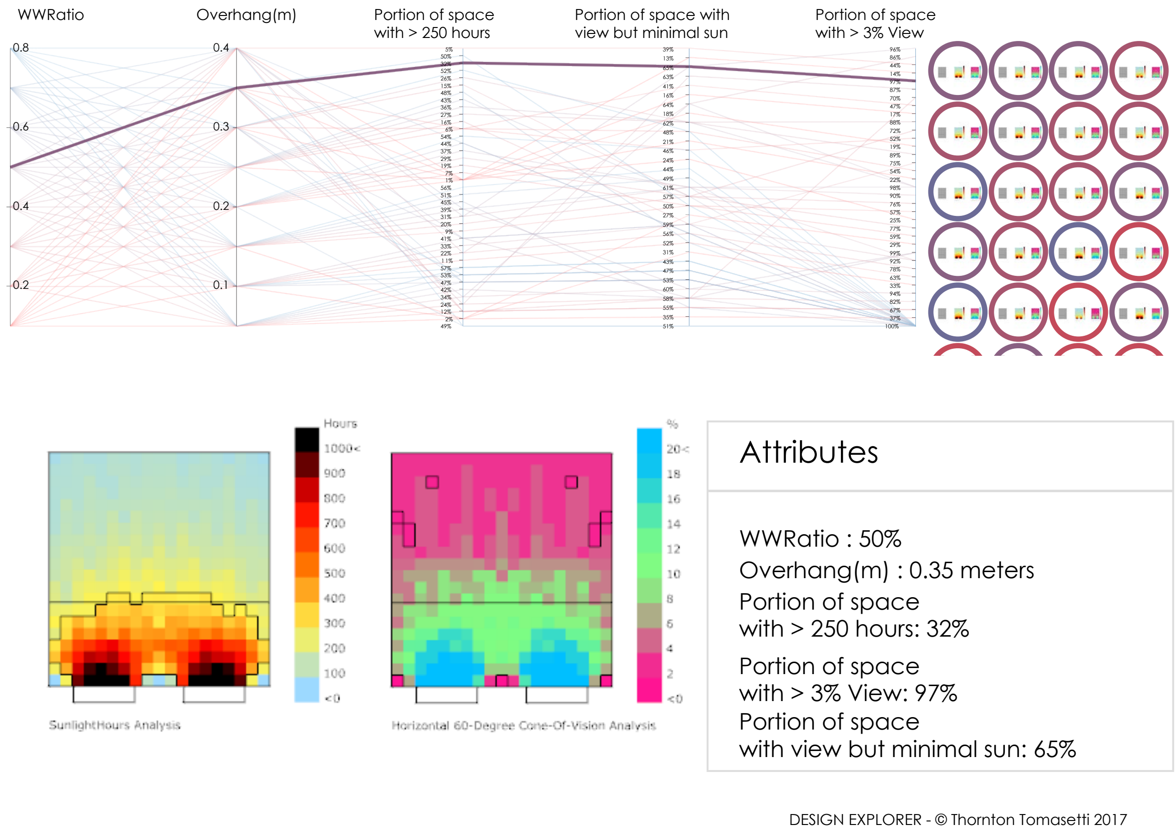


Figure 30: Glazing ratio and overhang simulation results [Ladybug tools and Design Explorer]

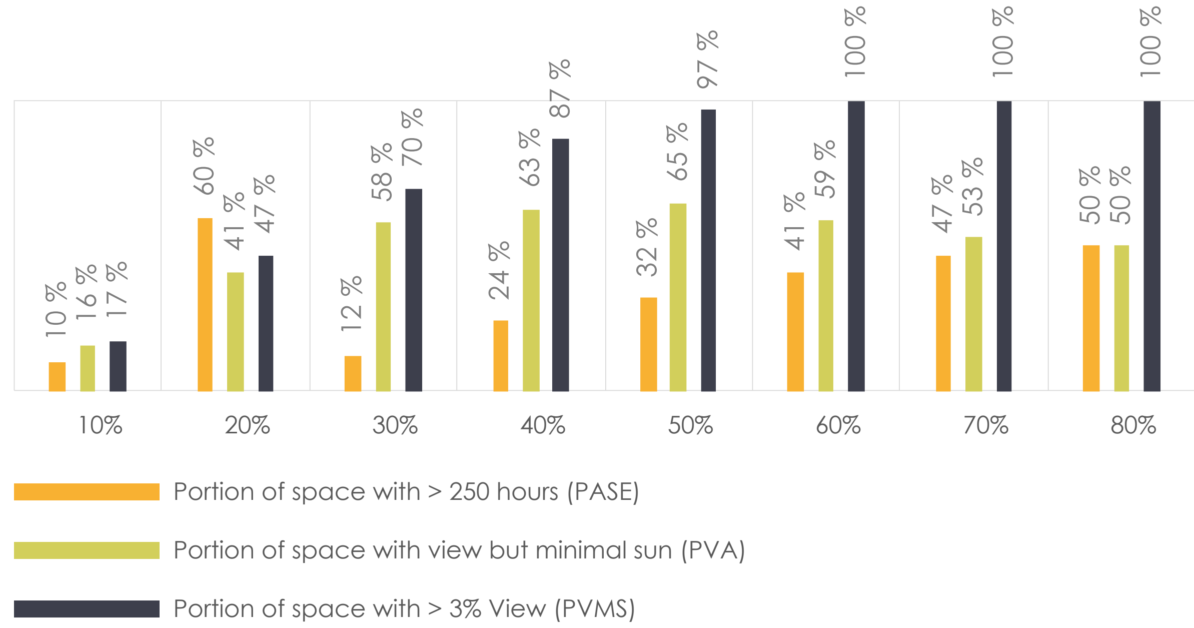


Figure 31: Glazing ratio and overhang simulation results comparative [Ladybug tools and Design Explorer]

| ANNUAL SOLAR EXPOSURE AND VIEW

The goal with this simulation is to find a comfortable glazing ratio and overhang, so that the user has a good VA. This will reduce the number of hours that the user might need to block the views with blinds.

The iterations for glazing ratio were from 10% up to 90% of the façade area. The window tested has overhang on all corners, from 0 up to 40 centimetres. The simulation needs to change the glazing ratio horizontally, and for that to happen it needs to be tested with two windows. Ladybug in combination with Meteonorm EPW from Saltstraumen gave the climate data relevant for ASE and VA. Honeybee was used to generate the geometry. Colibri was used to generate all the 72 iterations changing glazing ratio horizontally and overhang in all 4 corners, and Design Explorer displayed the final results.

The results for 'portion of space with view, but minimal sun'(PVMS), is measured by dividing 'portion of space with more than 3% of view inside the space'(PVA), by the 'portion of the space with more than 250 hours of ASE' (PASE). The highest of PVMS in this simulation, was with glazing ratio of 50% of the façade area, and 35 centimetres of overhang.

The results shows that with high glazing ratio the PVMS can reach up to 50%, but the ASE is also high. With low glazing ratio, ASE is low, together with PVMS and VA. The balance is somewhere in the middle.

Comparing the results for glazing ratio of 50% and 40% of the facade area the difference in PVMS is of only 2%. The results for PASE are different, so even though the best value was 50%, we can see that with 40% there is a decrease on PASE of 8 %. The areas affected by the view are mostly on the opposite side of the room, were the bathroom, storage and kitchen are located.

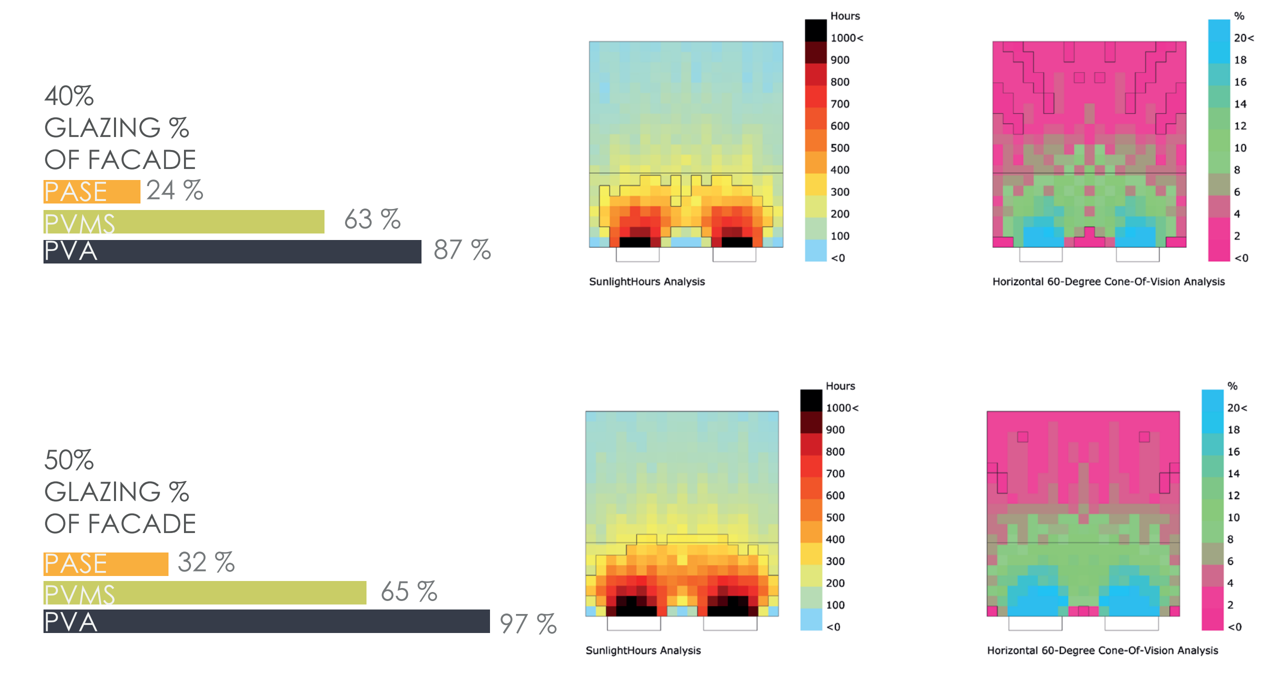


Figure 32: Glazing ratio results for double window [Ladybug tools and Design Explorer]

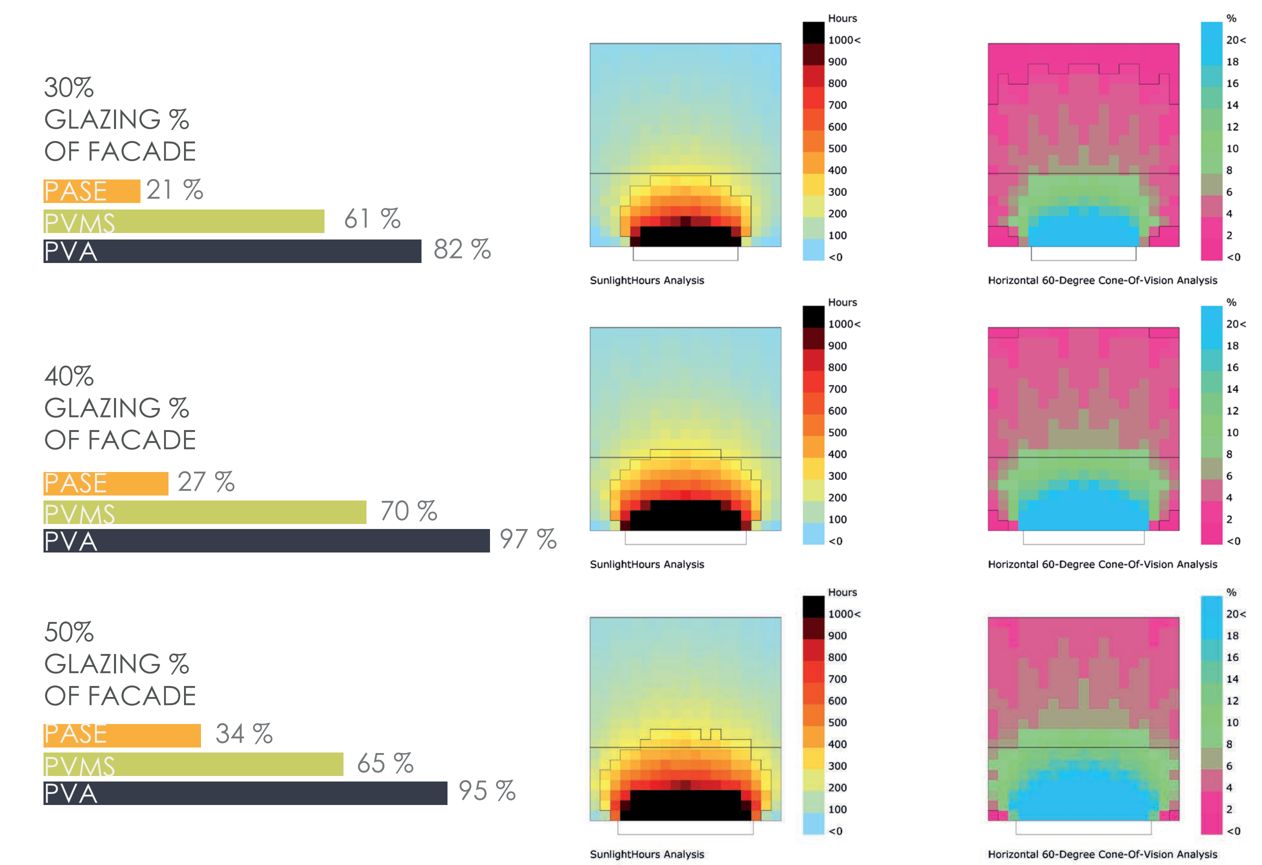


Figure 33: Glazing ratio results for a single window [Ladybug tools and Design Explorer]

Testing the glazing ratio with a single window, the best results for PVMS was with 40% of glazing ratio instead of 50%.

Taking into account the adaptable strategies, were the view needs to share the same facade with PV and ventilation, the window is restricted to 2,2 meters length and 1,4 meters tall, 23 % of glazing ratio. This way we can get 65% of PVMS, 88% of view and 23% PASE with more than 250 hours a year.

The Leadership in Energy and Environmental Design (LEED) standard require ASE under 20%, with use of shading devices for office spaces. The goal is not to achieve LEED standards, but achieving 23% should be acceptable for a holiday home. The areas with less view are also close to were the fireplace, entrance and bathroom are located, so the view will most likely be better on the main living space from many angles.

The next test is for the views towards a scenery of each site, with the glazing ratio of 23% of the façade area, and overhang of 35 centimetres. This way we can see if the window size will provide enough VA towards the scenery, considering topography, neighbours and threes, that might block the view.

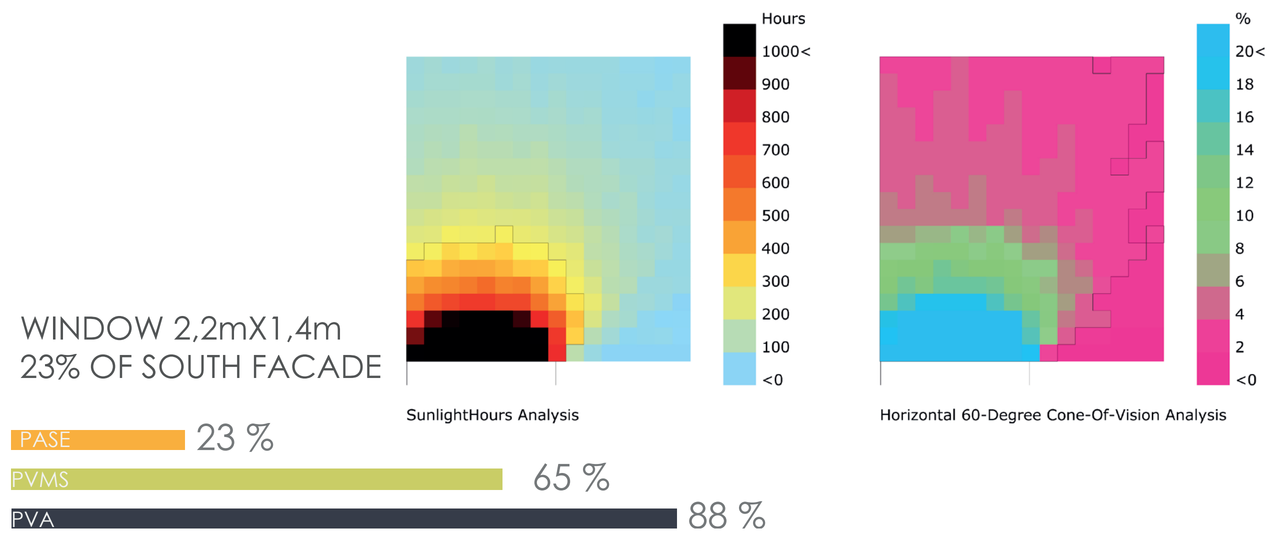


Figure 34: Window 2,2mx1,4m PVMS Analysis[Ladybug tools and Design Explorer]


Figure 35: Kittelfjäll view [Google Street View]

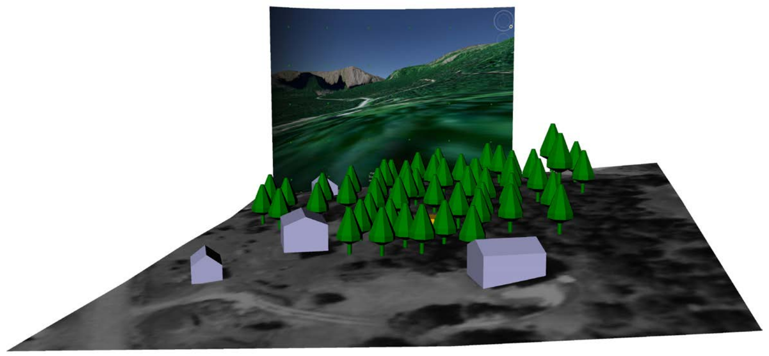


Figure 36: Kittelfjäll scenery view test points [Rhino5 and Lands Design]

| KITTELFJÄLL

The window orientation for this site is towards west. The neighbouring buildings, topography and the trees were also included in the simulation as the context that might block the view. 30 points were analysed in this case.


Figure 37: Saltstraumen view [Wikimedia ,Kefi]

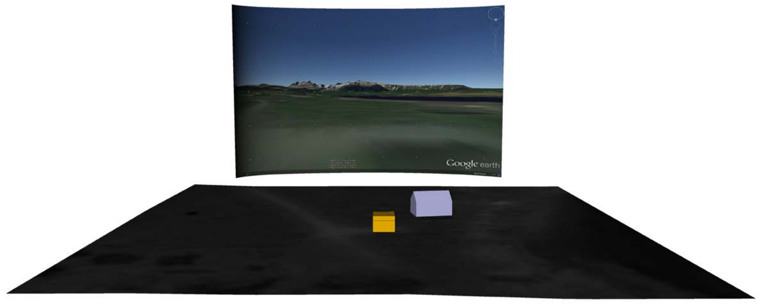


Figure 38: Saltstraumen scenery view test points [Rhino5 and Lands Design]

| SALTSTRAUMEN

The window orientation on this site is towards south, with view towards Børvasstindene mountains. The neighbouring building and topography were also included in the simulation as the context that might block the view. 40 points were analysed in this case.


Figure 39: Lysøysund view [Private photo]

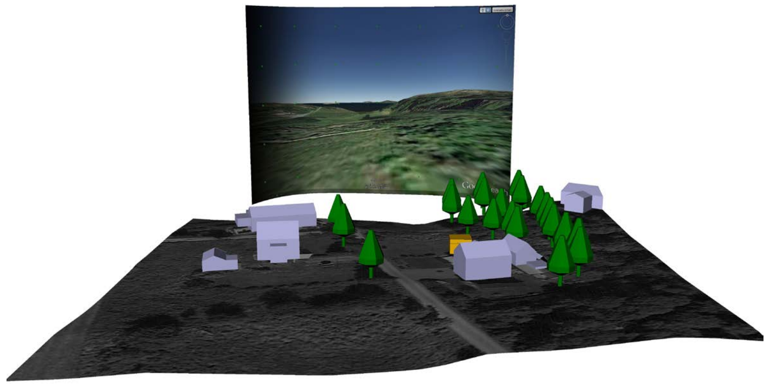


Figure 40: Lysøysund scenery view test points [Rhino5 and Lands Design]

| LYSØYSUND

The window orientation on this site is towards north, ocean views. The neighbouring buildings, topography and the trees were also included in the simulation as the context that might block the view. 35 points were analysed in this case.

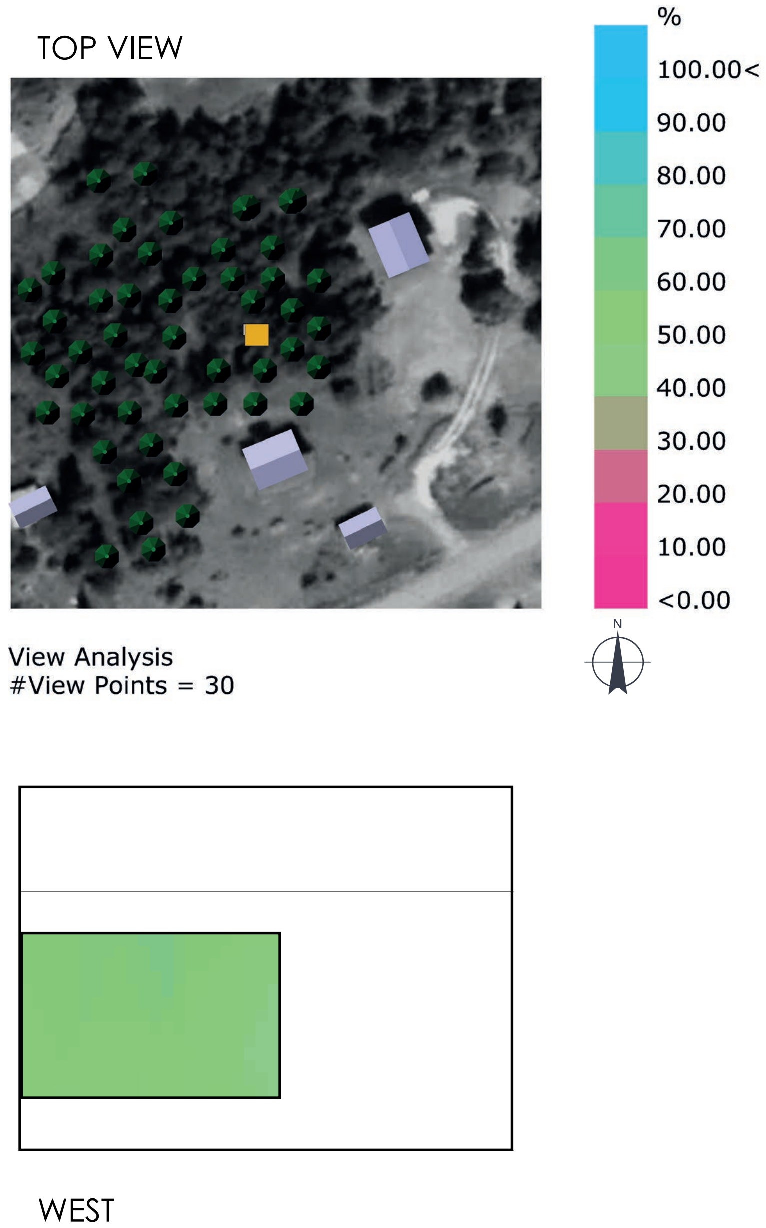


Figure 41: Kittelfjäll scenery view results [Ladybug Tools]

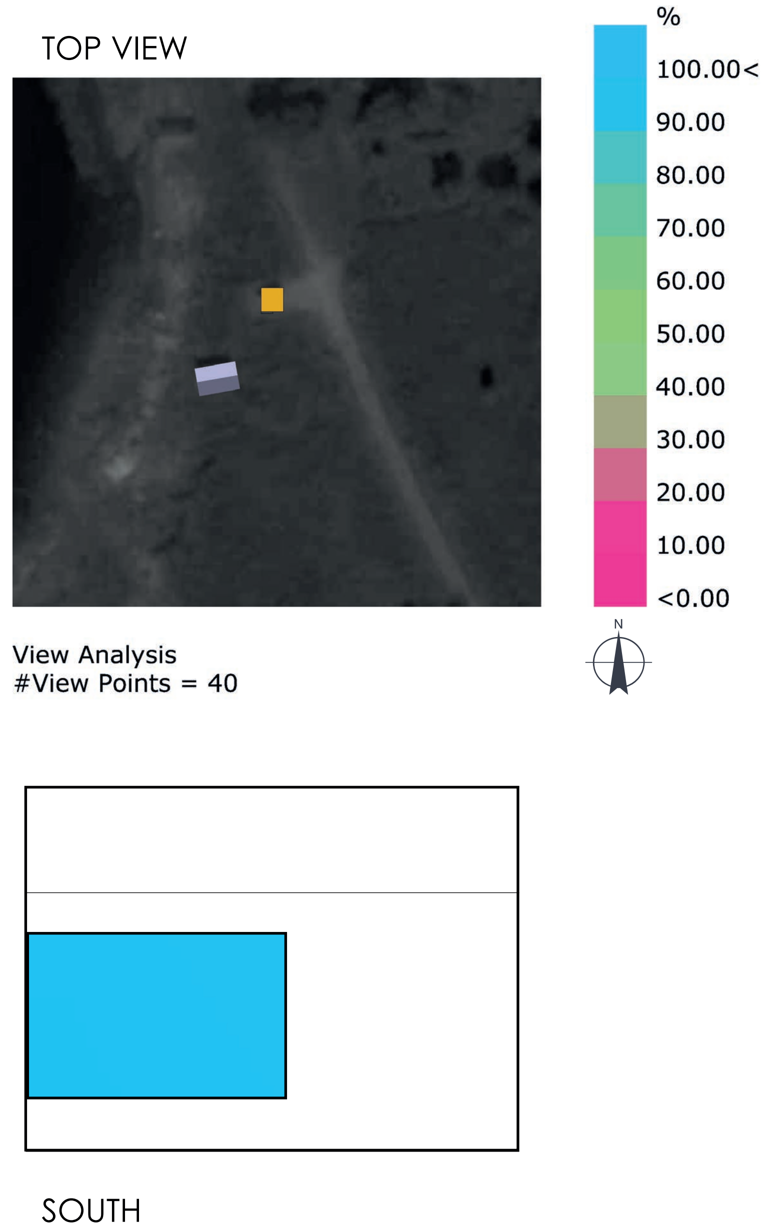


Figure 42: Saltstraumen scenery view results [Ladybug Tools]

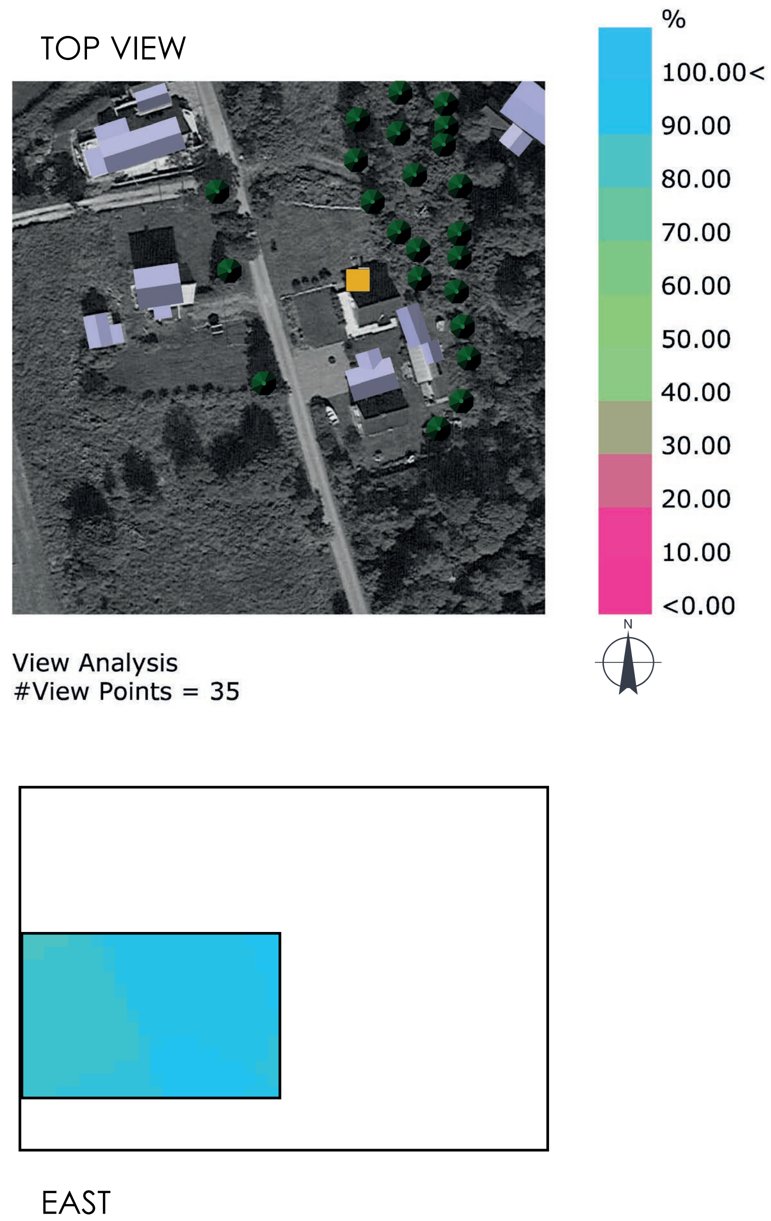


Figure 43: Lysøysund scenery view results [Ladybug Tools]

| KITTELFJÄLL

The simulation results shows that the views in this case got affected by its context, which seems to be the threes. But still got good VA towards the mountains and sky.

The adaptability for views in this case is met.

| SALTSTRAUMEN

Despite the neighbouring building and topography, there is good VA towards the mountains, sea, and sky.

The adaptability for views in this case is met.

| LYSØYSUND

Despite the neighbouring buildings, topography and the trees, there is a good VA of ocean and sky.

The adaptability for views in this case is met.

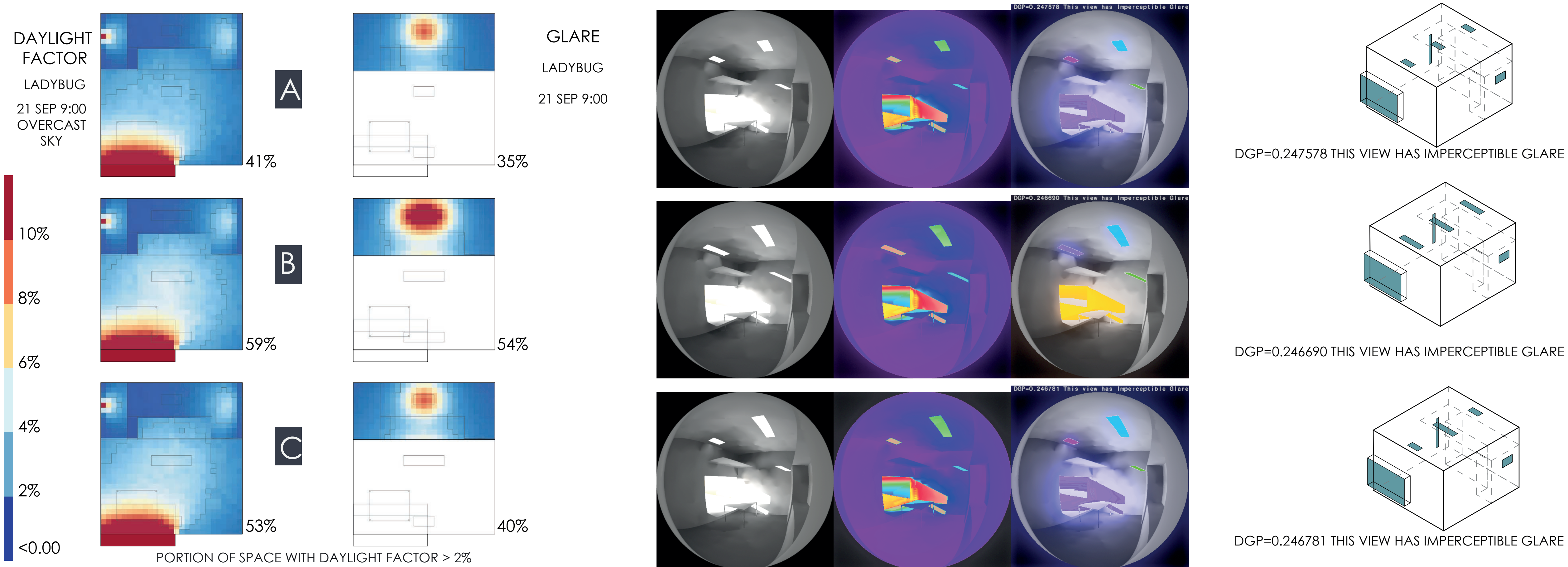


Figure 44: Daylight Factor and Glare simulations [Ladybug and Radiance]

| DAYLIGHT FACTOR

This simulation was to test three skylights sizes with Saltstraumen climate data. The simulation was set for overcast sky at 9:00 AM on September 21st, at 90 cm from floor for kitchen counter height. The required daylight factor for a dwelling, ranges from 2 to 5%. Considering that 2% is the minimum required in Norway, the simulation measured the portion of space with daylight factor higher than 2%.

The skylights width was defined by the beam structure of the roof. The length was tested with 60 centimetres and 120 centimetres.

Option A was tested with three skylights of 30 centimetres wide by 60 centimetres long.

Option B was with three skylights of 30 centimetres wide by 60 centimetres long.

Option C was a mix between options A and B, with skylights on the extremes of 30 centimetres wide by 60 centimetres long, and one in the middle of 30 centimetres wide by 1200 centimetres long.

The goal was to test which scenario would give the best daylight factor on the kitchen counter level.

Options B and C have a bigger portion of the space with daylight factor above 2%. Since the skylights on the extreme sides are for sleeping areas. Option C is the best for this project. The glare resulted imperceptible for all options.

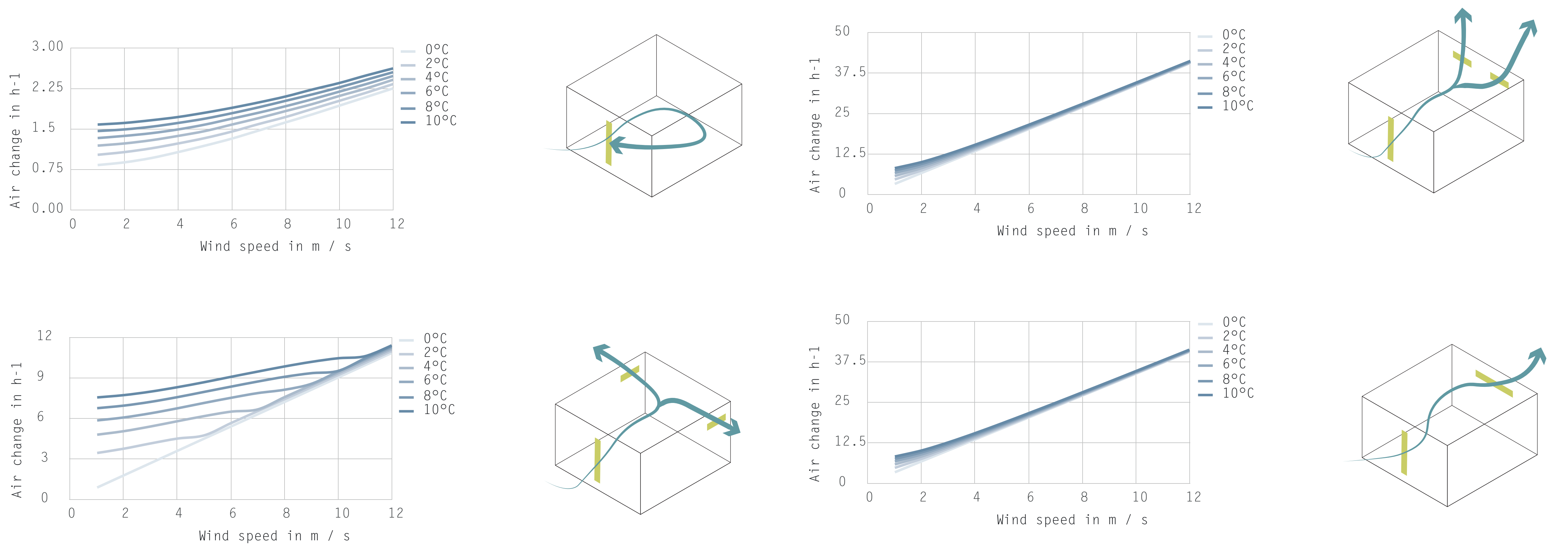


Figure 45: Natural ventilation Air Rate Calculator [Window-Master]

| AIR RATE

The cross natural ventilation is achieved using ventilation openings on both sides of the room, creating a current of air across the space due to overpressure on the side of the building, with prevailing wind and low pressure on the opposite side.

To achieve a good cross ventilation, the Window-Master website recommend the depth of the room to not exceed 5 times the room height. Our room height is almost one third of the room depth, which should be effective for cross ventilation. It is also recommended that the maximum air change inside the space are of approximately 2.5-3 h-1 (average during occupied hours) during winter and 4-6 h-1 in summer.

Window-master also provide a calculator for air rate exchange, to see which situation would give us a best air exchange.

The calculations for air change inside a space is based on building volume, landscape setting, location, and area of the openings inside the space. The line gradient shows the temperature differences between the inside and outside air. Four options were tested, as shown above.

According to the results, both options to the left with cross ventilation are the ones with best air rate change. Considering 0° light blue line as summer and dark blue 10° as winter, and the recommendations of approximately 4-6 h-1 during summer and 2.5-3 h-1 in winter, we can assume that the air rate in the summer is close to recommendations, and in winter the air rate is more than the recommended.

DESIGN

The wooden compact building offers a low-maintenance-living, so there is plenty of time to relax and enjoy nature.

The entrance is sheltered with space for dirty boots, fishing equipment and skis, which can also be stored indoors. The wooden interior with wooden burn fireplace provide a comfortable and cosy atmosphere.

To bring the nature indoors, a large window was designed, and it can be placed in one of three sides of the building, for different view orientations .

The wooden plate under the window can be used as sitting bench, bed and observatory.

The main space is used as sitting room, kitchen, dinning room, and sleeping.

The loft access is through a ladder by the kitchen and has space for up to four single mattresses, or a double mattress and two dressers on the sides for storage

An extra single bed can be added above the window, accessed by ladder.

Skylights are placed above the sleeping areas for sky views and daylight.

The cabin on grid has bathroom and fully equipped kitchen with induction plate, dish washer, fridge and freezer.

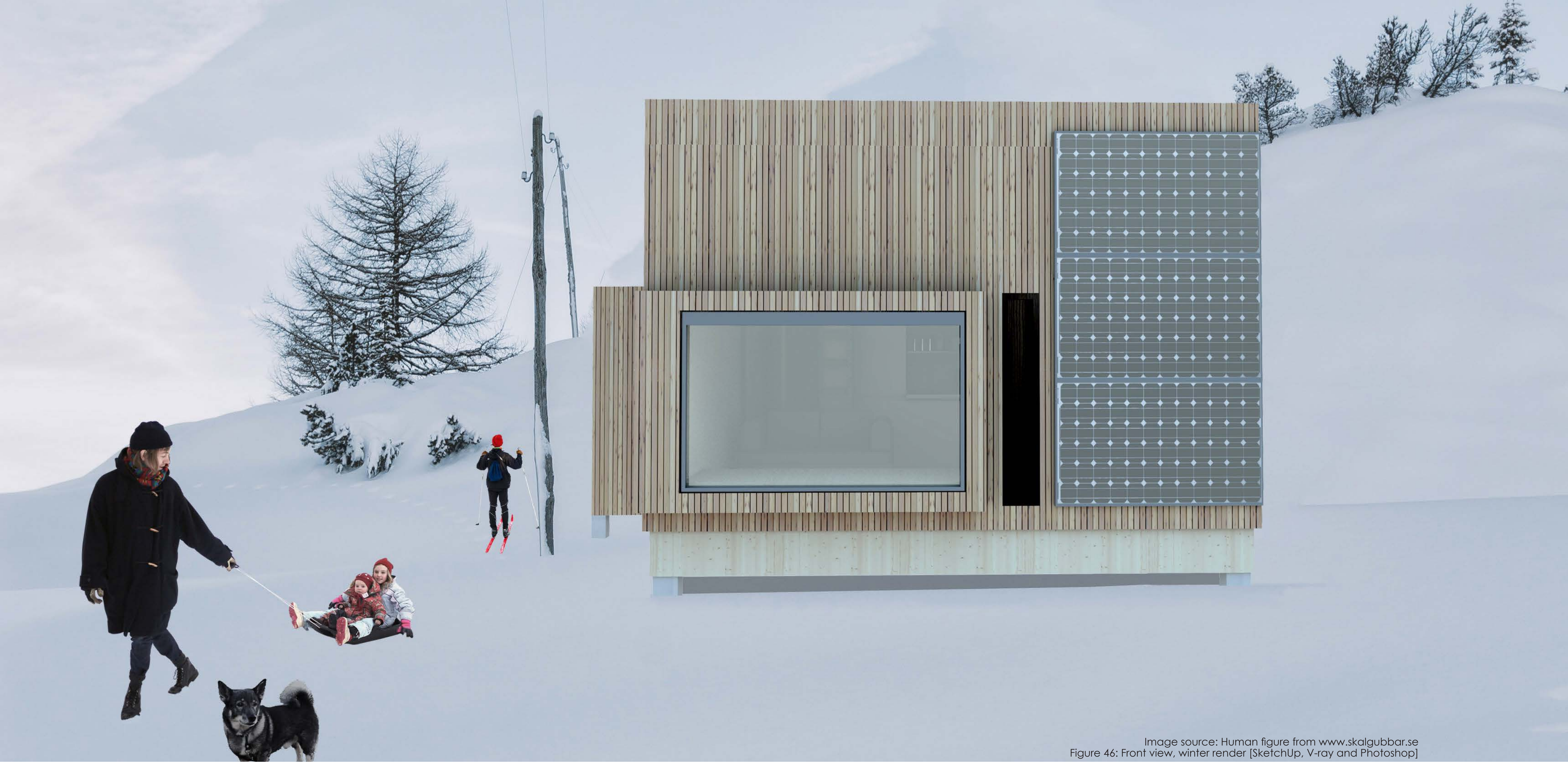


Image source: Human figure from www.skalgubbar.se

Figure 46: Front view, winter render [SketchUp, V-ray and Photoshop]

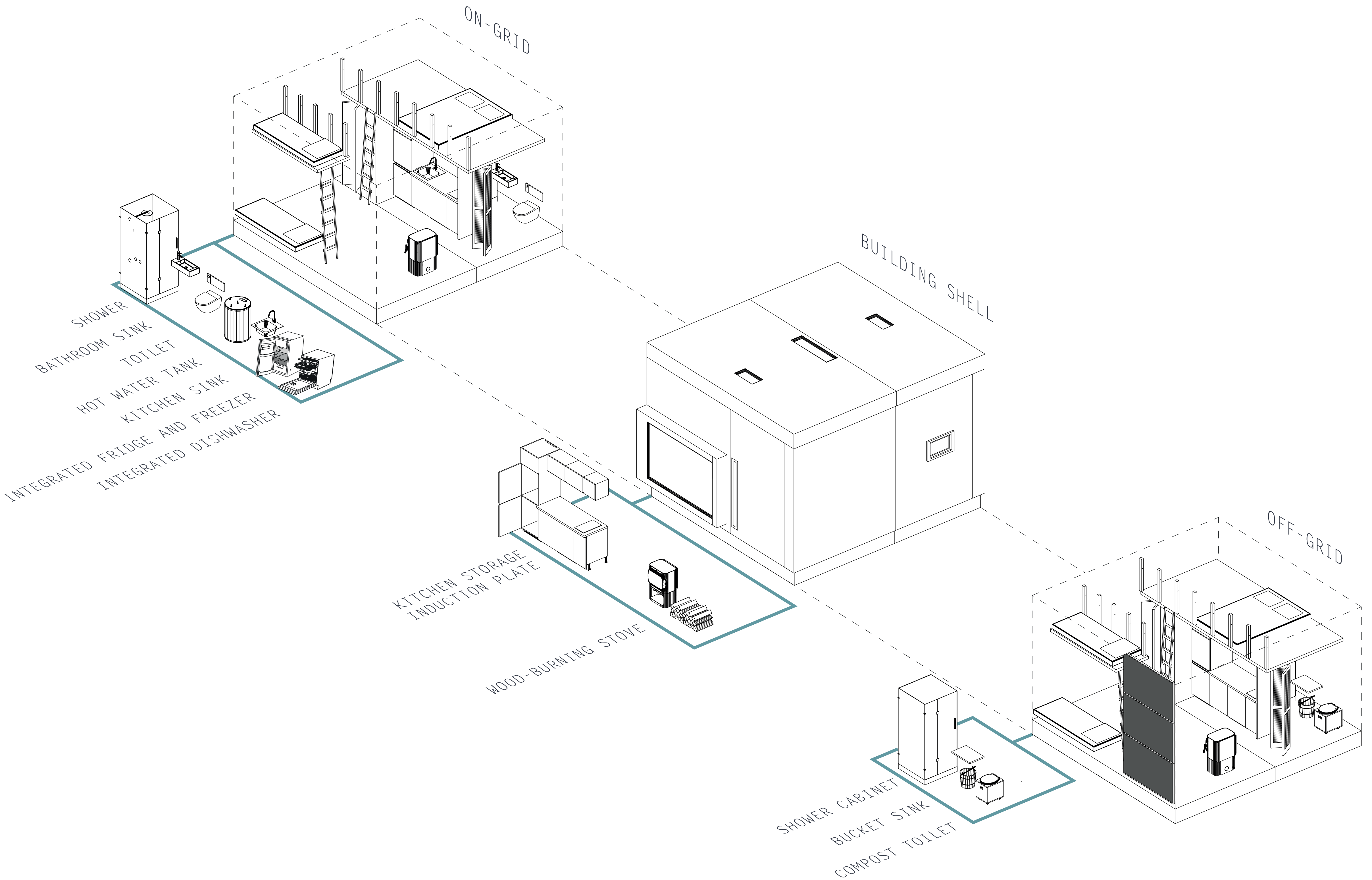
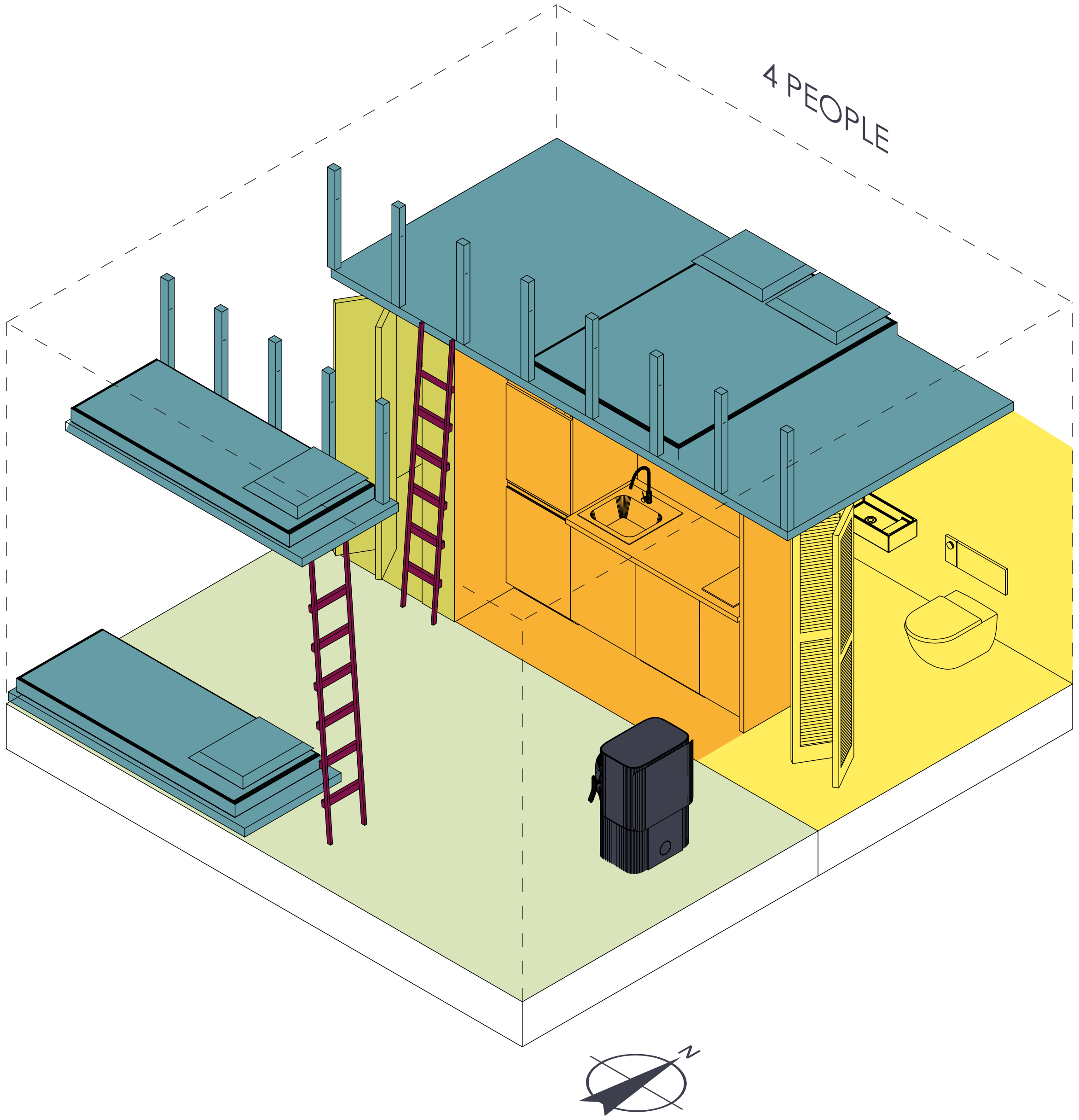


Figure 47: On-grid and off-grid conditions [Rhino and Illustrator]



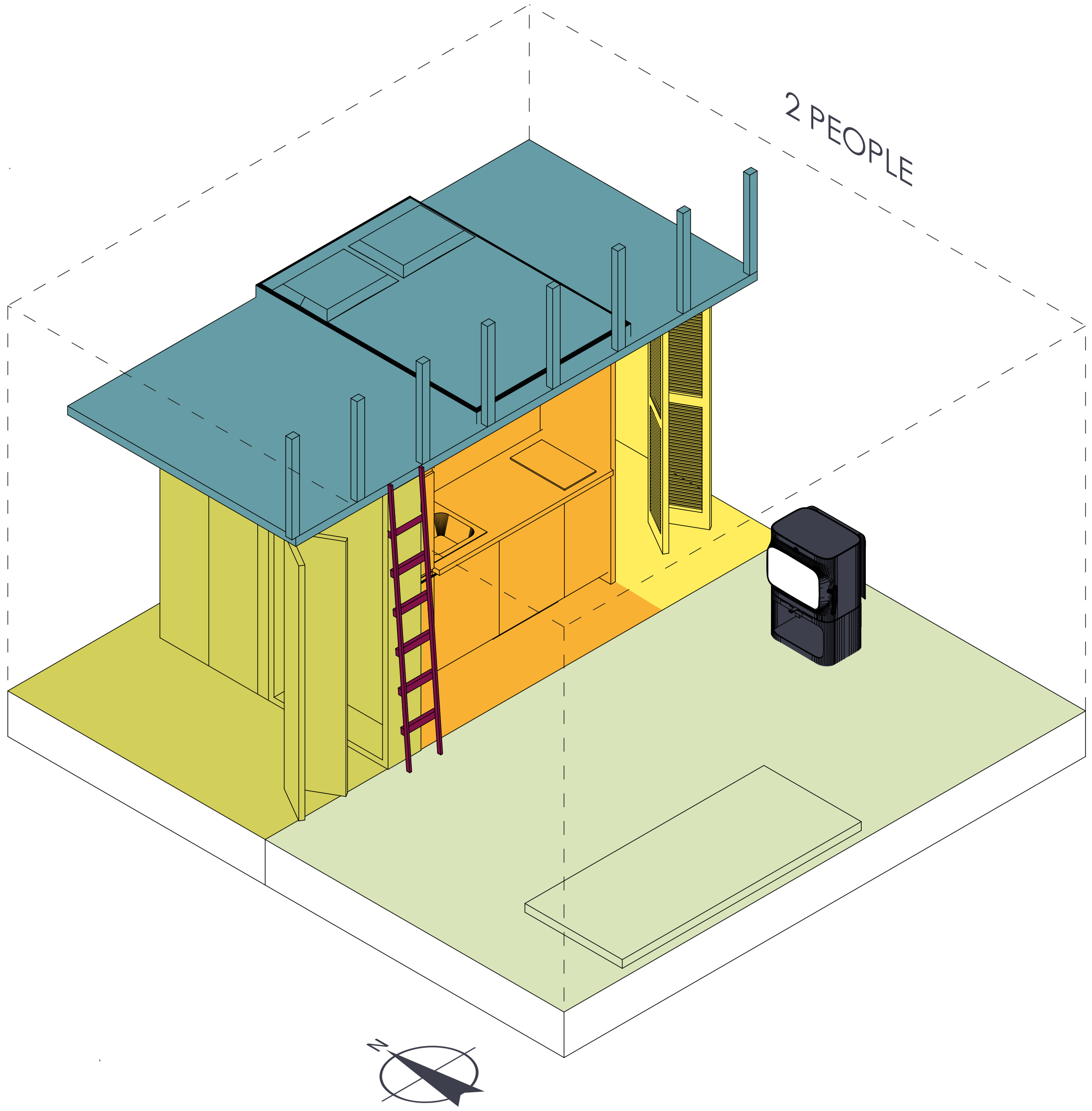


Figure 48: Layout [Rhino and Illustrator]

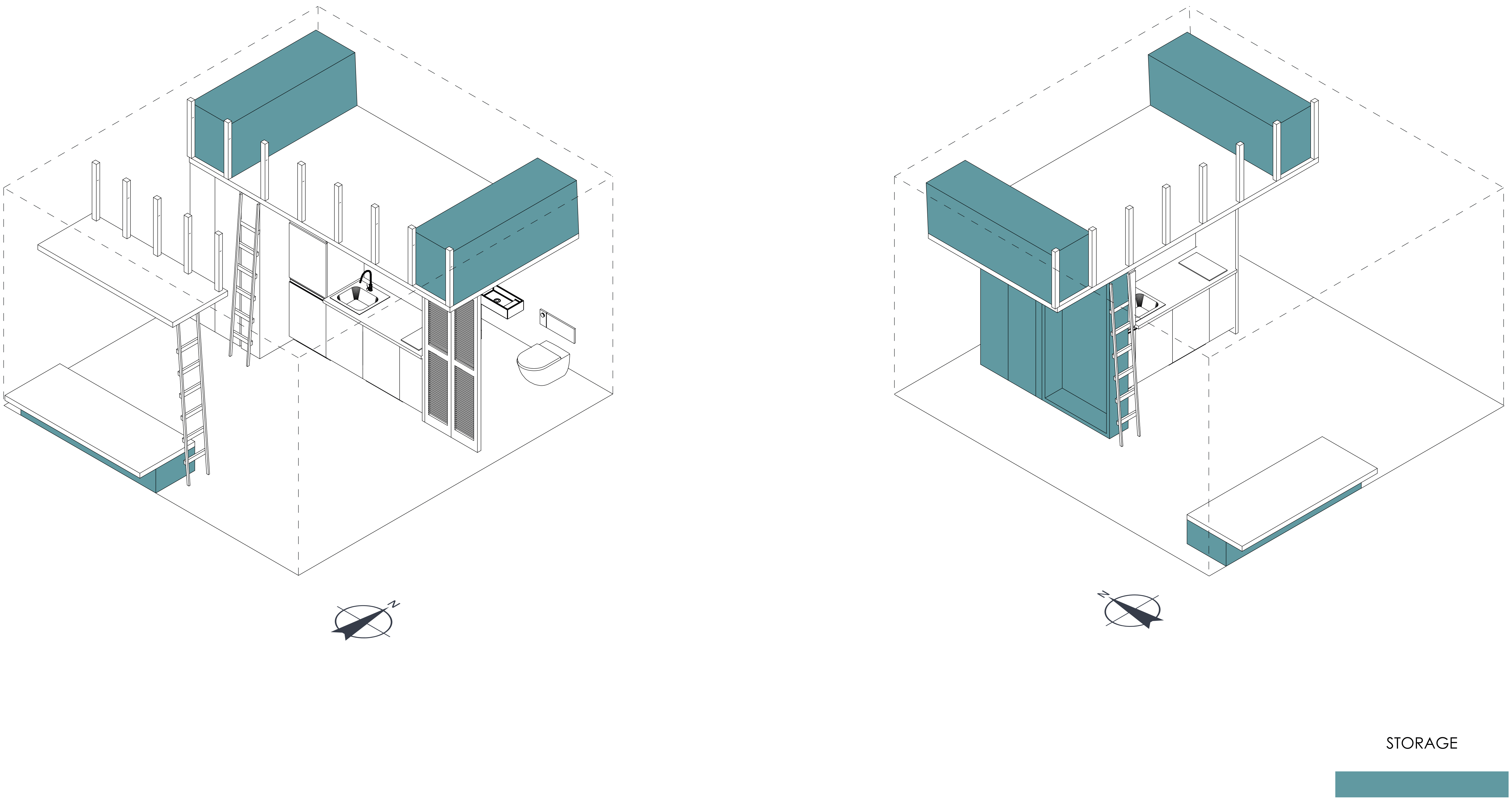
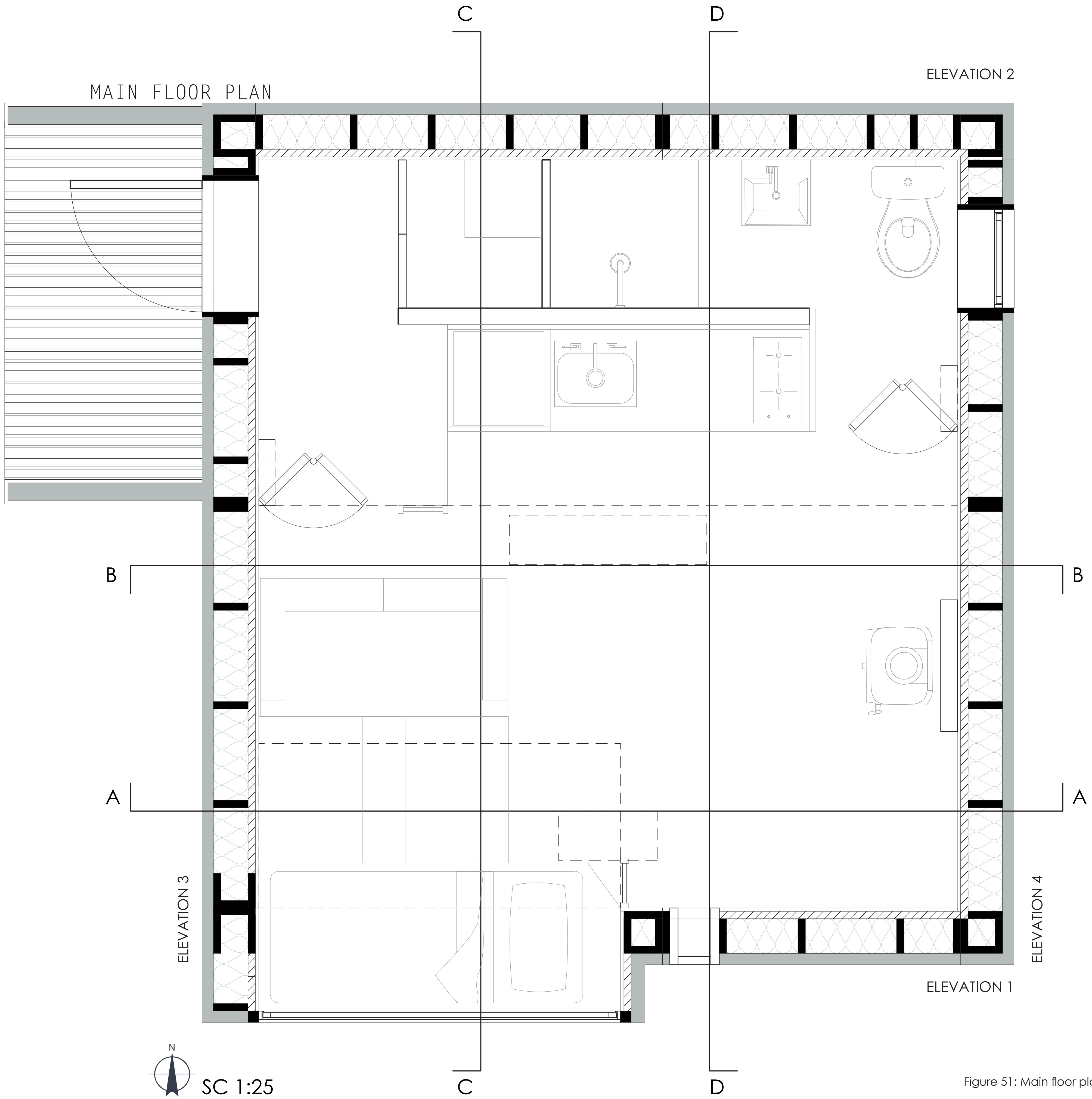


Figure 49: Storage arrangement [Rhino and Illustrator]

Image source: Human figure from www.skalgubbar.se
Figure 50: Interior renders [SketchUp, V-ray and Photoshop]



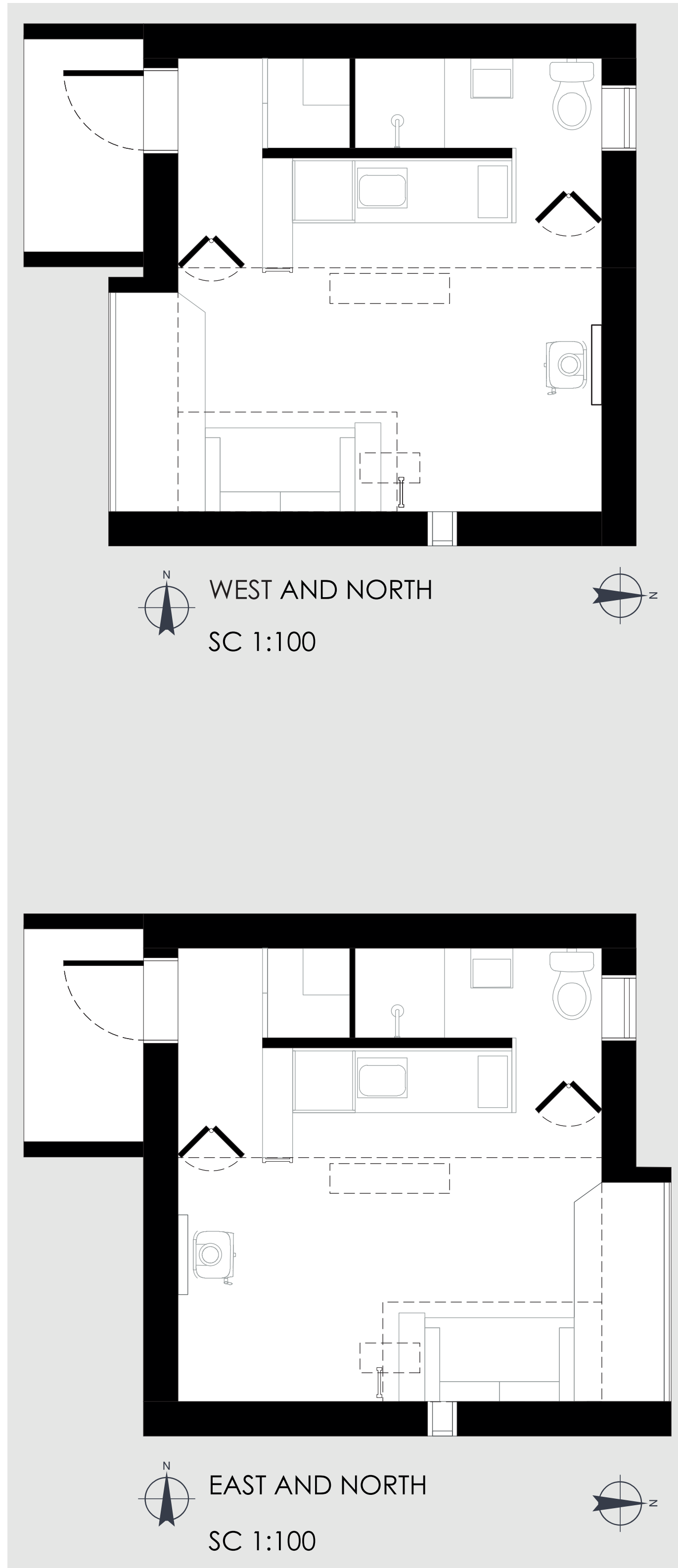
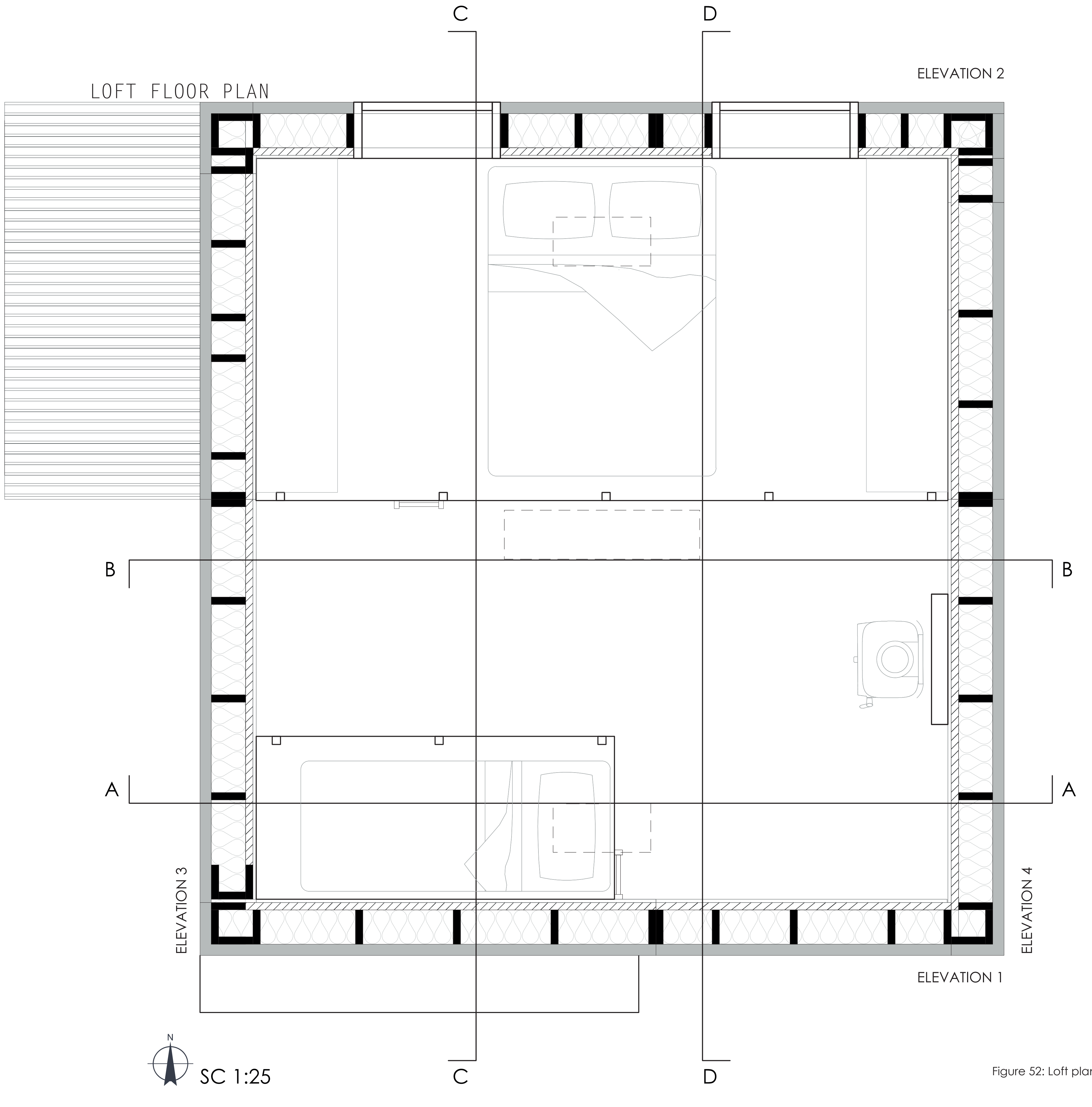


Figure 51: Main floor plan with window on south and other scenarios [AutoCAD and Illustrator]



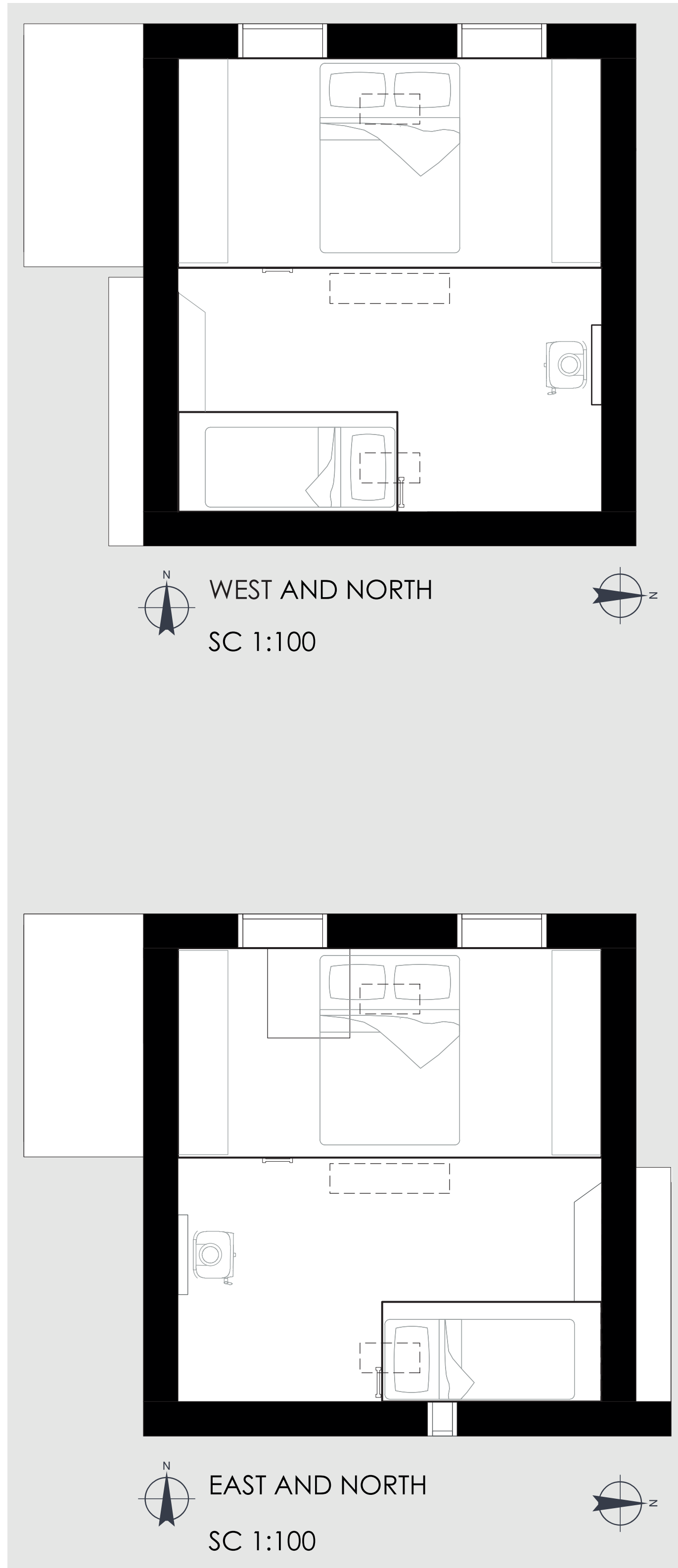
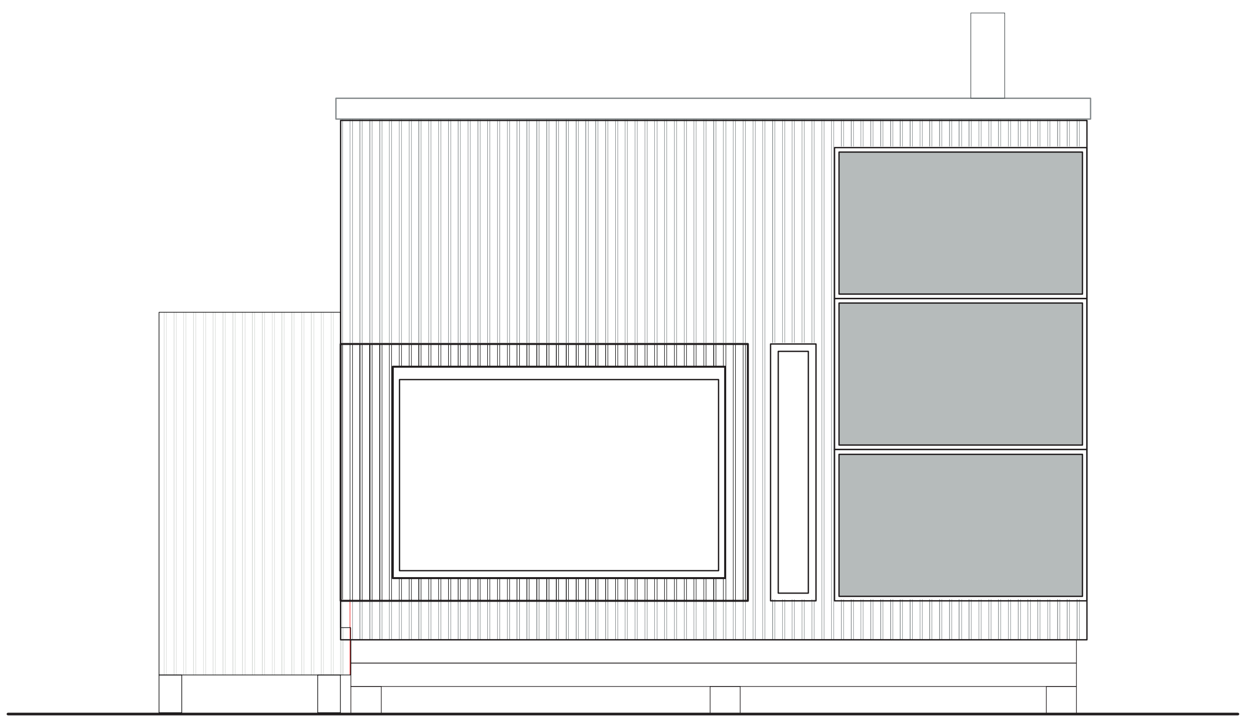
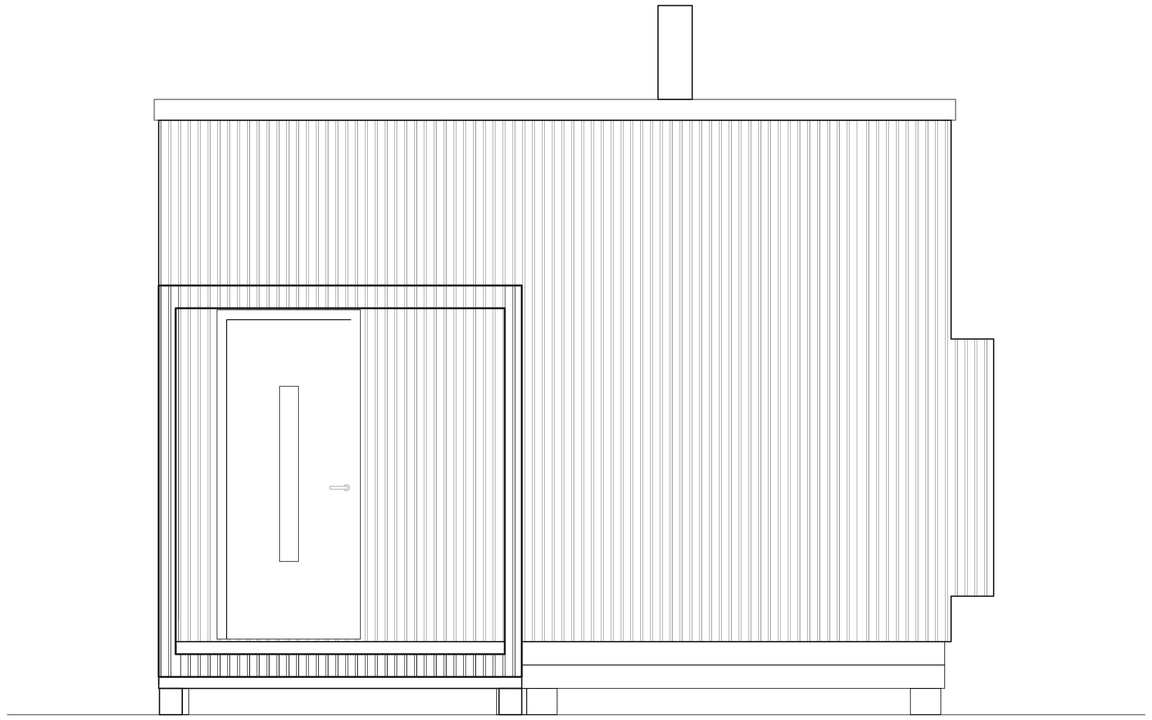


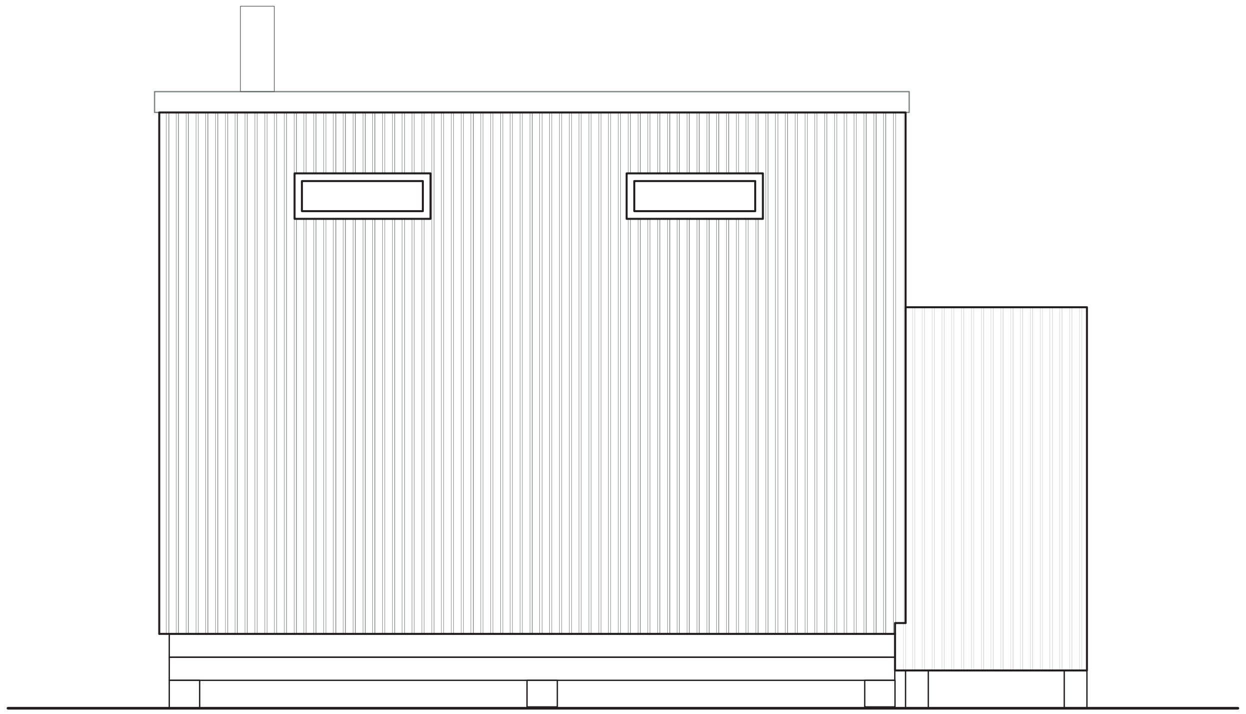
Figure 52: Loft plan with window on south and other scenarios[AutoCAD and Illustrator]



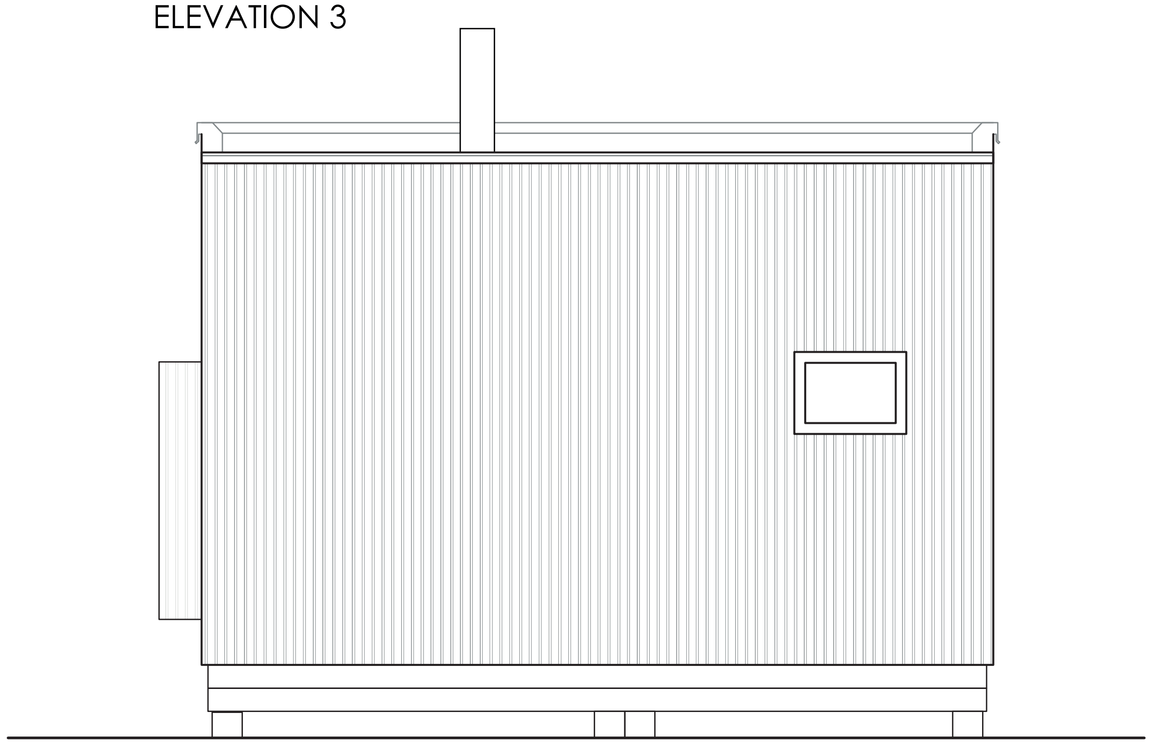
ELEVATION 1



ELEVATION 3



ELEVATION 2



ELEVATION 4

Figure 53: Facade Elevations SC 1:75 [AutoCAD and Illustrator]

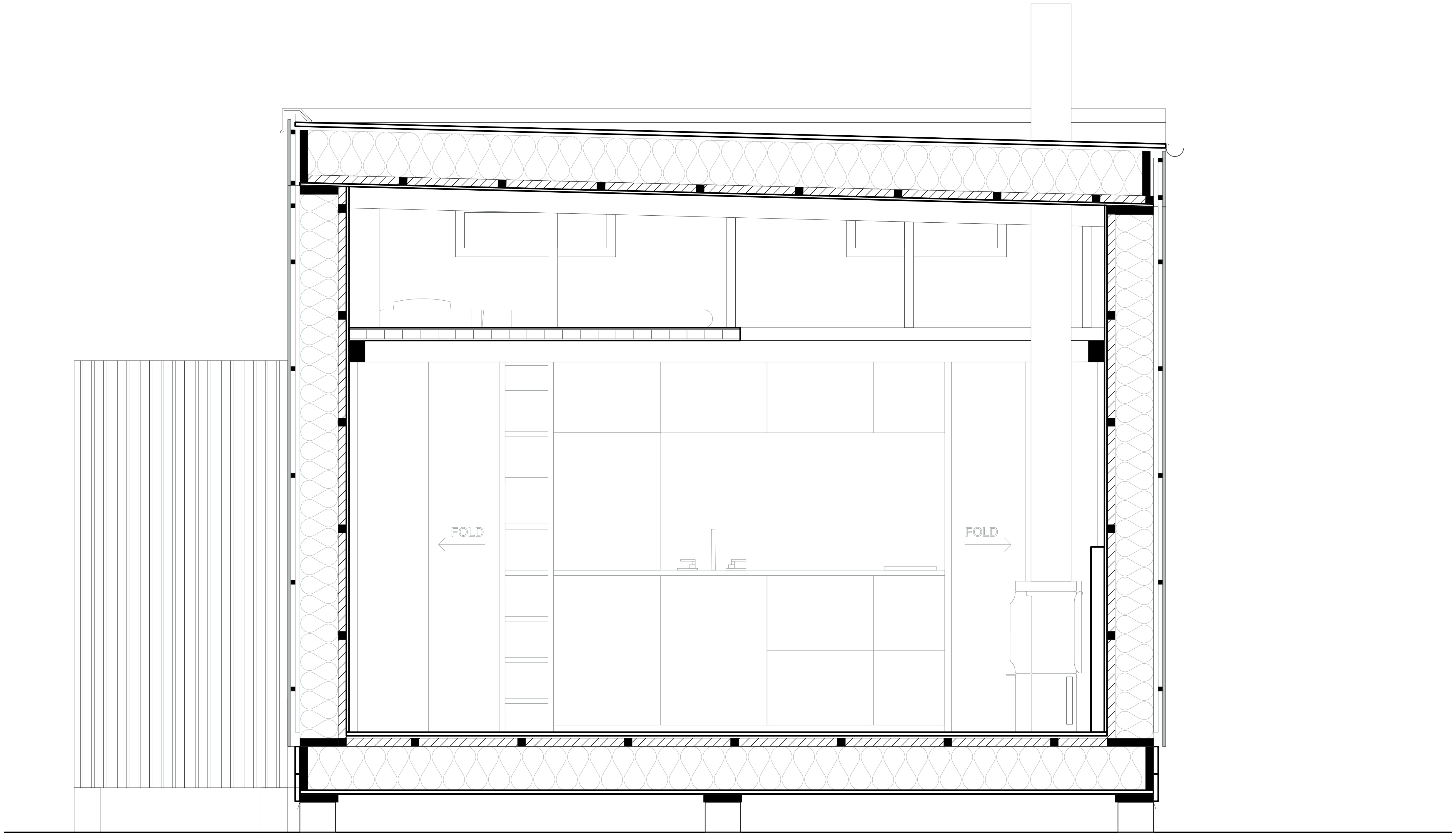


Figure 54: Section A SC 1:25 [AutoCAD and Illustrator]

SECTION B

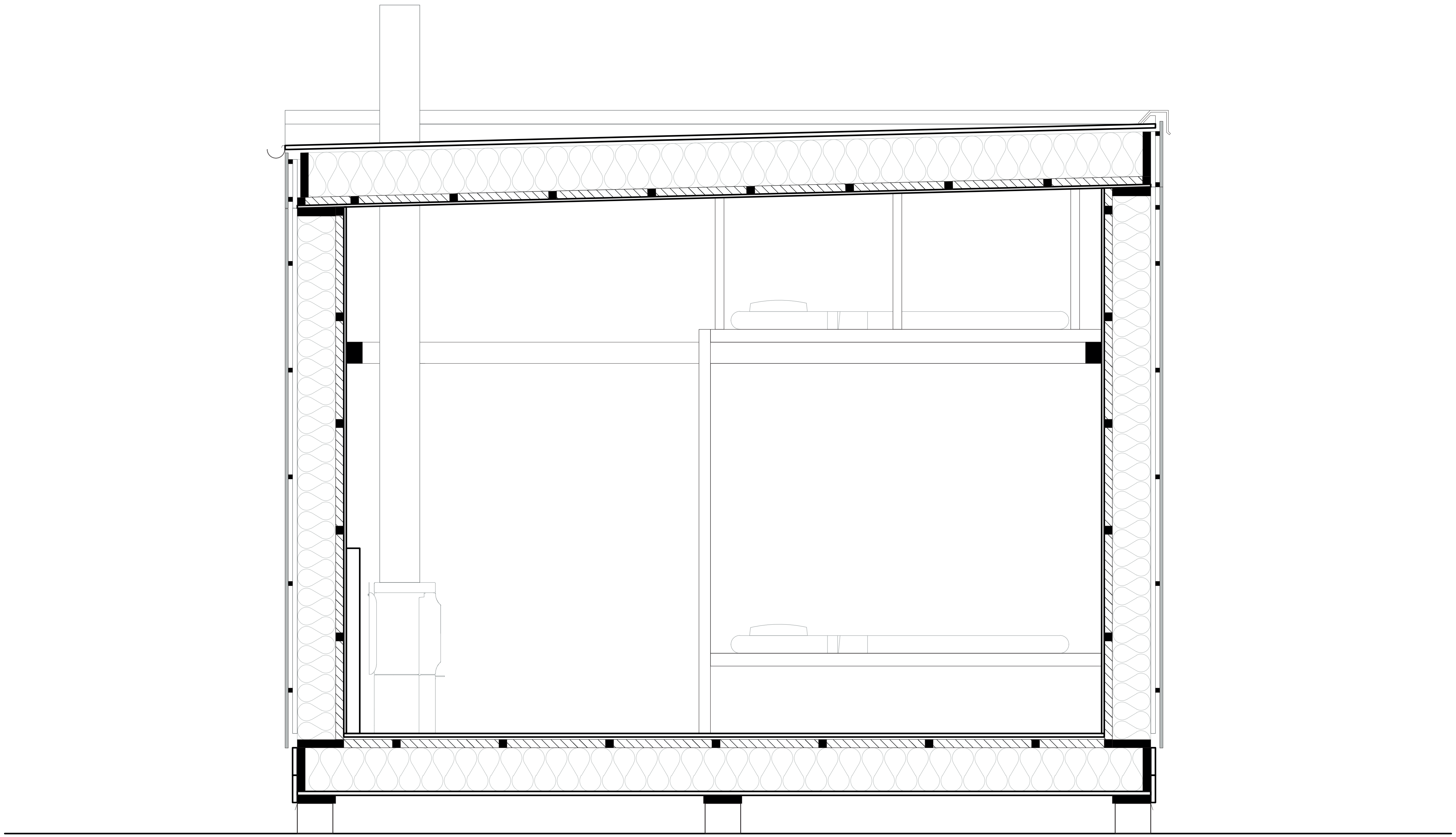


Figure 55: Section B SC 1:25 [AutoCAD and Illustrator]

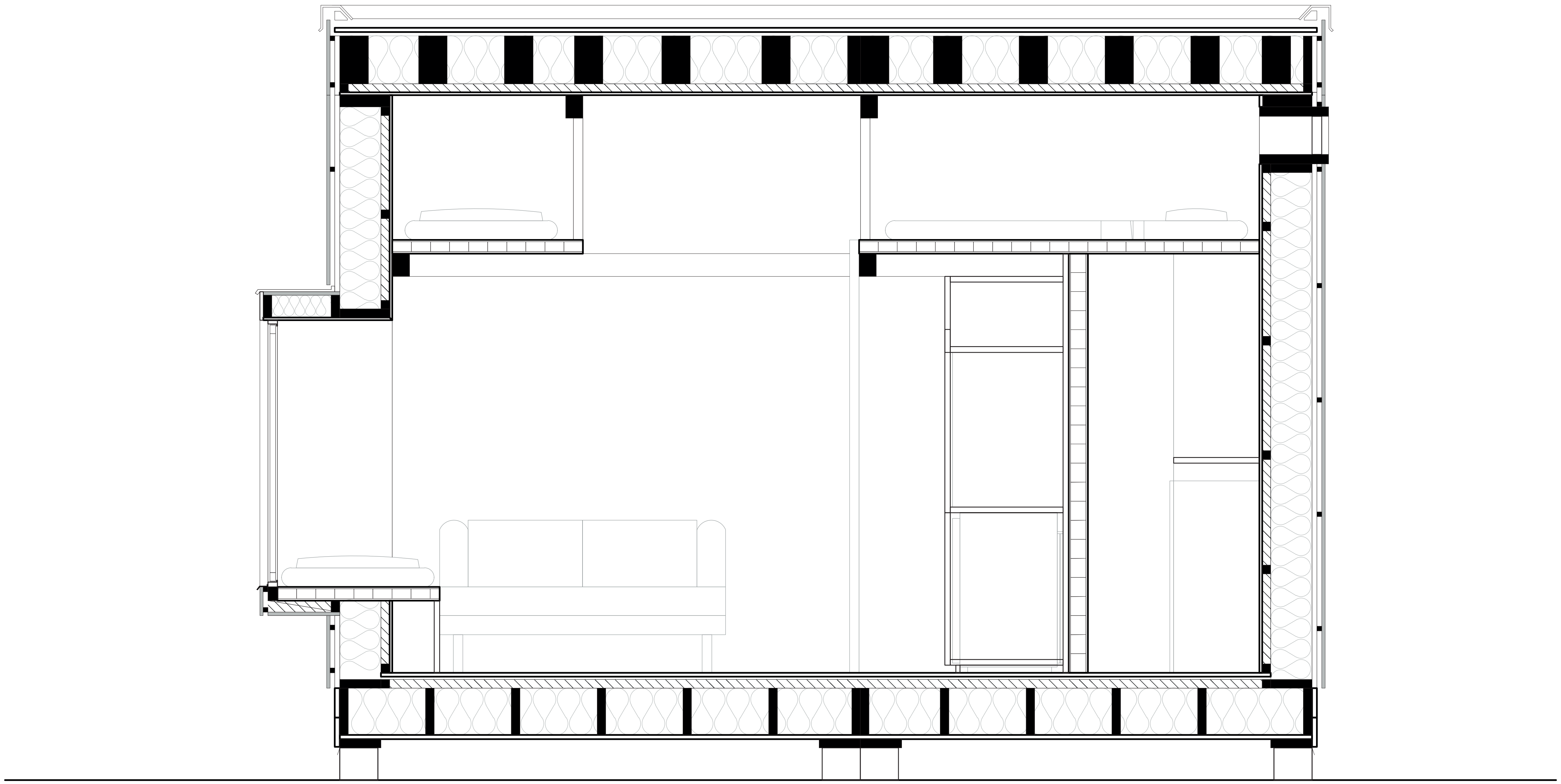


Figure 56: Section C SC 1:25 [AutoCAD and Illustrator]

SECTION D

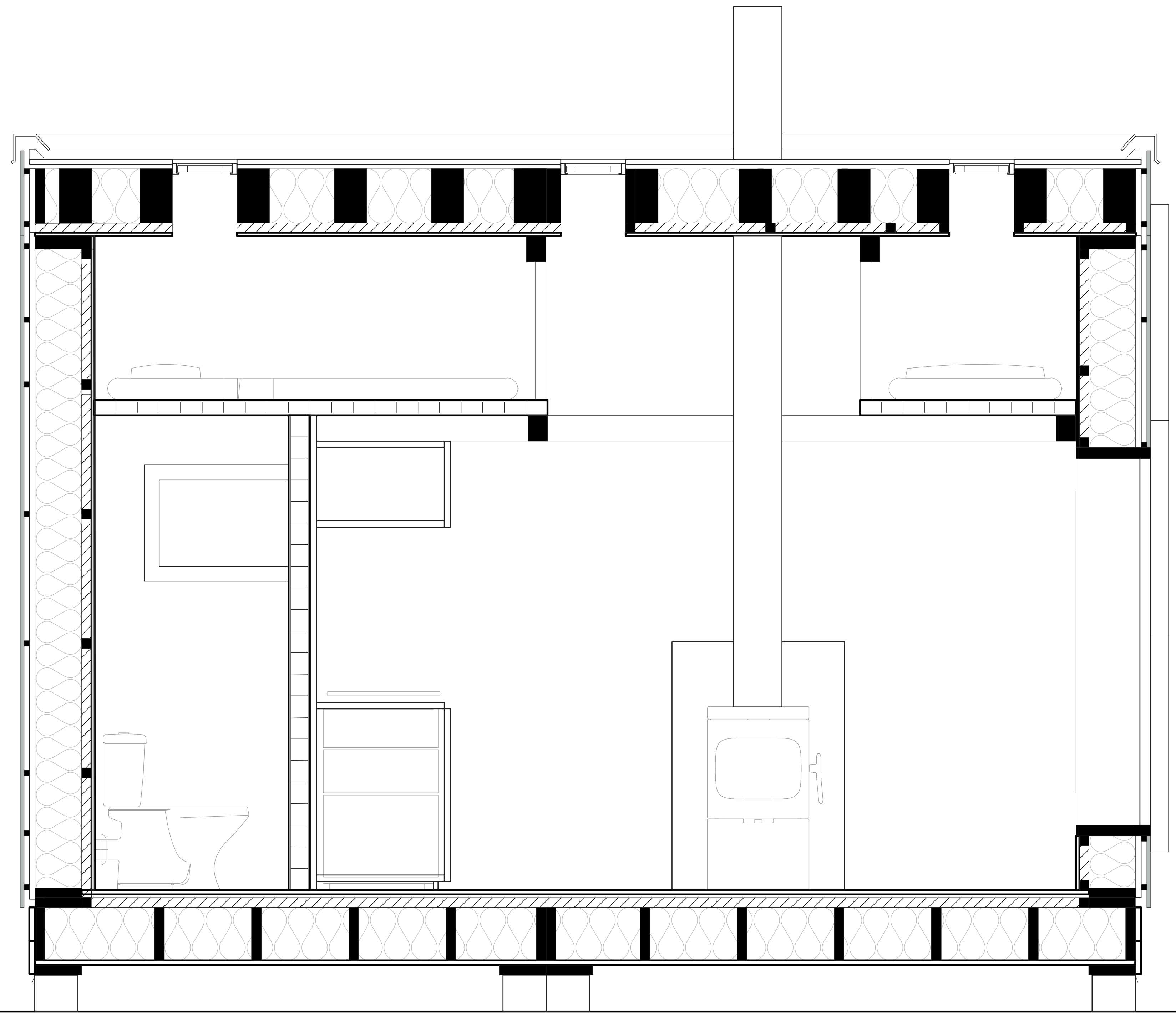


Figure 57: Section D SC 1:25 [AutoCAD and Illustrator]

Figure 58: Moving inside the space [SketchUp, V-ray and Photoshop]

Image source: Human figure from www.skalgubbar.se
Figure 59: Entrance perspective, summer render [SketchUp, V-ray and Photoshop]

CONSTRUCTION

In order to find the most suitable construction for the cabin, an analysis of three different types of constructions was made. The three different constructions that was analysed was: a wood frame construction (WFC), a massive wood construction (MWC) and a slim construction (SC).

The construction of the cabin needs to have a low CO2 emission, limited thickness and have a sufficiently U-valve to be placed in cold climate.

To be able to compare the three construction types, all the three constructions had the same U-value and the same outer and inner layer of the construction, all the constructions were also load bearing.

The WFC is a common way to build houses in Scandinavia, it has a wood frame construction and a cellulose insulation. MWC has a different load bearing structure of massive wood and the insulation is cellulose. The SC is a slimmer construction than the other two constructions. The SC will have a steel structure and a vacuum insulation, so that the thickness of the construction is reduced, which makes it possible to have a bigger indoor volume.

The most optimal construction for the cabin should be a construction that has a thickness that fits into the limited size of the cabin without sucking up too much of the indoor space in the cabin. It needs to be well insulated to reduce the heat losses and be able to maintain a good indoor climate. At the same time the construction needs to have low embodied CO2 emissions.

The analysis was limited to the extraction of raw materials and the manufacture of products and materials needed (A1 - A3), including the transport of goods to the site (A4), replacement of new materials over the lifetime of the building (B4) and waste processing and disposal (C3-C4).

The analysis was also limited to only analyse the main construction elements; outer roof, outer walls, groundwork and foundation.

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Roof	0,13	1	Water proof membran		2
		2	wood plank	0,14	20
		3	Nailing battens (70x20) and air gap		20
		4	Wind barrier		1
		5	Insulation layer 1, Cellulose blown	0,037	300
			Load bearing timber beams (250x150, c450)		
		6	Vapor barrier		1
		7	Insulation layer 2, Cellulose sheet	0,036	45
			Stud (45x45, cc60)		
		8	Wooden surface	0,14	15
			Total		404
External Wall	0,18	1	Wood cladding	0,14	19
		2	Nailing battens 25x25 mm and air gap (horizontal)		25
		3	Nailing battens 25x25 mm and air gap (vertical)		25
		4	Wind barrier	0,1	1
		5	Insulation layer 1, Cellulose sheet	0,036	193
			Load bearing stud (45x193, c600)		
		6	Vapor barrier		1
		7	Insulation layer 2, Cellulose sheet	0,036	45
			Stud (45x45, cc60)		
		8	Wood surface	0,14	15
			Total		324
Ground slab	0,1	1	Wooden floor	0,14	20
		2	Under floor	0,14	15
		3	Vapor barrier		1
		4	Insulation layer 1 , Cellulose sheet	0,036	45
			Stud 45x45		
		5	Insulation layer 2, Cellulose sheet	0,036	338
			Load bearing timber (45x338, c450)		
		6	Wind barrier plate K-board	0,14	6
		7	Wood plank	0,14	22
			Total		447

Figure 60: Wood Frame Construction [Excel]

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Roof	0,13	1	Water proof membran		2
		2	Wood plank	0,14	20
		3	Nailing battens (70x20) och air gap		20
		4	Wind barrier		1
		5	Insulation layer 1, Cellulose blown	0,037	290
			Studs (290x150, c600)		
		6	Vapor barrier		1
		7	Massive wood	0,14	120
			Total		454
External Wall	0,18	1	Wood cladding	0,14	19
		2	Nailing battens 25x25 mm and air gap (horizontal)		25
		3	Nailing battens 25x25 mm and air gap (vertical)		25
		4	Wind barrier	0,1	1
		5	Insulation layer 1, Cellulose sheet	0,036	206
			Stud (45x206, c600)		
		6	Vapor barrier		1
		7	Massive wood	0,14	120
			Total		397
Ground slab	0,1	1	Wooden floor	0,14	20
		2	Under floor	0,14	15
		3	Vapor barrier		1
		4	Insulation layer 1 , Cellulose sheet	0,036	45
			Stud 45x45		
		5	Insulation layer 2, Cellulose sheet	0,036	285
			Studs (45x285, c600)		
		6	Massive wood	0,14	120
		7	Wood plank	0,14	22
			Total		508

Figure 61: Massive Wood Construction [Excel]

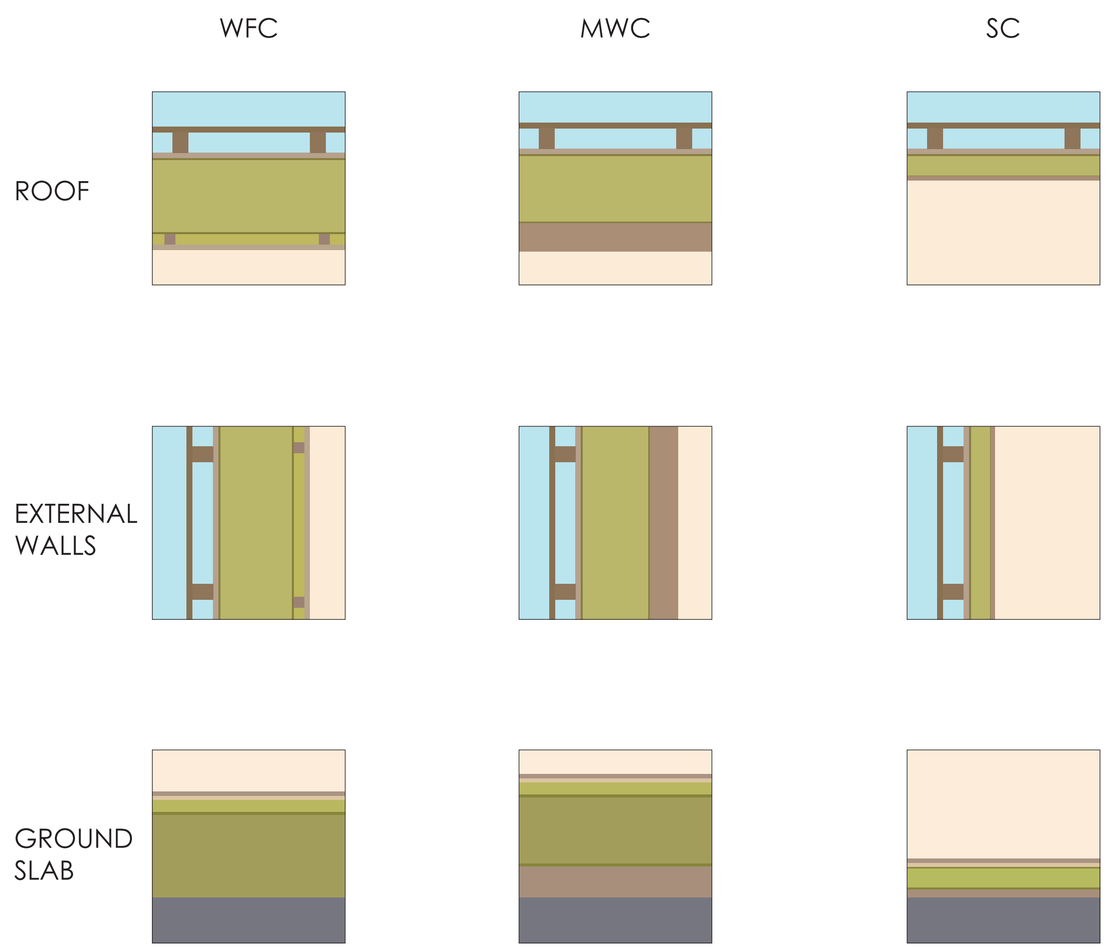
Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Roof	0,13	1	Water proof membran		2
		2	Raspont	0,14	20
		3	Nailing battens (70x20) och air gap		20
		4	Wind barrier		1
		5	Insulation layer, VIP	0,00213	90
			Load bearing steel beams (IPE 160)		
		6	Vapor barrier		1
		7	Wooden surface	0,14	15
			Total		149
External Wall	0,18	1	Wood cladding	0,14	19
		2	Nailing battens 25x25 mm and air gap (horizontal)		25
		3	Nailing battens 25x25 mm and air gap (vertical)		25
		4	Wind barrier	0,1	1
		5	Insulation layer 1, VIP	0,00213	78
			Load bearing steel pillars (VKR pillar 50x50)		
		6	Vapor barrier		1
		7	Wood surface	0,14	15
			Total		164
Ground Slab	0,1	1	Wooden floor	0,14	20
		2	Under floor	0,14	15
		3	Vapor barrier		1
		5	Insulation layer, VIP	0,00213	83
			Load bearing steel beam (IPE 160)		
		6	Wind barrier plate K-board	0,14	6
		7	Wood plank	0,14	22
			Total		147

Figure 62: Slim Construction [Excel]

The result of the analysis of the three different construction types showed that they all have different thickness and amount of CO2 emissions. The thickest construction is the massive wood construction because of the load bearing massive wood panels, the thinnest construction is the slim construction with steel beams and vacuum insulation and the wood frame construction is slightly thinner then the massive wood construction. Looking into the CO2 emissions, the result is that the construction with the highest emissions is the slim construction, because of the steel construction and vacuum insulation made in the United States of America, that both have high emissions. The massive wood construction and wood frame construction are both made of wood and have almost the same emissions. The massive wood construction has slightly more emissions than the wood frame construction.

The analysis shows the result that the construction that is most optimal for the cabin is the wood frame construction. The wood frame construction has a thickness that is 50-70 mm slimmer than the massive wood construction and will fit into the limited size of the cabin. The wood frame construction has also the lowest CO2 emissions.

Based on the results of this analysis, the wood frame construction was chosen for the cabin, the wood frame construction was therefore further developed to work together with the rest of the elements of the cabin.



Element	U-value [W/m2K]	Construction type	Thickness [mm]	CO2eq
26 Outer roof	0,13	WFC	404	Low
		MWC	454	Middel
		SC	149	High
Element	U-value [W/m2K]	Construction type	Thickness [mm]	CO2eq
22 Outer walls	0,18	WFC	324	Low
		MWC	397	Middel
		SC	164	High
Element	U-value [W/m2K]	Construction type	Thickness [mm]	CO2eq
25 Floor structure	0,1	WFC	447	Low
		MWC	508	Middel
		SC	147	High

Figure 63: Different Construction elements [Excel]

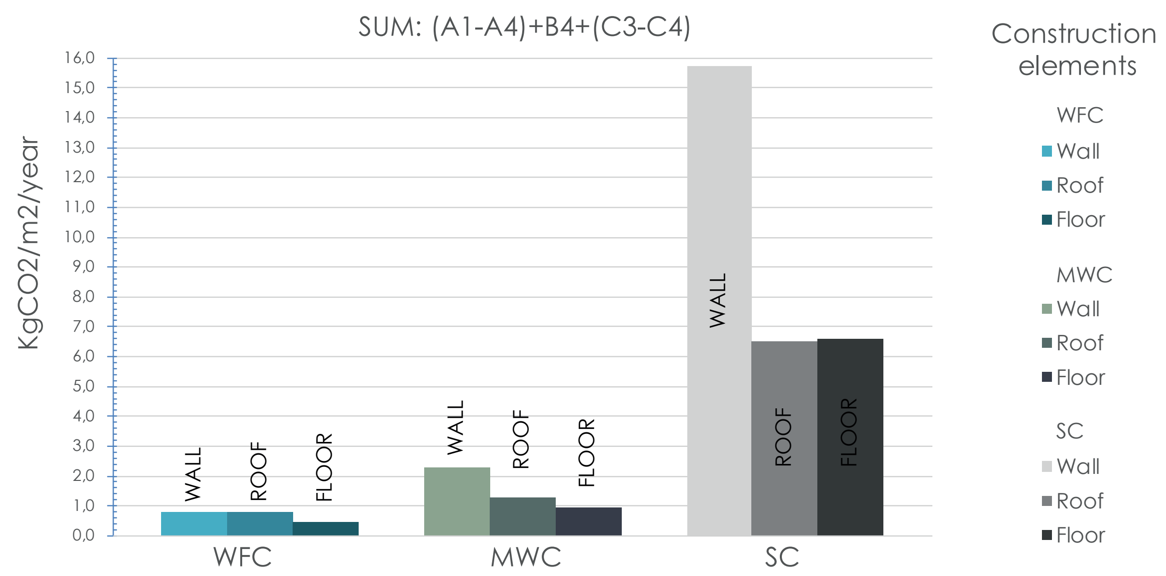


Figure 64: Different Construction elements LCA[Excel]

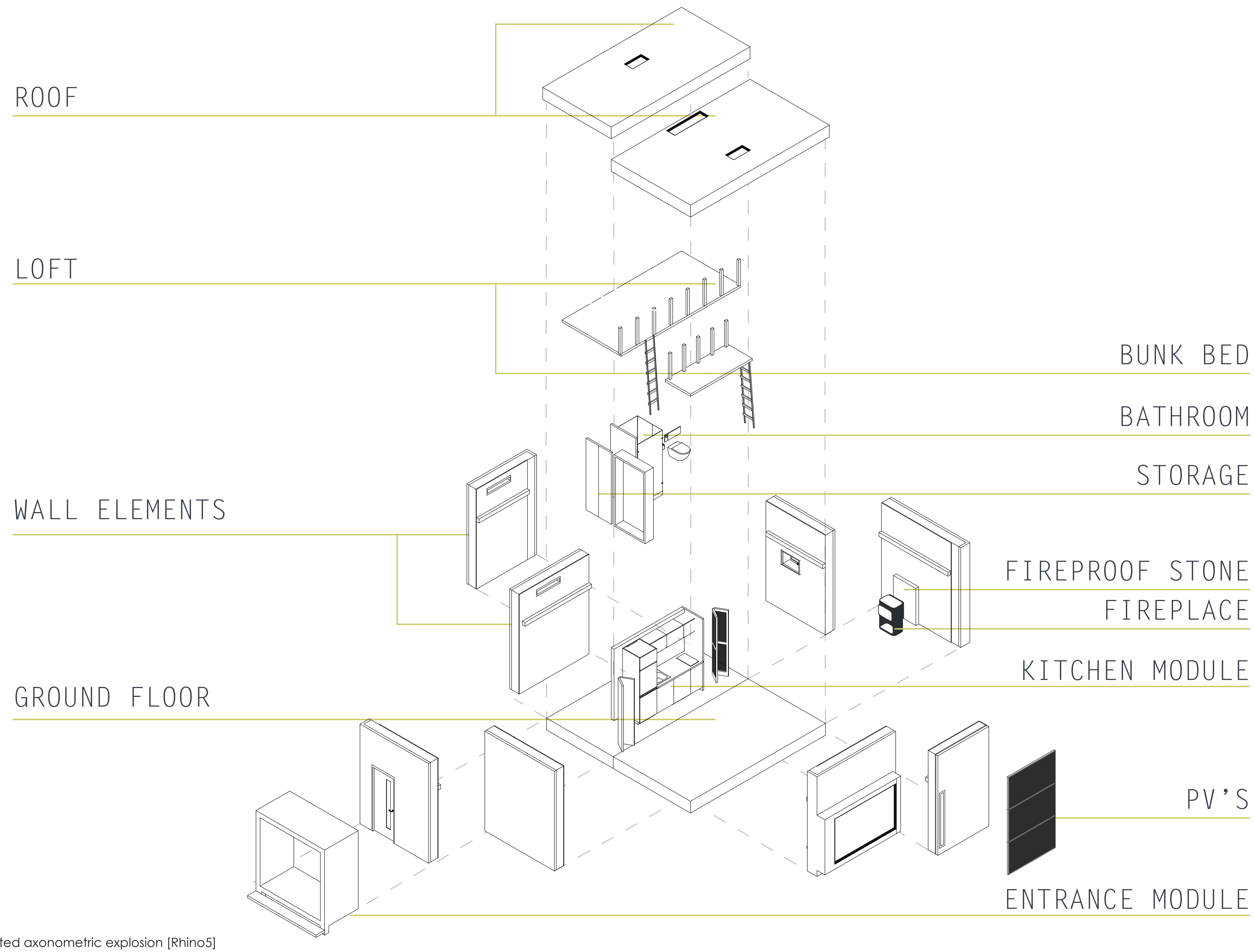


Figure 65: Prefabricated axonometric explosion [Rhino5]

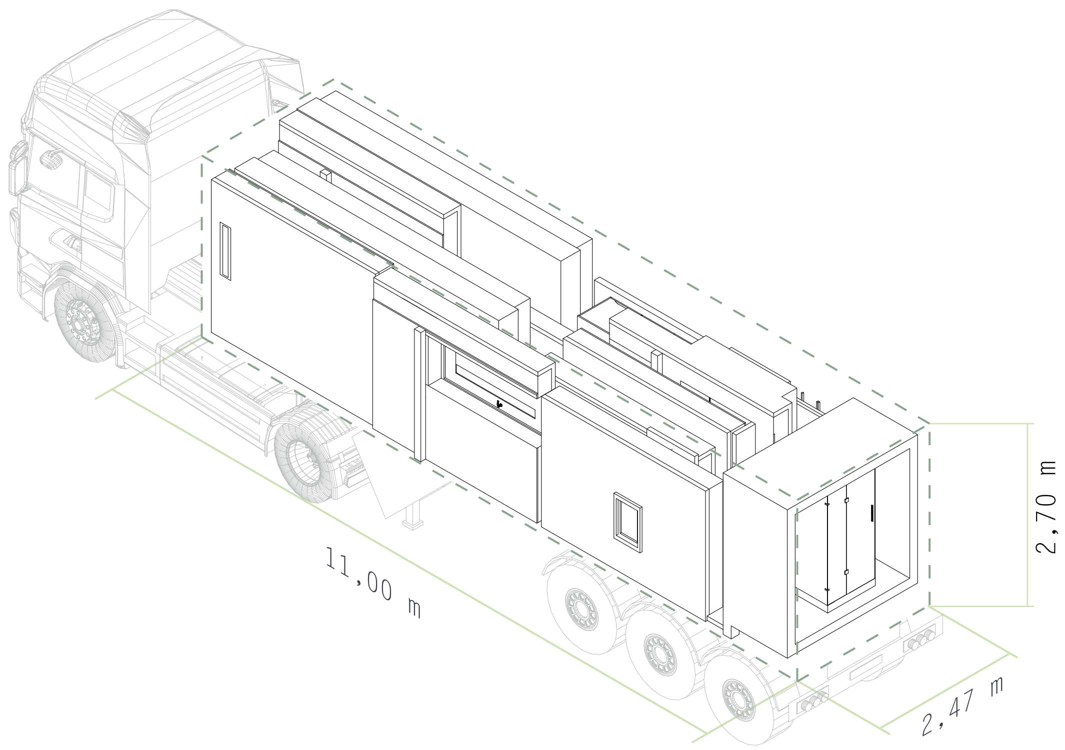


Figure 66: Isometric prefabricated components inside a semitrailer [Rhino5]

The cabin is prefabricated in modules that will be built together on site. The modules are prefabricated in the factory in Mo I Rana and will be transported by a truck to the site.

The prefabricated elements are: 8 pieces outer wall, 2 pieces outer roof, 2 pieces ground floor slab, 2 pieces inner wall, 2 pieces inner loft and 1 piece entrance module. The kitchen will also be prefabricated and arrive in one piece and the bathroom furnishings, wood stove and water tank will be installed on site.

The wall construction can be made differently depending on where the resident wants to place the big window for view. The PV modules will always be placed on the outer wall facing south.

The cabin can be made for on-grid situations and for off-grid situations. The building envelopes and inside building parts will be the same for on-grid or off-grid. The difference between the on-grid situation and the off-grid situation is that the off-grid cabin is working as a dry cabin without water installed.

It will be possible to transport the whole cabin in one truck and will approximately take about one week to build on site, depending on the weather conditions and the tracking. The construction time on site was based on the case studies. When building the cabin on site there is need of a crane for heavy lifting of the elements.

Before the cabin arrive to the site preparatory work of the pillar foundation will have to be made. Each site is individual and unique and because of this the pillar foundation can be different at each site.

The steps from drawing to complete cabin on site is:

1. Resident decide how to place and to orientate the cabin and the big window.
2. Cabin is prefabricated in factory.
3. Preparatory work of pillar foundation is finished before the cabin arrives at site.
4. Cabin arrives to the site.
5. Ground slab is placed and connections to drain and electrical grid are made.
6. The outer walls will be attached to the ground slab.
7. Kitchen and bathroom will be installed.
8. Loft will be connected to the walls.
9. The roof is lifted in place and loft is attached to it.
10. The entrance module is placed.
11. Ready to move in.

Depending on the ground conditions an Attefall house can be built on different types of foundation, for example; concrete slab, ventilated/not ventilated crawl foundation, hybrid foundation, string foundation, pillar foundation etc. A foundation needs to be able to take loads and the part of the foundation that is in contact with the ground needs to be able to handle humid conditions. This leads to high demands on the material chosen for the loadbearing and ground contact parts of the foundation resulting in that these materials usually have a high CO2 emission. (Husgrunder(1) ,2018)

To minimise the material use and ground work for the foundation the pillar foundation was chosen for the cabin. The pillar foundation can be built on different sites with different ground conditions. The pillars will be made of concrete and need to stick up 20 cm above the ground level to get a well-ventilated foundation. (Husgrunder(2) ,2018)attefallshus/#plintgrund)

The concrete pillar foundation will be made before the cabin arrives to the site. When the cabin arrives to the site it will be mounted on top of the pillar foundation.

The pillar foundation will not be calculated in the LCA calculations because the design of the pillars and amount of concrete will be very site specific and will vary depending on the ground conditions and terrain levels.

| FOUNDATION

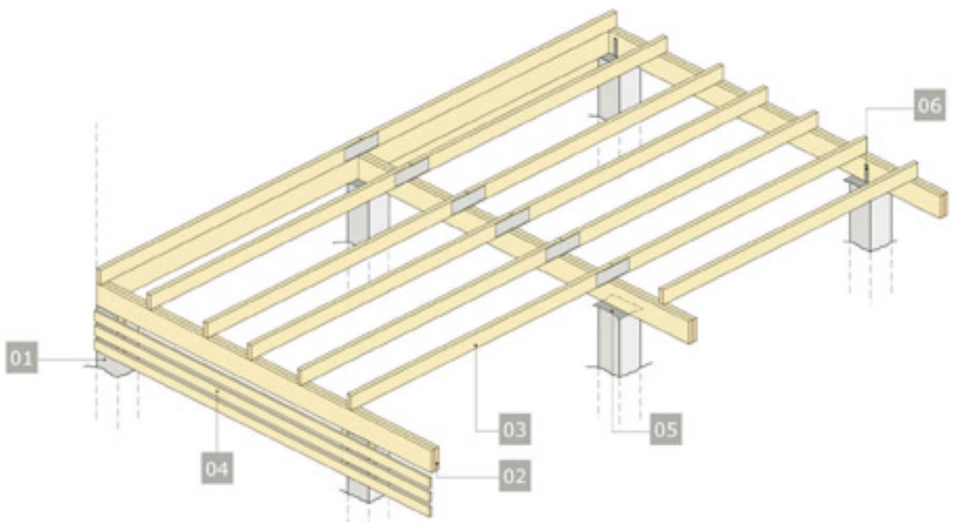


Image source: https://www.traguiden.se/konstruktion/konstruktionsexempel/grundlaggning/oppen-plintgrund/principlosning/
Figure 67: Pilar Foundation [Svenskt Träguiden]

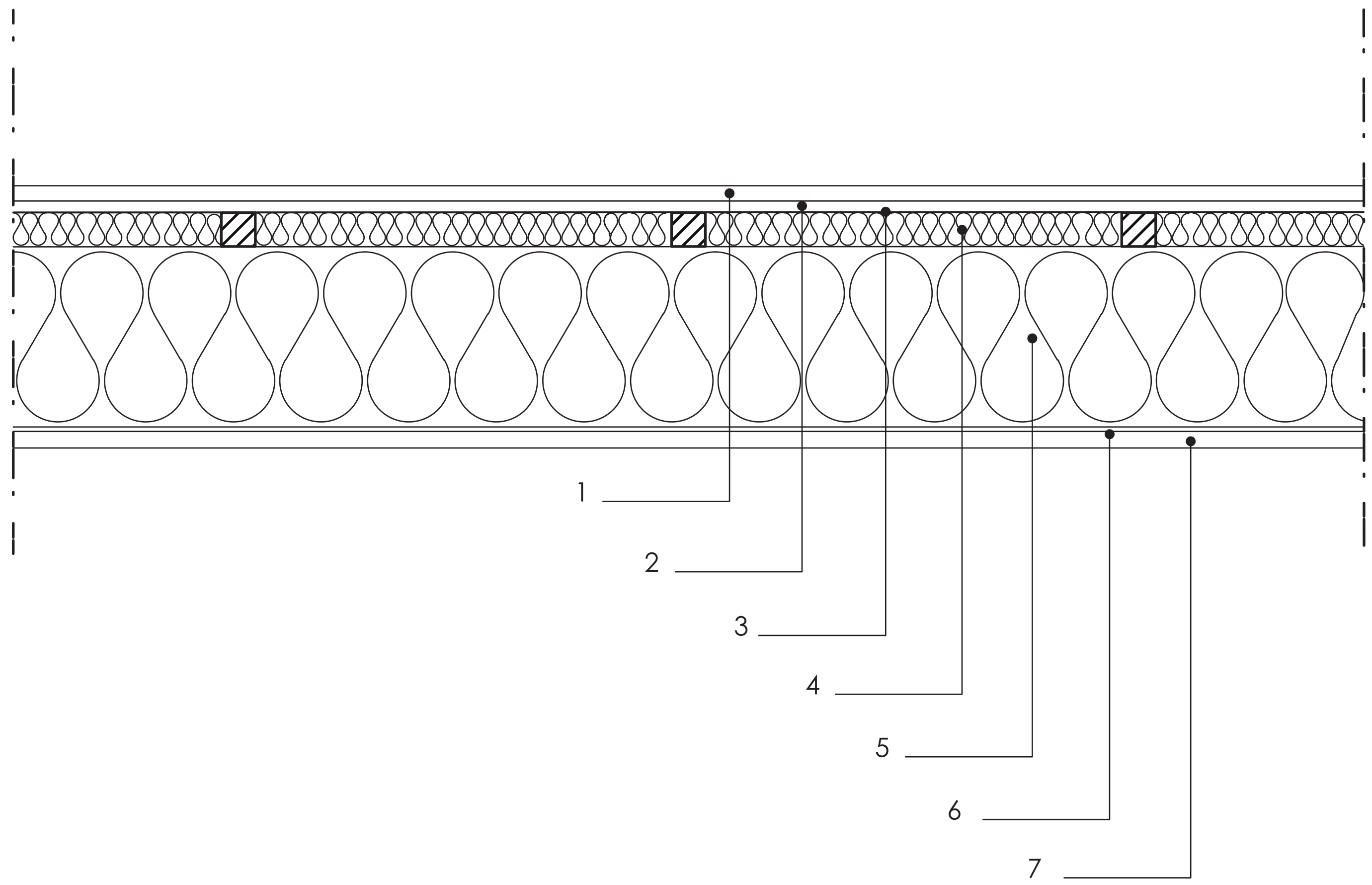


Figure 68: Ground slab detail, scale 1:10 [AutoCAD]

| GROUND SLAB

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Ground slab	0,125	1	Wooden floor	0,14	20
		2	Under floor	0,14	15
		3	Vapor barrier		1
		4	Insulation layer 1 , Cellulosa sheet	0,036	45
			Stud 45x45		
		5	Insulation layer 2, cellulosa sheet	0,036	240
			Load bearing timber (45x240, c450)		
		6	Vind barrier plate K-board	0,14	6
		7	Wood plank	0,14	22
			Total		349

Figure 69: Ground slab table of material layers [Excel]

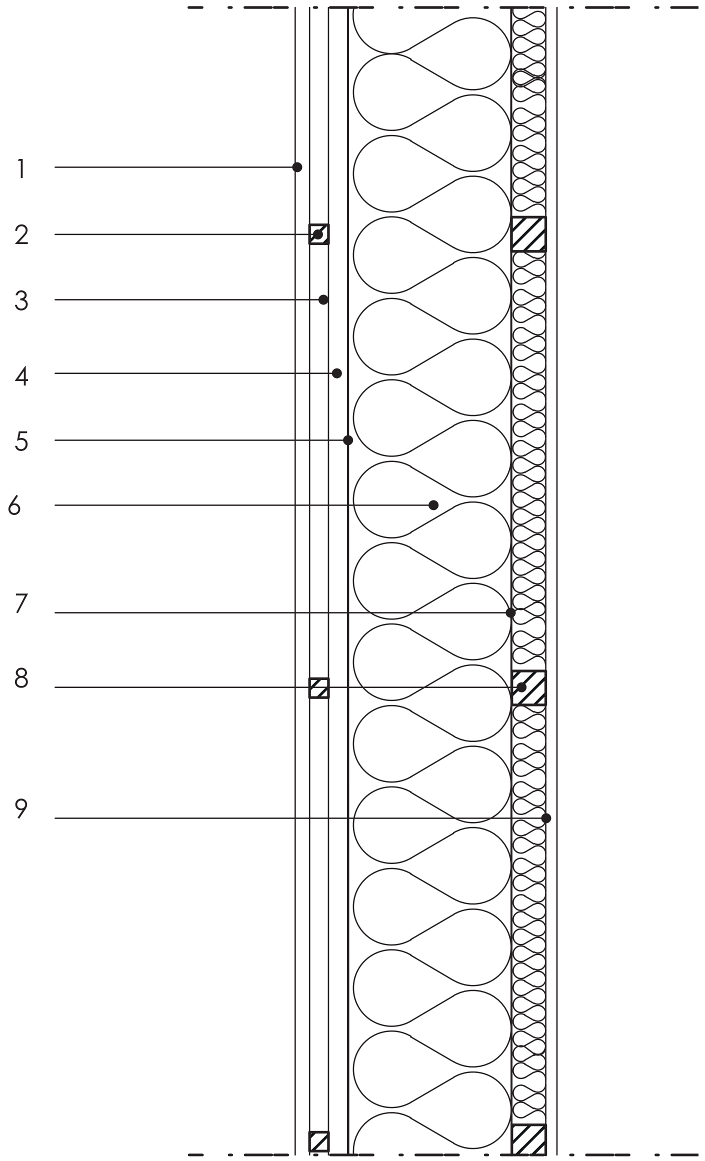


Figure 70: External Walls detail, scale 1:10 [AutoCAD]

| EXTERNAL WALLS

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
External walls	0,166	1	Wood cladding	0,14	19
		2	Nailing battens 25x25 mm and air gap (horisontal)		25
		3	Nailing battens 25x25 mm and air gap (vertical)		25
		4	Wind barrier	0,1	1
		5	Insulation layer 1, Cellulosa sheet	0,036	215
			Load barring stud (45x215, c600)		
		6	Vapor barrier		1
		7	Insulation layer 2, Cellulosa sheet	0,036	45
			Stud (45x45, cc60)		
		8	Wood surface	0,14	15
			Total		346

Figure 71: External Walls table of material layers [Excel]

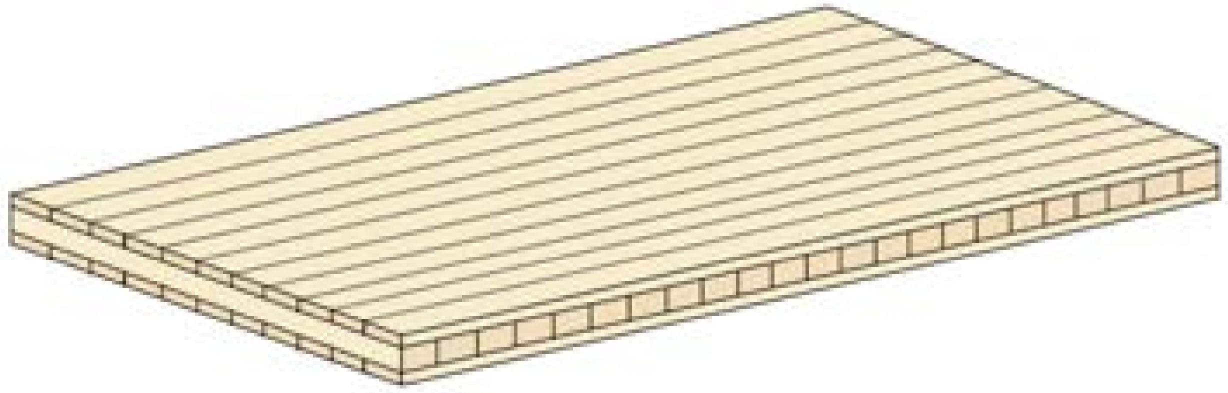


Image source: https://www.traguiden.se/konstruktion/kl-trakonstruktioner/bjalklag/5.1-bjalklag---oversikt/5.1.1-plattbjalk-lag/?previousState=1000000

Figure 72: Internal walls and internal slab [Svenskt Träguiden]

| INNER WALLS AND LOFT SLAB

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Loft slabs			Massive wood slab		72
Inner walls			Massive wood		72

Figure 73: Inner walls and loft slab table of material layers [Excel]

BLECKHALL

Image source: https://www.doorly.se/ytterdorrar/gaso-ytterdorr-glas.html

NORDVESTVINDUET

Image source: http://epd.nsp01cp.nhosp.no/getfile.php/EPDer/Byggevarer/D%C3%B8rer%20og%20vinduer/NEPD-386-265-NO_Nordvestvinduet-Fastkarm-vindu.pdf

Figure 74: Entrance door and windows [Doorly and Nordvestvinduet]

| WINDOWS AND ENTRANCE DOOR

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Windows	0,708		3-glass window with wood frame and aluminum cladding		
Entrance door	0,9		Wood door with 2-glass window		

Figure 75:Windows and Entrance door slab table of material layers [Excel]

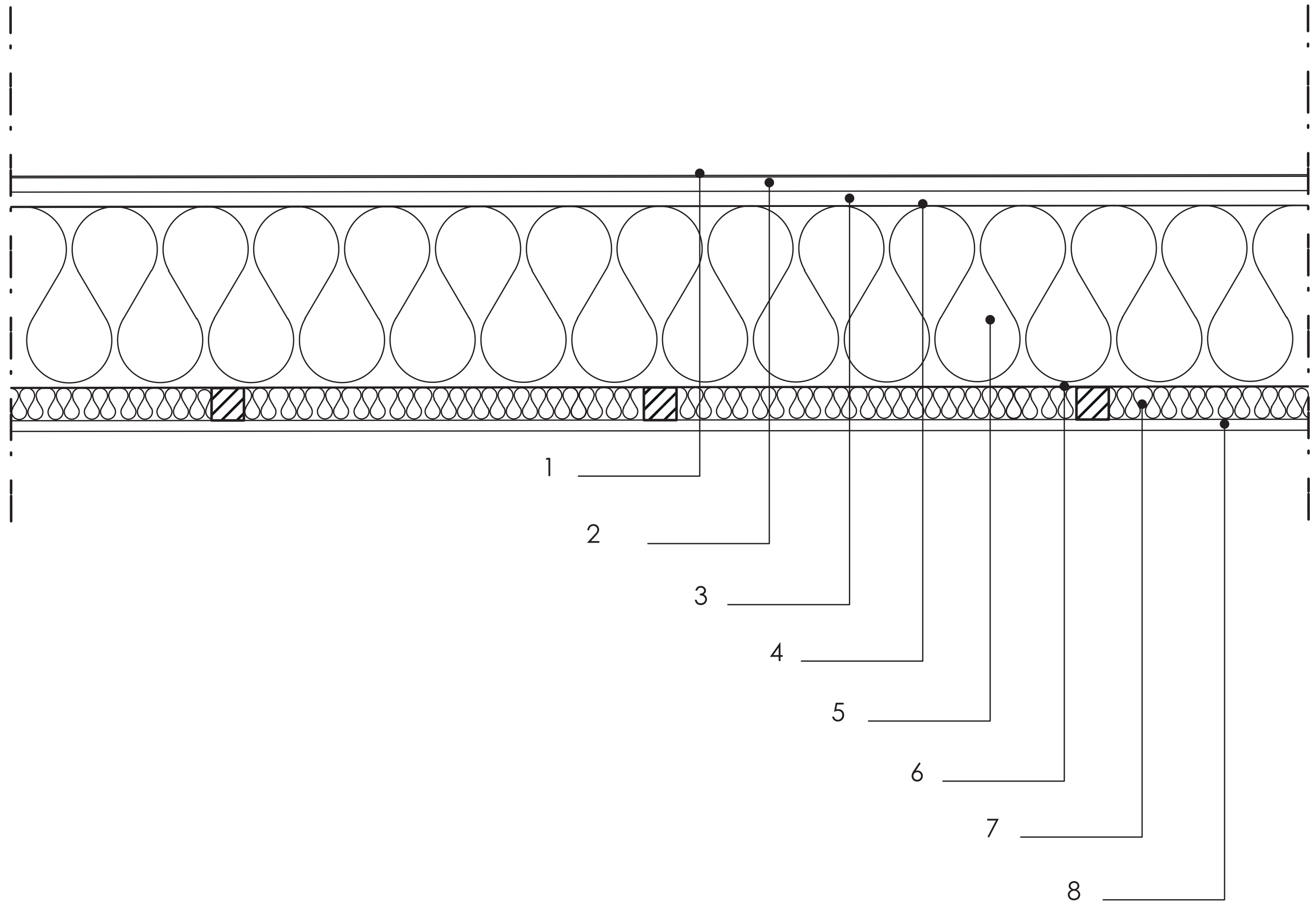


Figure 76: Roof detail, scale 1:10 [AutoCAD]

| ROOF

Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]
Roof	0,158	1	Water proof membran		2
		2	Wood plank	0,14	20
		3	Nailing battens (70x20) and air gap		20
		4	Wind barrier		1
		5	Insulation layer 1, Cellulosa blown	0,037	250
			Load bearing timber beams (250x150, c450)		
		6	Vapor barrier		1
		7	Insulation layer 2, Cellulosa sheet	0,036	45
			Stud (45x45, cc60)		
		8	Wooden surface	0,14	15
			Total		354

Figure 77: Roof slab table of material layers [Excel]

OPERATIONAL

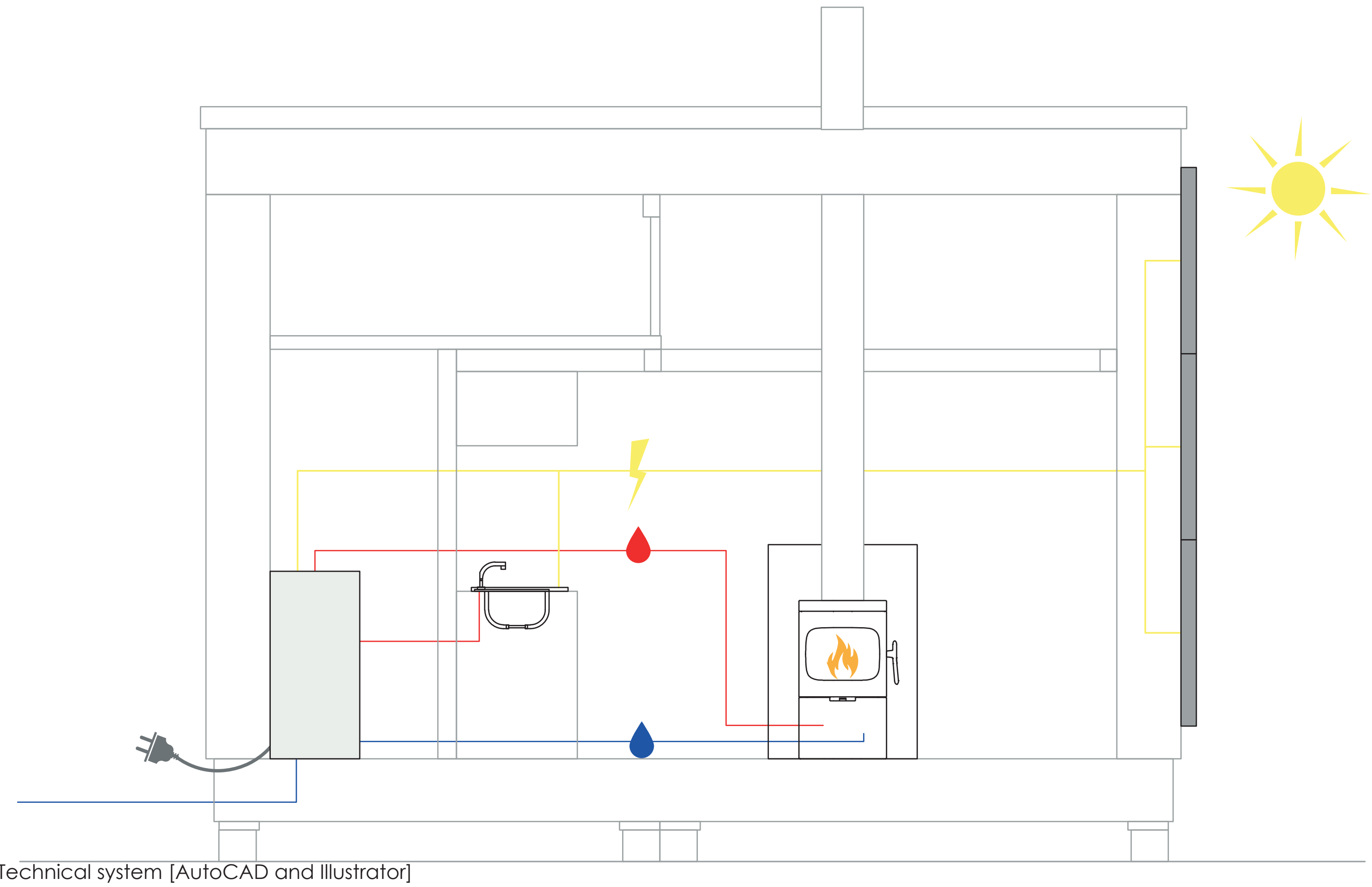


Figure 78: Technical system [AutoCAD and Illustrator]

The cabin will be heated by a wood stove. The wood stove will work as a space heater and also heat the domestic tap water. 90 % of the energy from the stove will heat the air and 10 % will heat the water. The water tank is connected to the stove and to electricity. When the water is not heated by the stove it will be heated by electricity.

The cabin has 5m2 PV modules which will produce renewable energy as electricity, during the year. The electricity will be used in the cabin for house hold use and for the water tank to heat the water. The cabin can be connected to the grid to complement the electricity need.

When the cabin is not used there is no maintenance heat. When no one is using the cabin, everything will be turned off and the water will be emptied from the cabin to avoid freezing.

Image source: https://jotul.com/no/produkter/vedovner/f-105-serien/jotul-f-105-b#technical-area
Figure 79: Fireplace [Jøtul]

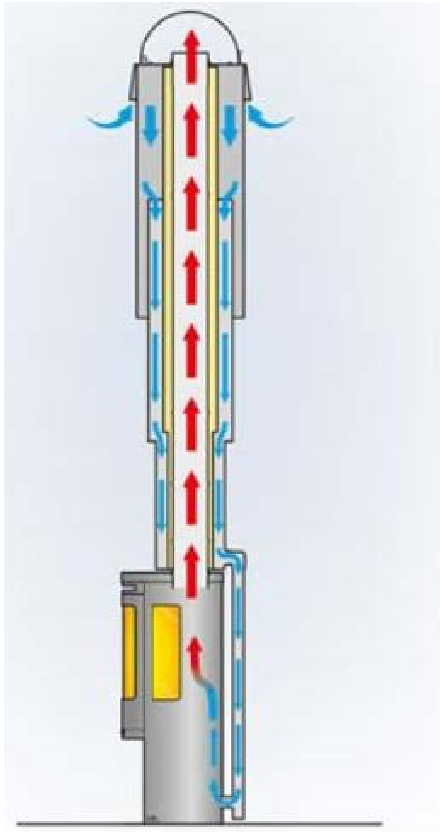


Image source: https://www.contura.se/kaminer/skorstenar/tilluftsskorsten/
Figure 80: Skorsten [Contura]

Image source: https://prisguiden.no/produkt/bakesten-kleberstein-234833
Figure 81: Soapstone [Alfavarme]

The heat source in the cabin is a wood stove, the stove is also connected to the water system in the cabin so that it will be able to heat both the indoor space and the domestic water. Since the size of the cabin is very limited, the volume of indoor air that needs to be heated and the need for domestic hot water is much less than for a normal permanent residence. The range of wood stoves combined with water heater on the market dimensioned for such a small cabin is limited or non-existing therefore most of the wood stoves on the market will be over dimensioned for the cabin. With the lack of smaller wood stoves combined with water heater on the market, the heating system for the cabin was designed with one of the smaller wood stoves without a water heater. This stove was then combined with a water tank fit for the size of the cabin and then the heating allocation for heating of the air and the domestic water was designed to fit the heating demand.

The wood stove installed to heat the air and heat the tap water is a wood stove called Jøtul F 105 B made in Norway by the Norwegian stove company Jøtul. The stove picked for the cabin has the dimensions 690 x 410 x 350 mm (H x W x D) and is one of the smallest wood stoves on the market.

The fuel for the wood stove is biofuel and it has an effect of a minimum of 2,4 kW, nominal of 4,5 kW and a maximum effect of 6,0 kW and an efficiency of 83 %. (Jøtul, 2018)

The wood stove will be connected to the domestic water in the cabin. The wood stove will heat both the air and the domestic water, 90 % of the effect will heat the air and 10 % will heat the domestic water.

The installation of the wood stove is in the center of the cabin, in the living room in order to more efficiently spread the heated air in the cabin. To make the temperature more stabilized in the cabin, a 720 x 774 x 100 mm (H x W x D) Soapstone is placed behind the wood stove in order to store the heat and realize the heat for a longer period during the day and night. The soapstone comes from Otta in Norway. (Alfa, varme & pipeteknikk AS, 2018)

To get the maximum effect out of the wood stove an air supply chimney is installed to the wood stove. The chimney supplies air to the stove and at the same time the smoke from the wood stove can be released. (Contura, 2018)

Figure 82: Water boiler [Metrotherm]
Image source: http://www.metrotherm.se/assets/upload/METRO_VVB_1603_webb.pdf

The cabin has an electrical boiler for heating of the tap water. The electrical boiler is connected to electricity and to the wood stove installed in the cabin. The preliminary source for heating the tap water is by the heat from the wood stove and the secondary source to heat the tap water is by electricity when the wood stove is not in use.

The model chosen for the electrical boiler is FOCUS Power which is made in Finland. The size of the electrical boiler is 100 litres and shall suffice shower, wash up the dishes and sanitation for four people under shorter periods. The effect of the electrical boiler is 3 kW and it takes 99 min to heat the water using electricity only. The water temperature in the tank is 65 °C. (Metro Therm, 2018)

Figure 83: Photovoltaic module [Innotech Solar]
Image source: http://www.renugen.co.uk/its-innotech-designblack-250-watt-solar-panel-module/

The photovoltaic (PV) modules that are chosen for the cabin is a model called Design Black 250 made by the manufacture Innotech Solar, the modules are produced in Sweden and the cells are made in Germany. The cell technology is Poly-Si and the power rate per module is 250 Wp with an efficiency of 15,5 % and a lifetime of 30 years.

Each module size is 1665 x 991 mm, there are in total 3 modules installed at the cabin, which gives a total area of 4,95 m2.

The PV modules are installed on the outside of the external walls, which means that they are not integrated in the facade. Since the PV modules are not integrated in the facade, both the PV modules and the mounting structure can be removed or replaced without any impact on the physical function of the external walls. (Torhildur Fjola Kristjansdottir, 2016,)

The PV modules are always orientated to the south with a tilt angel of 90 degrees on the cabin. The tilt of angel of 90 degrees are not the most optimal angel, but it will avoid snow on the surface of the PV module which can lower the electricity production of the PV modules.

For the inhabitants to live comfortable in the cabin, the indoor climate had to be optimized. The indoor climate is affected by several factors such as humidity, daylight, airflow, temperature and CO_2 levels, however limitations had to be made in this study so the only two factors that were considered for the indoor climate was the temperature and the CO_2 levels. The optimization was done by analysing the temperatures and the CO_2 levels in the cabin through simulations in Simien. The ventilation system and the heating system were then optimized until a satisfactory indoor climate was achieved.

| TEMPERATURE

The indoor temperature can be measured by both dry bulb temperature and operative temperature. The indoor dry bulb temperature for residential buildings should be around 18-20 °C with some degrees plus or minus, to give a good indoor climate for the residents. During the night the temperature can be a little bit lower than the temperature during the day.

The temperature that is perceived by persons will be described as the operative temperature, which is the radiation temperature from the surrounding surfaces and the dry bulb temperature. The temperature from the surrounding can be from surface of the elements, radiators, drafts, heat losses and thermal bridges and more. For residential buildings the operational temperature should not be lower than 20 °C. (Petersson, 2011)

| CO2 CONCENTRATION

The CO_2 concentrations is measured in parts per million, PPM, which is the amount of CO_2 molecules per one million air molecules. The CO_2 concentration outdoor is around 300-400 PPM and in well ventilated residence, the CO_2 concentration can be around 600-800 PPM. The CO_2 concentration increases by the amount and the activity level of people in the room. There are no regulations for residential buildings with regards to maximum CO_2 concentration in a building, but an increasing CO_2 concentration can have negative effects on the health, the first signs are often headache and a CO_2 concentration of 100 000 PPM can even be fatal. The CO_2 concentration can easily be measured and is often used as an indicator to when the ventilation in a building is not working properly, the Swedish Public Health Agency recommends to check the ventilation system if the concentration of CO_2 is above 1000 PPM. (Folkhälsomyndigheten, 2018)

| CABIN PROPERTIES

Cabin properties

Description		Unit
Building	Cabin	
Type	Prefabricated	
Location	Norway and Sweden	
Construction	Wood frame construction	
Ventilation	Natural	
Heating: air	Wood stove	
Heating: domestic water	Wood stove + electricity	
Operational time	3	month
Resident	4	people
Heated floor area	18,9	m2
Thermal bridges	0,05	W/mK
U-value: External walls	0,158	W/m2K
U-value: Roof	0,166	W/m2K
U-value: Ground slab	0,125	W/m2K
U-value: Windows	0,9	W/m2K
U-value: Door	0,9	W/m2K

Figure 84: Cabin properties [Excel]

Element areas

Element	Area	Unit
Heated floor area	18,9	m2
Roof area	23,27	m2
External wall area	69,242	m2
Ground slab area	24,5	m2
Loft area	10,38	m2
Inner walls area	7,48	m2
Windows	4,04	m2
Entrance door	1	piece
PV area	4,95	m2

Figure 85: Element areas [Excel]

For each location three types of simulations were made in Simien; Summer simulation, Winter simulation and Annual simulation. The winter and summer simulations were made to dimension the ventilation-, heating, and/or cooling-system. The results that are shown in the winter and summer simulation are the indoor temperature and the indoor CO2 concentration. The annual simulation was made in order to find the net energy demand of the cabin and how much external energy that was supplied to the cabin. The results that are shown in the annual simulations are the annual net energy demand, the annual energy supply, heating demand, heat losses and also the electricity production of the PV modules.

The Simien software has some limitations, one of which is that it is not possible to simulate the utilization of the cabin as it most likely would be used in reality; during weekends, holidays and single weeks spread out over the year. Therefore, the total yearly utilization of the cabin had to be summed up and simulated as a 90 days coherent period. The rest of the year was set to be out of operational time and all input in Simien for these months, for example the domestic water, technical equipment and lightning were set to Zero since the cabin is not in use.

To make the winter simulations, the three coldest months of the year was picked out. The chosen months were December, January and February, when the temperature outdoors is as it lowest, based on the climate analysis. In Simien you must choose a day to simulate, the simulation day chosen was in the middle of the period; 15 January, with duration of 3 days.

To make the summer simulations, the three warmest months of the year was picked out. The chosen months were June, July and august, when the temperature outdoors is as it highest, based on the climate analysis. The simulation day chosen was in the middle of that period 15 July, with duration of 3 days.

The yearly/annual simulation was made for three months that could represent a year. The three months that were picked out were three months that had one month with warmer temperature, another month with a yearly average temperature and the last month with a colder temperature, based on the climate analysis. The chosen months were September, October and November and the simulation day was in the middle of that period, 15 October, with duration of 3 days. During the annual simulation the input in Simien was the same input as for a winter simulation, when the temperature and CO2 concentration are at a good level.

All the in-data is put in manually in Simien and is thoughtfully put in to as close as possible imitate the real properties and conditions of the cabin.

The soapstone is working as a thermal mass in the cabin. To simulate that the inner walls, and inner slab received properties of heavy walls and heavy slab. The outer wall with the PV modules is also simulated as a heavy wall because the PV module are placed on that wall. The rest of the walls, roof and ground slab was simulated as wood elements.

Simien has some limitations with regards to cross ventilation through ventilation openings, Therefore the simulations had to be performed differently for the summer and winter simulation. Details on how the ventilation was simulated in Simien is described in the winter and summer simulations.

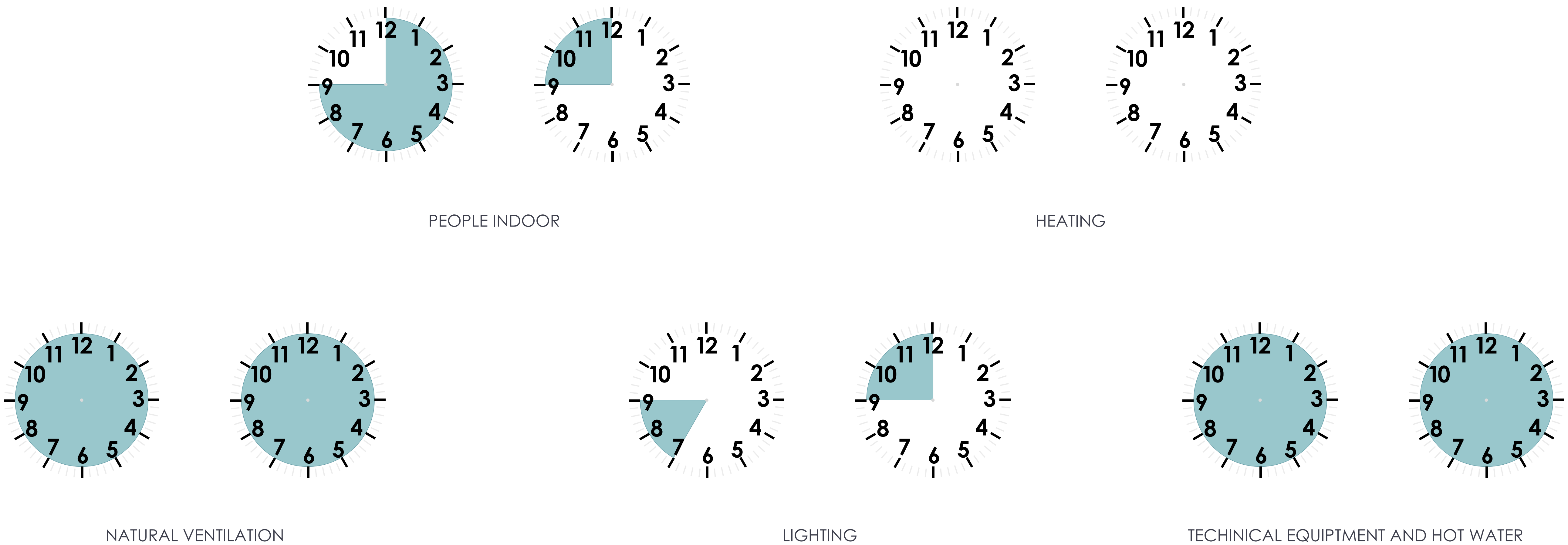


Figure 86: Operational summer schedule[Simien and Illustrator]

During summer simulation the inhabitants were calculated to be outdoor most of the day 12 hours a day, from 09.00-21.00 and the lightning was estimated to be used in the morning and in the evening. The cabin has no need for heating during the summer simulation and the ventilation was natural cross ventilation. Because of the limitations in Simien, it is not possible to simulate the natural cross ventilation through the ventilation openings of the house. To illustrate the natural cross ventilation through summer, the air leakage number (N50) was put to 40.0 [1/h] which represents an air change value in normal conditions of 2,8. This corresponds to the lowest value in the results from the simulations performed in Window-Master website.

During summer simulation the sunscreen of the windows are put to fast (constant) sun screening with a value of 0,05, which is represents sun screening on the outside of the windows.

The simulation was made for the period; June, July and August and the simulation day was the 15th of July with a duration of three days.

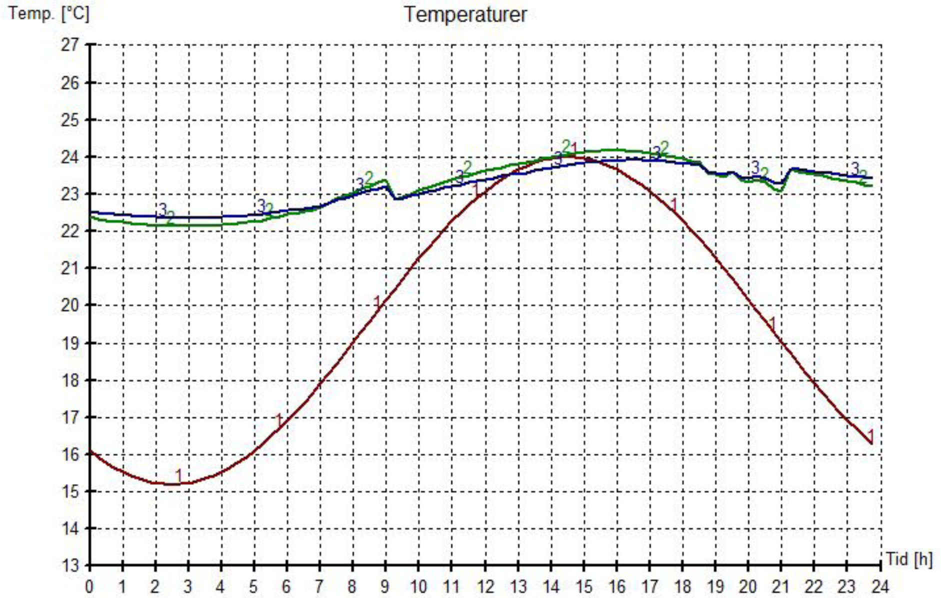


Figure 87: Temperature during summer in Kittelfjäll. 1; Outdoor temperature, 2; Dry bulb temperature, 3; Operative temperature[Simien]

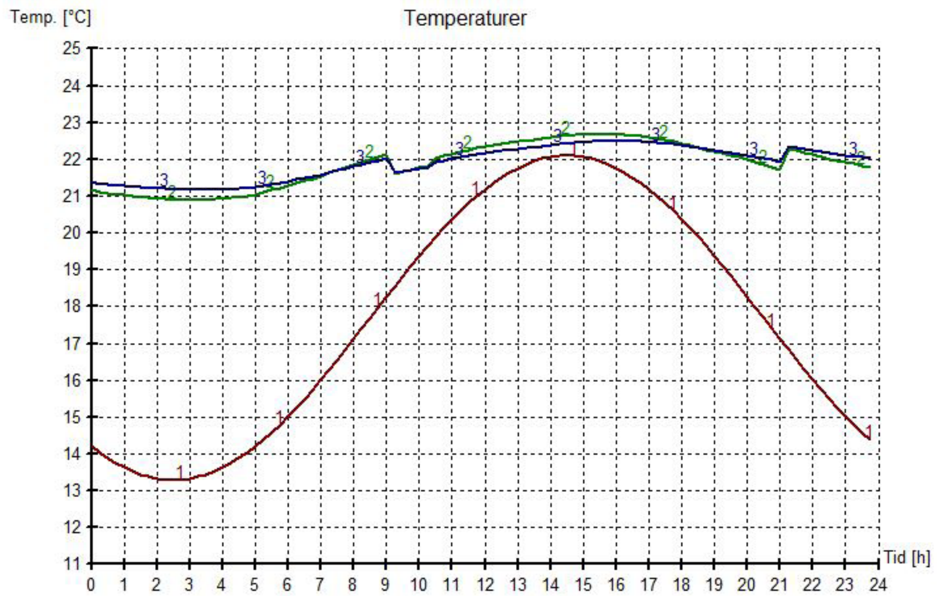


Figure 88: Temperature during summer in Saltstraumen. 1; Outdoor temperature, 2; Dry bulb temperature, 3; Operative temperature[Simien]

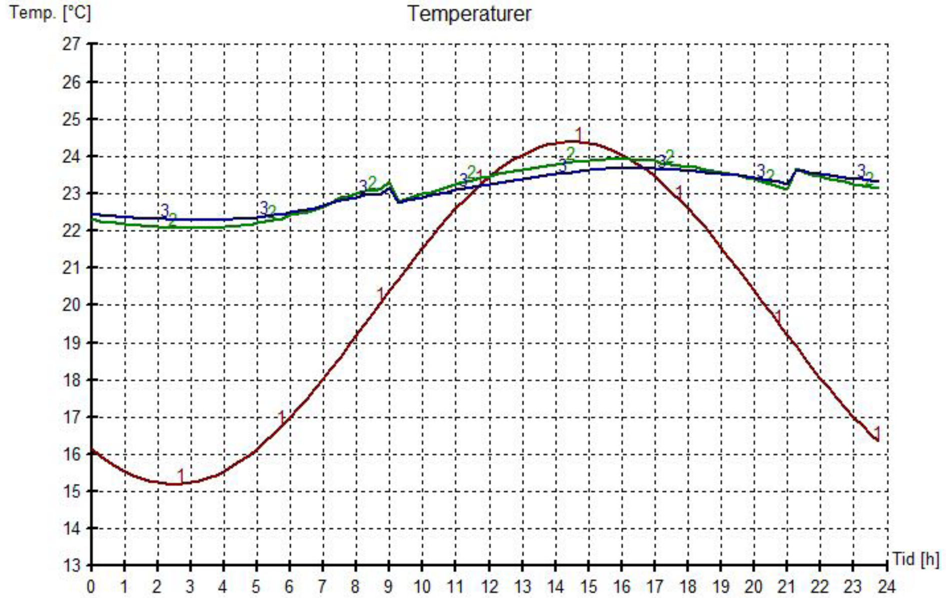


Figure 89: Temperature during summer in Lysøysund. 1; Outdoor temperature, 2; Dry bulb temperature, 3; Operative temperature[Simien]

| KITTELFJÄLL

At the simulation day the temperature outdoors is at lowest 15,2° C at 02.00-03.00 in the midnight and highest 24° C at 14.00-15.00 in the afternoon. Inside the cabin the temperature varies from 22,2° C to 24,2° C dry bulb temp.

| SALTSTRAUMEN

At the simulation day the temperature outdoors is at lowest 13,3° C at 02.00-03.00 in the midnight and highest 22,1° C at 14.00-15.00 in the afternoon. Inside the cabin the temperature varies from 20,9° C to 22,7° C dry bulb temp.

| LYSØYSUND

At the simulation day the temperature outdoors is at lowest 15,2° C at 02.00-03.00 in the midnight and highest 24,4° C at 14.00-15.00 in the afternoon. Inside the cabin the temperature varies from 22,1° C to 23,9° C dry bulb temp.

CO^2 CONCENTRATION

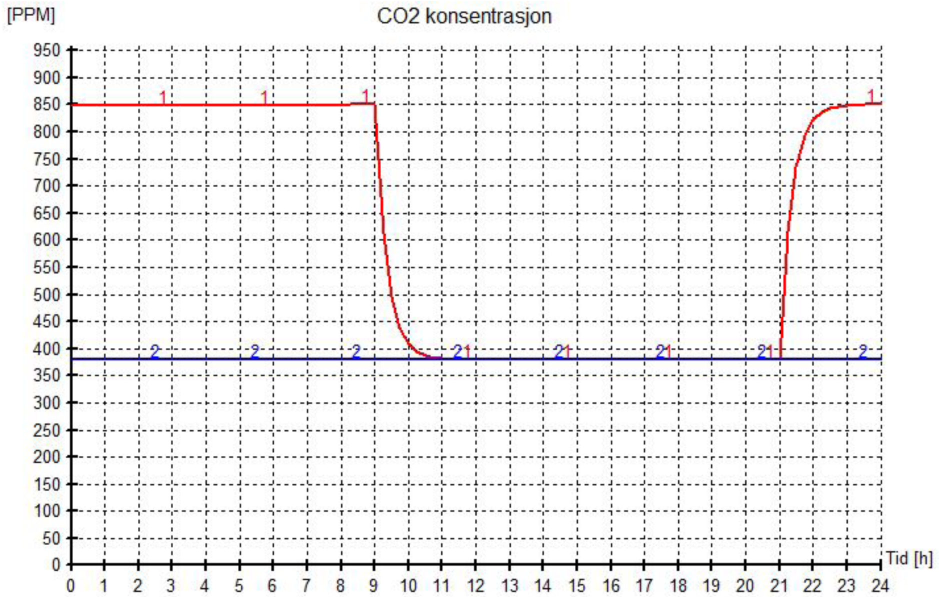


Figure 90: CO2 concentration during summer in Kittelfjäll. 1; CO2 concentration indoor air. 2; CO2 concentration outdoor air.[Simien]

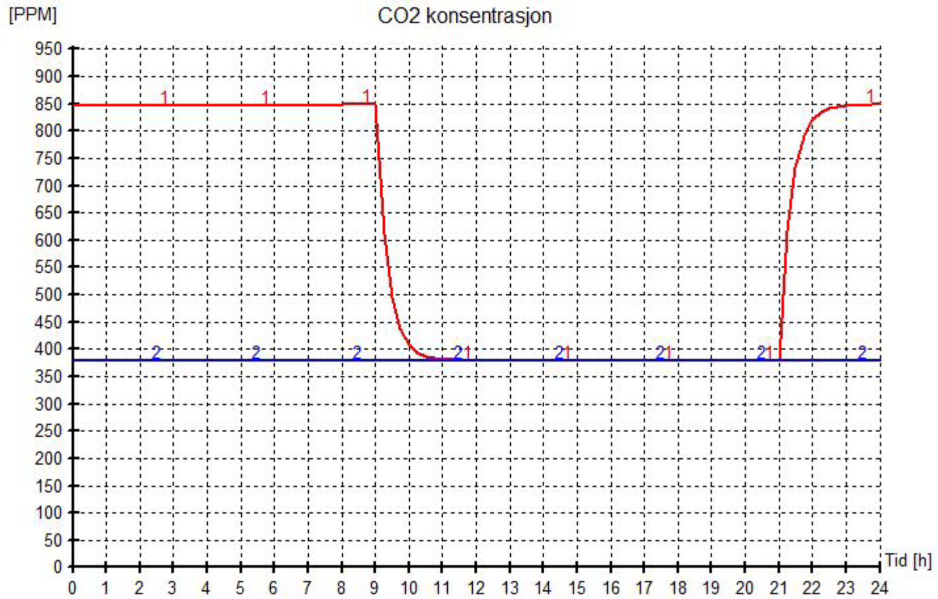


Figure 91: CO2 concentration during summer in Saltstraumen. 1; CO2 concentration indoor air. 2; CO2 concentration outdoor air.[Simien]

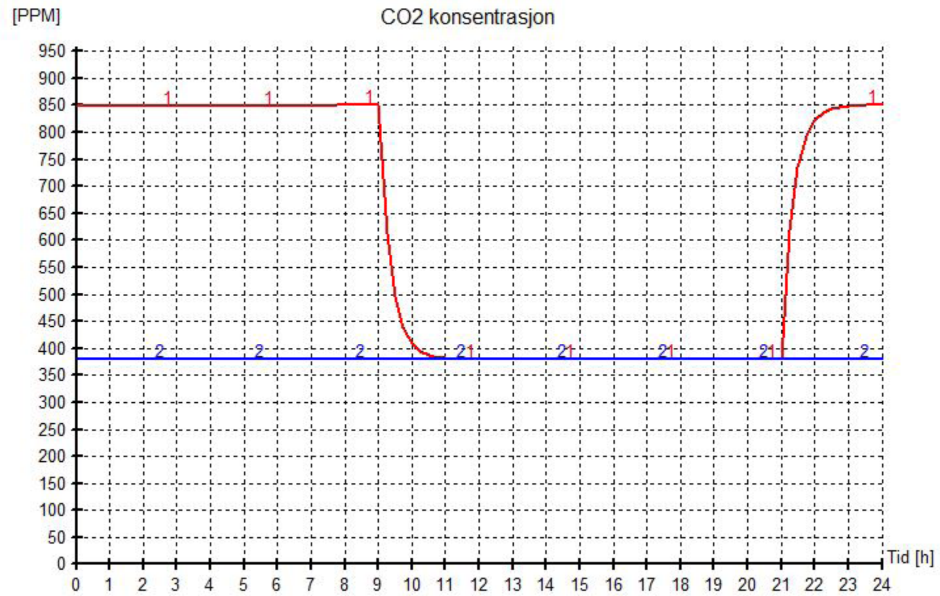
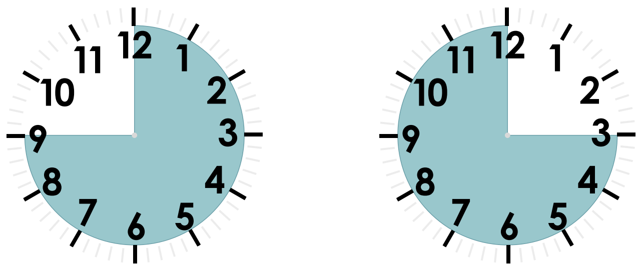


Figure 92: CO2 concentration during summer in Lysøysund. 1; CO2 concentration indoor air. 2; CO2 concentration outdoor air.[Simien]

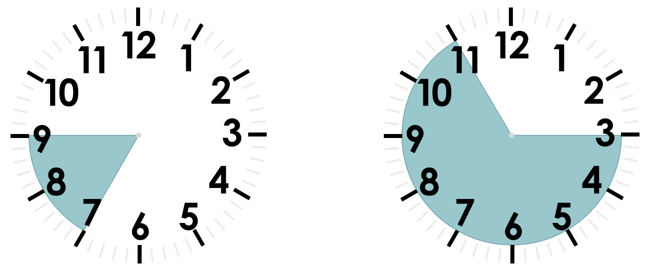
| CO2 CONCENTRATION FOR KITTELFJÄLL, SALTSTRAUMEN AND LYSØYSUND

During the simulation day the CO2 concentration got the same result for all locations. The CO2 concentration reaches a maximum level of 850 PPM during night time and in the morning. When the residents are outside the cabin between 09.00-21.00 the CO2 concentration is reduced to the same CO2 concentration as the outside fresh-air.

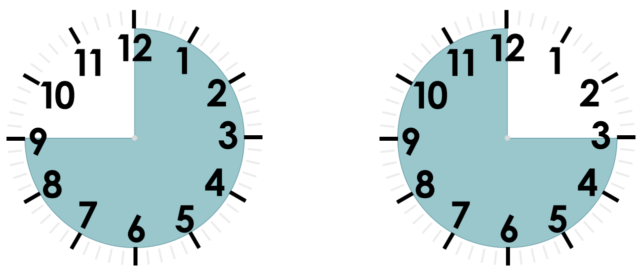
WINTER SIMULATION



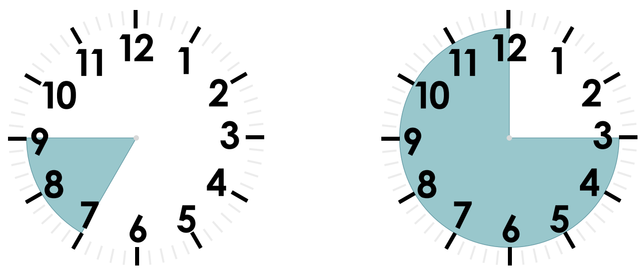
PEOPLE INDOOR



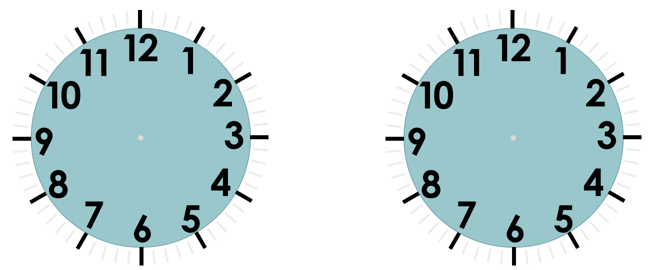
HEATING



NATURAL VENTILATION



LIGHTING



TECHINICAL EQUIPTMENT AND HOT WATER

Figure 93: Operational winter schedule[Simien and Illustrator]

During winter simulation the inhabitants were calculated to be outdoor most of the day 6 hours a day, from 09.00-15.00 and the lightning was estimated to be used in the morning and from the afternoon until midnight. The cabin was heated by the wood stove for 10 hours a day, 07.00-09.00 in the morning and 15.00-23.00 in the afternoon and evening.

During winter simulation the air leakage number (N50) was put to 0,6 [1/h] which is according to the Passive house – demand, and was considered to be a reasonable air leakage value for a prefabricated house. During the winter time it is not realistic to ventilate the cabin such as it can be done in the summer time with full natural cross ventilation. The dimensions of the natural ventilation in winter time will be adjusted by a CAV-ventilation, which will represent natural ventilation. During operational time the in-put data for the ventilation is 5,2 which is given an air change of 98 m3/h, which is lower than the max-value in the results from the simulation in Window-Master website.

During winter simulation the sunscreen of the windows are put to a standard Variable (adjustable sun screening that can be adjusted manually).

The simulation was made for the period December, January and February, the chosen simulation day was the 15th of January and duration of three days.

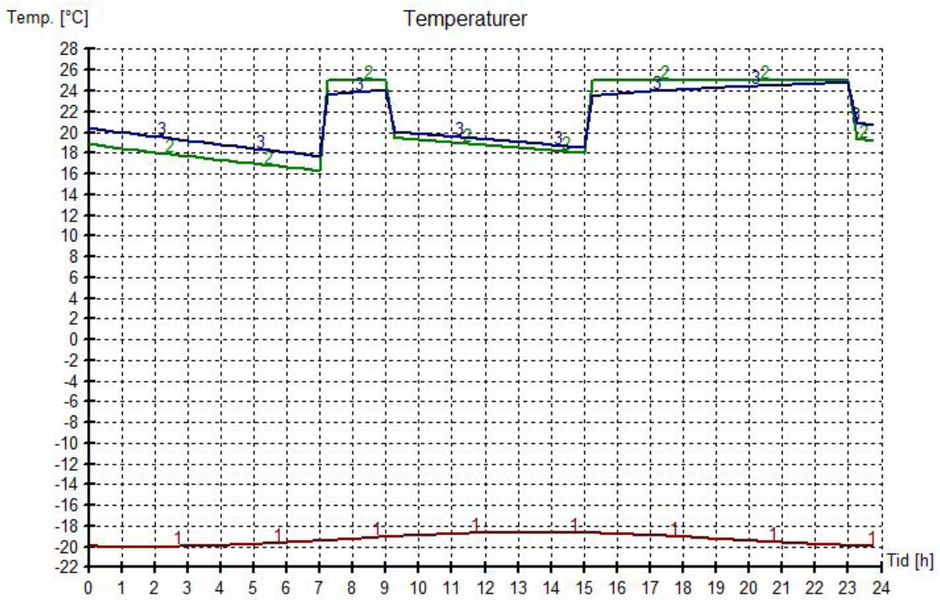


Figure 94: Temperature during winter in Kittelfjäll. 1; Outdoor temperature, 2; Dry bulb temperature, 3; Operative temperature[Simien]

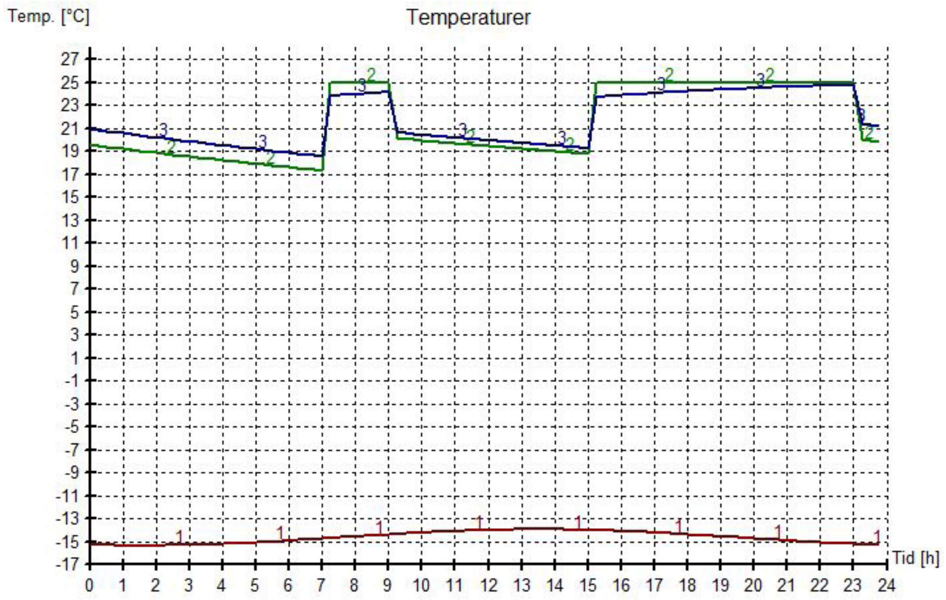


Figure 95: Temperature during winter in Saltstraumen. 1; Outdoor temperature, 2; Dry bulb temperature, 3; Operative temperature[Simien]

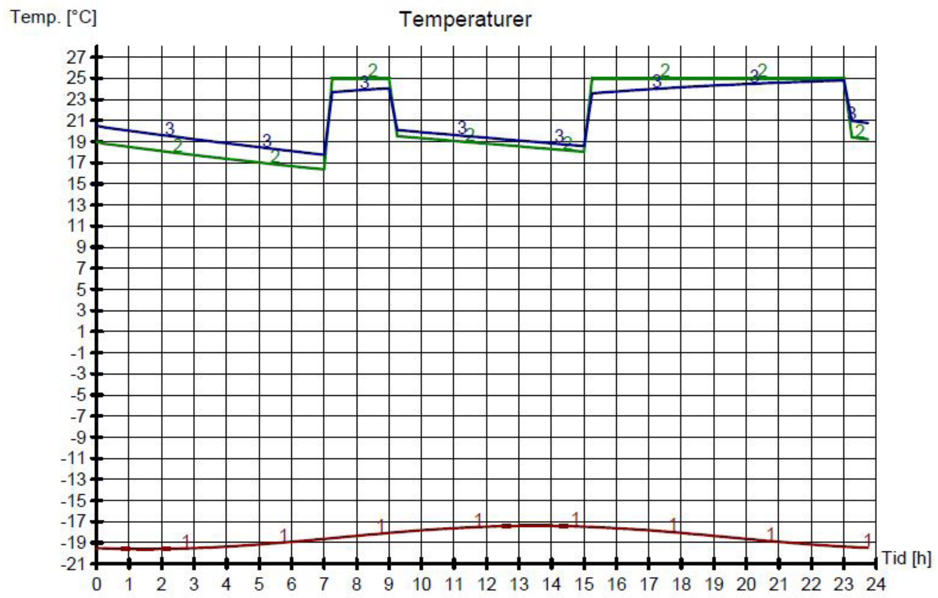


Figure 96: Temperature during winter in Lysøysund. 1; Outdoor temperature, 2; Dry bulb temperature, 3; Operative temperature[Simien]

| KITTELFJÄLL

At the simulation day the temperature outdoors is at lowest -20° C at 01.00-02.00 in the midnight and highest -18,5° C at 13.00-14.00 in the afternoon. Inside the cabin the temperature varies from 16,3° C to 25° C dry bulb temperature. The temperature increases every time the wood stove is used for heating. The wood stove generates heat and are used 07.00-09.00 in the morning and from 15.00-23.00 in the afternoon to the evening. The wood stove is not in use during the time which the residents are either sleeping or when they are outdoors, during this time the temperature decreases in the cabin.

| SALTSTRAUMEN

At the simulation day the temperature outdoors is at lowest -15,2° C at 01.00-02.00 in the midnight and highest -14° C at 13.00-14.00 in the afternoon. Inside the cabin the temperature varies from 17,3° C to 25° C dry bulb temperature. The temperature increases every time the wood stove is used for heating. The wood stove generates heat and are used 07.00-09.00 in the morning and from 15.00-23.00 in the afternoon to the evening. The wood stove is not in use during the time which the residents are either sleeping or when they are outdoors, during this time the temperature decreases in the cabin.

| LYSØYSUND

At the simulation day the temperature outdoors is at lowest -19,9° C at 01.00-02.00 in the midnight and highest -16,8° C at 13.00-14.00 in the afternoon. Inside the cabin the temperature varies from 16,4° C to 25° C dry bulb temperature. The temperature increases every time the wood stove is use for heating. The wood stove generates heat and are used 07.00-09.00 in the morning and from 15.00-23.00 in the afternoon to the evening. The wood stove is not in use during the time which the residents are either sleeping or when they are outdoors, during this time the temperature decreases in the cabin.

CO^2 CONCENTRATION

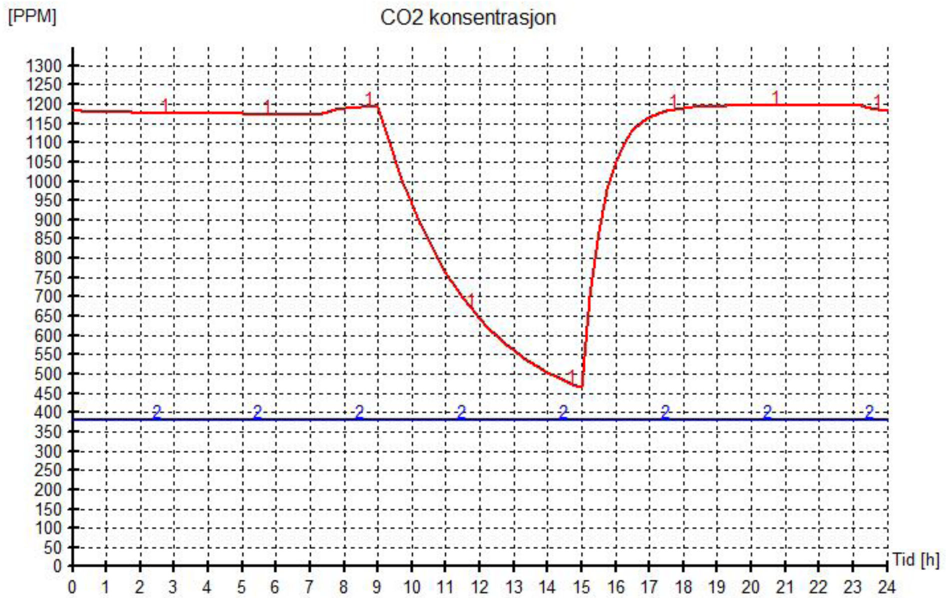


Figure 97: CO2 concentration during winter in Kittelfjäll. 1; CO2 concentration indoor air. 2; CO2 concentration outdoor air.[Simien]

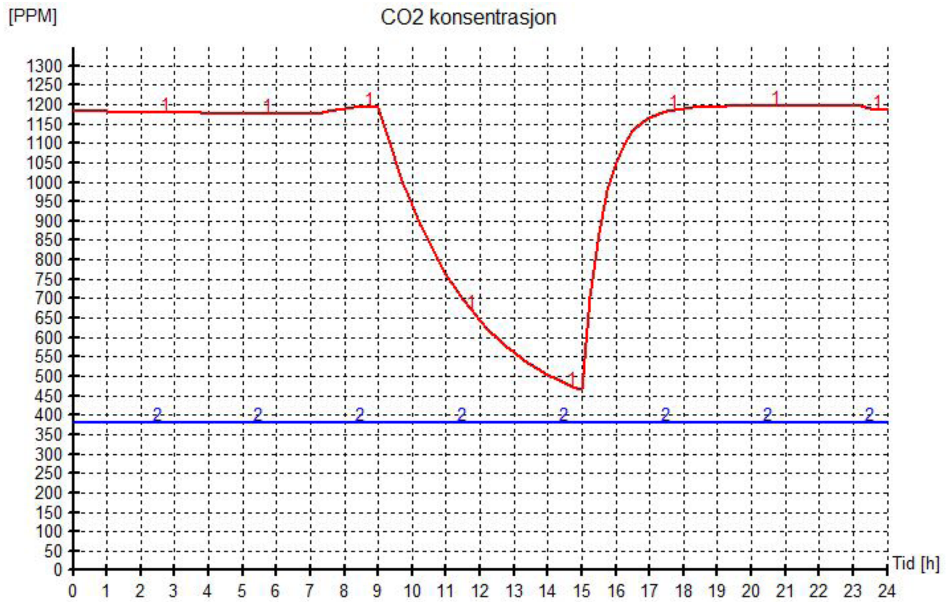


Figure 98: CO2 concentration during winter in Saltstraumen. 1; CO2 concentration indoor air. 2; CO2 concentration outdoor air.[Simien]

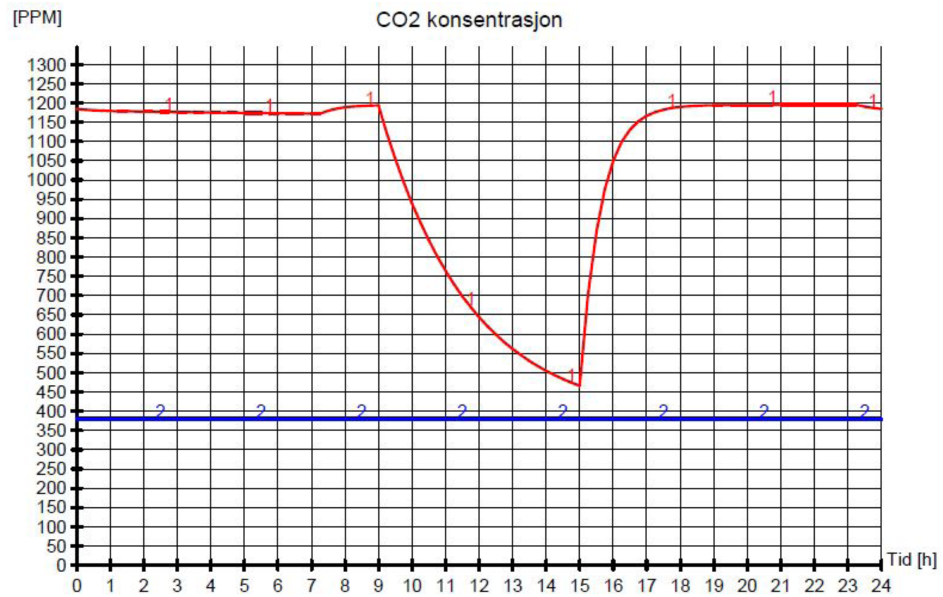


Figure 99: CO2 concentration during winter in Lysøysund. 1; CO2 concentration indoor air. 2; CO2 concentration outdoor air.[Simien]

| CO2 CONCENTRATION FOR KITTELFJÄLL, SALTSTRAUMEN AND LYSØYSUND

The result for the simulation day showed that the CO2 concentration was the same for all the locations. The CO2 concentration reaches the maximum level of 1195 PPM during at 09.00 morning. When the resident are outside the cabin between 09.00-15.00 the CO2 concentration decreases to 470 PPM.

During the annual simulation the input in Simien was the same input as for a winter simulation, showing a result when the temp and CO_2 concentration are at a good level.

The simulation was made of the period September, October and November and the simulation day was the 15th of October and duration of three days.

Energy usage	kWh	kWh/m2
Space heating	1641	86,8
Domestic hot water	140	7,4
Lightning	55	2,9
Technical equipment	454	24,0
Total net energy demand	**2291**	**21,2**

Figure 100: Net energy demand of cabin in Kittelfjäll [Excel]

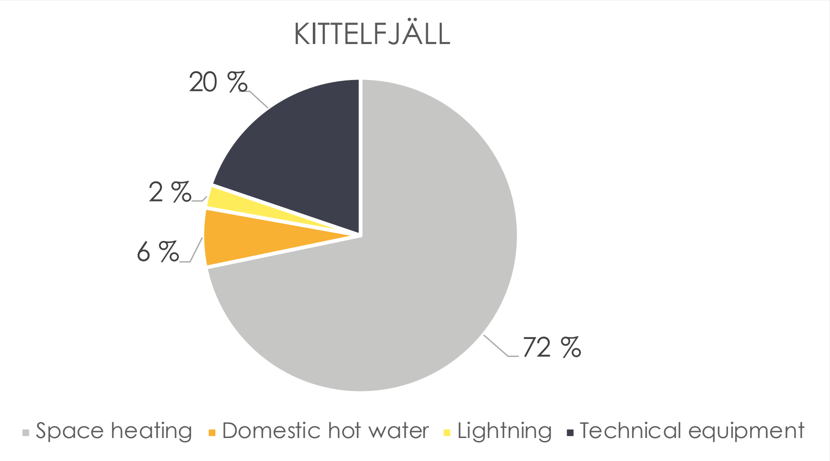


Figure 101: Net energy demand in percentage, of the cabin in Kittelfjäll [Excel]

Energy usage	kWh	kWh/m2
Space heating	986	52,2
Domestic hot water	140	7,4
Lightning	55	2,9
Technical equipment	454	24
Total net energy deman d	**1635**	**86,5**

Figure 102: Net energy demand of cabin in Saltstraumen [Excel]

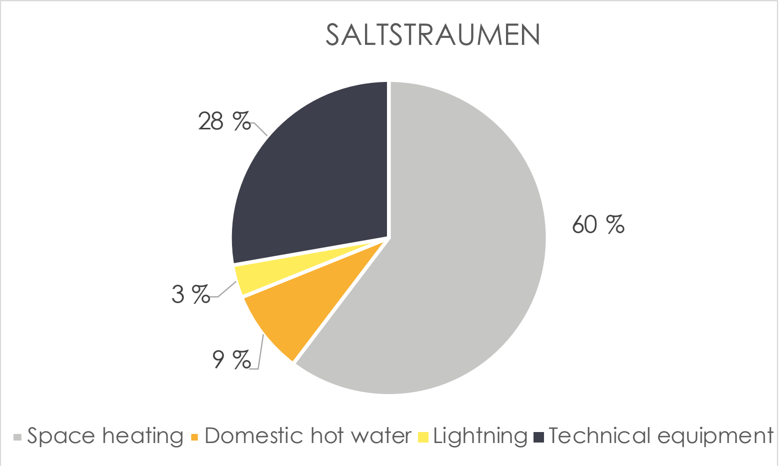


Figure 103: Net energy demand in percentage, of the cabin in Saltstraumen [Excel]

Energy usage	kWh	kWh/m2
Space heating	1220	64,6
Domestic hot water	140	7,4
Lightning	55	2,9
Technical equipment	454	24
Total net energy demand	**1869**	**98,9**

Figure 104: Net energy demand of cabin in Lysøysund [Excel]

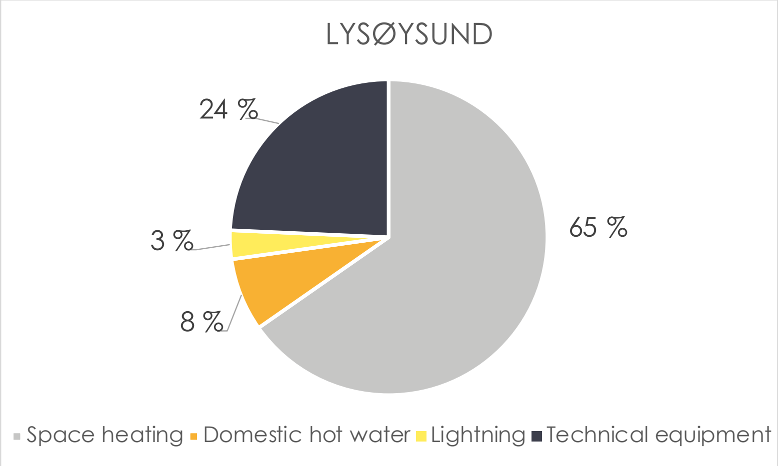


Figure 105: Net energy demand in percentage, of the cabin in Lysøysund [Excel]

| KITTELFJÄLL

The net energy demand is the energy demand for the cabin placed in Kittelfjäll. The table shows the demand for each energy usage and the total energy demand for the cabin, per year, when the cabin is used 90 days.

| SALTSTRAUMEN

The net energy demand is the energy demand for the cabin placed in Saltstraumen. The table shows the demand for each energy usage and the total energy demand for the cabin, per year, when the cabin is used 90 days.

| LYSØYSUND

The net energy demand is the energy demand for the cabin placed in Lysøysund. The table shows the demand for each energy usage and the total energy demand for the cabin, per year, when the cabin is used 90 days.

Energy usage	kWh	kWh/m2
Electricity	641	35
Biofuel	2392	126,6
Electricity produced	-411	-21,8
Total sum	**2643**	**139,8**

Figure 106: Delivered energy to the cabin in Kittelfjäll [Excel]

Energy usage	kWh	kWh/m2
Electricity	662	35
Biofuel	1482	78,4
Electricity produced	-369	-19,5
Total sum	**175**	**93,9**

Figure 107: Delivered energy to the cabin in Saltstraumen [Excel]

Energy usage	kWh	kWh/m2
Electricity	662	35
Biofuel	1807	95,6
Electricity produced	-461	-24,3
Total sum	**2008**	**106,3**

Figure 108: Delivered energy to the cabin in Lysøysund [Excel]

| KITTELFJÄLL

The delivered energy to the cabin placed in Kittelfjäll, comes from electricity from the grid, electricity from the PV's and biofuel. The electricity is used for the domestic hot water, fan, lightning and technical equipment and the energy from biofuel is for space heating. Any excess energy produced by the PV's is exported to the grid. The total summery of the energy need and the electricity production gives a total number of 2643 kWh (139,8 kWh/m2) per year, when the cabin is used 90 days.

| SALTSTRAUMEN

The delivered energy to the cabin placed in Saltstraumen, comes from electricity from the grid, electricity from the PV's and biofuel. The electricity is used for the domestic hot water, fan, lightning and technical equipment and the energy from biofuel is for space heating. Any excess energy produced by the PV's is exported to the grid. The total summery of the energy need and the electricity production gives a total number of 1775 kWh (93,9 kWh/m2) per year, when the cabin is used 90 days.

| LYSØYSUND

The delivered energy to the cabin placed in Lysøysund, comes from electricity from the grid, electricity from the PV's and biofuel. The electricity is used for the domestic hot water, fan, lightning and technical equipment and the energy from biofuel is for space heating. Any excess energy produced by the PV's is exported to the grid. The total summery of the energy need and the electricity production gives a total number of 2008 kWh (106,3 kWh/m2) per year, when the cabin is used 90 days.

Energy usage	
Source	**kWh/m2**
Electricity	4,5
Bio fuel	3
Total sum	**7**

Figure 109: Energy use for domestic hot water in Kittelfjäll,Saltstraumen and Lysøysund [Excel]

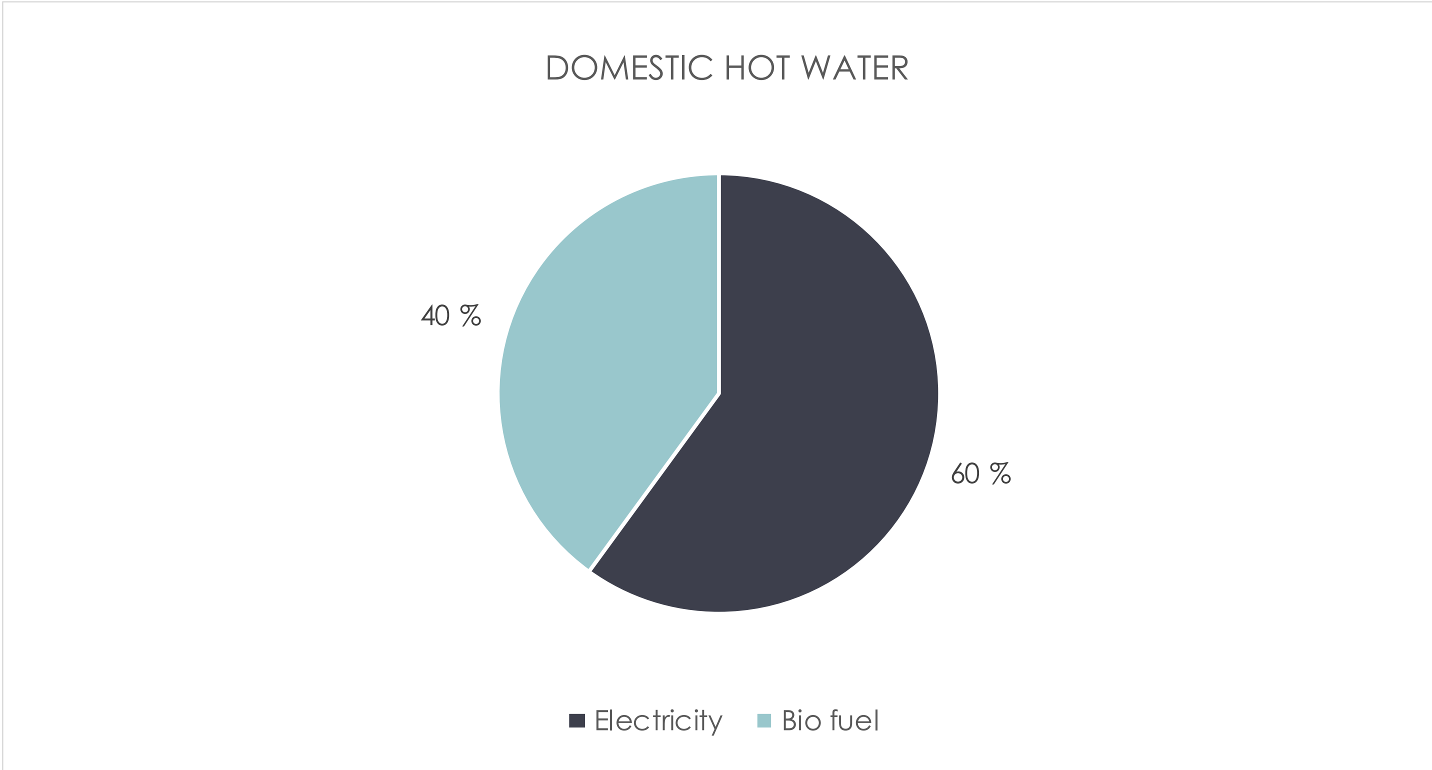


Figure 110: The division of percentage of the energy use for domestic hot water for Kittelfjäll, Saltstraumen and Lysøysund. [Excel]

The energy need for heating the domestic hot water is the same for all three locations. The result shows that the total energy use for heating the domestic hot water and the result are shown in kWh/m2.

Heat losses		
Outerwalls	0,63	W/m2K
Roof	0,2	W/m2K
Ground slab	0,17	W/m2K
Windows and door	0,33	W/m2K
Thermal bridges	0,05	W/m2K
Infiltration	0	W/m2K
Ventilation	0,35	W/m2K
Total heat losses	**1,72**	**W/m2K**

Figure 111: Heat losses of the cabin in Kittelfjäll, Saltstraumen and Lysøysund [Excel]

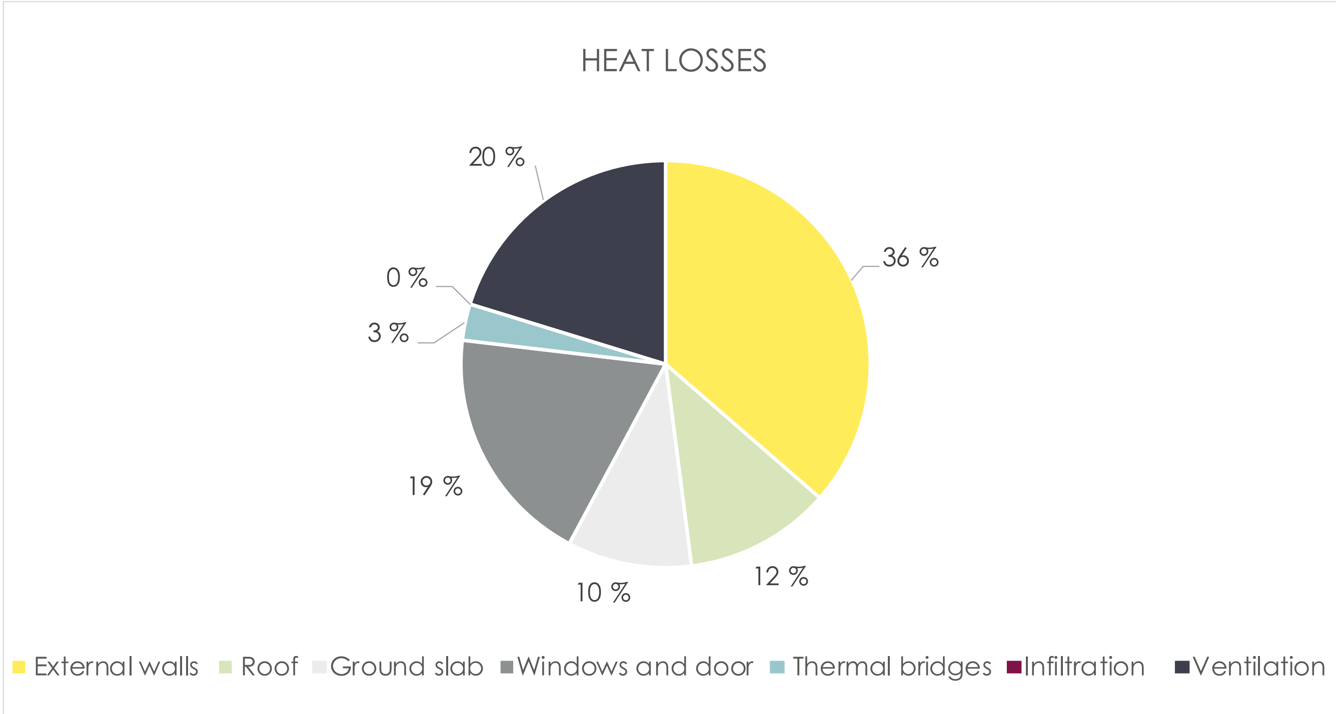
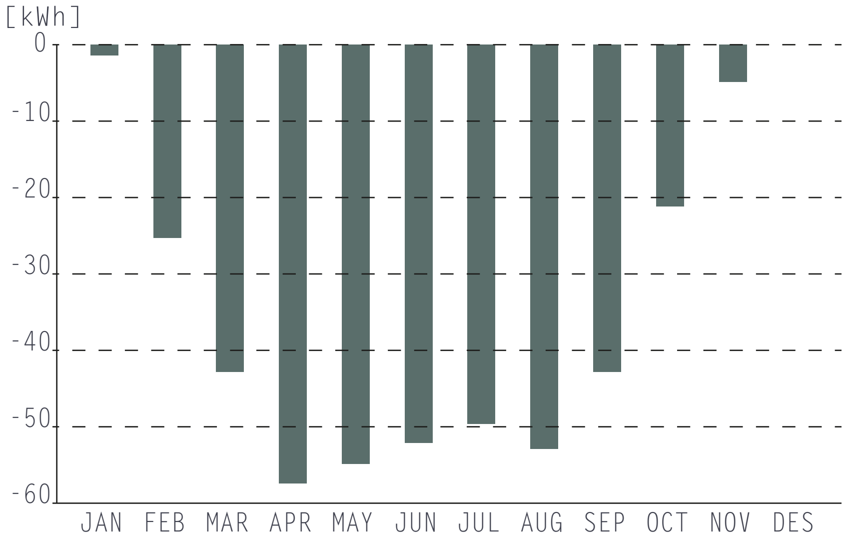
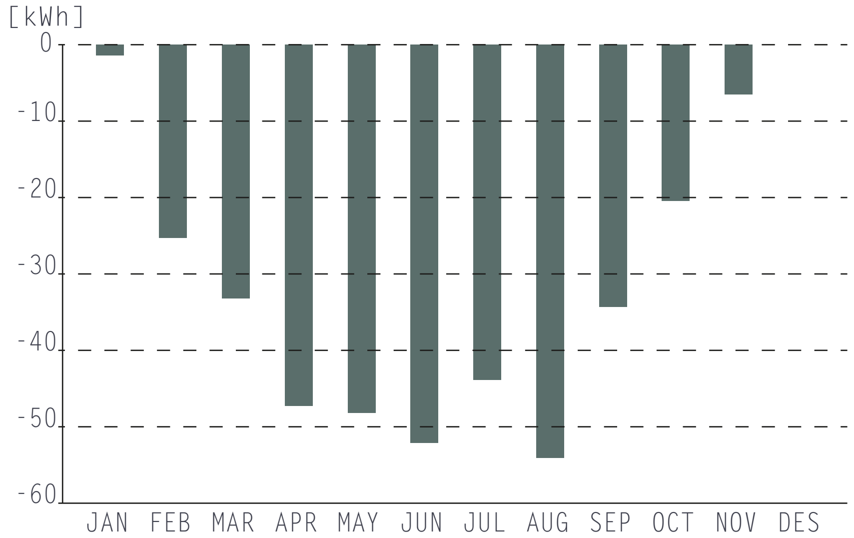
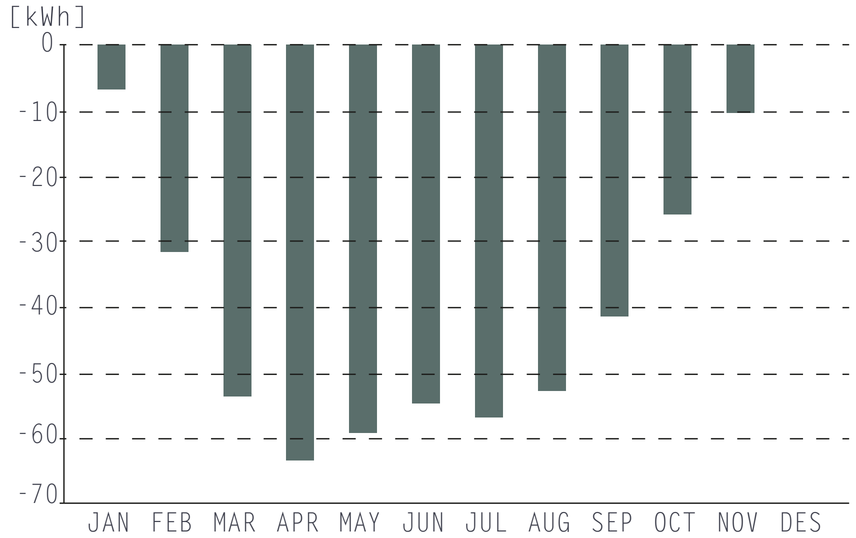


Figure 112: Heat losses in the cabin in percentage, in Kittelfjäll, Saltstraumen and Lysøysund.[Excel]

The heat losses in the cabin are through all construction elements, infiltration, ventilation and thermal bridges. The highest heat losses are through the external walls of 0,63 W/m2K which is 36 % of the total heat losses of the cabin and the lowest heat losses are infiltration and through thermal bridges which represent 0 % and 0,05%. The total number of the heat losses of the cabin is 1,72 W/m2K. The heat losses are the same for all the locations.







Electricity production from PV modules, in Kittelfjäll during a year[kWh]

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES
2	26	44	58	55	53	50	53	43	21	5	0

Electricity production from PV modules, in Saltstraumen during a year[kWh]

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES
0	26	33	48	48	53	44	54	35	21	7	0

Electricity production from PV modules, in Lysøsund during a year[kWh]

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES
7	32	54	64	60	55	57	53	42	26	11	0

Figure 113: Electricity production from PV modules at different sites during a year[Simien]

| KITTELFJÄLL

Simulation of the electricity production from the PV modules during a year in Kittelfjäll shows that the highest electricity production from the PV modules is during the spring and summer. April has the highest electricity production of 58 kWh and December is the month with the lowest electricity production of 0 kWh. The total electricity production from the PV modules are 411 kWh per year.

| SALTSTRAUMEN

The electricity production from the PV modules during a year in Saltstraumen shows that the highest electricity production from the PV modules is during the summer. August has the highest electricity production of 54 kWh and December is the month with the lowest electricity production of 0 kWh. The total electricity production from the PV modules are 369 kWh per year.

| LYSØYSUND

The electricity production from the PV modules during a year in Lysøysund shows that the highest electricity production from the PV modules is during the spring and summer. April has the highest electricity production of 64 kWh and December is the month with the lowest electricity production of 0 kWh. The total electricity production from the PV modules are 461 kWh per year.

The cabin has 5 m2 of PV modules installed to produce electricity for the cabin. The electricity production from the PVs can be used for heating of the domestic hot water, lighting and other technical equipment. Any surplus electricity produced by the PVs is possible to store in a battery or sell back to the electricity grip companies.
A battery is not installed in the cabin since the electricity production from the PV modules will be low and much of it will be consumed by the residents, the surplus electricity will if possible be sold back to the grid.

| NORWAY

When selling back the surplus electricity in Norway, the household needs to be connected to the grid and the electricity company will be able to receive the surplus electricity those month when the production is higher than the consummation of the household. The maximum electricity a household can sell back to the electrical grid company is 100 kW. (NVE - Norges Vassdrags - og Energidirektorat, 2018)

| SWEDEN

When selling back the surplus electricity in Sweden the electricity producer needs to be connected to the grid and it is only possible to sell back the electricity if the household buys more electricity during a year than the household sells back. The price of electricity that will be sold back the grid company, depends on the company and by selling back electricity it is possible to get a tax reduction for the surplus electricity that will be sold back. (Vattenfall, 2018)

LIFE CYCLE ASSESSMENT

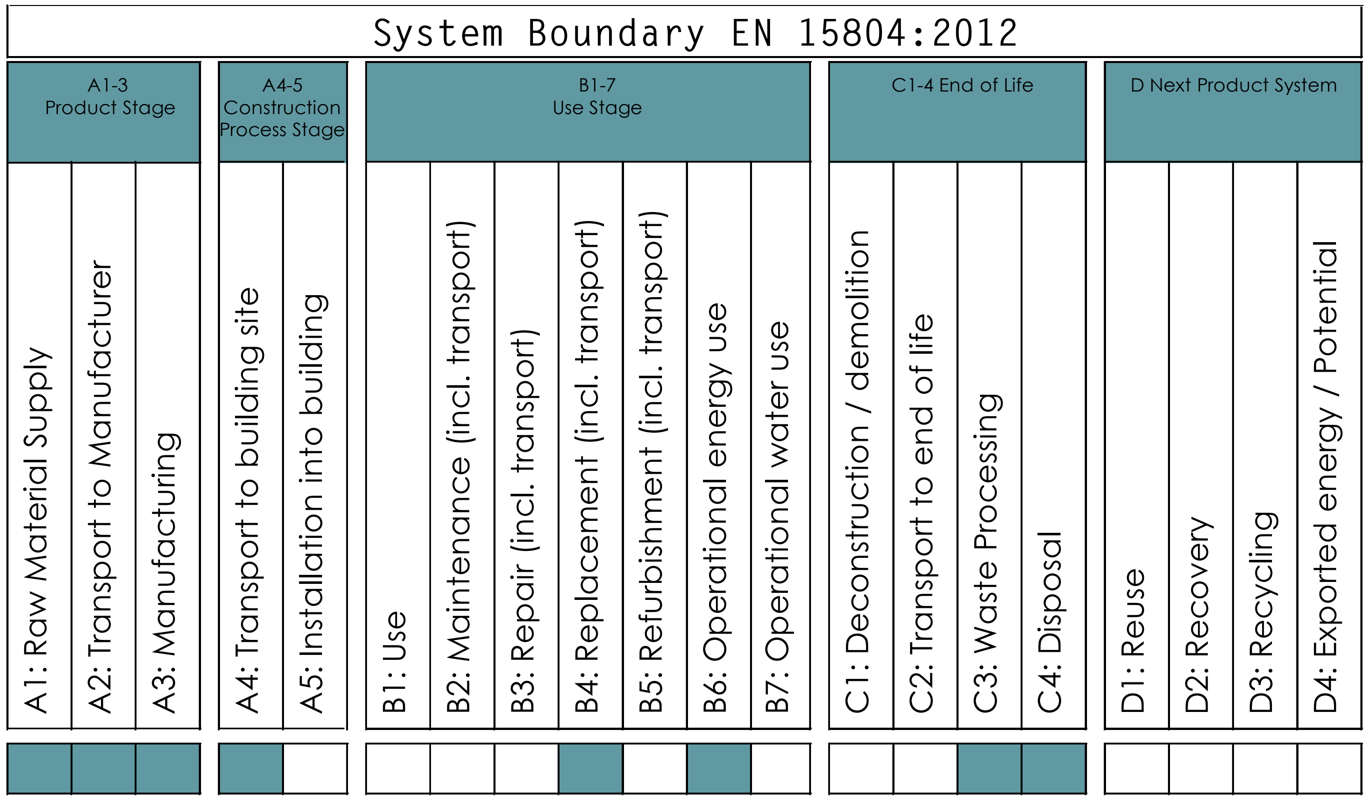


Figure 114: System boundary marked stages in calculations of LCA [System Boundary EN 15804:2012]

Building parts	2 Building envelop	4 Electric Power Supply
Building components	23 Outer walls	49 Other
	24 Inner walls	
	25 Floor structure	
	26 Outer roof	

Figure 115: Building parts included in LCA [Excel]

| SYSTEM BOUNDARY

The boundary for the analysis was limited to the extraction of raw materials and the manufacturing of products and materials needed (A1 - A3), including the transport of goods to site (A4), replacement of new materials over the lifetime of the building (B4), operational energy use (B6) and waste processing and disposal (C3-C4) was also included.

The analysis was also limited to analysis of the building envelop: 23 outer walls including windows and doors, 24 inner walls, 25 floor structures, 26 outer roofs and 49 PV modules. The pillar foundations are not calculated in the LCA.

| MATERIAL INVENTORY

The material inventory was calculated manually using drawings and product literature. The life cycle CO2 emissions are calculated manually by using data from EPD for each material. The materials made of wood are calculated with CO2 emission stored in the material which lead to the result that the phase A1-A3 has a negative value. To compensate for the negative value phase C3 and C4 was taken into account. For the materials for which no specific EPD was found a similar EDP was used for the material.

EPD SPECIFICATION

Construction	Material	EPD for specific product	EPD for similar product	Generic LCA GWP
External walls	Wood cladding	x		
	Nailing battens 25x25 mm and air gap (horisontal)	x		
	Nailing battens 25x25 mm and air gap (vertical)	x		
	Wind barrier	x		
	Insulation layer 1, Cellulosa sheet		x	
	Load bearing stud (45x215, c600)	x		
	Vapor barrier	x		
	Insulation layer 2, Cellulosa sheet		x	
	Stud (45x45, cc60)	x		
	Wood surface		x	
	Total			
Roof	Water proof membran	x		
	Wood plank	x		
	Nailing battens (70x20) and air gap	x		
	Wind barrier	x		
	Insulation layer 1, Cellulosa blown		x	
	Load bearing timber beams (250x150, c450)	x		
	Vapor barrier	x		
	Insulation layer 2, Cellulosa sheet		x	
	Stud (45x45, cc60)	x		
	Wooden surface		x	
	Total			
Ground slab	Wooden floor		x	
	Under floor	x		
	Vapor barrier	x		
	Insulation layer 1 , Cellulosa sheet		x	
	Stud 45x45	x		
	Insulation layer 2, cellulosa sheet		x	
	Load bearing timber (45x240, c450)	x		
	Vind barrier plate K-board	x		
	Wood plank		x	
	Total			
Loft slabs	Massive wood slab	x		
Extended entrance	Wood cladding	x		
	Construction timber (45x90, c450)	x		
Inner walls	Massive wood	x		
Windows	3-glass window with wood frame and aluminum cladding	x		
Entrance door	Wood door with 2-glass window		x	
PV module	Model, transport and mounting aluminim	x		

Figure 116: EPD material specifications[Excel]

The LCA for the PV modules is based on the report: Embodied greenhouse gas emissions from PV systems in Norwegian residential Zero Emission Pilot Buildings, (Torhildur Fjola Kristjansdottir, 2016).
The PV modules that are chosen for the cabin is a model called Design Black 250 made by the manufacture Innotech Solar, the same PV module that are used for Multicomfort, designed by the architect Kristian Edward, working for Snøhetta, with the ambitions set to ZEB-OM.
These PV modules are chosen since the modules are produced in Sweden and the cells are made in Germany. This means that the embodied emissions are 50 % lower compared to the PV modules produced in Asia.
The total embodied emissions for the PV modules for the period 2018-2048 is calculated to; 230 kgCO2/m2 which is a result based on; 0 % reused cells, mounting system frame based on aluminium and transport by ship and truck.
The lifetime of the PV modules are 30 years and the lifetime of the cabin is 60 years, this means that the PV modules must be replaced at least once within the lifetime of the building. It can be assumed that by then the CO2 emissions from the materials of the PV modules are 65 % lower than the CO2 emissions today (Torhildur Fjola Kristjansdottir, 2016). The total embodied emissions for the PV modules for the period 2018-2048 will be 230 kgCO2eq/m2 and for the period 2048-2078 will be 80,5 kgCO2eq/m2, which will result in a total embodied CO2 emission for 60 years of: 310 kgCO2eq/m2.
The first 30 years the PV modules have an efficiency of 15 %, the new PV modules that are going to be installed after 30 years is assumed to be 36% more efficient which result in an efficiency of 21,1 %. (Torhildur Fjola Kristjansdottir, 2016)
When calculating the building operational energy, the CO2 emission number used for the electrical grid factor was 1,32 gCO2/kWh and the specific CO2 emission number from selected biofuel GROT (GROT = wood residue) wood chip of 3,6 gCO2/kWh.
(Lien, 2013)

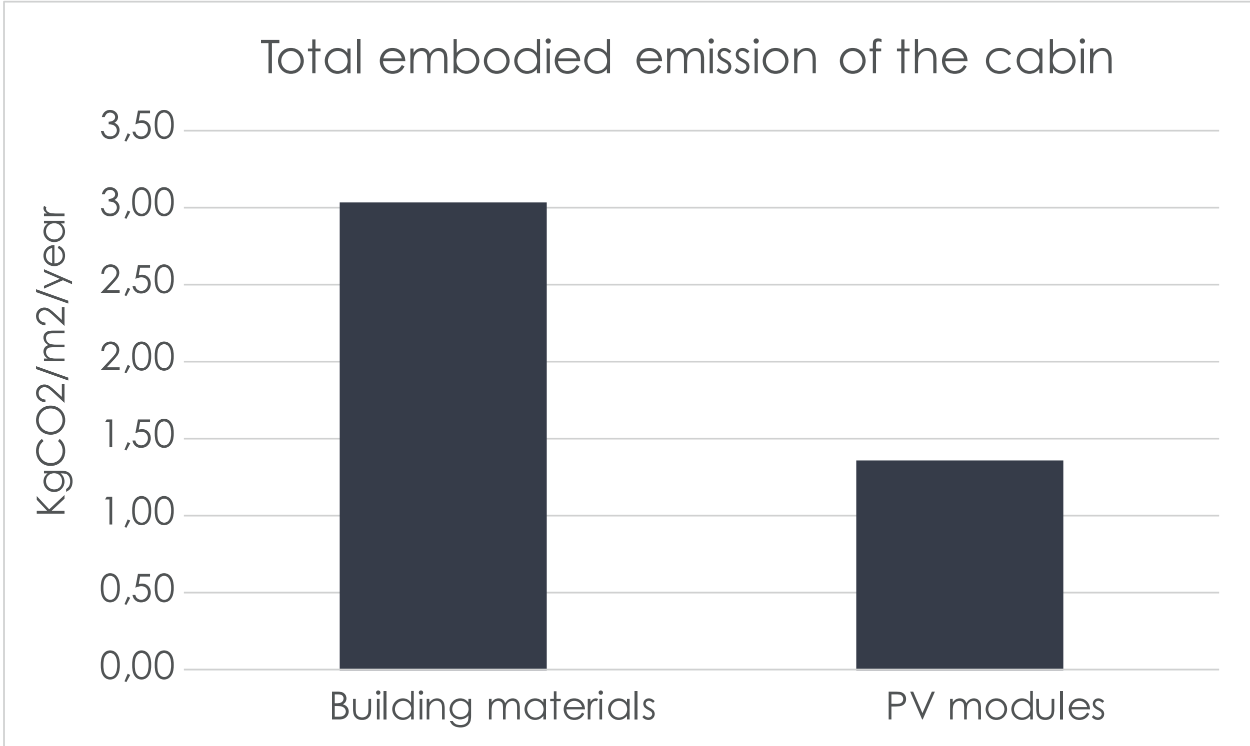
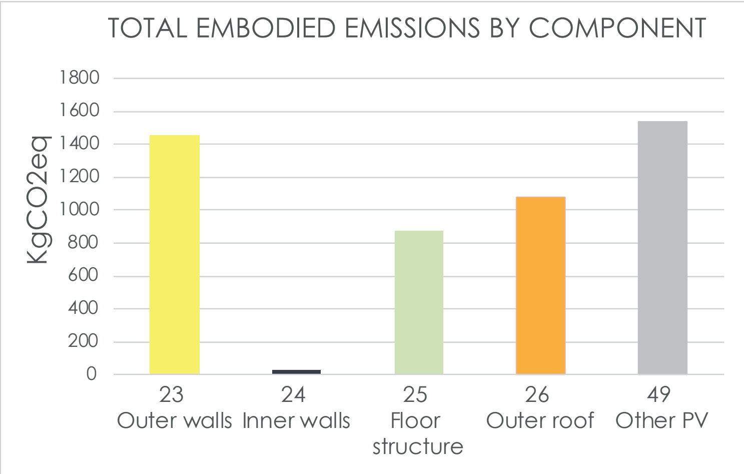


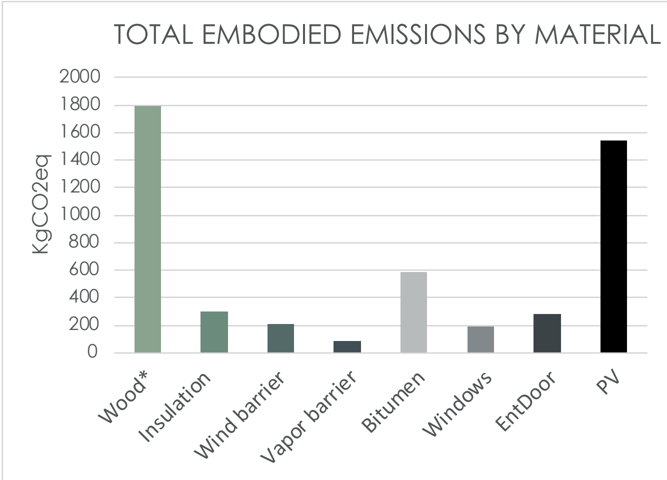
Figure 117: Total embodied emissions of the cabin [Excel]

| ON THE FACTORY SITE
Building materials: 3,03 kgCO2eq/m2/year
PV modules: 1,36 kgCO2eq/m2/year
The result from the total embodied emission is shown in kgCO2eq/m2/year.
The result of the total embodied emission is the result of the cabin at the factory. The cabin is not in use, that is the reason why there is no embodied emission from the operational energy and there is no PV compensation of the cabin at the factory.
The result of the total embodied emissions of the cabin shows that the building material are representing 3,03 kgCO2eq/m2/year and the total embodied emissions from the PV modules are representing 1,36 kgCO2eq/m2/year. Calculating the total embodied emissions from the building materials and the total embodied emissions from the PV modules will give the total embodied emission of 4,39 kgCO2eq/m2/year for the cabin.



23 Outer walls	1455 kgC$_2$O eq
24 Inner walls	28 kgC$_2$O eq
25 Floor structure	874 kgC$_2$O eq
26 Outer roof	1080 kgC$_2$O eq
49 Other PV	1537 kgC$_2$O eq

Figure 118: Total embodied emissions, by component [Excel]



Wood*	1794 kgC$_2$O eq
Insulation	295 kgC$_2$O eq
Wind barrier	208 kgC$_2$O eq
Vapor barrier	82 kgC$_2$O eq
Bitumen	585 kgC$_2$O eq
Window	192 kgC$_2$O eq
Entrance door	282 kgC$_2$O eq
PV	1537 kgC$_2$O eq

Figure 119: Total embodied emissions, by material [Excel]

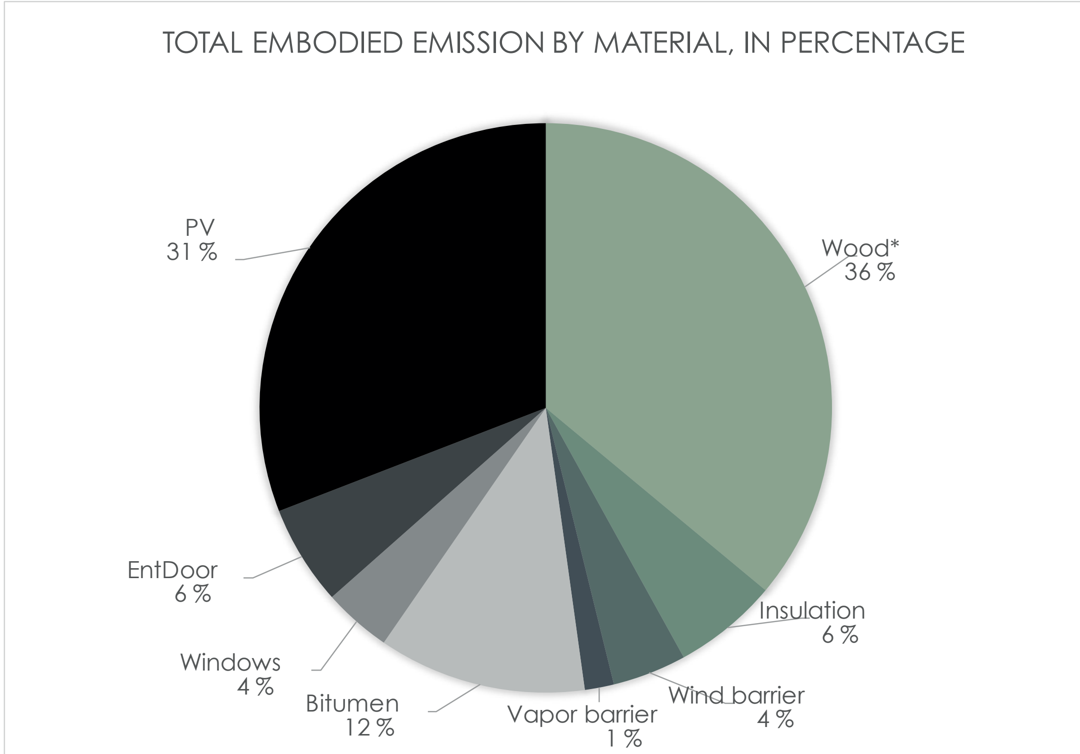


Figure 120: Total embodied emissions, by material, in percentage [Excel]

| TOTAL EMBODIED EMISSIONS BY COMPONENT

The result from the total embodied emission, by component is shown in kgCO2eq.

In the result of the total embodied emission by components it is shown that the PV modules stands for the highest total embodied emissions of 1537 kgCO2eq. The outer walls component is the component that stands for the second highest emission of; 1455 kgCO2eq. This includes the wood frame construction and windows. The component that stands for the lowest emission is the inner walls, made of massive wood.

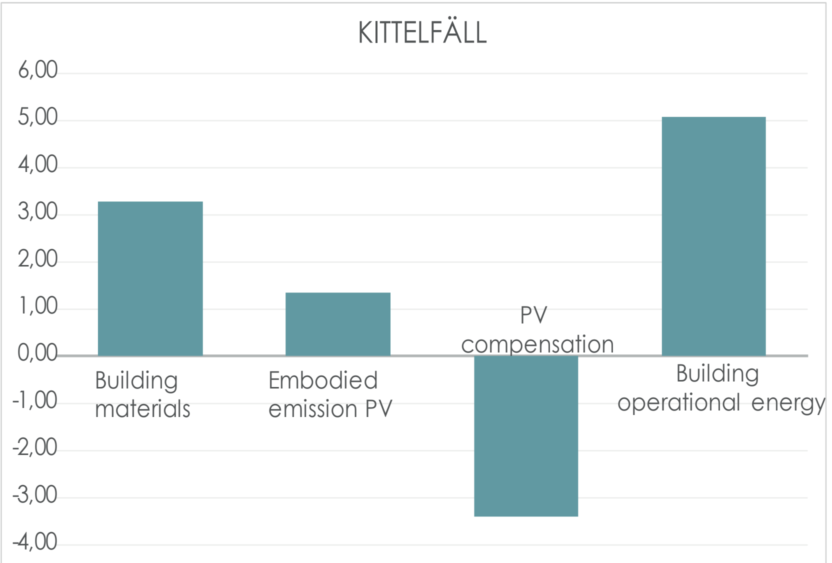
| TOTAL EMBODIED EMISSIONS BY MATERIAL

The result from the total embodied emission, by component are shown in kgCO2eq.

The result of the total embodied emissions by material, shows that the material which in total gives the highest emissions is wood with the total embodied emission of 1800 kgCO2eq. Wood* includes; cladding, construction timber, nailing battens, wood panel, massive wood plank, under floor and K-board. The material that has the lowest total embodied emission is the vapour barrier.

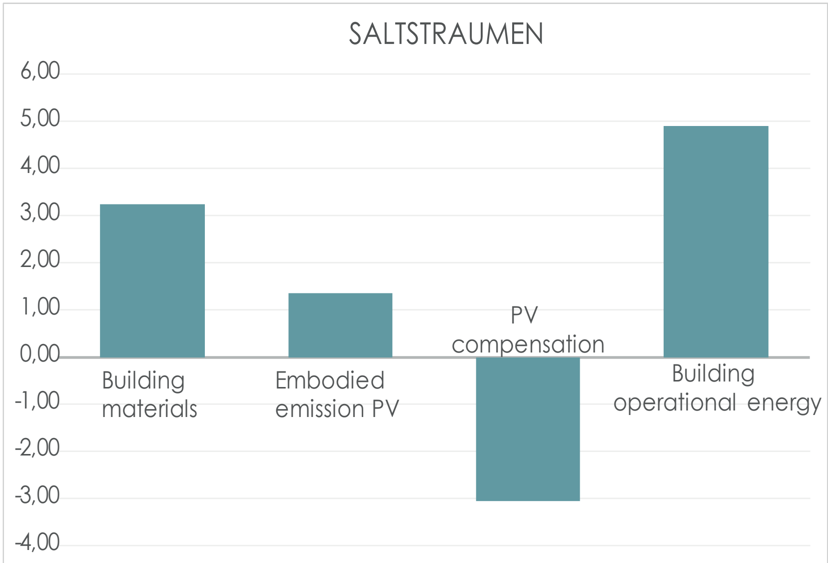
| TOTAL EMBODIED EMISSIONS BY MATERIAL (%)

When looking into the result of the total embodied emission by material, in percentage. It shows that wood stands for 36 % of the total embodied emission by materials and the PV modules stands for almost as much with 31 % of the total embodied emission by material. The vapour barriers stands for the least embodied emission with 1 % of the total embodied emissions by material.



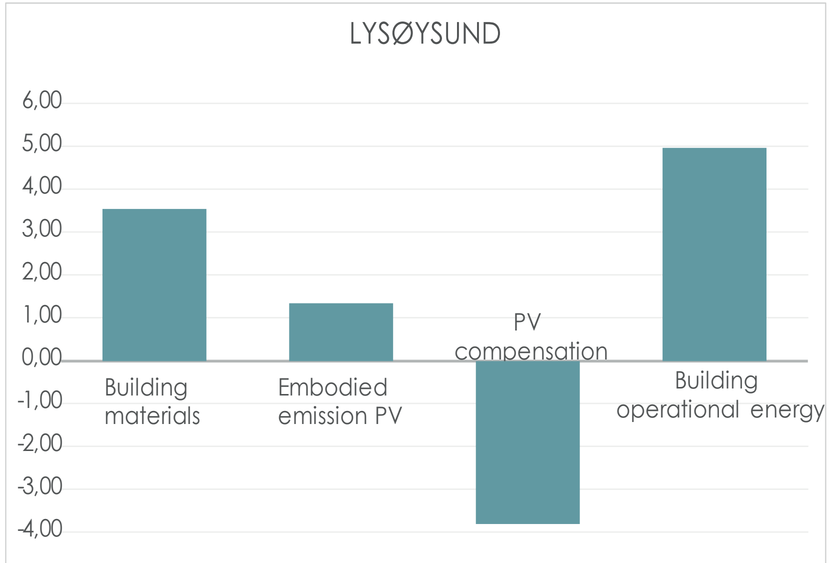
Building materials	3,27	kgCO2eq/m2/year
Embodied emission PV	1,36	kgCO2eq/m2/year
PV compensation	-3,39	kgCO2eq/m2/year
Building operational energy	5,08	kgCO2eq/m2/year

Figure 121: Total embodied emission of the cabin placed in Kittelfjäll [Excel]



Building materials	3,25	kgCO2eq/m2/year
Embodied emission PV	1,36	kgCO2eq/m2/year
PV compensation	-3,04	kgCO2eq/m2/year
Building operational energy	4,90	kgCO2eq/m2/year

Figure 122: Total embodied emission of the cabin placed in Saltstraumen [Excel]



Building materials	3,55	kgCO2eq/m2/year
Embodied emission PV	1,36	kgCO2eq/m2/year
PV compensation	-3,80	kgCO2eq/m2/year
Building operational energy	4,96	kgCO2eq/m2/year

Figure 123: Total embodied emission of the cabin placed in Lysøysund [Excel]

| KITTELFJÄLL

The result from the total embodied emission, by component is shown in kgCO2eq/m2/year.

The calculations of the total embodied emission of the cabin placed in Kittelfjäll gives the result that the Building operational energy stands for the highest emissions of 5,08 kgCO2eq/m2/year, after that comes the total embodied emissions from the Building material with 3,27 kgCO2eq/m2/year and the total embodied emissions from the PV modules are 1,36 kgCO2eq/m2/year. The electricity produced by the PV modules gives a compensation of -3,39 kgCO2eq/m2/year, which is covering the total embodied emissions from the building materials of 3,27 kgCO2eq/m2/year.

| SALTSTRAUMEN

The result from the total embodied emission, by component are shown in kgCO2eq/m2/year.

The calculations of the total embodied emission of the cabin placed in Saltstraumen gives the result that the Building operational energy stands for the highest emissions of 4,90 kgCO2eq/m2/year, after that comes the total embodied emissions from the Building materials with 3,25 kgCO2eq/m2/year and the total embodied emissions from the PV modules are 1,36 kgCO2eq/m2/year. The electricity produced by the PV modules gives a compensation of -3,04 kgCO2eq/m2/year, which does not cover the total embodied emissions from the building materials of 3,25 kgCO2eq/m2/year.

| LYSØYSUND

The result from the total embodied emission, by component are shown in kgCO2eq/m2/year.

The calculations of the total embodied emission of the cabin placed in Lysøysund gives the result that the Building operational energy stands for the highest emissions of 4,96 kgCO2eq/m2/year, after that comes the total embodied emissions from the Building material with 3,55 kgCO2eq/m2/year and the total embodied emissions from the PV modules are 1,36 kgCO2eq/m2/year. The electricity produced by the PV modules gives a compensation of -3,80 kgCO2eq/m2/year, which is covering the total embodied emissions from the building materials of 3,55 kgCO2eq/m2/year.

DISCUSSIONS

| SIMULATIONS IN SIMIEN

The Simien software has some limitations, one of which is that it is not possible to simulate the utilization of the cabin as it most likely would be used in reality; during weekends, holidays and single weeks spread out over the year. Therefore, the total yearly utilization of the cabin had to be summed up and simulated as a 90 days coherent period. Because of these limitations the result of the annual simulations could have been different if it would have been possible to make the simulations more alike to the reality. Most likely the energy demand would then have been higher since the cabin would have to be heated up from low temperatures more often.

| WINTER SIMULATION

In the winter simulations the temperature indoor is different for all sites. But the result shows that the temperature are under the recommendations for comfort indoor temperature, for all the sites. The time of the day when the temperature is at the lowest point is at 07.00 in the morning. This is because it has been the longest time since the stove was used. To stabilize the indoor temperature, a soapstone was installed to work as a thermal mass. Because of the limitations in Simien there is not possible to simulate the effect of the soapstone, instead the inner walls and inner slab were changed from light walls to heavy walls so that they could act as the thermal mass from the soapstone. But the result of the temperature with the input of heavy indoor walls and heavy indoor slab as thermal mass, did not give enough stored heat to keep the temperature within the recommendations. The result would probably be different if Simien could illustrate a soapstone and the temperature would probably been within the recommendations. The argument for this is that the soapstone would be placed behind the stove and would therefore receive a much higher temperature and have more thermal energy stored than the heavy walls and slab had in the simulations.

The CO2 concentration in the winter time are slightly over the recommendations because the residents are indoor most of the time during a day. The CO2 concentration is also high because of the high number of residents in such a small cabin. To make the CO2 concentration within the recommendations during winter time, without lowering the temperature indoor, a ventilation system with heating would have had to be installed.

| SUMMER SIMULATION

The result from the summer simulation shows that the temperature indoor are different from the different sites. All the cabins are over the recommended value of indoor temperature. But during the days when it is warm outside, it is assumed that the residents will be outside most of the hours of the day.

The CO2 concentration are the same for all the locations, because all the locations have the same ventilation. The level of the CO2 concentration is within the recommendations.

| ANNUAL SIMULATION

During the annual simulation the net demand are different from site to site because of the heating demand of space heating changes from the different sites. The reason the space heating demand changes is that the climate is different from site to site. The site that have the highest space heating demand is Kittelfjäll which also has the coldest climate.

Looking into the heat losses the percentage of the heat losses of the different sites are the same, because they have the same building construction and the same thickness of the insulation. The element that have the highest heat losses are the outer walls, because that element has a slightly slimmer insulation and the area of the outer walls are also the biggest façade area, which means that it is the biggest area in the cabin that can release heat.

The infiltration is the part that have the lowest heat losses. That is because the input of the air leakage is put to be the same as passive house standard. This is just an approximation of the number how air tight the building is, and this number would probably be different if the house was built in real life. Therefore, the house would need to be tested for airtightness if it were to be built.

VENTILATION

Since Simien cannot simulate ventilation through window and ventilation openings properly, it had to be simulated with natural ventilation using the CAV function for winter simulation and for summer simulation the air leakage number (N50) was put to 40 [1/h] to illustrate natural cross ventilation. It is a bit uncertain how well this simulates the true conditions making the results from the annual simulation with regards to the heating demand also a bit uncertain. The air exchange rate was however checked against the simulations in the Wind Master and it was within the maximum air change rate so that factor should be realistic.

| DOMESTIC HOT WATER

The energy need for heating of the domestic hot water are energy generated from the wood stove and by electricity. The wood stove is both heating the air in the cabin and the domestic hot water, the energy produced from the wood stove are divided so that 10 % will heat the water and 90 % will heat the air. This system is designed specifically for the cabin and the distribution of the energy from the cabin are an approximation based on the tap water heating demand. When the domestic water is not heated by the stove, it will be heated by electricity. The real electricity need to heat the water depends on how much the wood stove is used and if the hot water is used when the stove is in use or not, so the heating demand for the domestic hot water is therefore expected to vary.

The need of domestic water is probably too low in the simulations, because Simien calculates the domestic water demand in relation to the heated floor area (W/m2) when it is calculating the domestic water demand. Since the cabin has such a small heated floor area the result of the domestic water demand calculated by Simien will be low, because 4 people in the cabin is not something Simien takes into account.

In a report Brukardata bostäder the annual domestic water demand is estimated to 800 kWh/year/person and 200 kWh/3 month/person, which will give 4*200kWh/3 month = 800 kWh compared to the result from the simulations which gave a total energy need of 140 kWh.

LCA

The calculations of the amount of the materials for the cabin was made manually based on drawings and material properties. This gives a slightly uncertain result and the result could be different if the cabin would be built in real life and the material use could be measured.

Each location has a different number of total embodied emission from the building materials, because the transport distance was different from the factory to the different site. The location of the cabin placed in Lysøysund gave the highest emission from the building materials because that was the longest distance from the factory to the site.

The result of the emissions from the building operational are different between the sites. The site with the highest emission from the building operational energy was Kittelfjäll, because Kittelfjäll is the site with the coldest climate.

The result of the embodied emission from the PV modules are the same in the LCA, because of the lack of information and lack of emission factor for the PV modules. If all the information about the PV modules needed for the LCA were available a different result for each site would have been given.

The PV compensation was different from site to site because there are different hours of sun on the different sites. The site that had the highest electricity production was Lysøysund because Lysøysund are the most southern one of the sites.

The results from the LCA shows that the emissions of the building materials, embodied emissions from PV modules and emissions from the building operational energy are changing from site to site. The only cabin that have enough compensation to cover the emissions from the building materials is the cabin placed in Kittelfjäll, because it has a short transport distance from the factory to the site.

| PV MODULE

The LCA made for the PV are based on the report, Embodied greenhouse gas emissions from PV systems in Norwegian residential Zero Emission Pilot Buildings. The efficiency and embodied emission of the new replaced PV modules are estimations made in the report. This makes the result of the compensation and embodied emission a bit uncertain.

The PV modules are installed on top of the facade of the outer wall. The PV modules can then be replaced without damaging the facade. But if the PV modules would have been integrated in the facade, it would then instead have resulted in a reduction of the cladding material. Reducing the amount of cladding, would result in a lower embodied CO2 emission, but since the cladding is made from wood the result of lower embodied CO2 emission would have been limited since wood has a low emission factor.

| THE ELECTRICITY PRODUCTION BY PV MODULES

The PV modules are installed at the outer wall of the cabin, with a tilted angel of 90 degrees. This angel for PV modules are not the most optimal angel to get the highest efficient. By placing the PV modules in 90 degrees it affects the electricity production which also affects the compensation in the LCA. If the PV modules were installed in the most efficient angel this could have given a better result of electricity production and then the compensation would have been higher.

In the early stages of the designing proses the roof of the cabin was tested to be tilted in different angels. One of the angels that was tested for the roof, during the design process was 35 degrees. Placing the PV modules on the roof with a tilted angel of 35 degrees would have given a better electricity production. But because of the limited area and height of the cabin the design had to be optimized to get a better utilization of the cabin volume and the roof was made flat to give more space indoor.

An advantage with placing the PV modules in 90 degrees results in less snow on the PV modules, which result in that the PV modules can produce electricity even though it is snow on the roof.

FURTHER WORK

For further work of the cabin, it would have been good to have the opportunity to install solar thermal collectors that could heat the domestic water. This was not done for this report because of the lack of information about embodied emission of solar thermal collector and a limited research time.

Calculations for LCA calculations during construction phase on factory and on site, to estimate the reduction using pre-fabricated process instead of construction on site.

Detailing of the prefabricated elements for production and construction process on site.

Study of the how the different wind speed and directions will affect natural ventilation, for each site, considering the cross ventilation with their local wind weather data.

Solution for adaptable foundation with low embodied emissions.

Figure 124: Front perspective, night render [SketchUp, V-ray and Photoshop]
Image source: https://www.harriniva.fi/en/component/travius/32031

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APPENDIX

Different construction				A1 - A3			A4							Notes	B4			C3+C4						
External walls Wood Frame Construction																								
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	0,019	-738	-14,022		12,72	0,24168	m3	100	0,0024168	1169	2,8252392		60			802,0202	15,2383838				
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,0025	-607	-1,5175		11,4	0,0285	m3	100	0,000285	1014	0,28899		60			667,3	1,66825				
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	1	0,335	0,335		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	0,067	0,225	0,225				
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,021875	-607	-13,278125		11,4	0,249375	m3	100	0,00249375	1011	2,52118125		60			667,3	14,5971875				
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	0,238	-35,9	-8,5442				m3			742	0,91476728	see calculation 1. below	50	0,2	-1,70884	39,2	9,3296				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
					A1 - A3	-46,712825	kgCO2eq						Total A4	8,64729716			Total B4	-1,64184	Total C3+C4	52,32742288	Total all	12,62005504	69,242	0,770580116
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2eq]									
						1.	truck		742	0,238	28	6,664	0,185		0,91476728									
							summa								0,91476728									
Roof Wood Frame Construction																								
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	1	2,88	2,88		0,25	0,25	m2	492	0,00050813	1126	0,572154472		30	1	2,88	9,67402	9,67402				
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,02	-672	-13,44		2,37	0,0474	m3	85	0,000557647	792	0,441656471		60			722,2	14,444				
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,0028	-607	-1,6996		11,4	0,03192	m3	100	0,0003192	1014	0,3236688		60			667,3	1,86844				
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	1	0,335	0,335		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	0,067	0,225	0,225				
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,09405	-607	-57,08835		11,4	1,07217	m3	100	0,0107217	1011	10,8396387		60			667,3	62,759565				
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	0,345	-35,9	-12,3855				m3			742	1,3260282	see calculation 1. below	50	0,2	-2,4771	39,2	13,524				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
					A1 - A3	-91,08445	kgCO2eq						Total A4	15,60026607			Total B4	0,4699	Total C3+C4	113,7640266	Total all	38,74974265	23,27	0,795155654
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]									
						1.	truck		742	0,345	28	9,66	0,185		1,3260282									
							summa								1,3260282									
Ground floor Wood Frame Construction																								
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,015	-861	-12,915		33,2	0,498	m3	250	0,001992	855	1,70316		60			1079	16,185				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,03447	-607	-20,92329		11,4	0,392958	m3	100	0,00392958	1011	3,97280538		60			667,3	23,001831				
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	0,383	-35,9	-13,7497				m3			742	3,84356	see calculation 1. below	50	0,2	-2,74994	39,2	15,0136				
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,006	-861	-5,166		33,2	0,1992	m3	250	0,0007968	855	0,681264		60			1079	6,474				
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,022	-672	-14,784		2,37	0,05214	m3	85	0,000613412	792	0,485822118		60			722,2	15,8884				
					A1 - A3	-77,22399	kgCO2eq						Total A4	12,72260743			Total B4	-2,74994	Total C3+C4	87,83183258	Total all	20,58051001	24,5	0,444640648
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]									
						1.	truck		742	1	28	28	0,185		3,84356									
							summa								3,84356									
External walls Massive Wood Construction																								
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	0,019	-738	-14,022		12,72	0,24168	m3	100	0,0024168	1169	2,8252392		60			802,0202	15,2383838				
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,0025	-607	-1,5175		11,4	0,0285	m3	100	0,000285	1014	0,28899		60			667,3	1,66825				
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	1	0,335	0,335		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	0,067	0,225	0,225				
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,01854	-607	-11,25378		11,4	0,211356	m3	100	0,00211356	1011	2,13680916		60			667,3	12,371742				
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	0,206	-35,9	-7,3954				m3			742	0,768712	see calculation 1. below	50	0,2	-1,47908	39,2	8,0752				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Massive wood	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2080	11,89128828		60			701,91854	84,2302248				
					A1 - A3	-101,61568	kgCO2eq						Total A4	17,98615807			Total B4	-1,41208	Total C3+C4	122,1938022	Total all	37,15220025	69,242	2,268512037
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]									
						1.	truck		742	0,2	28	5,6	0,185		0,768712									
							summa								0,768712									
Roof Massive Wood Constrction																								
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	1	2,88	2,88		0,25	0,25	m2	492	0,00050813	1126	0,572154472		30	1	2,88	9,67402	9,67402				
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,02	-672	-13,44		2,37	0,0474	m3	85	0,000557647	792	0,441656471		60			722,2	14,444				
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,0028	-607	-1,6996		11,4	0,03192	m3	100	0,0003192	1014	0,3236688		60			667,3	1,86844				
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	1	0,335	0,335		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	0,067	0,225	0,225				
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,087	-607	-52,809		11,4	0,9918	m3	100	0,009918	1011	10,027098		60			667,3	58,0551				
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	0,29	-35,9	-10,411				m3			742	1,1146324	see calculation 1. below	50	0,2	-2,0822	39,2	11,368				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Massive wood	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2080	11,89128828		60			701,91854	84,2302248				
					A1 - A3	-142,9066	kgCO2eq						Total A4	24,44561785			Total B4	0,8648	Total C3+C4	180,2497864	Total all	62,65360423	23,27	1,285669639
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]									
						1.	truck		742	0,29	28	8,12	0,185		1,1146324									
							summa								1,1146324									

				A1 - A3			A4							Notes	B4			C3+C4						
Ground floor Massive Wood Construction																								
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,015	-861	-12,915		33,2	0,498	m3	250	0,001992	855	1,70316		60			1079	16,185				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				

Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,02967	-607	-18,00969		11,4	0,338238	m3	100	0,00338238	1011	3,41958618		60			667,3	19,798791				
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	0,33	-35,9	-11,847				m3			742	0	see calculation 1. below	50	0,2	-2,3694	39,2	12,936				
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,006	-861	-5,166		33,2	0,1992	m3	250	0,0007968	855	0,681264		60			1079	6,474				
Massive wood	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2080	11,89128828		60			701,91854	84,2302248				
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,022	-672	-14,784		2,37	0,05214	m3	85	0,000613412	792	0,485822118		60			722,2	15,8884				
				A1 - A3		-140,48369	kgCO2eq						Total A4	20,2171165			Total B4	-2,3694	Total C3+C4	166,7814174	Total all	44,14544388	24,5	0,95375959
							for ukjente verier																	
							mode	distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]										
						1.	truck	742	0,02967	28	0,83076	0,185		0,114038425										
							summa							0,114038425										

External walls Slim Construction

Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	0,019	-738	-14,022		12,72	0,24168	m3	100	0,0024168	1169	2,8252392		60			802,0202	15,2383838				
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,0025	-607	-1,5175		11,4	0,0285	m3	100	0,000285	1014	0,28899		60			667,3	1,66825				
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	1	0,335	0,335		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	0,067	0,225	0,225				
Steel pilars	SKANSKA: VKR-pillar 50x50mm	00241E	kg	8,7	2,89	25,143		0,0239	0,20793	kg	400	0,000519825	742	0,38571015		60				0				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
					A1 - A3	155,8625	kgCO2eq						Total A4	73,05353878			Total B4	0,067	Total C3+C4	28,40063538	Total all	257,3836742	69,242	15,71583807
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]									
						1	plan		6328	0,05	200	10	1,066		67,45648									
							summa								67,45648									

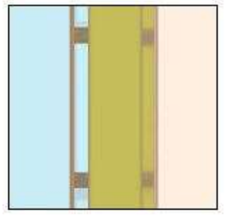
Roof Slim Construction

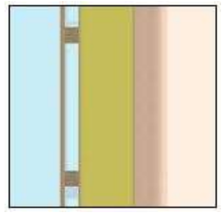
				A1 - A3			**A4**							Notes	B4			C3+C4						
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	1	2,88	2,88		0,25	0,25	m2	492	0,00050813	1126	0,572154472		30	1	2,88	9,67402	9,67402				
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,02	-672	-13,44		2,37	0,0474	m3	85	0,000557647	792	0,441656471		60			722,2	14,444				
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,0028	-607	-1,6996		11,4	0,03192	m3	100	0,0003192	1014	0,3236688		60			667,3	1,86844				
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	1	0,335	0,335		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	0,067	0,225	0,225				
Steel beams	SKANSKA: IPE160	00239EE	kg	31,6	1,45	45,82		0,0239	0,75524	kg	400	0,0018881	742	1,4009702		60								
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
					A1 - A3	203,7594	kgCO2eq						Total A4	72,29204937			Total B4	2,947	Total C3+C4	37,48046158	Total all	316,478911	23,27	6,494236559
							for ukjente verier																	
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]									
						1	plan		6328	0,05	200	10	1,066		67,45648									
							summa								67,45648									

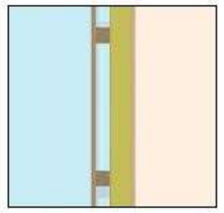
Ground floor Slim Construction

Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	1	-10	-10		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	10,884				
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,015	-861	-12,915		33,2	0,498	m3	250	0,001992	855	1,70316		60			1079	16,185				
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	1	0,314	0,314		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	0,38500158				
Steel beams	SKANSKA: IPE160	00239EE	kg	31,6	1,45	45,82		0,0239	0,75524	kg	400	0,00005975	742	0,0443345		60								
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,006	-861	-5,166		33,2	0,1992	m3	250	0,0007968	855	0,681264		60			1079	6,474				
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,022	-672	-14,784		2,37	0,05214	m3	85	0,000613412	792	0,485822118		60			722,2	15,8884				
					A1 - A3	182,819	kgCO2eq						Total A4	72,40705655			Total B4	0	Total C3+C4	49,81640158	Total all	305,0424581	24,5	6,590423478
							for ukjente verier																	
							mode	distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]										
						1	plan	6328	0,05	200	10	1,066		67,45648										
							summa							67,45648										

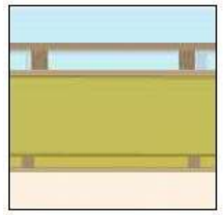
	Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]	Width [m]	Depth [m]	Length [m]	Mass	Amount/ m2	Total mass/m2	Unit	EPD for specific product	EDP for similar product	Generic LCA GWP
Outside			1	Wood cladding	0,14	19	0,148	0,019	1	0,002812	6,76	0,019009	m3	x		
			2	Nailing battens 25x25 mm and air gap (horizontal)		25	0,025	0,025	1	0,000625	2	0,00125	m3	x		
			3	Nailing battens 25x25 mm and air gap (vertical)		25	0,025	0,025	1	0,000625	2	0,00125	m3	x		
			4	Wind barrier	0,1	1	1	0,001	1	1	1	1	m2	x		
			5	Insulation layer 1, Cellulose sheet	0,036	193	1	0,193	1	0,193	1	0,193	m3		x	
	WFC	0,18		Load bearing stud (45x193, c600)			0,045	0,193	1	0,008685	2	0,01737	m3	x		
			6	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
			7	Insulation layer 2, Cellulose sheet	0,036	45	1	0,045	1	0,045	1	0,045	m3		x	
				Stud (45x45, cc60)			0,045	0,045	1	0,002025	2	0,00405	m3	x		
Inside			8	Wood surface	0,14	15	1	0,015	1	0,015	1	0,015	m3		x	
				Total		**324**										
Outside			1	Wood cladding	0,14	19	0,148	0,019	1	0,002812	6,76	0,019009	m3	x		
			2	Nailing battens 25x25 mm and air gap (horizontal)		25	0,025	0,025	1	0,000625	2	0,00125	m3	x		
			3	Nailing battens 25x25 mm and air gap (vertical)		25	0,025	0,025	1	0,000625	2	0,00125	m3	x		
			4	Wind barrier	0,1	1	1	0,001	1	1	1	1	m2	x		
	MWC	0,18	5	Insulation layer 1, Cellulose sheet	0,036	206	1	0,206	1	0,206	1	0,206	m3		x	
				Stud (45x206, c600)			0,045	0,206	1	0,00927	2	0,01854	m3	x		
			6	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
Inside			7	Massive wood	0,14	120	1	0,12	1	0,12	1	0,12	m3	x		
				Total		**397**										
Outside			1	Wood cladding	0,14	19	0,148	0,019	1	0,002812	6,76	0,019009	m3	x		
			2	Nailing battens 25x25 mm and air gap (horizontal)		25	0,025	0,025	1	0,000625	2	0,00125	m3	x		
			3	Nailing battens 25x25 mm and air gap (vertical)		25	0,025	0,025	1	0,000625	2	0,00125	m3	x		
			4	Wind barrier	0,1	1	1	0,001	1	1	1	1	m2	x		
	SC	0,18	5	Insulation layer 1, VIP	0,00213	78	1	0,078	1	0,078	1	0,078	m3		x	
				Load bearing steel pillars (VKR pillar 50x50)							2			x		
			6	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
Inside			7	Wood surface	0,14	15	1	0,015	1	0,015	1	0,015	m3		x	
				Total		**164**										

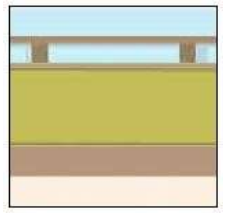




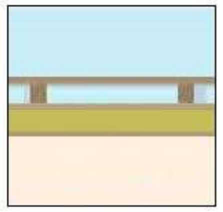


	Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]	Width [m]	Depth [m]	Length [m]	Mass	Amount/ m2	Total mass/m2	Unit	EPD for specific product	EDP for similar product	Generic LCA GWP
Outside			1	Water proof membran		2	1	2	1	1	1	1	m2	x		
			2	wood plank	0,14	20	1	0,02	1	0,02	1	0,02	m3	x		
			3	Nailing battens (70x20) and air gap		20	0,07	0,02	1	0,0014	2	0,0028	m3	x		
			4	Wind barrier		1	1	0,001	1	1	1	1	m2	x		
			5	Insulation layer 1, Cellulose blown	0,037	300	1	0,3	1	0,3	1	0,3	m3		x	
	WFC	0,13		Load bearing timber beams (250x150, c450)			0,15	0,3	1	0,045	2	0,09	m3	x		
			6	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
			7	Insulation layer 2, Cellulose sheet	0,036	45	1	0,045	1	0,045	1	0,045	m3		x	
				Stud (45x45, cc60)			0,045	0,045	1	0,002025	2	0,00405	m3	x		
Inside			8	Wooden surface	0,14	15	1	0,015	1	0,015	1	0,015	m3		x	
				Total		**404**										
Outside			1	Water proof membran		2	1	2	1	1	1	1	m2	x		
			2	Wood plank	0,14	20	1	0,02	1	0,02	1	0,02	m3	x		
			3	Nailing battens (70x20) och air gap		20	0,07	0,02	1	0,0014	2	0,0028	m3	x		
			4	Wind barrier		1	1	0,001	1	1	1	1	m2	x		
	MWC	0,13	5	Insulation layer 1, Cellulose blown	0,037	290	1	0,29	1	0,29	1	0,29	m3		x	
				Studs (290x150, c600)			0,15	0,29	1	0,0435	2	0,087	m3	x		
			6	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
Inside			7	Massive wood	0,14	120	1	0,12	1	0,12	1	0,12	m3		x	
				Total		**454**										

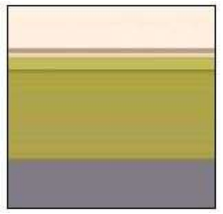




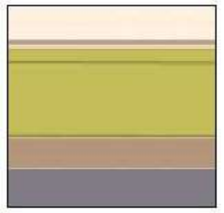
Outside	SC	**0,13**	1	Water proof membran		2	1	2	1	1	1	1	m2	x		
			2	Raspont	0,14	20	1	0,02	1	0,02	1	0,02	m3	x		
			3	Nailing battens (70x20) och air gap		20	0,07	0,02	1	0,0014	2	0,0028	m3	x		
			4	Wind barrier		1	1	0,001	1	1	1	1	m2	x		
			5	Insulation layer, VIP	0,00213	90	1	0,09	1	0,09	1	0,09	m3		x	
				Load bearing steel beams (IPE 160)							2		m3	x		
			6	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
Inside			7	Wooden surface	0,14	15	1	0,015	1	0,015	1	0,015	m3		x	
				Total		**149**										



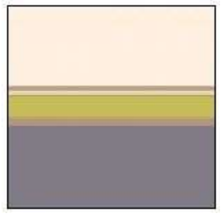
	Construction	U-value W/m2K	Layer	Material	Lambda W/mK	Thickness [mm]	Width [m]	Depth [m]	Length [m]	Mass	Amount/ m2	Total mass/m2	Unit	EPD for specific product	EDP for similar product	Generic LCA GWP
Inside	WFC	**0,1**	1	Wooden floor	0,14	20	1	0,02	1	0,02	1	0,02	m3		x	
			2	Under floor	0,14	15	1	0,015	1	0,015	1	0,015	m3	x		
			3	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
			4	Insulation layer 1 , Cellulose sheet	0,036	45	1	0,045	1	0,045	1	0,045	m3		x	
				Stud 45x45			0,045	0,045	1	0,002025	2	0,00405	m3	x		
			5	Insulation layer 2, Cellulose sheet	0,036	338	1	0,338	1	0,338	1	0,338	m3		x	
				Load bearing timber (45x338, c450)			0,045	0,338	1	0,01521	2	0,03042	m3	x		
			6	Wind barrier plate K-board	0,14	6	1	0,006	1	0,006	1	0,006	m3	x		
Outside			7	Wood plank	0,14	22	1	0,022	1	0,022	1	0,022	m3		x	
				Total		**447**										



Inside	MWC	**0,1**	1	Wooden floor	0,14	20	1	0,02	1	0,02	1	0,02	m3		x	
			2	Under floor	0,14	15	1	0,015	1	0,015	1	0,015	m3	x		
			3	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
			4	Insulation layer 1 , Cellulose sheet	0,036	45	1	0,045	1	0,045	1	0,045	m3		x	
				Stud 45x45			0,045	0,045	1	0,002025	2	0,00405	m3	x		
			5	Insulation layer 2, Cellulose sheet	0,036	285	1	0,285	1	0,285	1	0,285	m3		x	
				Studs (45x285, c600)			0,045	0,285	1	0,012825	2	0,02565	m3	x		
			6	Massive wood	0,14	120	1	0,12	1	0,12	1	0,12	m3	x		
Outside			7	Wood plank	0,14	22	1	0,022	1	0,022	1	0,022	m3		x	
				Total		**508**										



Inside	SC	**0,1**	1	Wooden floor	0,14	20	1	0,02	1	0,02	1	0,02	m3		x	
			2	Under floor	0,14	15	1	0,015	1	0,015	1	0,015	m3	x		
			3	Vapor barrier		1	1	0,001	1	1	1	1	m2	x		
			5	Insulation layer, VIP	0,00213	83	1	0,083	1	0,083	1	0,083	m3		x	
				Load bearing steel beam (IPE 160)							2		m3	x		
			6	Wind barrier plate K-board	0,14	6	1	0,006	1	0,006	1	0,006	m3	x		
Outside			7	Wood plank	0,14	22	1	0,022	1	0,022	1	0,022	m3		x	
				Total		**147**										



LCA factory		Unit
Lifetime PV	**30**	year
Lifetime cabin	**60**	year
Heated floor area	**18,9**	m2
Pv area	**4,95**	m2
Electrical grid factor	**132**	gCO2eq/kWh
Biofuel emission factor	**3,6**	gCO2eq/kWh

Element		
External walls	858,7546	kgCO2eq for 60 years
Roof	1079,5916	kgCO2eq for 60 years
Ground slab	699,5667	kgCO2eq for 60 years
Extended entrance	122,5626	kgCO2eq for 60 years
Loft slab	174,6675	kgCO2eq for 60 years
Inner walls	28,0455	kgCO2eq for 60 years
Windows	191,7752	kgCO2eq for 60 years
Entrance door	281,6948	kgCO2eq for 60 years
Total	3436,6583	kgCO2eq for 60 years
	3,0306	kgCO2eq/m2/year

PV modules (embodied emission) 2018-2048	230	kgCO2eq/m2
PV modules (embodied emission) 2048-2078	80,5	kgCO2eq/m2
PV embodied emission for 60 years	310,5	kgCO2eq/m2
PV embodied emission per year	5,175	kgCO2eq/m2/year

1536,975	kgCO2eq for 60 years	Total PV area
1,355357143	kgCO2eq/m2 per year	(per m2 heated floor)

Efficiency in 2018-2048	15,50	%
PV el.production per year (efficiency 15.5 %)	411	kWh/year
PV el.production per year and m2 of the house	21,74603175	kWh/year per m2
PV compensation	2870,47619	gCO2eq/m2/year
	2,87047619	kgCO2eq/m2/year
	-2,87047619	kgCO2eq/m2/year

Efficiency in 2048-2078 (will increase 36,2 % = 1,362)	21,11	%
1,362		
PV el.production per year (efficiency 21,11 %)	559,78	kWh/year
PV el.production per year and m2 of the house	29,62	kWh/year per m2
PV compensation	3909,59	gCO2eq/m2/year
	3,91	kgCO2eq/m2/year
	-3,91	kgCO2eq/m2/year

Efficiency 2018-2078	18,3055	%
PV el.production per year (efficiency 15,5 and 21,11 %)	485,391	kWh/year
PV el.production per year and m2 of the house	25,68206349	kWh/year per m2
PV compensation	3390,032381	gCO2eq/m2/year
	3,390032381	kgCO2eq/m2/year
	-3,390032381	kgCO2eq/m2/year
		per m2 cabin

Operational electrical energy for the building per year		
Electricity demand per m2year	36	kwh/m2year
Operational time for the building per year	4,752	kgCO2eq/kWh

Operational biofuel energy for the building per year		
Electricity demand per m2year	136,4	kwh/m2year
Operational time for the building per year	0,49104	kgCO2eq/kWh

Total operational energy for the building per year	5,24304

	Worst case: Module 0% reused = 210 kgCO2/m2
from 2048-2078 emission will be reduced by 65 %	Base line: (mounting structure 8,4 kgCO2) + (transport ship and truck) = 20 kgCO2/m2
	Resultat: sum total 210+20=230 kgCO2/m2

1 Final external walls factory					A1 - A3						A4				Notes		B4		C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	1,315598	-738	-970,911324		12,72	16,73440656	m3	100	0,1272	1169	148,6968		60			802,0202	1055,136171		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,173105	-607	-105,074735		11,4	1,973397	m3	100	0,114	1014	115,596		60			667,3	115,5129665		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	69,242	0,335	23,19607		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	4,639214	0,225	18,69534		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,6202628	-607	-983,4995196		11,4	18,47099592	m3	100	0,114	1011	115,254		60			667,3	1081,201366		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	18,00292	-35,9	-646,304828				m3			742	69,1953032	see calculation 1. below	60			39,2	705,714464		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	69,242	0,314	21,741988		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	26,6582794		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	69,242	-10	-692,42		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	753,629928		
					A1 - A3	-3353,272349	kgCO2eq						Total A4	450,8392226			Total B4	4,639214	Total C3+C4	3756,548515	Total all	858,7546034
			Area wall	69,242			for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2eq]							
						1.	truck		742	18,00292	28	504,08176	0,185		69,1953032							
							summa								69,1953032							

4 Final roof construction, factory					A1 - A3						A4				Notes		B4		C3+C4			
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	23,27	2,88	67,0176		0,25	0,25	m2	492	0,00050813	1126	0,572154472		30	1	67,0176	9,67402	450,2288908		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,4654	-672	-312,7488		2,37	1,102998	m3	85	0,027882353	792	22,08282353		60			722,2	336,11188		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,065156	-607	-39,549692		11,4	0,7427784	m3	100	0,114	1014	115,596		60			667,3	43,4785988		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	23,27	0,335	7,79545		0,00705	0,00705	m2	100	0,0000705	867	0,0611235		50	0,2	1,55909	0,225	6,2829		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,8394935	-607	-1116,572555		11,4	20,9702259	m3	100	0,114	1011	115,254		60			667,3	1227,494013		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,86465	-35,9	-246,440935				m3			742	26,38469415	see calculation 1. below	60			39,2	269,09428		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	23,27	0,314	7,30678		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	8,958986767		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	23,27	-10	-232,7		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	253,27068		
					A1 - A3	-1865,892152	kgCO2eq						Total A4	281,9867916			Total B4	68,57669	Total C3+C4	2594,920229	Total all	1079,591559
				Area roof	23,27																	
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	6,86465	28	192,2102	0,185		26,38469415							
							summa								26,38469415							

7 Final ground slab, factory					A1 - A3						A4				Notes		B4		C3+C4			
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	24,5	-10	-245		0,2	0,2	m2	100	0,002	1011	2,022		60			10,884	266,658		
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,3675	-861	-316,4175		33,2	12,201	m3	250	0,1328	855	113,544		60			1079	396,5325	80,115	
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	24,5	0,314	7,693		0,00905	0,00905	m2	258	3,50775E-05	399	0,01399593		60			0,38500158	9,43253871	17,12553871	
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,628425	-607	-381,453975		11,4	7,164045	m3	100	0,114	1011	115,254		60			667,3	419,3480025	37,8940275	
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,9825	-35,9	-250,67175				m3			742	94,16722	see calculation 1. below	60			39,2	273,714	23,04225	
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,147	-861	-126,567		33,2	4,8804	m3	250	0,1328	855	113,544		60			1079	158,613	32,046	
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,539	-672	-362,208		2,37	1,27743	m3	85	0,027882353	792	22,08282353		60			722,2	389,2658	27,0578	
					A1 - A3	-1674,625225	kgCO2eq						Total A4	460,6280395			Total B4	0	Total C3+C4	1913,563841	Total all	699,5666557
			Area slab	24,5																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	24,5	28	686	0,185		94,16722							
							summa								94,16722							

3 Final extended entrance, for the whole construction factory					A1 - A3						A4				Notes		B4		C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	0,46968	-738	-346,62384		12,72	5,9743296	m3	100	0,059743296	1169	69,83991302		60			802,0202	376,6928475		
Construction timber	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,12879	-607	-78,17553		11,4	1,468206	m3	100	0,01468206	1014	14,88760884		60			667,3	85,941567		
					A1 - A3	-424,79937	kgCO2eq						Total A4	84,72752186			Total B4	0	Total C3+C4	462,6344145	Total all	122,5625664

6 loft slab factory					A1 - A3						A4				Notes		B4		C3+C4			
Loft slab	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,74736	-567,3	-423,977328		34,54	25,8138144	m3	725	0,035605261	2080	74,05894338		60			701,91854	524,5858401		
					A1 - A3	-423,977328	kgCO2eq						Total A4	74,05894338			Total B4	0	Total C3+C4	524,5858401	Total all	174,6674554

8 inner walls factory					A1 - A3						A4				Notes		B4		C3+C4			
Inner walls	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2080	11,89128828		60			701,91854	84,2302248		
					A1 - A3	-68,076	kgCO2eq						Total A4	11,89128828			Total B4	0	Total C3+C4	84,2302248	Total all	28,04551308

5	**windows factory**				**A1 - A3**							**A4**			Notes		B4			C3+C4		
Windows	Nordvestvinduet Fastkarm vindu	NEPD-386-265-NO	m2	4,04	44,6	180,184		0,884615385	3,573846154	m2	300	0,011912821	973	11,59117436	EPD adjusted to m2	60			10,884	43,97136		
					A1 - A3	180,184	kgCO2eq						Total A4	11,59117436			Total B4	0	Total C3+C4	43,97136	Total all	191,7751744
					per FU	0,120122667	kgCO2eq/m2/yr															

9	**entrance door factory**				**A1 - A3**			**A4**							Notes	B4			C3+C4			
Entrance door	NorDan NTech Balcony security door 105/80	NEPD00258E	1 door	1	207,96	207,96		19,97	19,97	1 door	1500	0,013313333	2594	34,53478667		60			39,2	39,2		
					A1 - A3	207,96	kgCO2eq						Total A4	34,53478667			Total B4	0	Total C3+C4	39,2	Total all	281,6947867

Material break down factory		Unit
Lifetime PV	**30**	year
Lifetime cabin	**60**	year
Heated floor area	**18,9**	m2
Pv area	**4,95**	m2
Electrical grid factor	**132**	gCO2eq/kWh
Biofuel emission factor	**3,6**	gCO2eq/kWh

Element		
External walls	858,75	kgCO2eq (for 60 years)
Roof	1079,59	kgCO2eq (for 60 years)
Ground slab	699,57	kgCO2eq (for 60 years)
Extended entrance	122,56	kgCO2eq (for 60 years)
Loft slab	174,67	kgCO2eq (for 60 years)
Inner walls	28,05	kgCO2eq (for 60 years)
Windows	191,78	kgCO2eq (for 60 years)
Entrance door	281,69	kgCO2eq (for 60 years)
Total	3436,66	kgCO2eq (for 60 years)
	3,03	kgCO2eq/m2/year

PV modules (embodied emission) 2018-2048	230	kgCO2eq/m2	
PV modules (embodied emission) 2048-2078	80,5	kgCO2eq/m2	
PV embodied emission for 60 years	310,5	kgCO2eq/m2	
PV embodied emission per year	5,175	kgCO2eq/m2/year	
	1536,975	kgCO2eq for 60 years	Total PV area
	1,36	kgCO2eq/m2 per year	(per m2 heated floor)

Total embodied emission of the cabin		
Building materials	3,03	kgCO2eq/m2/year
PV modules	1,36	kgCO2eq/m2/year

Total embodied emission, by component		
23 outer walls	1455	kgCO2eq
24 Inner walls	28	kgCO2eq
25 Floor structur	874	kgCO2eq
26 Outer roof	1080	kgCO2eq
49 Other PV	1537	kgCO2eq

Material break down			
23 Outer walls	Wood cladding	232,9216	kgCO2eq
	Nailing battens	126,0342	kgCO2eq
	Wind barrier	46,5917	kgCO2eq
	Construction tim	212,9558	kgCO2eq
	Insulation	128,6049	kgCO2eq
	Vapor barrier	48,4143	kgCO2eq
	Wood panel	63,2319	kgCO2eq
	Entrance modul	122,5626	kgCO2eq
	Window	191,7800	kgCO2eq
	Door	281,6948	kgCO2eq
26 Outher roof	Bitumen	584,8362	kgCO2eq
	Wood underroo	45,4459	kgCO2eq
	Nailing battens	119,5249	kgCO2eq
	Wind barrier	15,6986	kgCO2eq
	Construction tim	226,1755	kgCO2eq
	Insulation	49,0380	kgCO2eq
	Vapor barrier	16,2798	kgCO2eq
	Wood panel	22,5927	kgCO2eq
25 Floor constuction	Wood panel	23,6800	kgCO2eq
	Under floor	193,6590	kgCO2eq
	Vapor barrier	17,1395	kgCO2eq
	Construction tim	153,1480	kgCO2eq
	Insulation	117,2095	kgCO2eq
	Wind barrier	145,5900	kgCO2eq
	Wood plank	49,1406	kgCO2eq
Loft slab	Massive wood	174,6675	kgCO2eq
24 Inner walls	Massive wood	28,04551308	kgCO2eq
49 Other	PV	1536,9750	kgCO2eq

Total embodied emission by material		
Wood*	1794	kgCO2eq
Insulation	295	kgCO2eq
Wind barrier	208	kgCO2eq
Vapor barrier	82	kgCO2eq
Bitumen	585	kgCO2eq
Windows	192	kgCO2eq
EntDoor	282	kgCO2eq
PV	1537	kgCO2eq

kittelfjäll		Unit
Lifetime PV	**30**	year
Lifetime cabin	**60**	year
Heated floor area	**18,9**	m2
Pv area	**4,95**	m2
Electrical grid factor	**132**	gCO2eq/kWh
Biofuel emission factor	**3,6**	gCO2eq/kWh

Element		
External walls	941,65	kgCO2eq for 60 years
Roof	1139,56	kgCO2eq for 60 years
Ground slab	794,57	kgCO2eq for 60 years
Extended entrance	139,83	kgCO2eq for 60 years
Loft slab	182,93	kgCO2eq for 60 years
Inner walls	29,37	kgCO2eq for 60 years
Windows	194,54	kgCO2eq for 60 years
Entrance door	284,78	kgCO2eq for 60 years
Total	3707,24	kgCO2eq for 60 years
	3,27	kgCO2eq/m2/year

PV modules (embodied emission) 2018-2048	230	kgCO2eq/m2
PV modules (embodied emission) 2048-2078	80,5	kgCO2eq/m2
PV embodied emission for 60 years	310,5	kgCO2eq/m2
PV embodied emission per year	5,175	kgCO2eq/m2/year

1536,975	kgCO2eq for 60 years	Total PV area
1,36	kgCO2eq/m2 per year	(per m2 heated floor)

Efficiency in 2018-2048	15,50	%
PV el.production per year (efficiency 15.5 %)	411	kWh/year
PV el.production per year and m2 of the house	21,74603175	kWh/year per m2
PV compensation	2870,47619	gCO2eq/m2/year
	2,87047619	kgCO2eq/m2/year
	-2,87047619	kgCO2eq/m2/year

Efficiency in 2048-2078 (will increase 36,2 % = 1,362)		21,11	%
	1,362		
PV el.production per year (efficiency 21,11 %)		559,78	kWh/year
PV el.production per year and m2 of the house		29,62	kWh/year per m2
PV compensation		3909,59	gCO2eq/m2/year
		3,91	kgCO2eq/m2/year
		-3,91	kgCO2eq/m2/year

Efficiency 2018-2078	18,3055	%
PV el.production per year (efficiency 15,5 and 21,11 %)	485,391	kWh/year
PV el.production per year and m2 of the house	25,68206349	kWh/year per m2
PV compensation	3390,032381	gCO2eq/m2/year
	3,390032381	kgCO2eq/m2/year
	-3,39	kgCO2eq/m2/year
		per m2 cabin

Operational electrical energy for the building per year		
Electricity demand per m2year	35	kwh/m2year
Operational time for the building per year	4,62	kgCO2eq/kWh

Operational biofuel energy for the building per year		
Energy demand from bio fuel per m2year	126,6	kwh/m2year
Operational time for the building per year	0,45576	kgCO2eq/kWh

Total operational energy for the building per year	5,08

	Worst case: Module 0% reused = 210 kgCO2/m2
from 2048-2078 emission will be reduced by 65 %	Base line: (mounting structure 8,4 kgCO2) + (transport ship and truck) = 20 kgCO2/m2
	Resultat: sum total 210+20=230 kgCO2/m2

Kittelfjäll

1	**Final external walls construction for, kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	1,315598	-738	-970,911324		12,72	16,73440656	m3	100	0,1272	1401	178,2072		60			802,0202	1055,136171		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,173105	-607	-105,074735		11,4	1,973397	m3	100	0,114	1246	142,044		60			667,3	115,5129665		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	69,242	0,335	23,19607		0,00705	0,00705	m2	100	0,0000705	1099	0,0774795		50	0,2	4,639214	0,225	18,69534		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,6202628	-607	-983,4995196		11,4	18,47099592	m3	100	0,114	1243	141,702		60			667,3	1081,201366		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	18,00292	-35,9	-646,304828				m3			974	69,1953032	see calculation 1. below	60			39,2	705,714464		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	69,242	0,314	21,741988		0,00905	0,00905	m2	258	3,50775E-05	631	0,022133915		60			0,38500158	26,6582794		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	69,242	-10	-692,42		0,2	0,2	m2	100	0,002	1243	2,486		60			10,884	753,629928		
					A1 - A3	-3353,272349	kgCO2eq						Total A4	533,7341166			Total B4	4,639214	Total C3+C4	3756,548515	Total all	941,6494974
			Area wall	69,242																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2eq]							
						1.	truck		742	18,00292	28	504,08176	0,185		69,1953032							
							summa								69,1953032							

4	**Final roof construction, kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	23,27	2,88	67,0176		0,25	0,25	m2	492	0,00050813	1358	0,69004065		30	1	67,0176	9,67402	450,2288908		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,4654	-672	-312,7488		2,37	1,102998	m3	85	0,027882353	1024	28,55152941		60			722,2	336,11188		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,065156	-607	-39,549692		11,4	0,7427784	m3	100	0,114	1246	142,044		60			667,3	43,4785988		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	23,27	0,335	7,79545		0,00705	0,00705	m2	100	0,0000705	1099	0,0774795		50	0,2	1,55909	0,225	6,2829		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,8394935	-607	-1116,572555		11,4	20,9702259	m3	100	0,114	1243	141,702		60			667,3	1227,494013		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,86465	-35,9	-246,440935				m3			974	26,38469415	see calculation 1. below	60			39,2	269,09428		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	23,27	0,314	7,30678		0,00905	0,00905	m2	258	3,50775E-05	631	0,022133915		60			0,38500158	8,958986767		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	23,27	-10	-232,7		0,2	0,2	m2	100	0,002	1243	2,486		60			10,884	253,27068		
					A1 - A3	-1865,892152	kgCO2eq						Total A4	341,9578776			Total B4	68,57669	Total C3+C4	2594,920229	Total all	1139,562645
				Area roof	23,27																	
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	6,86465	28	192,2102	0,185		26,38469415							
							summa								26,38469415							

7	**Final ground slab, kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	24,5	-10	-245		0,2	0,2	m2	100	0,002	1243	2,486		60			10,884	266,658		
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,3675	-861	-316,4175		33,2	12,201	m3	250	0,1328	1087	144,3536		60			1079	396,5325		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	24,5	0,314	7,693		0,00905	0,00905	m2	258	3,50775E-05	631	0,022133915		60			0,38500158	9,43253871		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,628425	-607	-381,453975		11,4	7,164045	m3	100	0,114	1243	141,702		60			667,3	419,3480025		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,9825	-35,9	-250,67175				m3			974	94,16722	see calculation 1. below	60			39,2	273,714		
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,147	-861	-126,567		33,2	4,8804	m3	250	0,1328	1087	144,3536		60			1079	158,613		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,539	-672	-362,208		2,37	1,27743	m3	85	0,027882353	1024	28,55152941		60			722,2	389,2658		
					A1 - A3	-1674,625225	kgCO2eq						Total A4	555,6360833			Total B4	0	Total C3+C4	1913,563841	Total all	794,5746995
					Area slab	24,5																
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	24,5	28	686	0,185		94,16722							
							summa								94,16722							

3	**Final extended entrance, for the whole construction, kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	0,46968	-738	-346,62384		12,72	5,9743296	m3	100	0,059743296	1401	83,7003577		60			802,0202	376,6928475		
Construction timber	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,12879	-607	-78,17553		11,4	1,468206	m3	100	0,01468206	1246	18,29384676		60			667,3	85,941567		
					A1 - A3	-424,79937	kgCO2eq						Total A4	101,9942045			Total B4	0	Total C3+C4	462,6344145	Total all	139,829249

6	**Loft slab, kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Loft slab	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,74736	-567,3	-423,977328		34,54	25,8138144	m3	725	0,035605261	2312	82,31936399		60			701,91854	524,5858401		
					A1 - A3	-423,977328	kgCO2eq						Total A4	82,31936399			Total B4	0	Total C3+C4	524,5858401	Total all	182,927876

8	**inner walls kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Inner walls	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2312	13,21762428		60			701,91854	84,2302248		
					A1 - A3	-68,076	kgCO2eq						Total A4	13,21762428			Total B4	0	Total C3+C4	84,2302248	Total all	29,37184908

5	**Windows kittelfjäll**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Windows	Nordvestvinduet Fastkarm vindu	NEPD-386-265-NO	m2	4,04	44,6	180,184		0,884615385	3,573846154	m2	300	0,011912821	1205	14,35494872	EPD adjusted to m2	60			10,884	43,97136		
					A1 - A3	180,184	kgCO2eq						Total A4	14,35494872			Total B4	0	Total C3+C4	43,97136	Total all	194,5389487
					per FU	0,120122667	kgCO2eq/m2/yr															

	9 entrance door kittelfjäll				**A1 - A3**			**A4**							Notes	B4			C3+C4			
Entrance door	NorDan NTech Balcony security door 105/80	NEPD00258E	1 door	1	207,96	207,96		19,97	19,97	1 door	1500	0,013313333	2826	37,62348		60			39,2	39,2		
					A1 - A3	207,96	kgCO2eq						Total A4	37,62348			Total B4	0	Total C3+C4	39,2	Total all	284,78348

Lysøysund		Unit
Lifetime PV	**30**	year
Lifetime cabin	**60**	year
Heated floor area	**18,9**	m2
Pv area	**4,95**	m2
Electrical grid factor	**132**	gCO2eq/kWh
Biofuel emission factor	**3,6**	gCO2eq/kWh

Element		
External walls	1039,5512	kgCO2eq for 60 years
Roof	1210,3906	kgCO2eq for 60 years
Ground slab	906,7825	kgCO2eq for 60 years
Extended entrance	160,2218	kgCO2eq for 60 years
Loft slab	192,6837	kgCO2eq for 60 years
Inner walls	30,9383	kgCO2eq for 60 years
Windows	197,8031	kgCO2eq for 60 years
Entrance door	288,4313	kgCO2eq for 60 years
Total	4026,8025	kgCO2eq for 60 years
	3,55	kgCO2eq/m2/year

PV modules (embodied emission) 2018-2048	230	kgCO2eq/m2
PV modules (embodied emission) 2048-2078	80,5	kgCO2eq/m2
PV embodied emission for 60 years	310,5	kgCO2eq/m2
PV embodied emission per year	5,175	kgCO2eq/m2/year

1536,975	kgCO2eq for 60 years	Total PV area
1,36	kgCO2eq/m2 per year	(per m2 heated floor)

Efficiency in 2018-2048	15,50	%
PV el.production per year (efficiency 15.5 %)	461	kWh/year
PV el.production per year and m2 of the house	24,39153439	kWh/year per m2
PV compensation	3219,68254	gCO2eq/m2/year
	3,21968254	kgCO2eq/m2/year
	-3,21968254	kgCO2eq/m2/year

Efficiency in 2048-2078 (will increase 36,2 % = 1,362)	21,11	%
1,362		
PV el.production per year (efficiency 21,11 %)	627,88	kWh/year
PV el.production per year and m2 of the house	33,22	kWh/year per m2
PV compensation	4385,21	gCO2eq/m2/year
	4,39	kgCO2eq/m2/year
	-4,39	kgCO2eq/m2/year

Efficiency 2018-2078	18,3055	%
PV el.production per year (efficiency 15,5 and 21,11 %)	544,441	kWh/year
PV el.production per year and m2 of the house	28,80640212	kWh/year per m2
PV compensation	3802,445079	gCO2eq/m2/year
	3,802445079	kgCO2eq/m2/year
	-3,80	kgCO2eq/m2/year
		per m2 cabin

Operational electrical energy for the building per year		
Electricity demand per m2year	35	kwh/m2year
Operational time for the building per year	4,62	kgCO2eq/kWh

Operational biofuel energy for the building per year		
Energy demand per m2year	95,6	kwh/m2year
Operational time for the building per year	0,34416	kgCO2eq/kWh

Total operational energy for the building per year	4,96

from 2048-2078 emission will be reduced by 65 %	Worst case: Module 0% reused = 210 kgCO2/m2 Base line: (mounting structure 8,4 kgCO2) + (transport ship and truck) = 20 kgCO2/m2 Resultat: sum total 210+20=230 kgCO2/m2

Lysøysund

1	**Final external walls construction for, Lysøysund**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	1,315598	-738	-970,911324		12,72	16,73440656	m3	100	0,1272	1675	213,06		60			802,0202	1055,136171		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,173105	-607	-105,074735		11,4	1,973397	m3	100	0,114	1520	173,28		60			667,3	115,5129665		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	69,242	0,335	23,19607		0,00705	0,00705	m2	100	0,0000705	1373	0,0967965		50	0,2	4,639214	0,225	18,69534		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,6202628	-607	-983,4995196		11,4	18,47099592	m3	100	0,114	1517	172,938		60			667,3	1081,201366		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	18,00292	-35,9	-646,304828				m3			1248	69,1953032	see calculation 1. below	60			39,2	705,714464		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	69,242	0,314	21,741988		0,00905	0,00905	m2	258	3,50775E-05	905	0,031745155		60			0,38500158	26,6582794		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	69,242	-10	-692,42		0,2	0,2	m2	100	0,002	1517	3,034		60			10,884	753,629928		
					A1 - A3	-3353,272349	kgCO2eq						Total A4	631,6358449			Total B4	4,639214	Total C3+C4	3756,548515	Total all	1039,551226
			Area wall	69,242																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2eq]							
						1.	truck		742	18,00292	28	504,08176	0,185		69,1953032							
							summa								69,1953032							

4	**Final roof construction, Lysøysund**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	23,27	2,88	67,0176		0,25	0,25	m2	492	0,00050813	1632	0,829268293		30	1	67,0176	9,67402	450,2288908		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,4654	-672	-312,7488		2,37	1,102998	m3	85	0,027882353	1298	36,19129412		60			722,2	336,11188		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,065156	-607	-39,549692		11,4	0,7427784	m3	100	0,114	1520	173,28		60			667,3	43,4785988		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	23,27	0,335	7,79545		0,00705	0,00705	m2	100	0,0000705	1373	0,0967965		50	0,2	1,55909	0,225	6,2829		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,8394935	-607	-1116,572555		11,4	20,9702259	m3	100	0,114	1517	172,938		60			667,3	1227,494013		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,86465	-35,9	-246,440935				m3			1248	26,38469415	see calculation 1. below	60			39,2	269,09428		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	23,27	0,314	7,30678		0,00905	0,00905	m2	258	3,50775E-05	905	0,031745155		60			0,38500158	8,958986767		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	23,27	-10	-232,7		0,2	0,2	m2	100	0,002	1517	3,034		60			10,884	253,27068		
					A1 - A3	-1865,892152	kgCO2eq						Total A4	412,7857982			Total B4	68,57669	Total C3+C4	2594,920229	Total all	1210,390566
			Area roof	23,27																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	6,86465	28	192,2102	0,185		26,38469415							
							summa								26,38469415							

7	**Final ground slab, Lysøysund**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	24,5	-10	-245		0,2	0,2	m2	100	0,002	1517	3,034		60			10,884	266,658		
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,3675	-861	-316,4175		33,2	12,201	m3	250	0,1328	1361	180,7408		60			1079	396,5325		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	24,5	0,314	7,693		0,00905	0,00905	m2	258	3,50775E-05	905	0,031745155		60			0,38500158	9,43253871		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,628425	-607	-381,453975		11,4	7,164045	m3	100	0,114	1517	172,938		60			667,3	419,3480025		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,9825	-35,9	-250,67175				m3			1248	94,16722	see calculation 1. below	60			39,2	273,714		
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,147	-861	-126,567		33,2	4,8804	m3	250	0,1328	1361	180,7408		60			1079	158,613		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,539	-672	-362,208		2,37	1,27743	m3	85	0,027882353	1298	36,19129412		60			722,2	389,2658		
					A1 - A3	-1674,625225	kgCO2eq						Total A4	667,8438593			Total B4	0	Total C3+C4	1913,563841	Total all	906,7824755
			Area slab	24,5																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	24,5	28	686	0,185		94,16722							
							summa								94,16722							

3	**Final extended entrance, Lysøysund**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	0,46968	-738	-346,62384		12,72	5,9743296	m3	100	0,059743296	1675	100,0700208		60			802,0202	376,6928475		
Construction timber	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,12879	-607	-78,17553		11,4	1,468206	m3	100	0,01468206	1520	22,3167312		60			667,3	85,941567		
					A1 - A3	-424,79937	kgCO2eq						Total A4	122,386752			Total B4	0	Total C3+C4	462,6344145	Total all	160,2217965

6	**Loft slab Lysøysund**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Loft slab	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,74736	-567,3	-423,977328		34,54	25,8138144	m3	725	0,035605261	2586	92,07520557		60			701,91854	524,5858401		
					A1 - A3	-423,977328	kgCO2eq						Total A4	92,07520557			Total B4	0	Total C3+C4	524,5858401	Total all	192,6837176

8	**inner walls Lysøysund**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Inner walls	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2586	14,78407283		60			701,91854	84,2302248		
					A1 - A3	-68,076	kgCO2eq						Total A4	14,78407283			Total B4	0	Total C3+C4	84,2302248	Total all	30,93829763

5	Windows lysøysund				A1 - A3			A4							Notes		B4		C3+C4			
Windows	Nordvestvinduet Fastkarm vindu	NEPD-386-265-NO	m2	4,04	44,6	180,184		0,884615385	3,573846154	m2	300	0,011912821		1479	17,61906154	EPD adjusted to m2	60			10,884	43,97136		
					A1 - A3	180,184	kgCO2eq						Total A4		17,61906154			Total B4	0	Total C3+C4	43,97136	Total all	197,8030615
					per FU	0,120122667	kgCO2eq/m2/yr																

9	Entrance door lysøysund				A1 - A3			A4								Notes	B4			C3+C4			
Entrance door	NorDan NTech Balcony security door 105/80	NEPD00258E	1 door	1	207,96	207,96		19,97	19,97	1 door	1500	0,013313333		3100	41,27133333		60			39,2	39,2		
					A1 - A3	207,96	kgCO2eq						Total A4		41,27133333			Total B4	0	Total C3+C4	39,2	Total all	288,4313333

saltstraumen		Unit
Lifetime PV	**30**	year
Lifetime cabin	**60**	year
Heated floor area	**18,9**	m2
Pv area	**4,95**	m2
Electrical grid factor	**132**	gCO2eq/kWh
Biofuel emission factor	**3,6**	gCO2eq/kWh

Element		
External walls	936,2897	kgCO2eq for 60 years
Roof	1135,6852	kgCO2eq for 60 years
Ground slab	788,4319	kgCO2eq for 60 years
Extended entrance	138,7129	kgCO2eq for 60 years
Loft slab	182,3938	kgCO2eq for 60 years
Inner walls	29,2861	kgCO2eq for 60 years
Windows	194,3603	kgCO2eq for 60 years
Entrance door	284,5838	kgCO2eq for 60 years
Total	3689,7437	kgCO2eq for 60 years
	3,25	kgCO2eq/m2/year

PV modules (embodied emission) 2018-2048	230	kgCO2eq/m2
PV modules (embodied emission) 2048-2078	80,5	kgCO2eq/m2
PV embodied emission for 60 years	310,5	kgCO2eq/m2
PV embodied emission per year	5,175	kgCO2eq/m2/year

1536,975	kgCO2eq for 60 years	Total PV area
1,36	kgCO2eq/m2 per year	(per m2 heated floor)

Efficiency in 2018-2048	15,50	%
PV el.production per year (efficiency 15.5 %)	369	kWh/year
PV el.production per year and m2 of the house	19,52380952	kWh/year per m2
PV compensation	2577,142857	gCO2eq/m2/year
	2,577142857	kgCO2eq/m2/year
	-2,577142857	kgCO2eq/m2/year

Efficiency in 2048-2078 (will increase 36,2 % = 1,362)	21,11	%
1,362		
PV el.production per year (efficiency 21,11 %)	502,58	kWh/year
PV el.production per year and m2 of the house	26,59	kWh/year per m2
PV compensation	3510,07	gCO2eq/m2/year
	3,51	kgCO2eq/m2/year
	-3,51	kgCO2eq/m2/year

Efficiency 2018-2078	18,3055	%
PV el.production per year (efficiency 15,5 and 21,11 %)	435,789	kWh/year
PV el.production per year and m2 of the house	23,05761905	kWh/year per m2
PV compensation	3043,605714	gCO2eq/m2/year
	3,043605714	kgCO2eq/m2/year
	-3,04	kgCO2eq/m2/year
		per m2 cabin

Operational electrical energy for the building per year		
Electricity demand per m2year	35	kwh/m2year
Operational time for the building per year	4,62	kgCO2eq/kWh

Operational biofuel energy for the building per year		
Electricity demand per m2year	78,4	kwh/m2year
Operational time for the building per year	0,28224	kgCO2eq/kWh

Total operational energy for the building per year	4,90

	Worst case: Module 0% reused = 210 kgCO2/m2
from 2048-2078 emission will be reduced by 65 %	Base line: (mounting structure 8,4 kgCO2) + (transport ship and truck) = 20 kgCO2/m2
	Resultat: sum total 210+20=230 kgCO2/m2

Saltstraumen

1	**Final external walls construction for, saltstraumen**				**A1 - A3**							**A4**			Notes	B4			C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding.	NEPD-1476-494-NO	m3	1,315598	-738	-970,911324		12,72	16,73440656	m3	100	0,1272	1386	176,2992		60			802,0202	1055,136171		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,173105	-607	-105,074735		11,4	1,973397	m3	100	0,114	1231	140,334		60			667,3	115,5129665		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	69,242	0,335	23,19607		0,00705	0,00705	m2	100	0,0000705	1081	0,0762105		50	0,2	4,639214	0,225	18,69534		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,6202628	-607	-983,4995196		11,4	18,47099592	m3	100	0,114	1228	139,992		60			667,3	1081,201366		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	18,00292	-35,9	-646,304828				m3			959	69,1953032	see calculation 1. below	60			39,2	705,714464		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	69,242	0,314	21,741988		0,00905	0,00905	m2	258	3,50775E-05	616	0,021607752		60			0,38500158	26,6582794		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	69,242	-10	-692,42		0,2	0,2	m2	100	0,002	1228	2,456		60			10,884	753,629928		
					A1 - A3	-3353,272349	kgCO2eq						Total A4	528,3743214			Total B4	4,639214	Total C3+C4	3756,548515	Total all	936,2897023
			Area wall	69,242																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2eq]							
						1.	truck		742	18,00292	28	504,08176	0,185		69,1953032							
							summa								69,1953032							

4	**Final roof construction, Saltstraumen**				**A1 - A3**							**A4**			Notes	B4			C3+C4			
Bitumen	Isola Mestertekk, roof membrand	00186N	m2	23,27	2,88	67,0176		0,25	0,25	m2	492	0,00050813	1343	0,682418699		30	1	67,0176	9,67402	450,2288908		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,4654	-672	-312,7488		2,37	1,102998	m3	85	0,027882353	1009	28,13329412		60			722,2	336,11188		
Nailing battens	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,065156	-607	-39,549692		11,4	0,7427784	m3	100	0,114	1231	140,334		60			667,3	43,4785988		
Wind barrier	Isola Soft Xtra, Wind Barrier	NEPD-1472-492-EN	m2	23,27	0,335	7,79545		0,00705	0,00705	m2	100	0,0000705	1084	0,076422		50	0,2	1,55909	0,225	6,2829		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	1,8394935	-607	-1116,572555		11,4	20,9702259	m3	100	0,114	1228	139,992		60			667,3	1227,494013		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,86465	-35,9	-246,440935				m3			959	26,38469415	see calculation 1. below	60			39,2	269,09428		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	23,27	0,314	7,30678		0,00905	0,00905	m2	258	3,50775E-05	616	0,021607752		60			0,38500158	8,958986767		
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	23,27	-10	-232,7		0,2	0,2	m2	100	0,002	1228	2,456		60			10,884	253,27068		
					A1 - A3	-1865,892152	kgCO2eq						Total A4	338,0804367			Total B4	68,57669	Total C3+C4	2594,920229	Total all	1135,685204
			Area roof	23,27																		
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	6,86465	28	192,2102	0,185		26,38469415							
							summa								26,38469415							

7	**Final ground slab, Saltstraumen**				**A1 - A3**							**A4**			Notes	B4			C3+C4			
Wood panel	Moelven Wood AS: Indoor wood panel	NEPD309-180-NO	m2	24,5	-10	-245		0,2	0,2	m2	100	0,002	1228	2,456		60			10,884	266,658		
Under floor	Forestia AS: Sponplater	NEDP00274N	m3	0,3675	-861	-316,4175		33,2	12,201	m3	250	0,1328	1072	142,3616		60			1079	396,5325		
Vapor Barrier	Tommen Gram Folie AS: Vapor barrier	NEPD-341-230-NO	m2	24,5	0,314	7,693		0,00905	0,00905	m2	258	3,50775E-05	616	0,021607752		60			0,38500158	9,43253871		
Construction wood	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,628425	-607	-381,453975		11,4	7,164045	m3	100	0,114	1228	139,992		60			667,3	419,3480025		
Insulation	Cellulose insulation, nominell densitet 32 kg/m3	EPD-ISOCELL-2014-1-Ecoinvent	m3	6,9825	-35,9	-250,67175				m3			959	94,16722	see calculation 1. below	60			39,2	273,714		
Wind barrier	Forestia AS: Sponplater, K-board	NEDP00274N	m3	0,147	-861	-126,567		33,2	4,8804	m3	250	0,1328	1072	142,3616		60			1079	158,613		
Wood under roof	Moelven Wood AS: Skurlast av gran eller furu	NEPD-307-179-NO	m3	0,539	-672	-362,208		2,37	1,27743	m3	85	0,027882353	1009	28,13329412		60			722,2	389,2658		
					A1 - A3	-1674,625225	kgCO2eq						Total A4	549,4933219			Total B4	0	Total C3+C4	1913,563841	Total all	788,4319381
				Area slab	24,5																	
							for ukjente verier															
							mode		distance [km]	m3	kg/m3	weight [kg]	emission factor [kgCO2e/(t*km)]		resultat [kgCO2e]							
						1.	truck		742	24,5	28	686	0,185		94,16722							
							summa								94,16722							

3	**Final extended entrance, for the whole construction, Saltstaumen**				**A1 - A3**							**A4**			Notes	B4			C3+C4			
Wood cladding	Moelven Wood AS: Malm100, cladding	NEPD-1476-494-NO	m3	0,46968	-738	-346,62384		12,72	5,9743296	m3	100	0,059743296	1386	82,80420826		60			802,0202	376,6928475		
Construction timber	Moelven Wood AS: Konstruksjonsvirke av gran og furu	NEPD-308-179-NO	m3	0,12879	-607	-78,17553		11,4	1,468206	m3	100	0,01468206	1231	18,07361586		60			667,3	85,941567		
					A1 - A3	-424,79937	kgCO2eq						Total A4	100,8778241			Total B4	0	Total C3+C4	462,6344145	Total all	138,7128687

6	**Loft slab saltstraumen**				**A1 - A3**							**A4**			Notes	B4			C3+C4			
Loft slab	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,74736	-567,3	-423,977328		34,54	25,8138144	m3	725	0,035605261	2297	81,78528507		60			701,91854	524,5858401		
					A1 - A3	-423,977328	kgCO2eq						Total A4	81,78528507			Total B4	0	Total C3+C4	524,5858401	Total all	182,3937971

8	**inner walls saltstraumen**				**A1 - A3**							**A4**			Notes	B4			C3+C4			
Inner walls	Moelven Wood AS: Cross laminated timber panels	NEPD-1269-410-EN	m3	0,12	-567,3	-68,076		34,54	4,1448	m3	725	0,005716966	2297	13,13186979		60			701,91854	84,2302248		
					A1 - A3	-68,076	kgCO2eq						Total A4	13,13186979			Total B4	0	Total C3+C4	84,2302248	Total all	29,28609459

5	**windows saltstraumen**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Windows	Nordvestvinduet Fastkarm vindu	NEPD-386-265-NO	m2	4,04	44,6	180,184		0,884615385	3,573846154	m2	300	0,011912821	1190	14,17625641	EPD adjusted to m2	60			10,884	43,97136		
					A1 - A3	180,184	kgCO2eq						Total A4	14,17625641			Total B4	0	Total C3+C4	43,97136	Total all	194,3602564
					per FU	0,120122667	kgCO2eq/m2/yr															

9	**entrance door saltstraumen**				**A1 - A3**			**A4**							Notes		B4		C3+C4			
Entrance door	NorDan NTech Balcony security door 105/80	NEPD00258E	1 door	1	207,96	207,96		19,97	19,97	1 door	1500	0,013313333	2811	37,42378		60			39,2	39,2		
					A1 - A3	207,96	kgCO2eq						Total A4	37,42378			Total B4	0	Total C3+C4	39,2	Total all	284,58378