AAR4546- Design of Zero Emission Buildings

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Campus Kalvskinnet

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REPORT

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INTRODUCTION

Trondheim is characterized by a vibrant student life, serving as a home to several colleges.

The Campus Kalvskinnet project focuses on the interface between the community and the various campuses in the area. One of the main goals of this project is to simulatneously create an exhibition space for students to display their work and also provide community members an oppurtunity to engage with the forefront of academic research and creativity.

The Campus Kalvskinnet project also seeks to not only foster creativity, but sustainability as well. Energy concepts and embodied emission calculations were done in order to improve the building’s performance. Photovoltaic panels were also implemented to produce electricity and improve the building’s energy balance.

THE SITE AT A GLANCE

1. STUDENTER SAMFUNDET
2. NIDAROS CATHEDRAL
3.TORGET
4. TRONDHEIM TEATER
5. HiST
6. NTNU LIBRARY
7. TRONDHEIM SPEKTRUM

CLIMATE

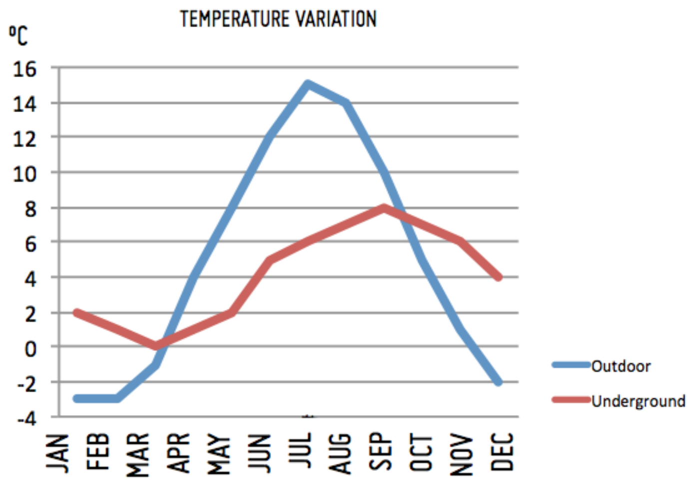
The climate in Trondheim is a combination of a hemiboreal oceanic climate and a humid continental and subarctic climate.

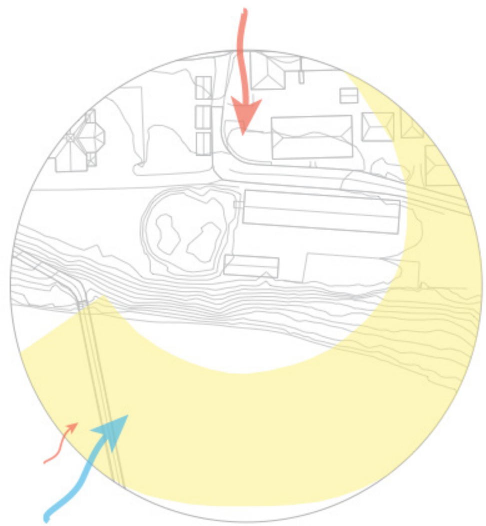
The weather is greatly influenced by its location on the border of the "westerly wind belt" in the northern hemisphere. The climate zone is temperate, but is in close proximity to the polar circle.

The site's unique location leads to cold, polar air from the north and warm masses of air from the south. This creates a very unstable climate, where it is possible to experience a wide range of weather types in a single day. The varying weather also leads to unpredictable seasonal behaviour. For example, one winter may experience heavy snowfall that does not melt until May, while the next winter may have very little snow.

The mean temperature in summer is 13,7°C. If it's a sunny day the temperature is usually around 23°C. On a rainy overcast day, the temperatures might be as low as 8°C. Winters are cold and windy in Trondheim, with the lowest measured temperature being -26,1°C. The average yearly precipitation is 895mm.

The optimal orientation for the project has been obtained with the help of Autodesk Ecotect Software and the weather file proportioned by the university.





SITE SPECIFICATIONS

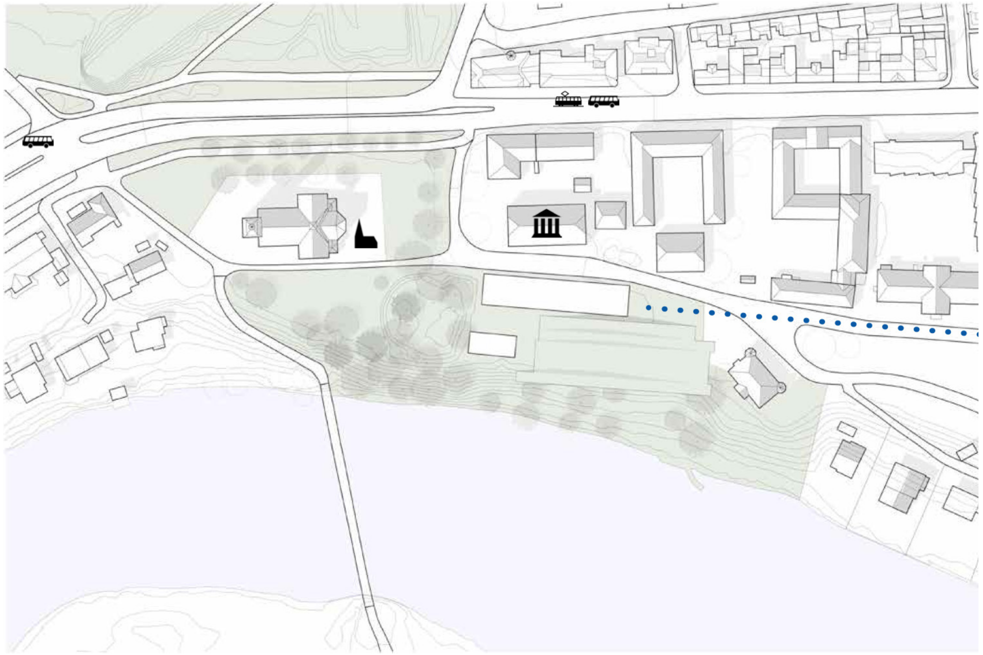
Microclimate

The entire site is on a south facing slope, which is the optimal orientation for receiving the maximum amount of sunlight. Additionally, the neighbouring buildings are situated to the north, so their shadows will not affect the amount of light the site receives. This area has a rich birdlife due the close proximity to the river and the presence of trees in the area. The southern border is drawn by the river, causing a cold draft. In the summer, the wind is primarily from the north, while in the winter, the prevailing winds come from the south east.

Accessibility

The site is near several transportation hubs due to its close proximity to the city center. To the north, there is a bus stop that is frequented by many different lines, making the site readily accessible to those who wish to visit. Additionally, there is a tram stop which connects the city to Byåsen. The site is also located near the train station, which is convenient for visitors who come to Trondheim by train.

To the south of the site, across the river, is the Trondheim Spektrum. This provides a large parking lot for those who wish to drive to the site. There is a pedestrian bridge that connects the Trondheim Spektrum to Campus Kalvskinnet, creating easy access for those who park at the Spektrum.



Existing Buildings

Kalvskinnet is an area in the western part of the Trondheim city center. Most of the buildings in the area are wooden houses from ca 1800-1900, so many of them are protected. The buildings on the site and part of the outdoor area are protected to ensure that their architectural and cultural value is not lost. On the site for campus Kalvskinnet, there are two existing buildings: Erling Skakkes gate 57 and 59.

Erling Skakkes Gate 57, “The lonely prison” Erlings Skakkes Gate 57 is one out of two protected buildings on the site of Campus Kalvskinnet. This building was built in 1857 and used as a prison. It was later used by the military, and is today used as work spaces for students in the military. The building has two stories and a loft and the main building material is brick. The building interior and exterior are protected.

It is uncertain when Erlings Skakkes Gate 59 was built, but according to older documents, it is built before 1826. The building was used as a storage for the military. The building has a timber structure and has two stories. All windows and doors on the first floor has shutters.

Program

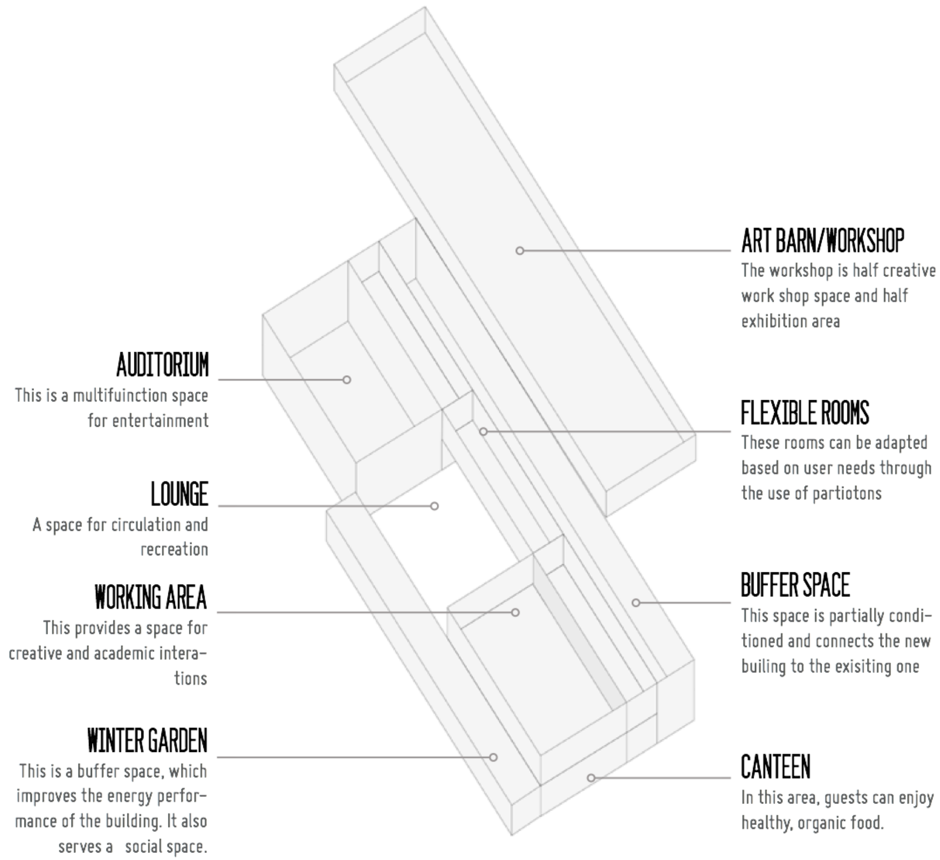
The creation of a space for both community members and academics called for a diverse and complex program. An exhibition space was necessary, that would showcase various projects from different disciplines.

Additionally, a space was needed that could be used for both lectures and performances, further inviting the community to get involved with university life. A hostel for turists and visitng scholars would also be added to create a dynamic atmosphere, even after the standard 9-5 day. Several creative rooms were also added to the program, giving students and community members alike, a space to solidify and explore their ideas.

In order to reduce the energy demand of the building, the size of the project needed to be reduced. The proposed design was able to achieve this by utilizing the existing buildings, and therefore limiting the amount of new infrastructure.

Erlings Skakkes Gate 59 will be used as an exhibition space, while Erling Skakkes gate 57 will be converted to a hostel for visiting researchers and tourists.

By utilizing these spaces, 960 m^2 of new construction is saved. The newly proposed building will consist of only 2404m^2, leading to decreased heating and cooling demand, as well as reduced embodied emissions.

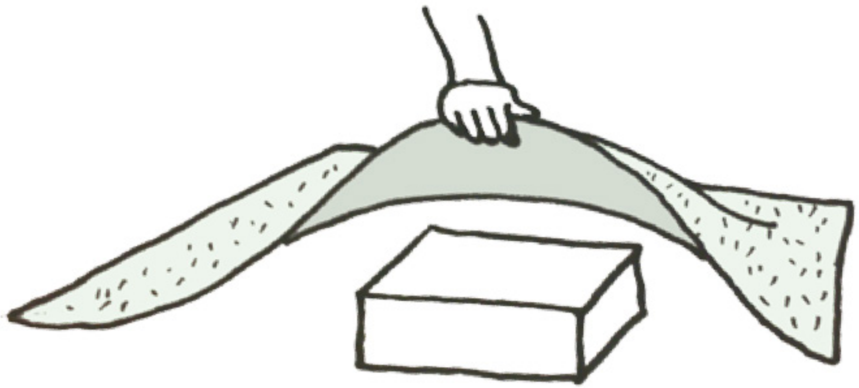


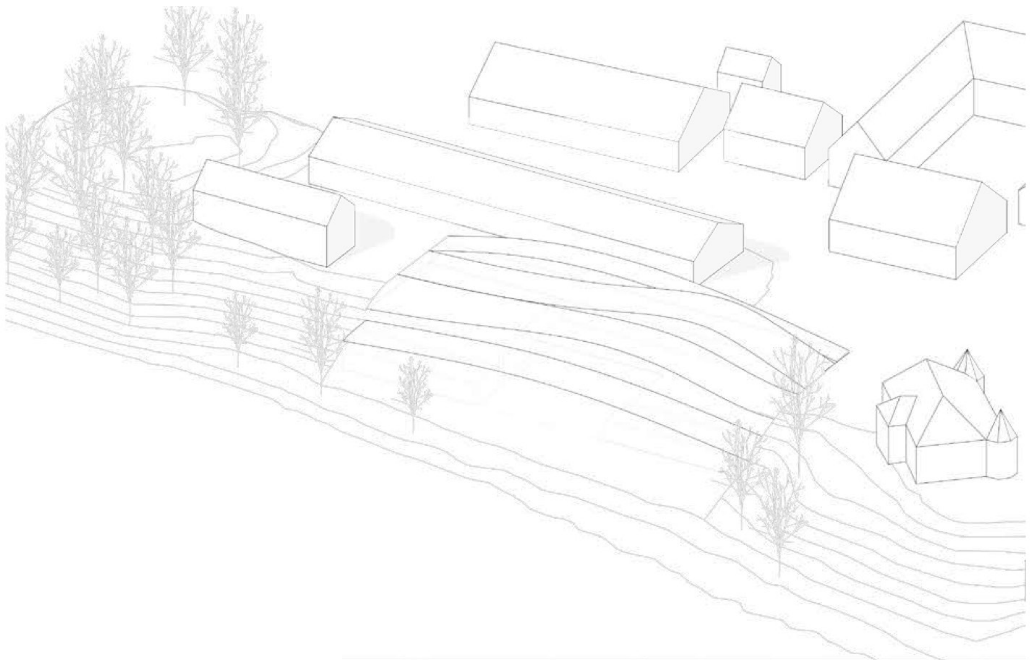
THE IDEA

The main idea of the project seeks to preserve the identity of the site introducing an element with a big program. From the very beggining we decided that we did not want to create a 'lighthouse' flaghship project.

Our final idea was to create a project that shaped the terrain, so a small portion of our project was directly visible from the outside. We had a very strong reason for doing this: the temperature underground is constant all over the year, and this is a very important fact when considering the climate of Trondheim. Besides, we could implement a green roof solution, that apart from create a great space for summer with lawn and helping the integration in the site, it enhaced the energetic performance of the building.

This was checked with a shoebox model of the auditorium, when evaluating the resource consumption above and below ground.



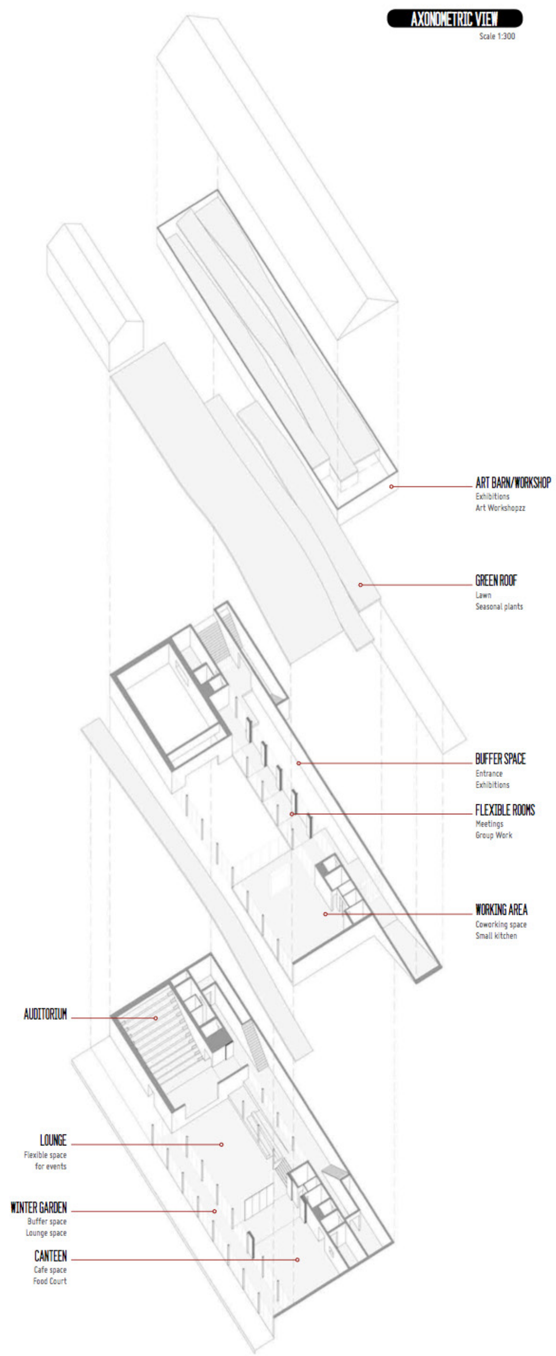



INTEGRATION IN LANDSCAPE

The program has been distributed in two storeys; a ground floor with all the public spaces, with a big central lounge, and a first floor, more private, with the working spaces.

The purpose of the central lounge is to provide a space where things can happen. It is amazing to observe how students improvise performances, concerts, how companies create stands to provide information for students and how researchers show they work in the Norwegian University of Science and Technology. Everyday things happen at all the faculties, so we thought in creating a big space where events like this can take place.

The flexibility of this space is incredible. Canteen can be opened, so catering can be served and extended to lounge if necessary. Auditorium backstage can be also opened, and more informal concerts can be held in the lounge space.



TRANSVERSAL SECTION

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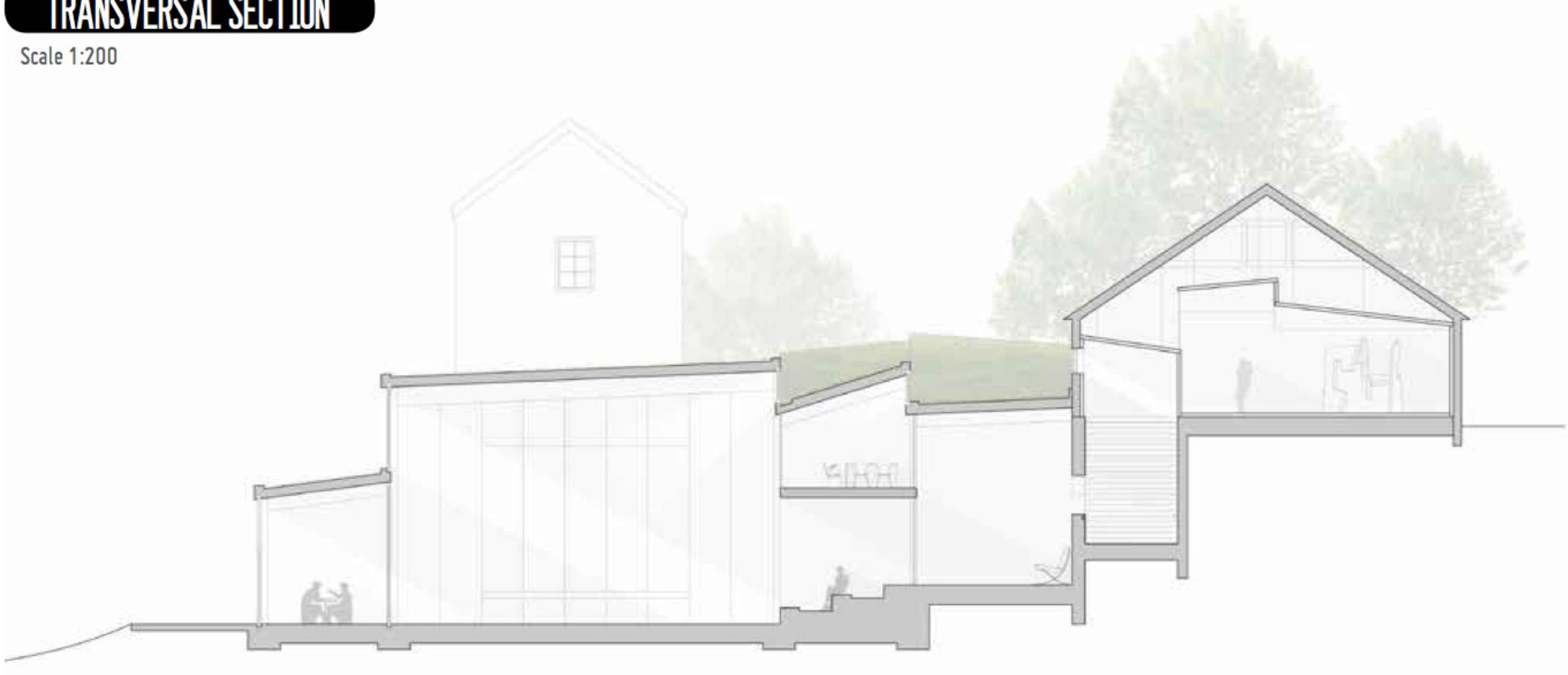


ENERGY CONCEPT

Passive strategies

– Thermal mass

Big south oriented windows in the lounge may cause overheating in the summer. To reduce the overheating exposed thermal mass in the floor of the lounge will function as a heat sink by absorbing some of the heat during the day and releasing the heat in the evening when the sun is in the west.

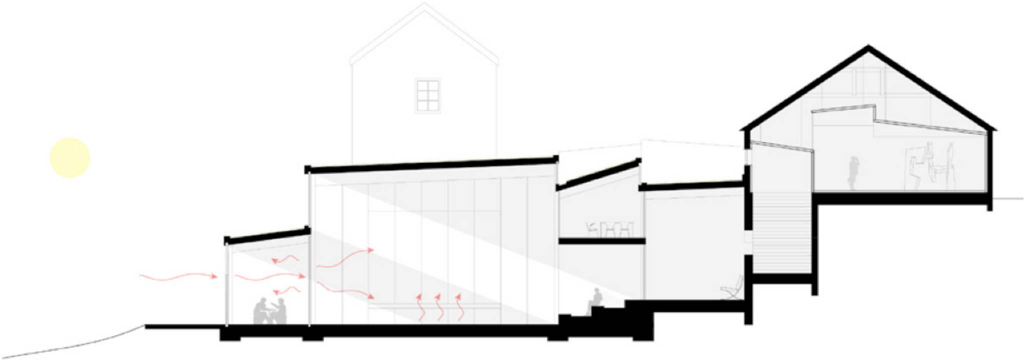
– Half climatised zones

Originally two this project had two buffer spaces; one on the north between the existing building and the new building and the winter garden on the south. The buffer space on the north is necessary to connect the buildings and still function as a buffer space that would improve the thermal performance of the new building. It was pointed out that the opposite effect could accure in the winter. When the buffer space were cold in the coldest part of the winter this buffer space would be an undesired heat sink, especially since the wall between the buffer space and the lounge is glassed. To prevent this from happening the temperature of the buffer space where set to 18 degrees.

– Buffer spaces

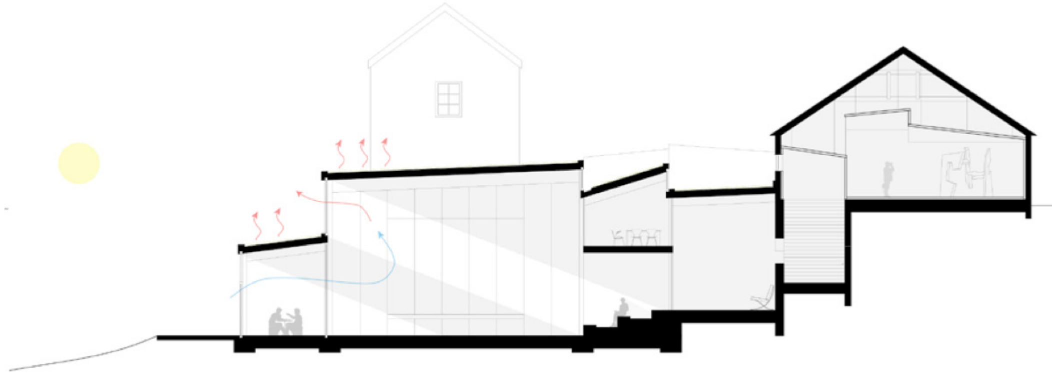
As mentioned Trondheim is known for a shifting climate. The buffer space on the south creates a pleasant space to be in as well as contributing to the energy performance of the canteen and the lounge. A buffer space also allows more glassed areas since the buffer space will reduce heat loss to the outside through windows as well as walls. As shown in the sections under the buffer space affect the indoor climate differently during the year.

FALL



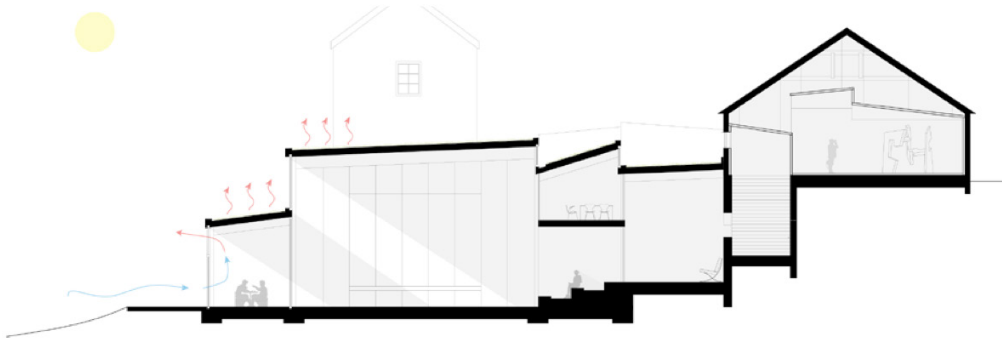
In spring and fall on cold sunny days the air inside the buffer space can be preheated due to the greenhouse effect. When the air is warm it can be let in to the lounge or the canteen.

SPRING



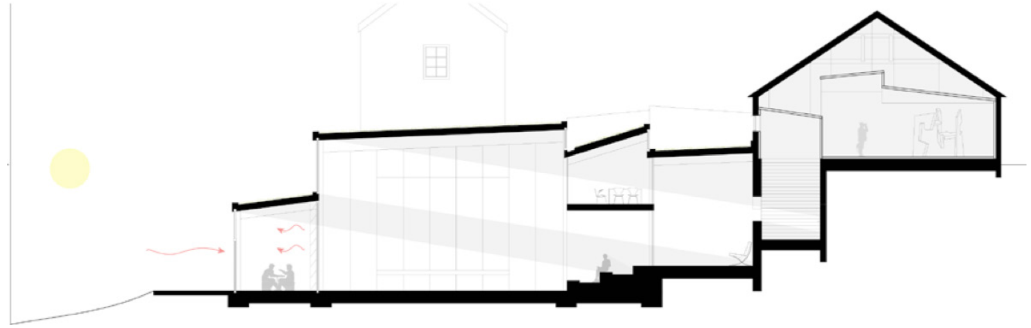
In late spring and early fall the weather is warmer and the vent and doors in the buffer space can be opened up for natural ventilation.

SUMMER



In summer the overhang provides some shade and additional interior shutters can regulate the amount of sunlight let in to the building. The vents and doors can also in this season be open to provide natural ventilation.

WINTER



In winter, interior insulation shutters will be used in the buffer space, prevent great heat loss.

Half climatised zones

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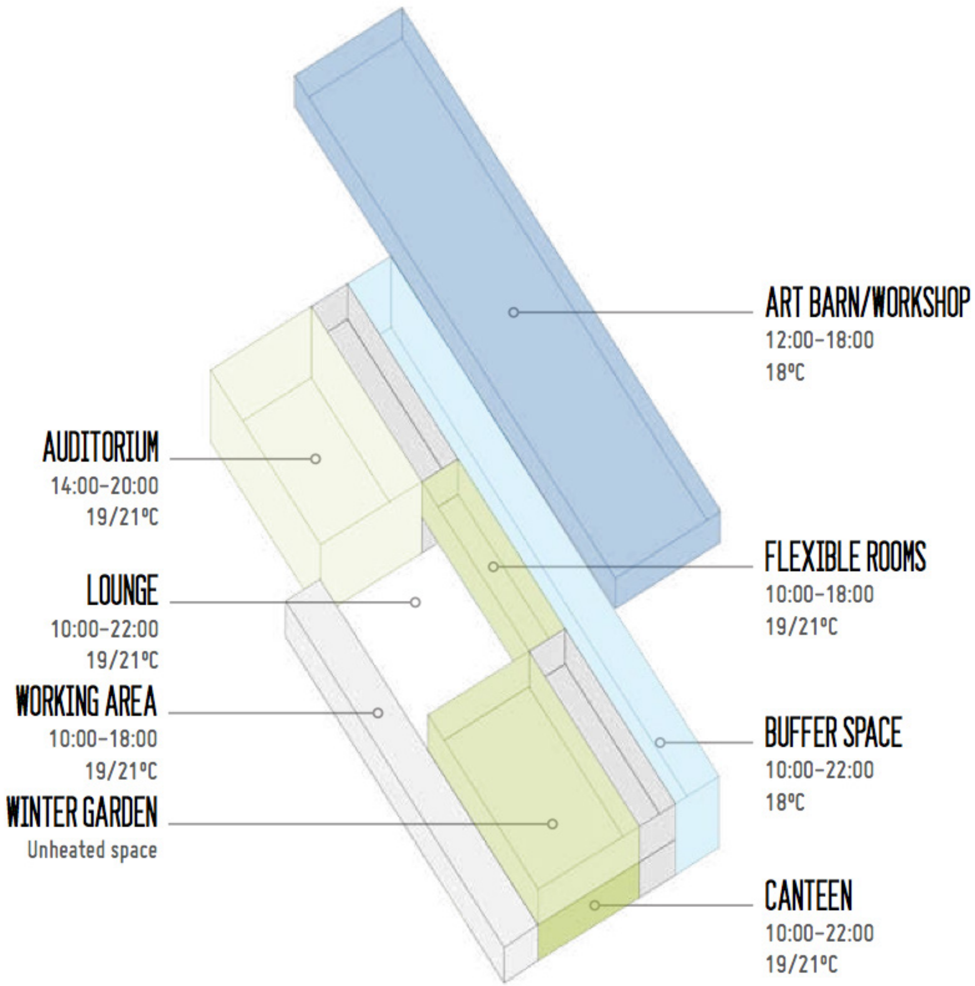
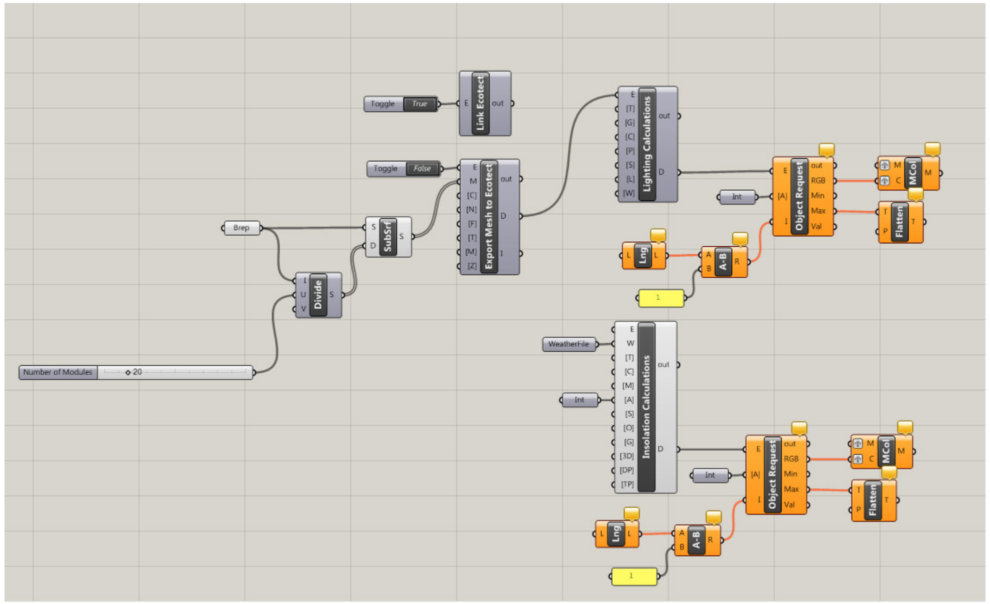


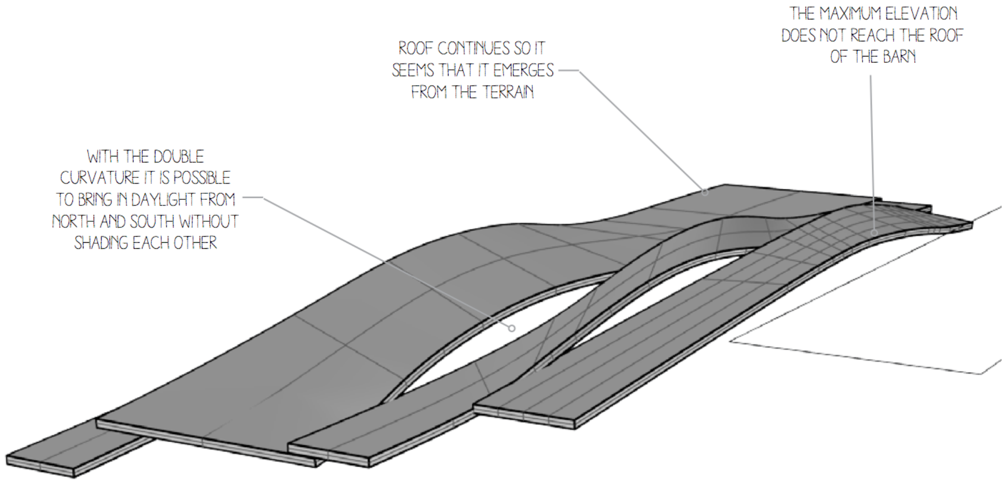
DAYLIGHT

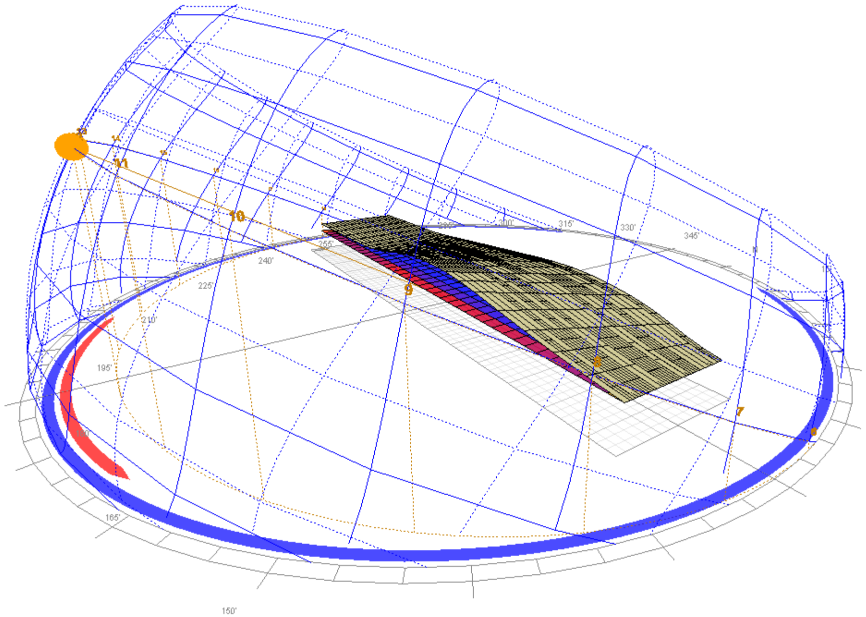
Daylight is introduced into the building through clerestories created by the curvature of the roof. The roof has been highly optimised with the help of Grasshopper pulg in for parametric design in Rhinoceros. The geometry has been linked to Ecotect and DIVA to evaluate the performance of the diferent options.

Firstly we tried implementing Galapagos evolutionary solver to achieve the best solution; once we found the form that was working the best, we mofied manually the parameters that generate the curves so we could also take into account other architectural parameters, as the final height of the ceiling, the use of the rooms, etc.

The final solution is generated by two curves displazed so the clerestories generated do not shade nor cover each other.







MATERIALS

Concrete

Since the building is subterranean there are retaining walls holding back the massive earth pressure. After checking with the producer of the low emissive product ytong, we learned that retaining walls have to be made out of reinforced concrete. The floor on the ground is also reinforced concrete. Additional materials used for the concrete walls and floors are drainage plate for removing water away from the construction, radon membrane to prevent radon gas to enter the building and XPS insulation.

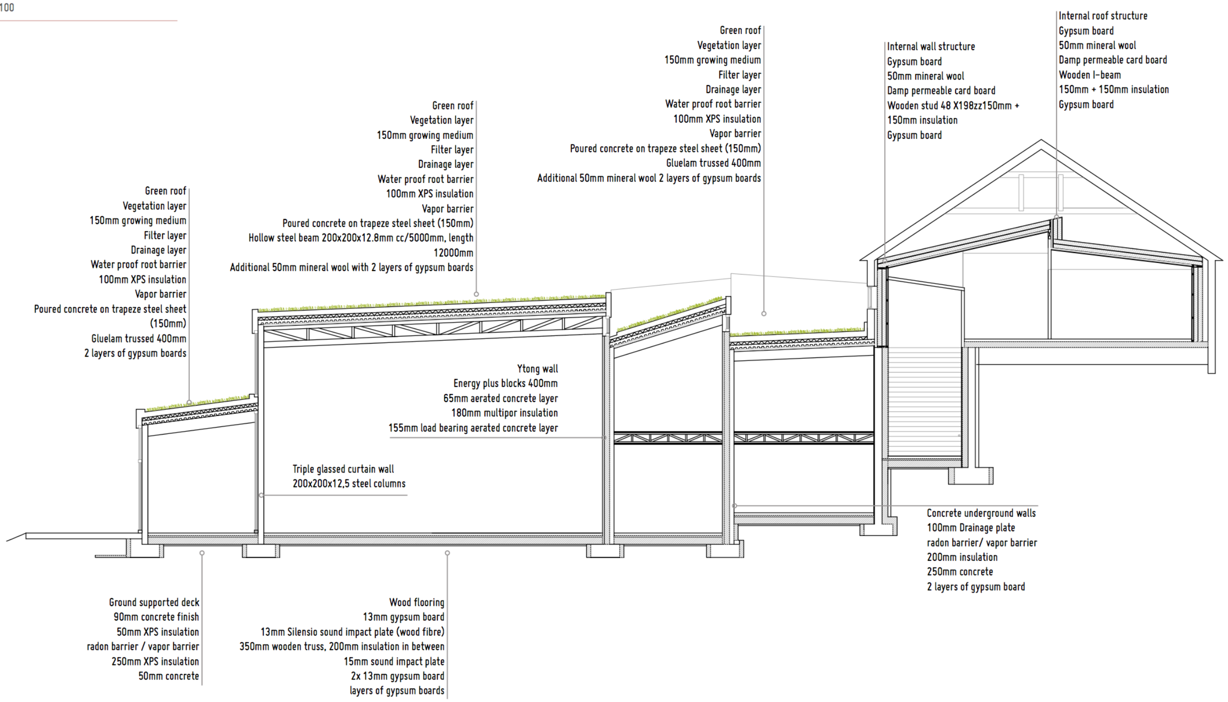
Mineralwool

Mineral wool is the most common material used for insulation in Norway. There are producers of glass wool near Trondheim, which makes their product out of recycled glass. Since this material is affordable, locally available and has good thermal performance.

Ytong

For the interior walls that are not glassed we used ytong. Ytong has necessary acoustic, fire, insulating and load bearing capacity for the zones. The material is also less emissive than concrete.

CONSTRUCTIVE SECTION
Scale 1:100



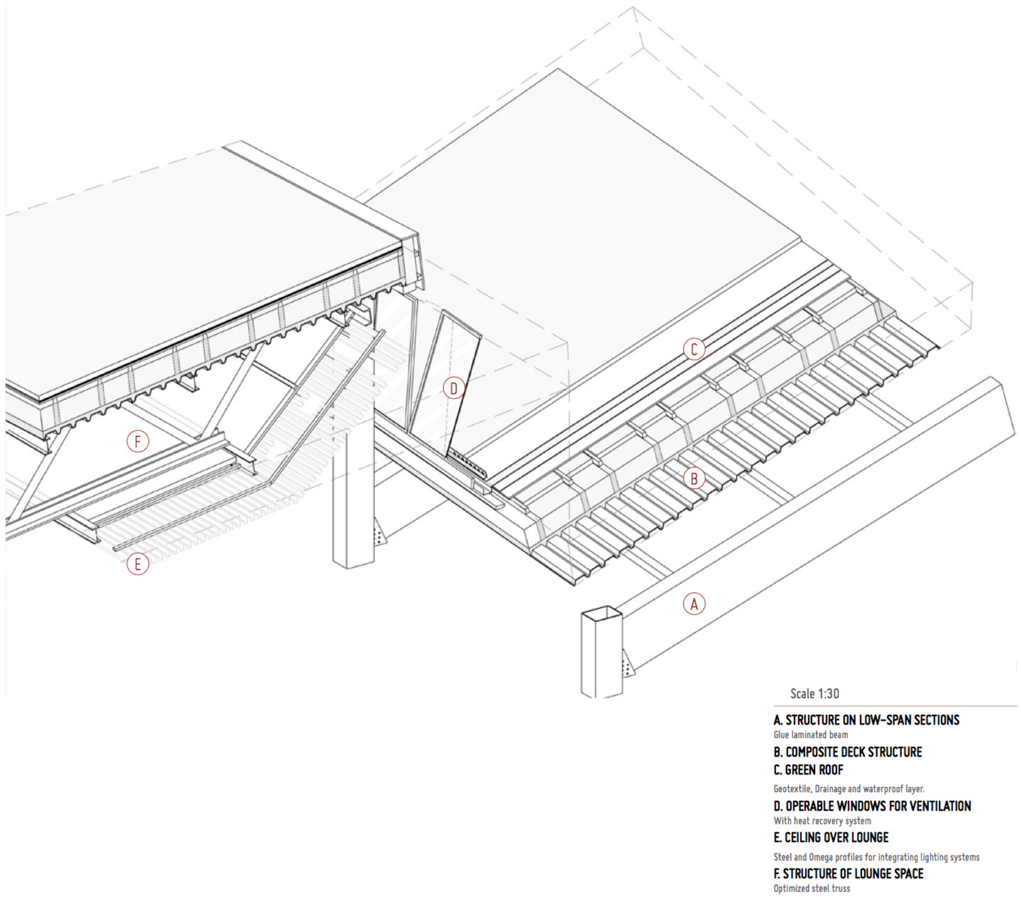
Structural elements in the roof

Where the spans are 4 meters we decided to use glulam beam since this is less emissive than concrete and steel. For the span of 12 meters we designed a steel truss using the software focus. Both of the glulam and the steel truss have 5 meter spacing.

Materials related to refurbishing the artillery building

After speaking to an expert in the field, we learned that one should always try to add elements to an existing building, rather than removing elements.

The protected facade will be preserved, and will function as the load bearing structure for the stresses for the weather such as wind, snow and rain. The freestanding interior structure, has load bearing elements to carry its own weight but not the stresses from the outside. This way the interior structure is not over dimensioned, and used unnecessary amounts of materials. The existing structure is not airtight so the gap between the old and the new structure is very well ventilated. This makes it natural to not add a plastic vapor barrier that would make the existing building airtight. Instead a vapor permeable cardboard is used, making also the new construction breathable.



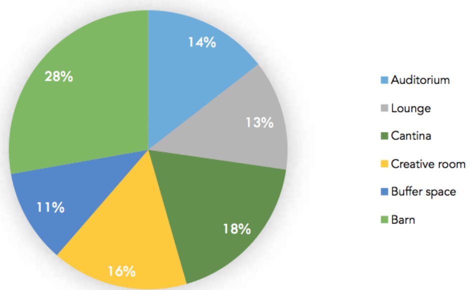
SIMIEN

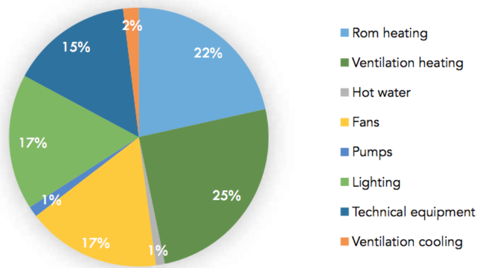
In order to achieve a ZEB level building, it was crucial to lower the energy demand as much as possible. Accordingly, we aimed to achieve passive house standards for non-residential buildings in our design. In the start of the project we worked with each zone of the project in separate files, so that we could see the specific resource consumption for each zone.

To minimize the resource consumption we set different operation hours for the different zones. The auditorium will host afternoon lectures, concerts and presentations so the operation hour for this zone was set fra 2 pm to 8 pm. The canteen and lounge will be open from 10 am to 10 pm since this is the public areas, open for everyone. The zones can be extended and closed of as explained under the plan.

This way the user of the building can operate the building in relations to the current need. This will impact the energy consumption as well. If the users operate the building carefully, heating only the zones that are used that day the buildings would naturally use less energy. However the user behavior can not be predicted in SIMIEN, so if this building were to be built in real life it would be of great importance that the users of the building are taught how to use the building.

TOTAL RESOURCE CONSUMPTION
51 kWh/m2/yr





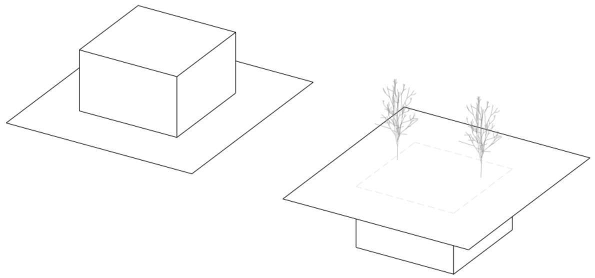
Zone	Auditorium		Lounge		Cantina		Creative room		Buffer space		Barn	
Area (m²)	312		312		322		450		288		720	
	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²
Rom heating	5887	18,9	5132	16,4	2452	7,6	4075	9,1	443	1,5	8420,0	11,7
Ventilation heating	3779	12,1	2675	8,6	3598	11,2	3865	8,6	6928	24,1	10145,0	14,1
Hot water	0	0,0	0	0,0	1360	4,2	0	0,0	0	0,0	0,0	0,0
Fans	2128	6,8	3374	10,8	2805	8,7	4300	9,6	2498	8,7	5356,0	7,4
Pumps	175	0,6	252	0,8	193	0,6	373	0,8	176	0,6	448,0	0,6
Lighting	1098	3,5	3844	12,3	3967	12,3	6336	14,1	3041	10,6	2534,0	3,5
Technical equipment	4530	14,5	0	0,0	7792	24,2	0	0,0	0	0,0	6336,0	8,8
Room cooling	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	0,0	0,0
Ventilation cooling	205	0,7	382	1,2	264	0,8	463	1,0	227	0,8	841,0	1,2
Total	17802	57,1	15659,0	50,2	22431,0	69,7	19412,0	43,1	13313,0	46,2	34080,0	47,3

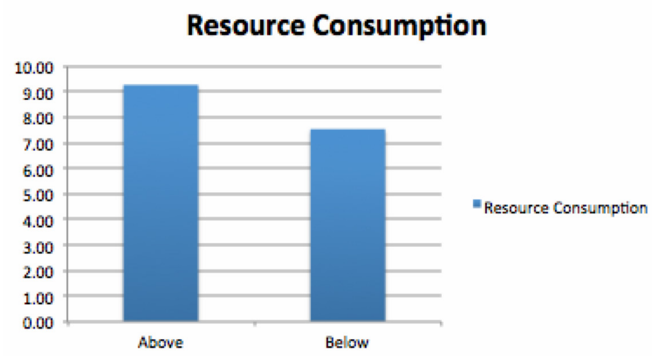
We also used SIMIEN to control that our decisions regarding the design responded with the architectural qualities as well as the resource consumption.

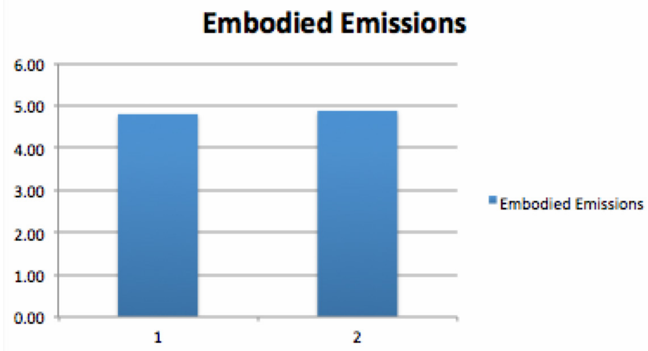
Two SIMIEN models of the auditorium were made, one above ground and one under ground. The model of the auditorium above ground has no buffer space, but to improve the energy performance of the building insulation were added.The model with the auditorium below the ground, has a 5m buffer space to the north.

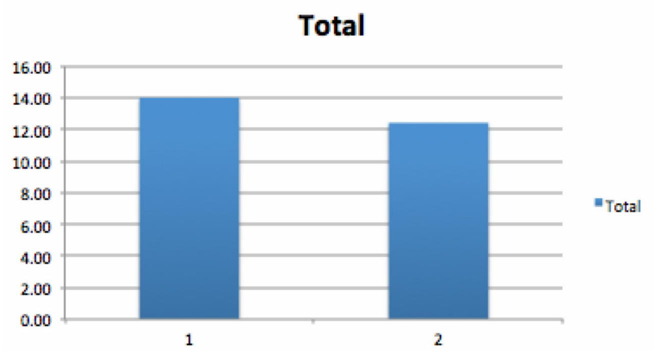
After running simulation from the resource consumption from both alternatives it was clear that the building under ground performed better than the building above ground. However, building above ground allows the use of wood instead of concrete. Since wood is less emissive than concrete, we wanted to compare the embodied emission together with the emissions from the energy consumption to see if the building above ground would have a lower emission than the building below ground.

As shown in graph we can see that in a 60 years perspective the total emissions from the building belove ground were lower than the building above ground. These simulations support the decision to include subterranean structures in our design. The insulation from the earth and buffer space had a significant impact on the energy consumption of the building.









HVAC CONCEPTS

Zoning (temperature)

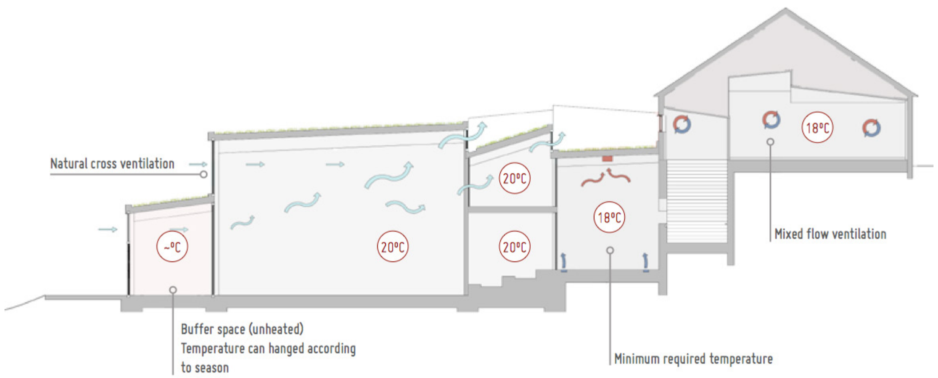
Thermal comfort expresses satisfaction of occupants with the environment in the building. Maintaining this standard of thermal comfort is main goal of HVAC, but also well planned building's design and its strategies.

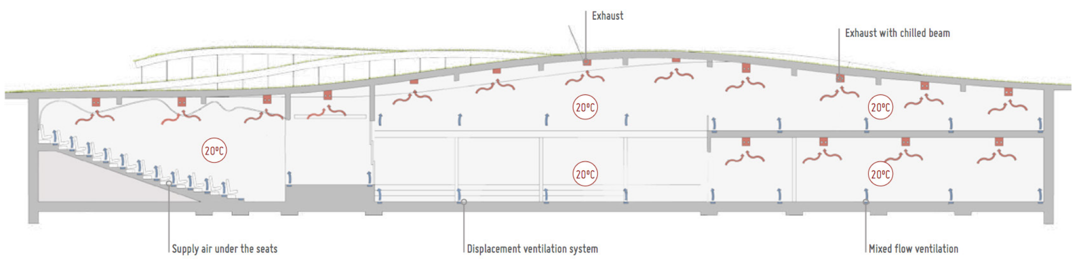
One of the strategy is temperature zoning, which defines temperature according to the function and possibilities of the area. If we look at the longitudinal section in the building there is 20 degrees, because all these areas are in the one cut and are used for longer occupation for studying, seating or eating.

The cross section presents zone's division. The first part is buffer space, which is not heated and the climate depends on the season. Then we have the part of the building, which is shown on the longitudinal section with 20 degrees.

Between actual building and the existing building there is connecting part which includes 2 entrances to the building and the underground connection to the barn.

This '' entrance path'' and the barn consist of the same temperature, which is 18 degree and both are heated. The thing what distinguish them one from another is they have to different ventilation systems that are described below.





Main ventilation system in the building:

– Displacement ventilation is efficient and popular nowadays ventilation system. It supplies the room with fresh air with low velocities, which causes minimum induction and mixing. The outlets are located near or in the floor depending on the needs of the room.This kind of ventilation use buoyancy forces, what means that the cold air from the floor going up getting heat from people, lighting, electrical equipments; and extracts it by the exhaust in the ceiling. Because this type of the system is designed with purpose of not mixing fresh and used air, it means the height of the room should be at least 3 meters.

– In the auditorium there can be found bleachers and expectedly bigger amount of people in the same time. Moreover, it has to be avoided that the people sitting at the highest row they could have warmer conditions the the first row. That is why displacement outlets are placed on the each row to fulfil thermal comfort for everybody.

– Additionally, the displacement system could cause very high temperature on the top of the room and gives troubles to go through exhaust all at once. That is why it is suggested to use passive cooling device, which are chilled beams. They are constructed together with exhaust and work with chilled water pipes in the hanging beam. The water cools down the air.

– Natural ventilation: In the summer there is possibility to use natural ventilation which comes from the west- south through the glazed facade. It can appear only in the lounge area, because we can achieve stack effect with the height. The openings, which were created from the differences of roof heights, can take the air out of the building.

– Mixedflowventilation(ventilatingexistingbuilding) This system is the strategy for the ventilating existing building. It is chosen due to the information that the existing building is listed and the existing structure should not be reconstructed much. So we cannot use the floor for displacement ventilation. We also do not need to achieve 20 degrees, but 18. New internal construction will be ventilated by traditional mixed flow ventilation in the ceiling.

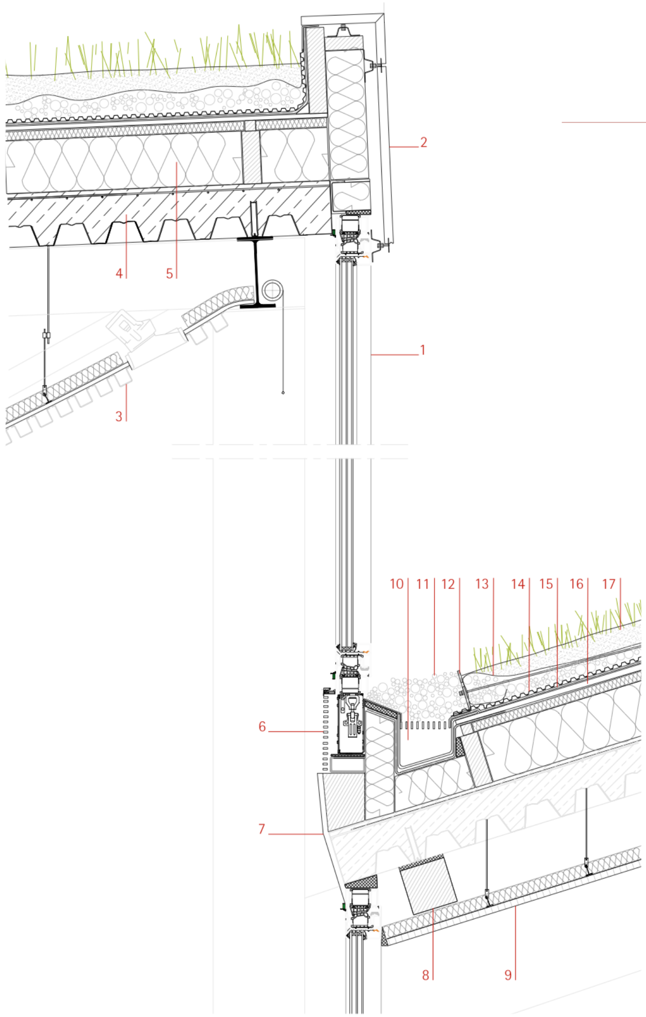
Green roof aspects

Green roof has an influence on the temperature in the buildings and plays really important role in this case. The membrane, which is placed under the green roof, will reach some temperatures depending on the weather and amount of water held in the soil. This temperature can balance the building heat flow by thermal mass, insulation, shading, evapotranspiration and protects against UV waves, frost and sunlight.

The roof can provide thermal performance by:

Cooling - During summer the roof underneath can be overheated because of wrong protection and lack of insulation of the roof. But the green roof can solve this problem by reduction of the solar energy directed into roof membrane by cooling it. It relies on connection of two processes made by plants – evapotranspiration and photosynthesis, and soil – evapo-transmission. It can reduce a need for air-conditioning.

Thermal insulation - During winter the heat loss increases through the roof but the green roof can act as a thermal barrier and have a positive effect on it. The green roof creates insulation by activity of plants, air layers and soil but the result of amount of heating depends on how much water is kept in the system.



ROOF DETAIL TYPE

Scale 1:10

1. OPERABLE WINDOW
Type Sky-Frame 3, Triple-glazed laminated with high penetration resistance film IG, 54mm insulated glass. Hidden frame.
Ug=0.7 W/m2K > Uw=1.0 W/m2K

2. FAÇADE CLADDING

3. CEILING

4.COMPOSITE DECK
Galvanised composite floor system.
Galvanised steel S280, 1,2mm thickness, quality Z-275. Maximum beam span of 4 meters. Concrete slab HA35/B/20/IIa (35N/mm^2) thickness 14cm and minimum of 5 cm, agregate of 20mm maximum to reduce retraction. Max. relation water/cement of 0.55. Minimum content of cement 235 kg/m^3. Not reinforced to negative tension for fire protection. Insulation to aerial noises >70dBA, to impact noises <30dBA. Type Arval Cofraplus 77.

5. INSULATION
Thermal and acoustic insulation, mineral wool, thickness 40mm, Tipo Isover Ecovent VN032 (=0,032W/mK)
Density: 90Kg/m2. Thermal Resistance: 0.73m2K/W

6. HEAT EXCHANGER
Volume flow 30 m^3/h, Power consumption 5 W Heat distribution 45%, Type Jaga or Schüco VentoTherm.

7. DRYWALL
Glass fiber reinforced gypsum board

8. GLUE LAMINATED BEAM

9. CEILING
Drywall ceiling, type KNAUF, superfitial water absorption <160 g/m^2, fastened to metallic deck, each 60cm, mineral wool impregned with fenolic resine, thickness 40mm, Tipo Isover Ecovent VN032 (=0,032W/mK). Density: 90Kg/m2. Thermal Resistance: 0.73m2K/W

10. DRAINAGE

11. GRAVEL

12. EARTH HOLDER
L profile perforated fastened to upper part of roof following the snow retainer tradition.

13. FILTER LAYER
Geotextile

14. DRAINAGE LAYER
Nodules panel, minimum thickness 20mm.

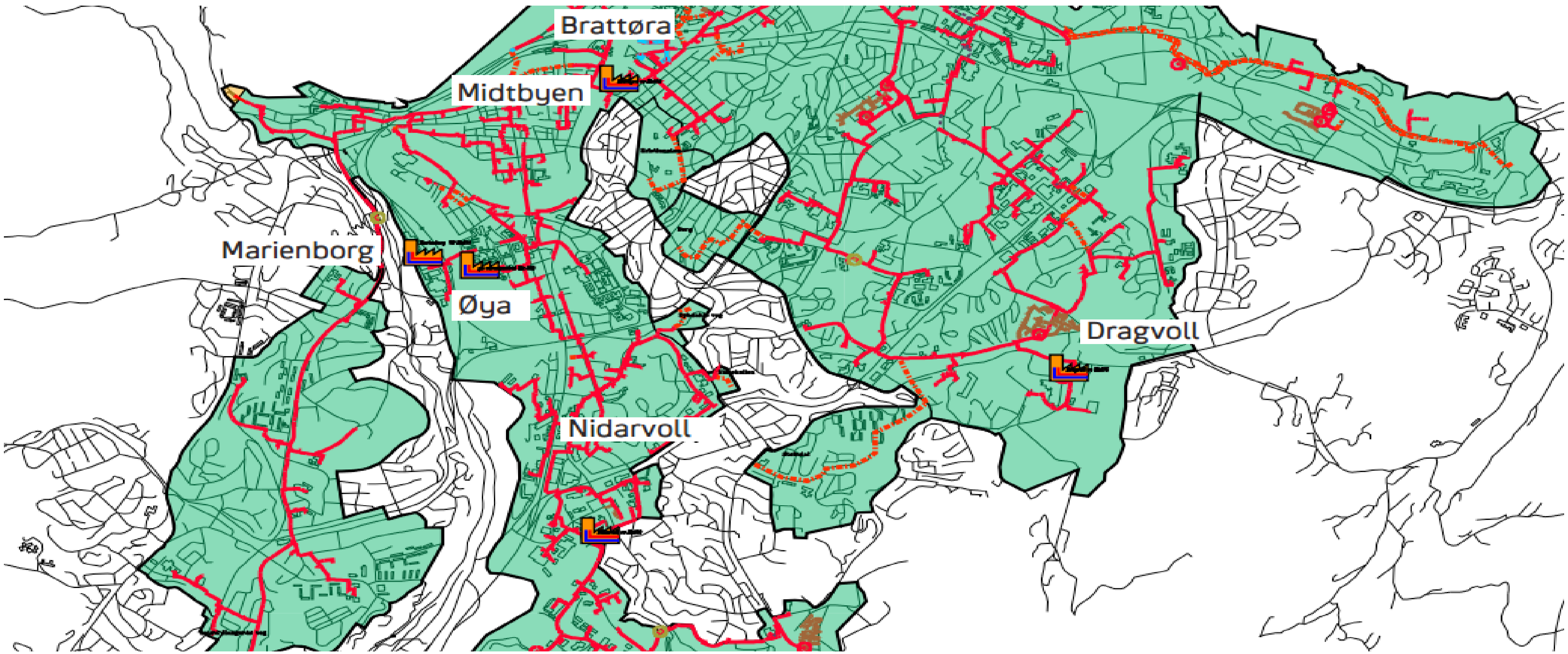
15. WATERPROOF LAYER

16. CONCRETE

17. EARTH

Water heating

The building is located on the district heating pipe's path, what allows us to be connected to the whole system. It is more efficient and much more ecological than creating our own new water heating system. The district heating relies on multiple energy consumers to optimal heat source through network. Source of the heat could include combined heat and power plants, biomass or other natural sources.



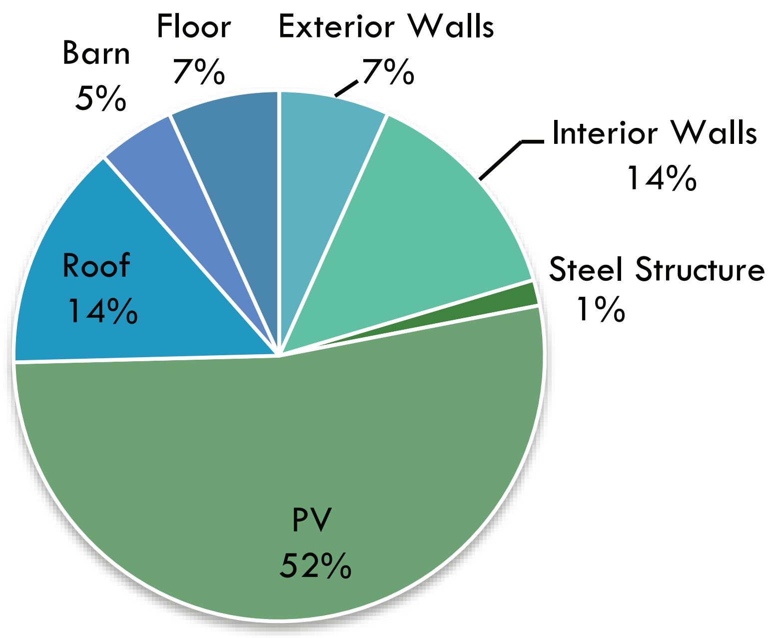
CO2 BALANCE

Embodied Emissions

Several calculations were made in order to estimate the embodied emissions of the material used in the construction of Campus Kalvskinnet. Most of the emissions factors were provided by Professor Aoife Wiberg, from EcoInvent. However, the emissions factors of the less conventional materials were taken from scientific reports or governmental databases.

The lifetime of the project was estimated to be 60 years, which required the replacement of certain materials, most notably, the photovoltaic panels. When accounting for the photovoltaic panels, which have a 30 year lifetime, the embodied emissions of the replacement panel after 30 years, was reduced by half. This was done under the assumption that the technology would improve, and therefore the creation of the photovoltaic panel would be less energy intensive.

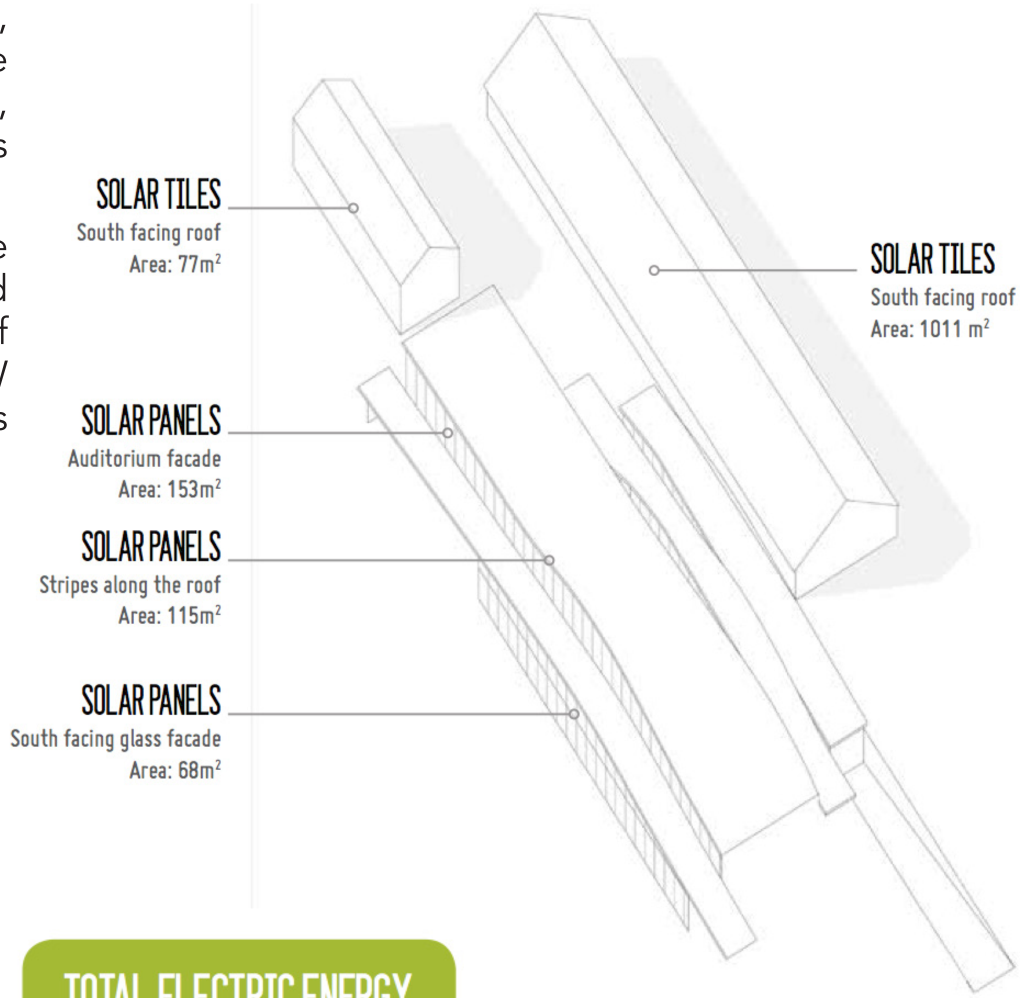
The embodied emissions calculations took the construction materials, such as steel, concrete, and various additions into account. However, it did not account for furniture, the heating/cooling and ventilation system, or details, such as railings or other metal fixtures. The calculated embodied emissions of the project is 4.19 kgCO2eq/m2/yr.



PV Production

In order to improve the energy balance of the building, photovoltaic panels were integrated into the project. There are four locations were PV was added: the roof of the barn, the roof of the hostel, part of the south facade, and on parts of the roof.

The PV panels used were from the manufacturer Grape Solar, with a nominal power of 200 Wp. The inverters used were from produced from GMDE with a nominal power of 12 kW AC, and Hyundai with a nominal power of 50 kW AC for the barn roof system. Altogether the PV system is 1423m2 and produced 120.11 MWh/yr.



TOTAL ELECTRIC ENERGY PRODUCED
120.11 MWh/yr

ZEB Balance

The ZEB ambition level that was reached depends on which electricity emission factor is used. The emission factors used when calculating the embodied emissions is static, and therefore does not change. The energy consumed from embodied emissions is 4.19kgCO2eq/m2/yr. However, the PV system and operational consumption is dependent on a dynamic factor. For example, the ZEB electricity emissions factor is .132, assuming improvement in the energy efficiency of electricity production and the increased use of renewable sources.

When using this emission factor, our project is able to reach ZEB-O, meaning that the energy produced from the PV is enough to balance the energy consumption during the operation phase of the building. Our PV system prevents the equivalent of 6.85kgCO2/m2/yr, while the operational energy consumed is equal to 5.48kgCO2eq/m2/yr.

However, if the UCTE electricity factor of .595 is used, which assumes minimal improvement to the european grid's sustainability, our project not only reaches ZEB-OM, but is a positive energy building. With the UCTE factor, the PV on our building prevent 24.69kgCO2eq/m2/yr and the operational energy consumed is 24.69kgCO2eq/m2/yr. This means that our building is just able to reach the ZEB-O ambition level.