CAR-FREE COMMUNITY IN EIDSVOLL

MASTER'S THESIS IN SUSTAINABLE ARCHITECTURE
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JUNE 2021
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ABSTRACT

According to the Paris Agreement, voted by 196 countries in Paris on December the 12th 2015, it is necessary to limit global warming below 2°C. CO2 emissions and greenhouse gases are primary drivers of global warming and climate change. In addition to that, Norway has set the goal of being carbon neutral by 2030. The building industry being responsible for 38% of greenhouse gases emissions, it is a challenge for architects, designers, and engineers to think about new solutions for a better environment.

Behind the building industry, the transportations are responsible for 32% of greenhouse gases emissions. Norway being a big country with a spread population, it generates considerable travel demand. Today, it is the role of the government and the challenge of city planners to densify the city and create a more centralized pattern, as well as to encourage people to reduce the use of private cars and go toward public transportations.

The Moelven wood constructions industry is moving from Eidsvoll Verk, 60km away from Oslo to another site. The plot is a 119 000m2 area with a river crossing the site. A small part of the site (42 000m2) is being analysed in this thesis, to understand the possibilities of building a new sustainable neighborhood, according to the challenges of today. Increase the density without losing quality, reducing the use of the car to enhance walkability in the neighborhood and increase the social aspect of the community, and using sustainable building constructions are the main goals of this project.

The first part of this thesis will investigate these concepts to understand them and set up some ground rules for the project. The second part of this thesis will be the conception of the project, according to the concepts studied in the first part.

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BACKGROUND

In Eidsvoll Verk, a plot of 119 000m2 belongs to Moelven Limtre Company. For many years, the site was a processing wood area, hosting warehouses and wood processing machinery. Today, the Moelven company is about to move from this site to another, leaving the site ready for a change. As the comune is hoping to see its area growing in the coming years, this site is a great opportunity for new houses to be built.

The terrain being rather flat and a river crossing the site, this location already looks like a high quality area for a living. The site itself has a relevant history and cultural aspect, being a wood processing area for hundreds of years; and is located a few hundreds meters away from the Constitution building in Eidsvoll. In addition to that, Oslo is located 64km away, and many comodities are located in a range of less than 6km.

But, the building industry today is responsible for 38% of all-energy related CO2 emissions (*UN Environmental Report, 2020*). This needs to be higly reduced to be able to reach the carbon neutral goal of 2050 (*Paris Agreement, 12 dec. 2015*). In addition to that, Norway has brought this goal to be achieved by 2030. It is now the role of all designers and engineers to design cities, neighborhoods or buildings with a lower carbon footprint. This means choosing the right materials, and building local and economical. It also means thinking about new strategies, using renweable energies.

Behind the building industry, the domestic transport sector (excluding air and sea transports) was responsible for 32% of Norway's CO2 emissions in 2013 (*Norwegian Transport Towards The Two-Degree Target, 6 aug. 2013*). The Norwegian governement has set up some regulations in order to reduce this number, gathered in a paper from the department of environment (*Meld. St. 21, 2011-2012*). The goal is to push the populations gruadually towards public transport, walking and biking. Other mesures like the fuel and vehicule taxation, or the use of biofuels and electric cars have also been put in place.

The challenge of building this new neighborhood is to think about a sustainable way of building and accessing the site.

Picture of the site, taken by Lukas O. Linder for the group

SCOPE

The subject of this Master's thesis is to design a car-free neighborhood in Eidsvoll Verk, 64km from Oslo. On this project, reducing the use of the car also needs a deep analysis of the surroundings, the infrastructure and the options that the future inhabitants could have when moving to the site. Going car-free means changing daily habits. It is important in this thesis to convince people that abandoning cars won't be a big constraint and will improve the quality of life of the neigborhood.

Being aware of the density is also an important factor on this project. Indeed, a higher density means more housing to sell for the contractor, but the higher the density gets, the lower the quality of life will be. Thus, it is important to find the correct balance between density and quality. One of the goals of this work is to ensure daylight sufficiency by finding the right density and good indoor and outdoor qualities by giving access to green spaces for the population living there.

Overall, this work shows the possibility of designing an eco-friendly neigborhood, by setting groundrules and adopting sustainable strategies. In addition, a sustainable neighborhood is also a neighborhood where social life is enhanced. On this work, the population live in a community, sharing gardens and terrasses. This project allows the community to feel implicated in the neighborhood.

METHODOLOGY

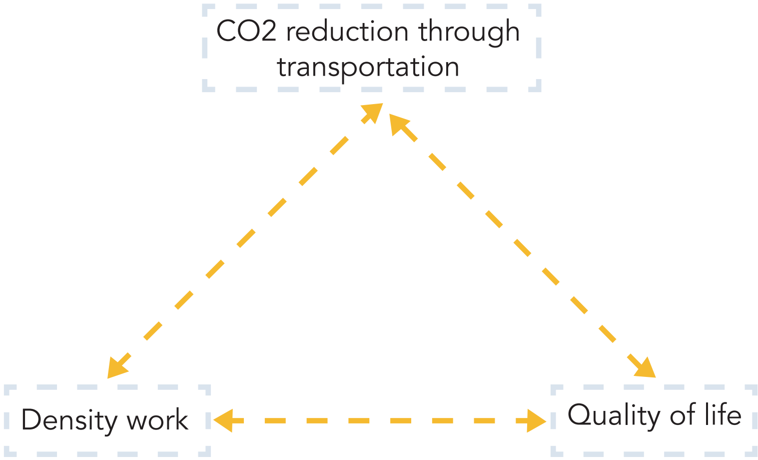
The first part of the project consisted of analysing the site. Knowing that the main goal was to reduce the use of the car, the first thing to do was analysing the infrastructure around the site. It was also necessary to gather and read documentation about the strategies set by the government to reduce CO2 emissions in transportations.

The analysis of the site continued with a site visit in Eidsvoll Verk and meetings with the Moelven company, to understand better their needs and expectations. A visit of every existing buildings on site (mostly wearhouses) was led by Moelven, to show what was to be kept and what was to be demolished. Spending three days on site at that time was very inspiring and considered as a kick start for the design phase. Other meetings with the company were held to discuss the project's progress. Every other week, a meeting with the supervisors enable us to get feedback and ensured that the project was on track.

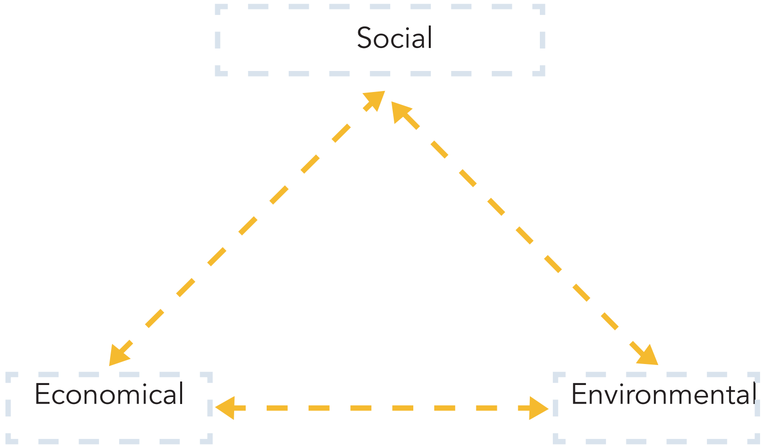
The design phase was a constant back and forth between conceptualizing, analysing and drawing. It was important to work regularly and make sure that every phase corresponded to each other. One small change in the design would affect the results and needed to be analysed again. Hand sketching at the beggining allowed to express ideas on paper and make quick changes. After the main concept was set, the use of software such as Sketchup, Autocad, Rhino and Velux daylight vizualizer allowed the project to be more accurate.

Combining 3D modeling and study models was important to get perspective on the site, especially when working on the density of the site.

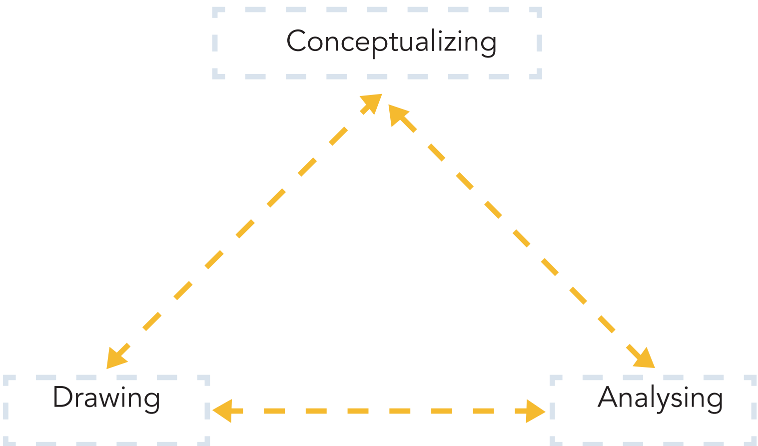
Finally, using Photoshop, Illustrator and Indesign allowed to put the work together in a graphical way.



Three main goals of the thesis



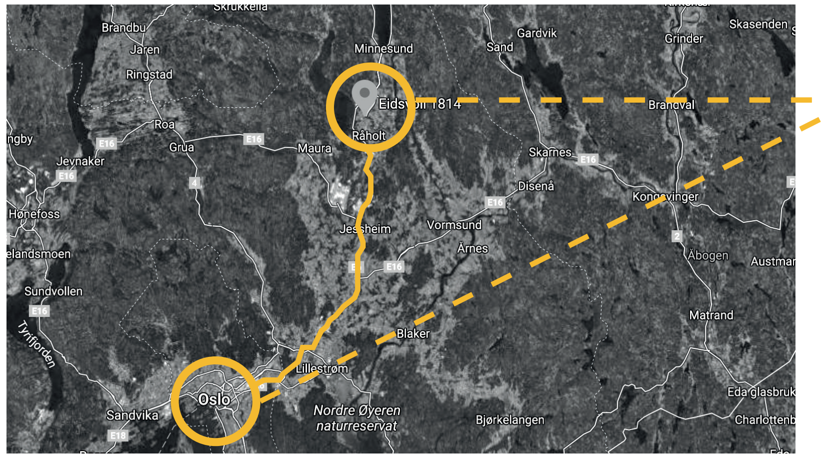
Sustainable aspects



Main workflow

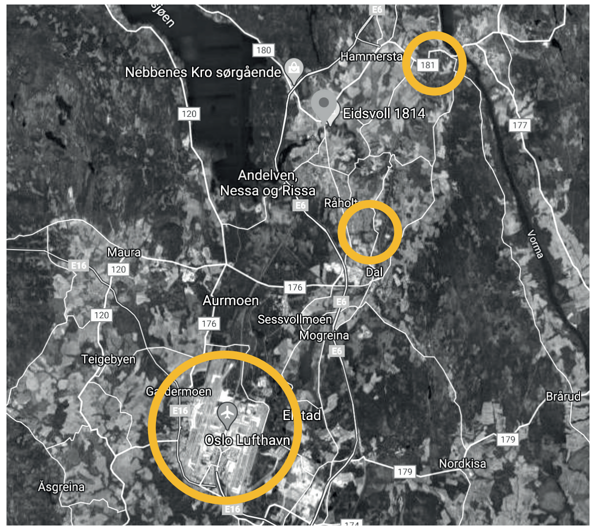
II. THE CONTEXT, THE SITE

INFRASTRUCTURE STUDY
CLIMATE ANALYSIS
PROGRAM



Eidsvoll Verk, connected to Oslo by the **E6 ROAD**

64KM apart

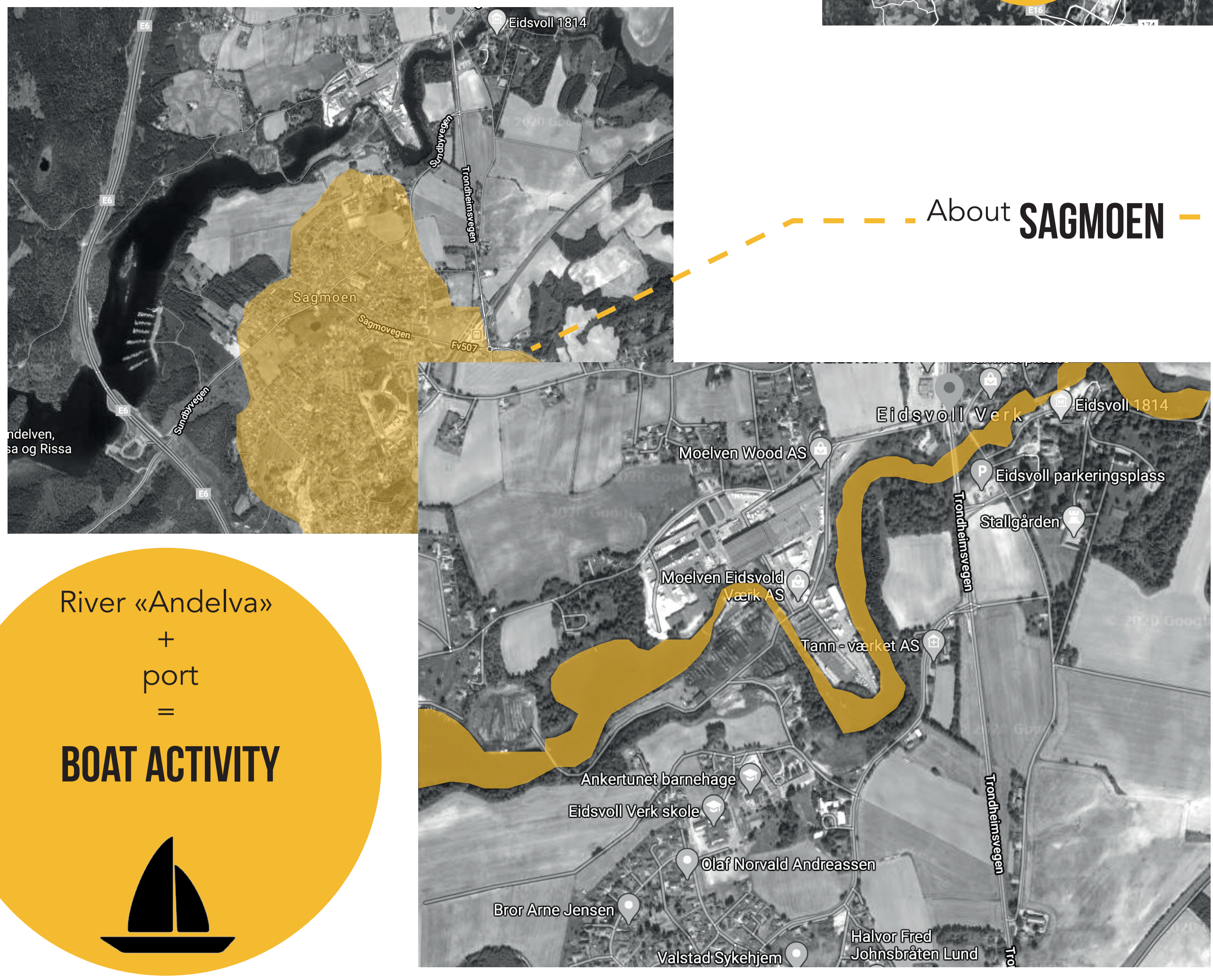


18,7KM away from the airport Oslo Gardermoen, via E6

2KM away from REMA1000 Raaholt

2KM away from Eidsvoll Verk station in Raaholt

7KM away from Eidsvoll Verk station in Hammerstad



About **SAGMOEN**

River «Andelva»
+
port
=
BOAT ACTIVITY

THE INFRASTRUCTURE

The site is connected to Oslo and the airport of Oslo Gardmoen by the E6 motorway. It is also well served by public transportation, the train and bus station being located 2km north of Sagmoen (a neighborhood of **2095** inhabitants on the border of the site). Several schools, sport facilities and amenities are located around the site and will help the developpement of the neighborhood. Further south, the village of Råholt with a population of **13 397** inhabitants hosts most of the conviniencies. Also, the river crossing the site and a port further down the river offer a great opportunity for developping activities along the river.

The comune of Eidsvoll hopes to see its population grow in the coming years, and the further work on density of this thesis will give an answer to how many people can be placed on the site.

SCHOOLS

4 schools, in a range of less than **4km**

Råholt ungdomsskole, 18 min walk,1,4 km

Eidsvoll Verk skole, 22 min walk,1,8 km

Bønsmoen skole, 26 min walk, 2,2 km

Råholt skole, 40 min walk, 3,3 km

3 kindergardens, in a range of less than **3km**

Ankertunet barnehage, 22 min walk,1,8 km

Veslebrunen Steinerbarnehage, 27 min walk, 2,4 km

Andungen barnehage, 35 min walk, 3 km

2 highschools, in a range of less than **14km**

Nannestad videregående skole, 17 min drive, 14,7 km

Eidsvoll videregående skole, 17 min drive, 12,4 km

AMENITIES

2 grocery stores, in a range of less than **2km**

Spar Råholt, 20 min walk,1,6 km

Rema 1000 Råholt, 22 min walk,1,8 km

1 vinmonopolet, in a range of less than **2km**

Vinmonopol AMFI Eidsvoll, 23 min walk,1,9 km

1 postoffice, in a range of less than **2km**

Spar Råholt-PostNord, 20 min walk,1,6 km

2 shopping centers, in a range of less than **15km**

AMFI Eidsvoll, 23 min walk,1,9 km

Nannestad Torg, 17 min drive,14,6 km

SPORTS & ACTIVITIES

4 sports halls / gym, in a range of less than **6km**

Råholt ungdomsskole, 18 min walk,1,4 km

Råholthallen - normalhall, 20 min walk,1,7 km

Trento Eidsvoll, 23 min walk,1,9 km

Puls Letohallen, 9 min drive,5,8 km

HEALTH

2 pharmacies, in a range of less than **2km**

Apotek 1 Eidsvoll Verk, 22 min walk,1,8 km

Apotek 1 Råholt, 23 min walk,1,9 km

1 hospital, in a range of less than **2km**

Valstad Nursing homes, 15 min walk,1,2 km

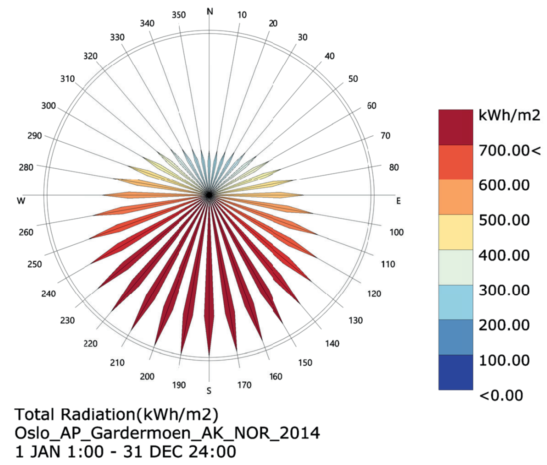
CLIMATE ANALYSIS

The entire Moelven site of 119 000m2 is crossed by the river Andelva and the project will be built on the southern side of that river (the right part on the picture). It is a rather flat area, directly connected to Sagmoen. This area covers 42 000m2 and is borded by trees on the South-West part of which can shade the sun in the winter but offers a quite and peacefull atmosthere when walking along the river.

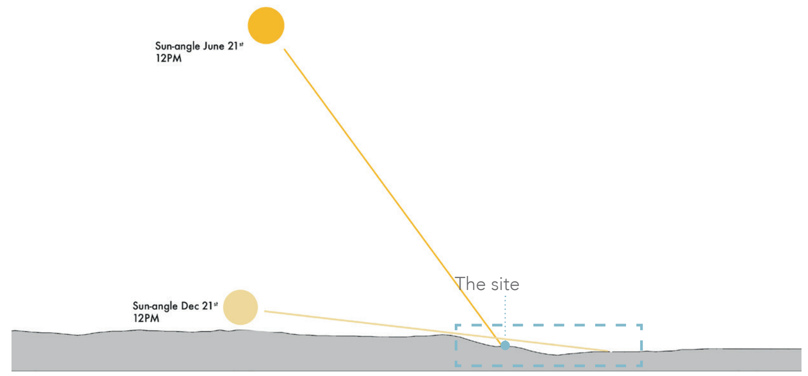
When looking at the sun angles, we notice that the plot won't get a lot of direct sun in the wintertimes, the sun being too low. The compromise to that is that by locating the neighborhood at the bottom of the small hill, it will be covered from winds coming from the south (cf. annual wind rose).

Finaly, the average temperatures will go down to -9°C in the colder months and up to 21°C in July. This cold climate will induce the necessity of well insulated housings on the neighborhood.

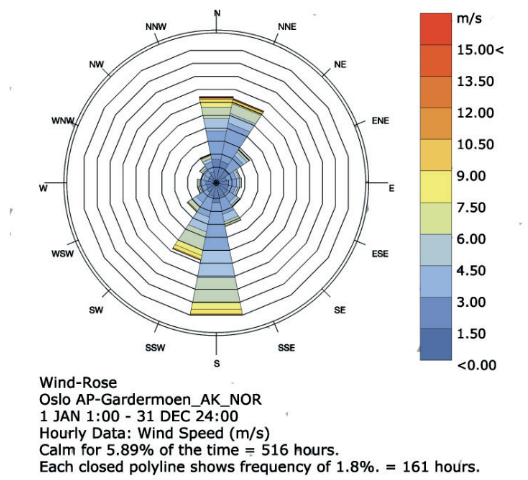
Picture of the site taken by Lukas O. Linder for the group



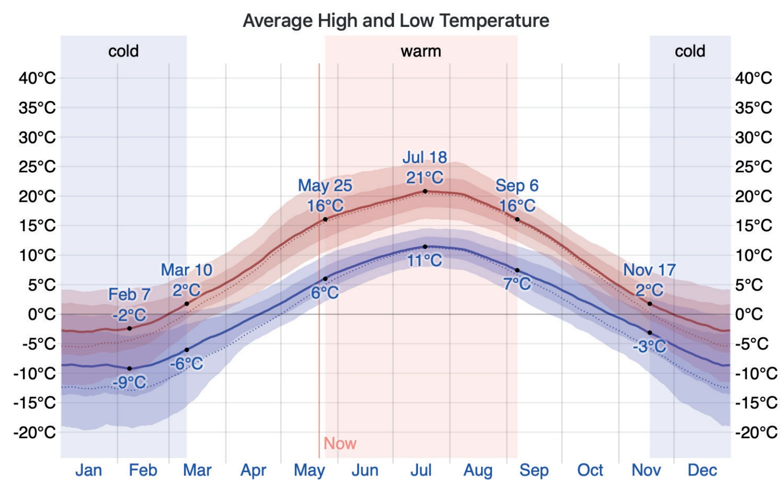
Annual solar radiations



Sun angles in the summer solstice and winter soltice



Annual wind rose



Monthly average high (red) and low (blue) temperature in Eidsvoll (graph and data from weatherspark.com, 2016)

THE PROGRAM

The site being surrounded by several easily accessible aminities, the neighborhood will be built essentially for **families**. Indeed, schools, kindergardens and highschools make it a good place for families to settle. The riverside bordering the site will offer a pedestrian walk for the inhabitant to enjoy the landscape and host some outdoor activities in the summer. The pedestrian walk will connect to the other side of the river with a bridge and will create a loop around the whole site. If extended further East, it will connect the site to the constitution building of Eidsvoll, 1km away.

III. THE CONCEPT

TRANSPORTATION STUDY

DENSITY STUDY

DAYLIGHT STUDY

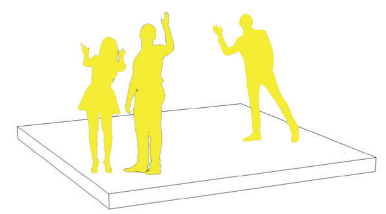
ABOUT THE CONCEPT

The concept of this project is to create a comunity, working together towards a better environement. For that, the neighborhood will be car-free (or partly car-free). Also, one of the key points of the Sustainable Developement Goals is enhancing social life. Keeping in mind this point, the population in this neighborhood will share gardens and green spaces. In that way, they will be encouraged to maintain the common gardens by being able to grow vegetables or herbs and will feel implicated in the developement of the neighborhood.

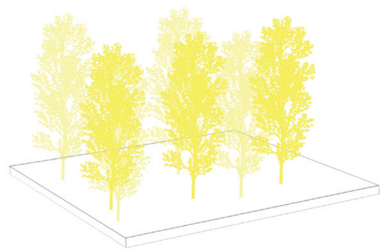
The area being car-free, if people need a car, a car-sharing parking will be located few meters away from the site. Carpooling will allow the community to work together in a social way and in an environmental way.

The right densification of the neighborhood is also a concept to be explored. A densification study to find out a good amount of houses to put on the site will be done.

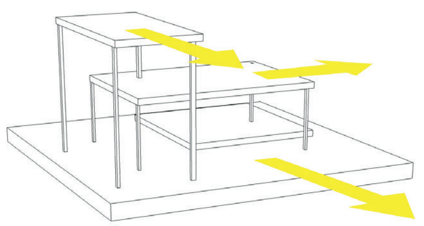
Finally, when densifying a neighborhood, it is necessary to make sure that we provide a good quality of life. This will be the object of a «daylight and views» study, the daylight in buildings being affected by the surroundings, the site and the buildings around.



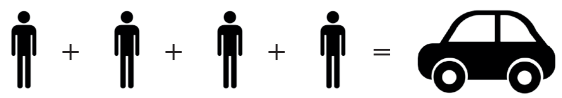
1) to enhance the social aspect of the neighborhood by creating a community working together



2) to keep spaces for greeneries and common gardens



3) to offer high-quality housings with playing with daylight and views on different levels

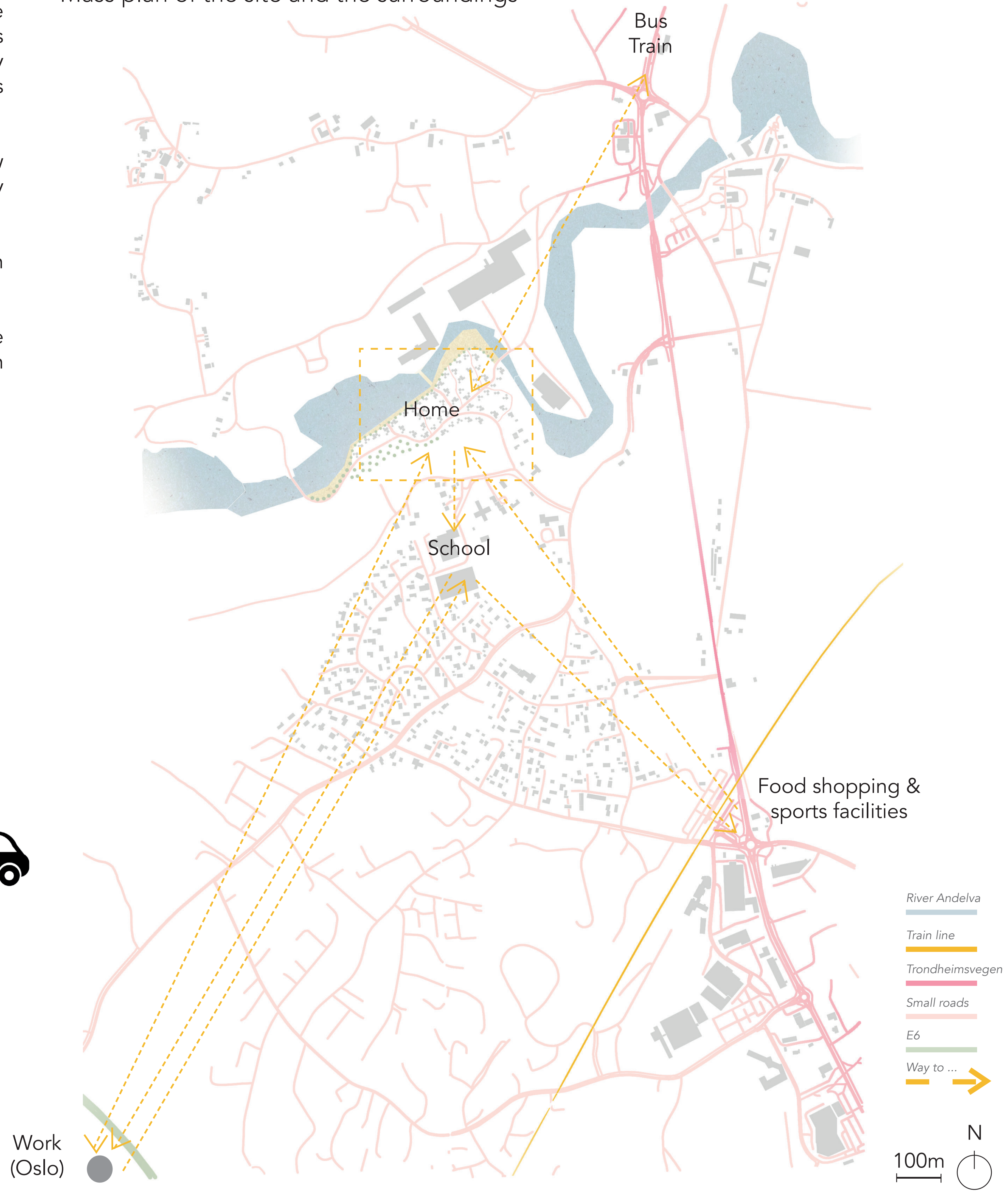


3) to influence reduction of the car with a car-sharing system

TRANSPORTATION STUDY

Eidsvoll - Oslo = around 50min / 1h (by car or by train)

Mass plan of the site and the surroundings



Looking at the infrastructure around the site allows us to understand how the area is structured and what facilities a family could reach by car or by foot. The neighborhood being designed for families, it is interesting to set up different scenarios to imagine how people would comute on a daily basis. This shows how much CO2 each family emits on transportations, on a daily basis, according to a scenario. On the figure «*Mass plan of the site and the surroundings* » is located the area that will be built («*Home* »). The map also shows how this area is connected to the school, the bus and train station and most of the amenities. Oslo train station is also located about 60km away from our site, connected to it by the E6, and Oslo Gardemoen airport is only 20km away. In this study, we will consider that people are working in Oslo and drive (or take the train) to Oslo train station. A residential area (Sagmoen) is located on the South border of the site.

According to data from The European Environment Agency (EEA), in Norway in 2019, a new passenger car emits an average of 122,4 gCO2/km. It remains bellow the target of 130 gCO2/km set by the EEA, but it is still a number that the government tries to lower.

The first scenario represents a family of four with both children going to school. Both parents work in Oslo and as they have different schedules, they need two cars. Like that, one parent will bring the children to school before going to work, whilst the other parent can go straight to work without loosing time. After work, one parent will pick up the children at school before taking them to handball training or other activities in Råholt. In the meantime, that parent can also go food shoping since many comodities are located in Råholt. At the end of the day, everyone drives home. With this scenario, the family would drive 265km in a day, emitting 32 436 gCO2 a day.

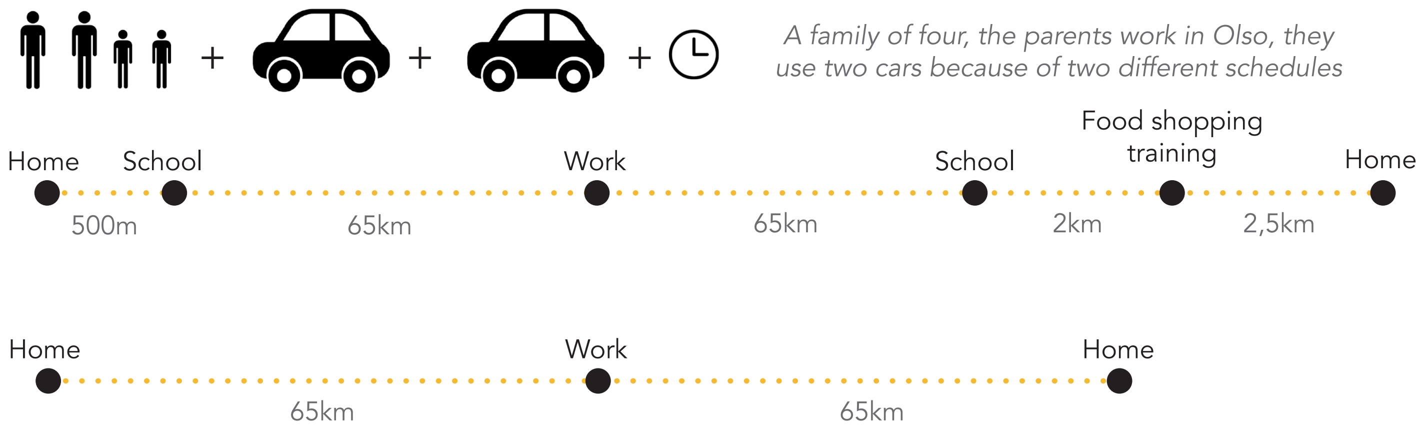
The second scenario represents the same family. This time they use only one car and both parents adapt their schedule. Like this, they will almost cut by half the amount of CO2 they emit, saving money and energy. Indeed, the family will drive only 135km a day, and emit 16 524 gCO2 a day in transportation.

The third scenario represents one young couple that settled down in the new neighborhood. They don't have kids yet but both work in Oslo. They share a car to drive there everyday. They can easily go food shopping and enjoy leisure activities in Oslo after work, and they don't need to drive by the school or Råholt after work. They still drive 130km a day, the longest distance in those scenarios being «home to work» or Eidsvoll to Oslo. They emit 15 912 gCO2 a day in transportation.

Finally, the fourth scenario represents a familly of four, with two children walking to school. The school being located in a diameter of 500m from our site, it is easily accessible by foot. Both parents are walking everyday to the bus station in Eidsvoll Verk, 800m from our site. The bus going from Eidsvoll Verk to Eidsvoll Verk station, they then take the train (35min) to Oslo station. At the end of the day, they take the train and the bus back. In this scenario, the distances are the same as the first scenario, although, by using public transportation, they only emit 1 300 gCO2 a day in transportation. Taking public transportation might take them 10 minutes more than taking the car. Although, taking the car is never acurate, depending on the traffic on the road. Taking public transportation might sound more work, but it has many qualities a part from emitting less CO2. People can use this time to work on the train, read, or even take a morning coffee.

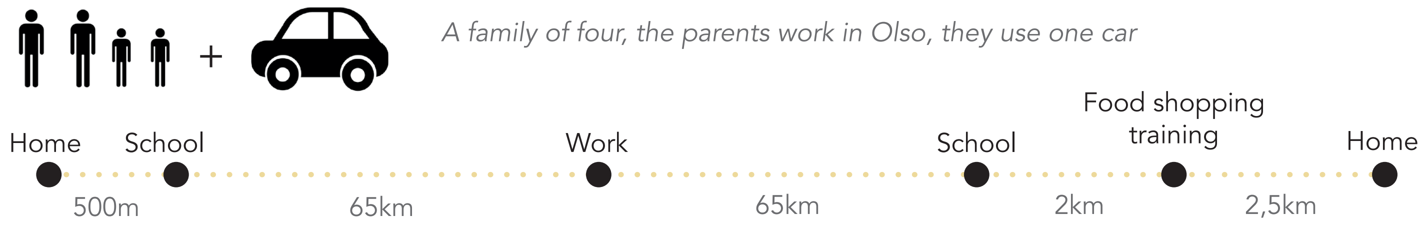
Looking at these four scenarios, public transportation is the best option in terms of CO2 emissions. Although, in this study, the average of 122,4 gCO2/km is used, but it doesn't represent every car or every scenario. Electric cars for exemple, will change the results. The goal of taking an averge is to give an idea and represent the population in a non-exhaustive way.

Scenario 1



Scenario 1 drives 265km in a day. In 2019, the average CO2 emission in Norway coming from cars is 122,4 gCO2/km. The family from scenario 1 emits about **32 436 gCO2** a day in transportation.

Scenario 2

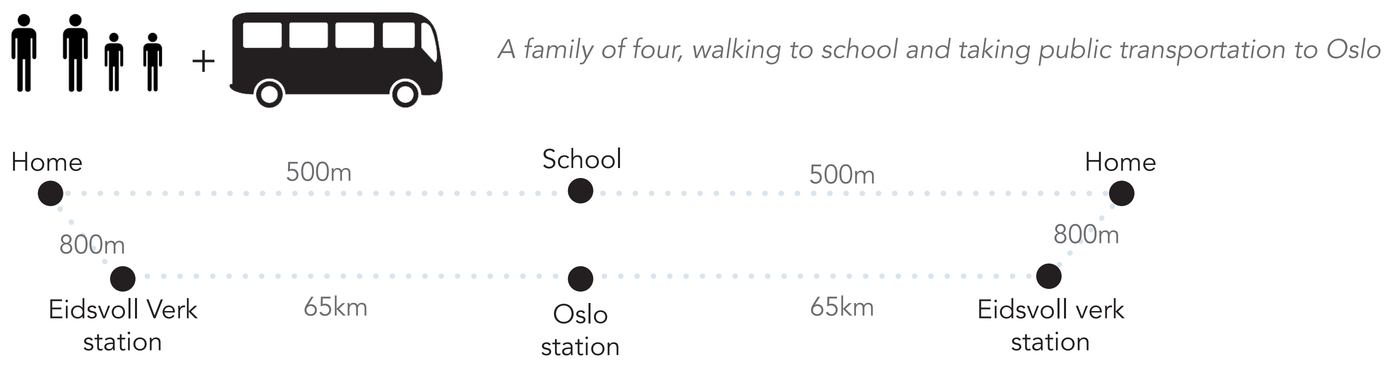


Scenario 2 drives 135km in a day. In 2019, the average CO2 emission in Norway coming from cars is 122,4 gCO2/km. The family from scenario 1 emits about **16 524 gCO2** a day in transportation.

Scenario 3

Scenario 3 drives 130km in a day. In 2019, the average CO2 emission in Norway coming from cars is 122,4 gCO2/km. The family from scenario 1 emits about **15 912 gCO2** a day in transportation.

Scenario 4

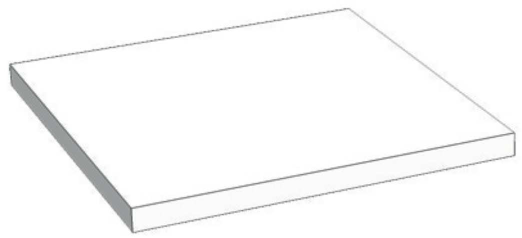


Scenario 4 takes the bus and the train to Oslo 2 times a day and emits about **1 300 gCO2** a day in transportation.

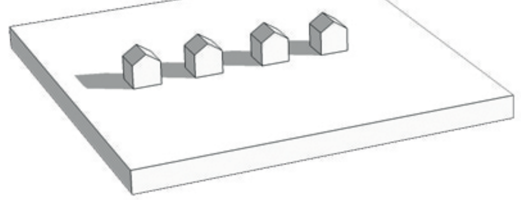
DENSITY STUDY

When planing a neighborhood, thinking about the density is necessary. In urban planing, density can be seen in a positive way or a negative way. A high density neighborhood will be more economical, more ecological (because less spread over the land) and more social: people will interract more, because of their proximity. On the other hand, a high density neighborhood can also affect que quality of life of the people living there, by creating overcrowded neighborhood for exemple. When designing a neighborhood, the challenge is to find a good balance between high density and quality of the environment.

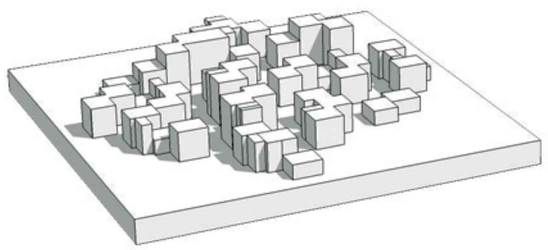
In 2008, the architect Rudy Uytenhaak explained in «*Cities full of space*» that a city should be full without being oppressive. Indeed, density will induce an «*inevitable loss of natural qualities*» (*Rudy Uytenhaak, 2008*) and to solve that, designers, planers and architects need to observe the site and understand its history. As the urban landscape grows more dense, it is necessary to be able to leave empty spaces or «vacant» spaces when planing an area. A good density should be a balance between built and unbuilt, hard materials and empty spaces (squares, gardens, common areas for exemple).



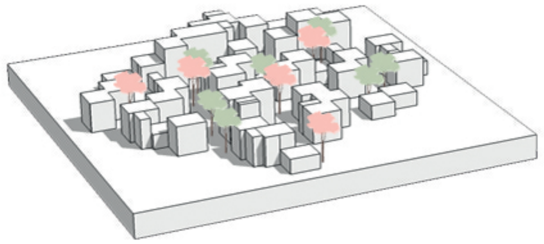
1) Empty land



2) Low density



3) High density, more connection between people but feeling of overcrowdness



3) High density with vacant spaces filled by trees and greeneries

Architect Dietmar Eberle explains that a qualitative neighborhood should have 40% of open spaces. A study («*Modern Compact Cities: How much Greenery Do We Need?*», Alessio Russo and Giuseppe T. Cirella, 2018) also explains that in a compact neighborhood, a person should have access to at least 9m2 of greenery. It is also said that accessibility in the neighborhood is an important factor of high-quality neighborhood. The term «walkability» is also an important factor when thinking about the quality of an area and defines how pedestrian friendly the area is. A good densification of the site should allow walkability and green spaces. In addition to that, walkability has showed improvement in health, environment and socializing.

How to measure density?

Density can be measured in many ways, but in urban planning, two methods are often used. The population density represents the number of people located in one area, and the building density represent the number of building structures on the area.

In this project, the density will be measured in number of people per m2. The density exercice in this project evolved all along the conception. At first, it was important to know that the site mesure 42 000m2. The average of living area per inhabitant in Nordic countries being 47-48m2 (« *The living conditions in the Nordic countries are the world's top class - why building of new dwellings there is still the most expensive in Europe*» Pekka Pajakkala, Briefing on European Construction April 2018), the first part of the density exercice was to calculate how many people could live on the site.

According that, one person should have 48m2 of living area + access to 9 m2 of greeneries: 42 000 / (48+9) = 736,8. This gives us the number of people that could live on the site, and will be a density of 0,017 hab/m2.

But, to this number, it is needed to substract streets (especially if we want the neighborhood to have a good walkability), to give enough space to the buildings so they get a fair amount of daylight, and to add common functions. Also, having different building heights will affect the density, even though the ground space index (built area/plan area) will be the same. In that way, the building density will define the urban form.

The density being studied all along the project, the final density will be calculated further in this report.

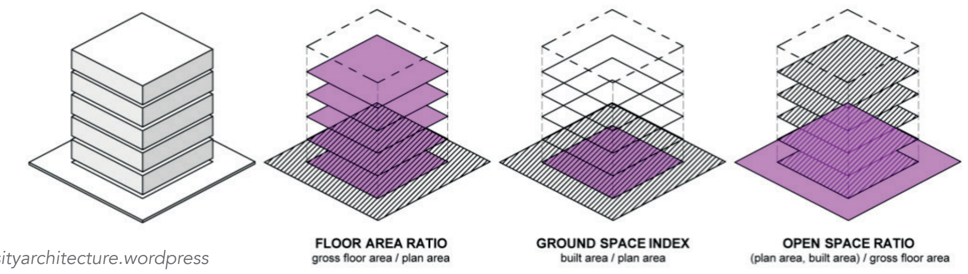


Illustration of building density, figure from densityarchitecture.wordpress

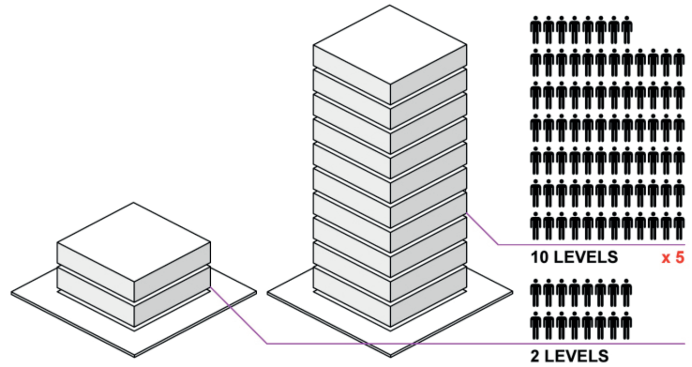


Illustration of population density, figure from densityarchitecture.wordpress

DAYLIGHT STUDY

When designing a neighborhood, daylight is related to density and quality of living. A high density will affect the amount of daylight in a building but also the views that a person can have towards the outside. At a human scale, having the right amount of daylight in the buildings will affect the health of the inhabitants. In their book «*Daylight Design of Buildings*», authors Nick Baker and Koen Steemers explain that people spend more than 80% of their time indoors and that they generaly don't get enough daylight. Especially in Nordic countries when the sun is at the lowest in winter, it is very hard to get direct sunlight. Making sure that people get a sufficient or good amount of daylight is therefor necessary when designing a building (or in our case, a neighborhood). A good amount of daylight will have a positive effect on the well-being of the inhabitants, due to the synchronizing effect of sun or daylight on the body's circardian rythm (*Baker&Steemers*).

To reach this necessary amount of daylight, many strategies can be adopted: large amounts of glazed area facing the South or West, to maximaze solar gains, heat and light in the building; skylight comming from roof windows; light reflectors or other devices allowing the light to penetrate the building.

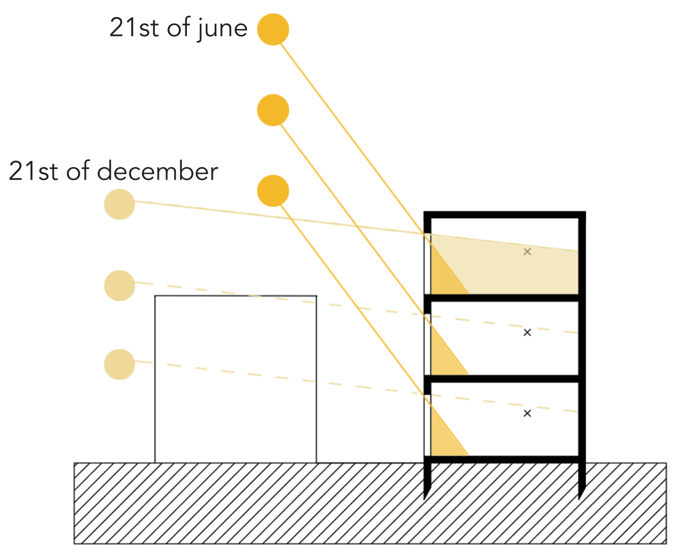
To mesure and see if the amount of daylight in a room is sufficient, we mesure the «Daylight Factor» of the room. The recommended average daylight factor (ADF) varies with the function of space. For exemple, the european recommendation is a minimum of 2% in living areas, and 1,8% in bedrooms or working spaces. In this project, the average daylight factor will be calculated further in the process, once the appartment plans will be settled.

When designing outdoor spaces, it is important to know where to place the buildings so they don't shade eachother too much. For that, a study on the dimensions between two buildings facing eachother and the shape of their rooves (flat or pitched) has been done. A minimum of 4m in between buildings has been chosen, in accordance with the Norwegian's planning regulations. From that, the distance has been increased to 5m and 6m. Also, two heights of buildings (2 story and 3 story) have been chosen. The idea is to see how much direct sunlight a room will get, depending on the position and height of the other buildings. Sun angles corresponds to the sun position on our site (Eidsvoll Verk).

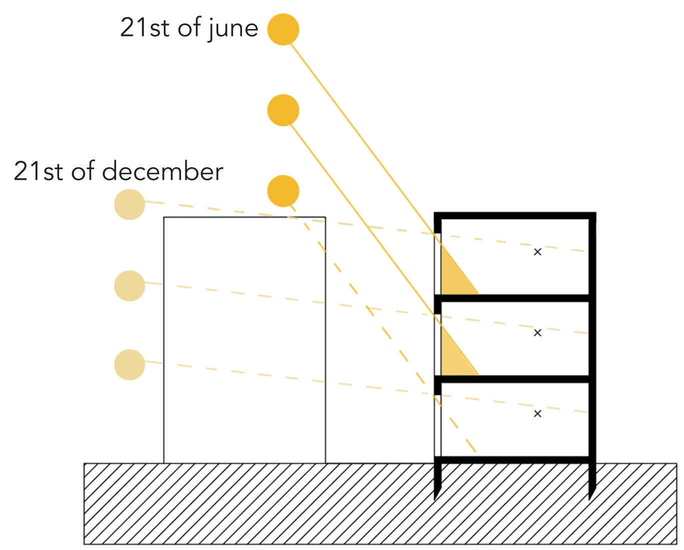
Figure 1 shows that with a 2 story building facing our building and 4m between them, every appartment will get direct sunlight in the summer, but only the top story appartment will also get direct sunlight in winter (which means all year long). Figure 3 and 4 (representing the same scenarios but with a space of 5m and 6m between the buildings) gives the same results.

When the building in the front gets higher (3 story), less direct sunlight penetrates in our building. On figure 2, we see that having a distance of 4m between two buildings and a height of 3 stories makes it very critical for the ground floor appartment, which doesn't get any direct sunlight all year long. Also, no appartment will get direct sunlight in the winter. On figure 4, with a space of 5m between both buildings, every appartments will get direct sunlight in the summer, but none in the winter. Finally, on figure 6, every appartment will get direct sunlight in the summer, and only the top one will get direct sunlight in the winter.

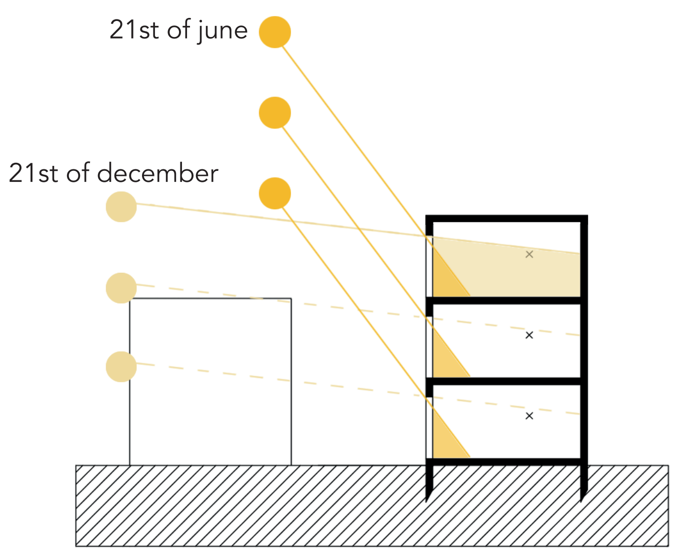
Direct sun in living rooms (flat roof)



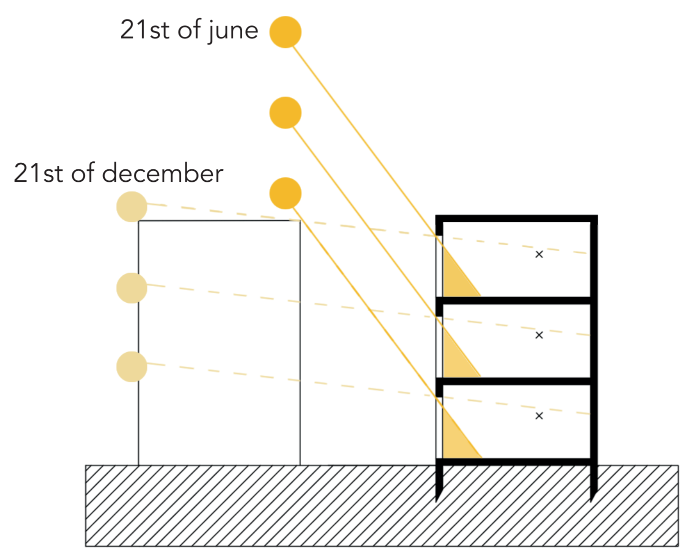
1) 4m between the buildings, front building being 2 story high



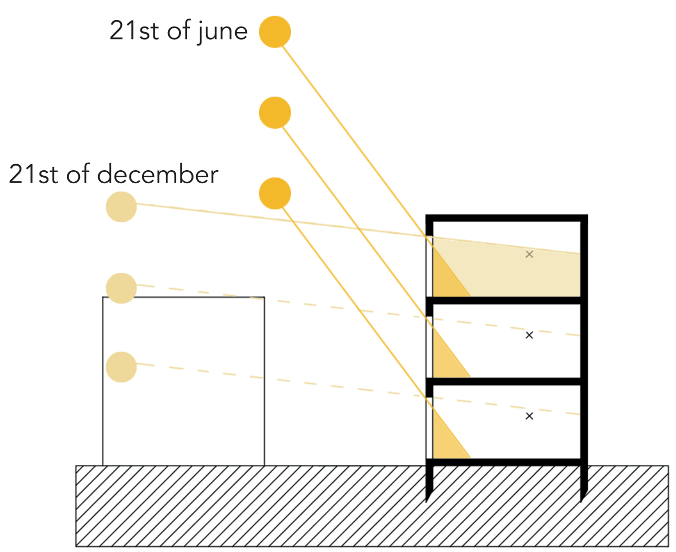
2) 4m between the buildings, front building being 3 story high



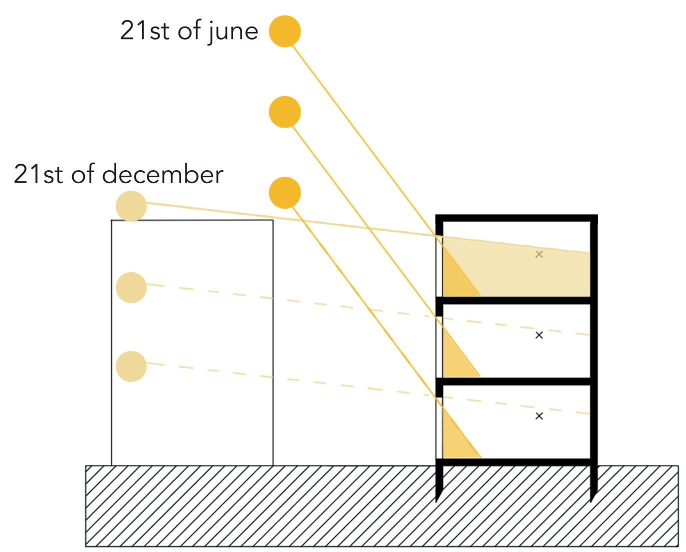
3) 5m between the buildings, front building being 2 story high



4) 5m between the buildings, front building being 3 story high

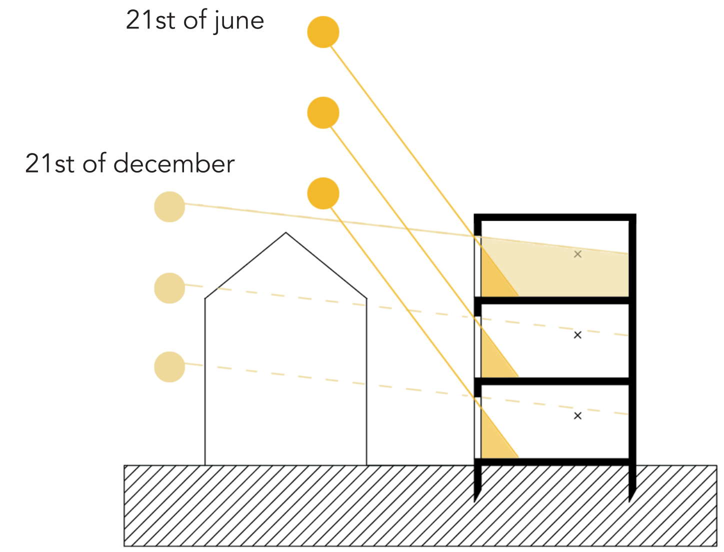


5) 6m between the buildings, front building being 2 story high

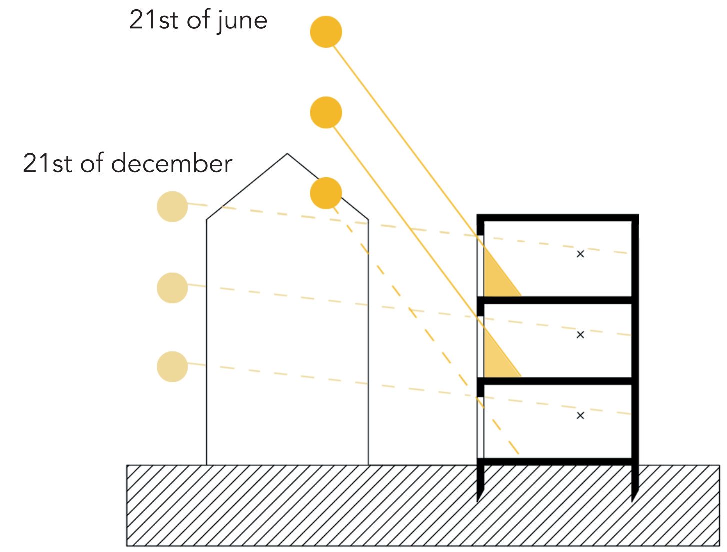


6) 6m between the buildings, front building being 3 story high

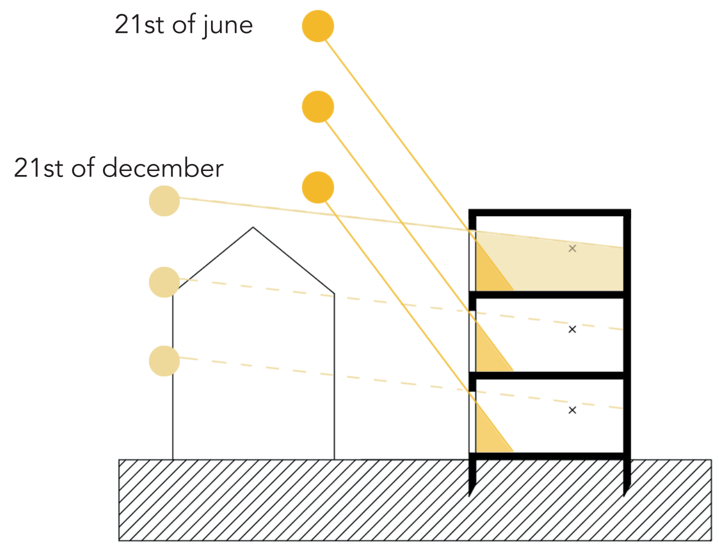
Direct sun in living rooms (pitched roof)



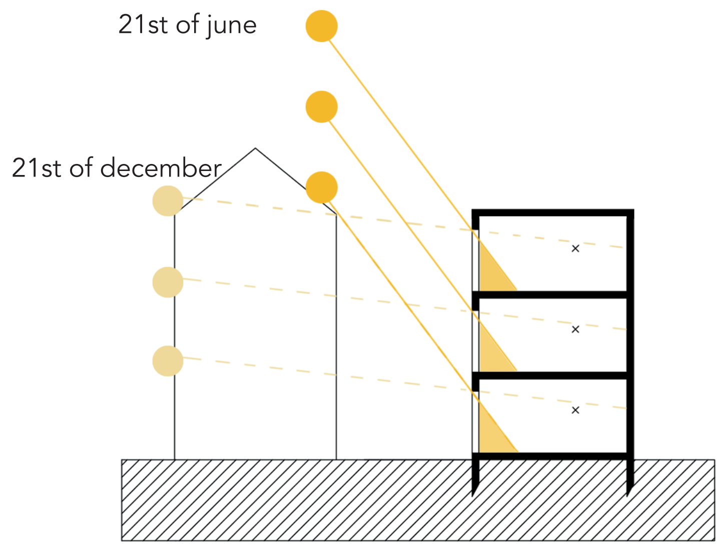
7) 4m between the buildings, front building being 2 story high



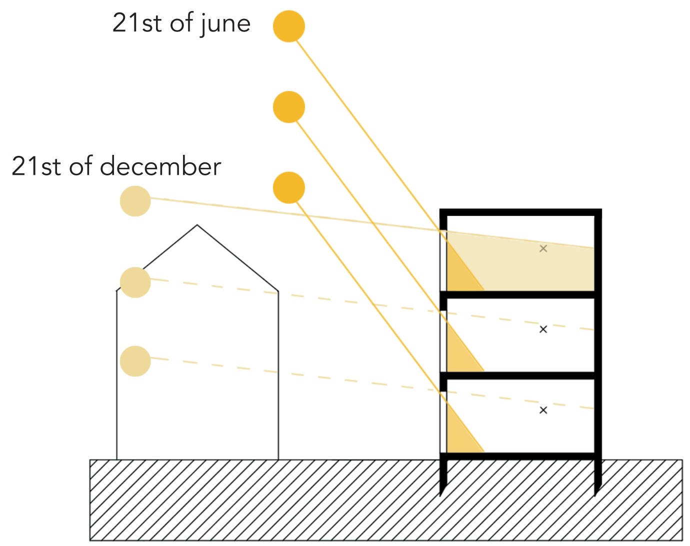
8) 4m between the buildings, front building being 3 story high



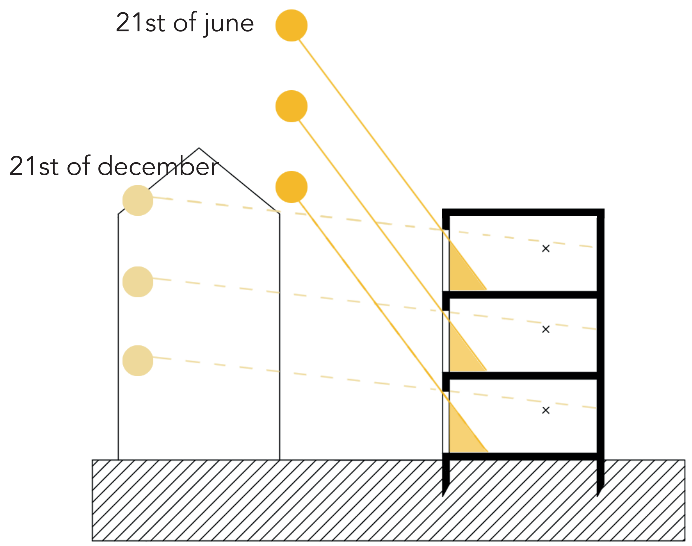
9) 5m between the buildings, front building being 2 story high



10) 5m between the buildings, front building being 3 story high



11) 6m between the buildings, front building being 2 story high



12) 6m between the buildings, front building being 3 story high

The shape of the roof also affecting the direct sunlight in the appartments, we now need to see if having a pitched roof would make a big difference. On figures 7,8,9,10,11, the sunlight penetrates in the same way into our building. But on figure 12, no appartment is getting direct sunlight in the winter.

Having a flat roof or a pitched roof does not make a big difference in terms of direct sunlight that people will get in their appartments. Choosing a pitched roof could be better for integrated PV panels and provide the building with electricity, whilst avec flat roof would allow more roof terrasses and green spaces.

Another factor to check is the sky component (SC). In her working document «*Daylight of buildings, the new European Standard*», professor Barbara Szybinska Matusiak explains that the view of the person living in a building can be categorized into 3 qualities: sufficient, good and excellent. The parameters are the width of view window; the outside distance of the view; the number of view layers (if people are able to see the sky, the landscape or/and the ground), and the environmental information (if people have information about their location, the time, the weather, or the surrounding nature).

In this project, the concern when building a dense neighborhood is that the buildings will be too close and won't provide a layered view (sky/landscape/ground). That is why another study about the sky component needs to be done.

The parameters are the same: 4m distance between both buildings, then 5m and 6m; a building height of 2 and 3 stories and a flat roof or a pitched roof. We place the «eye» 1m60 above the ground, 1m away from the window.

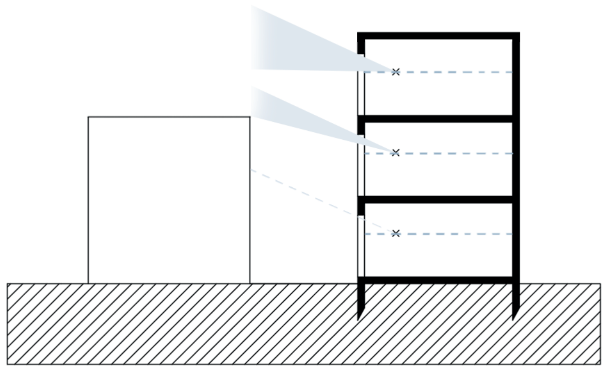
In figures 13, 15 and 17, the building in the front has 2 stories and the people living on the second and third floor have a good layered view with sky and landscape (buildings). The groundfloor appartment doesn't have a view of the sky. The more the buildings are spaced, the more the people get Sky Component.

In figures 14,16 and 18, the building in the front is higher (3 stories high), and only the top appartment gets a sky view.

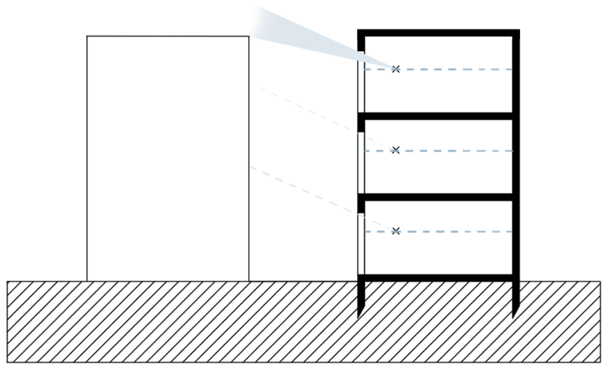
Finally, figures 19, 20, 21, 22, 23 and 24 represent the same scenarios with a pitched roof on the front building. The results are almost the same: top and middle appartment get sky component when the building in the front is 2 stories high, but when it is 3 stories high, only the top appartment gets Sky Component. Although, with a pitched roof, the appartment get less Sky Component than with a flat roof.

According to these studies, we will choose to have flat rooves, allowing a better view to the buildings arround and allowing to put greeneries on the rooves (roof terrasses). This won't prevent the choice of having solar panels, since we could place them on the top rooves that are not terrasses. Also, we will set a minimum of 6m distance between living spaces in two different buildings. These are some ground rules that we will keep in mind during our design process.

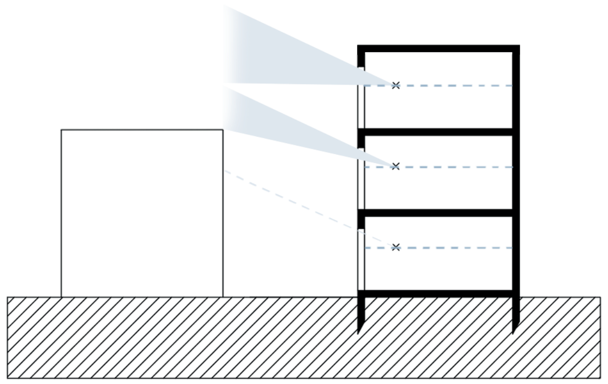
Sky component people can get (flat roof)



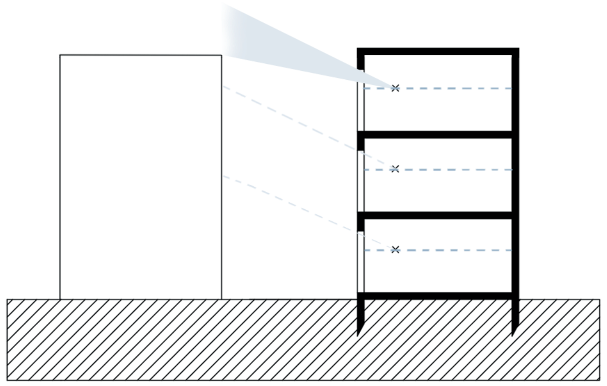
13) 4m between the buildings, front building being 2 story high



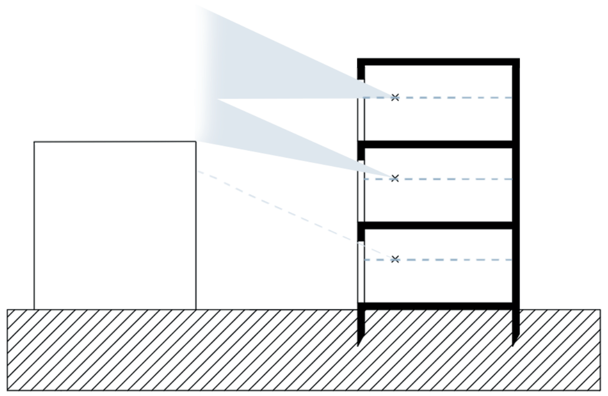
14) 4m between the buildings, front building being 3 story high



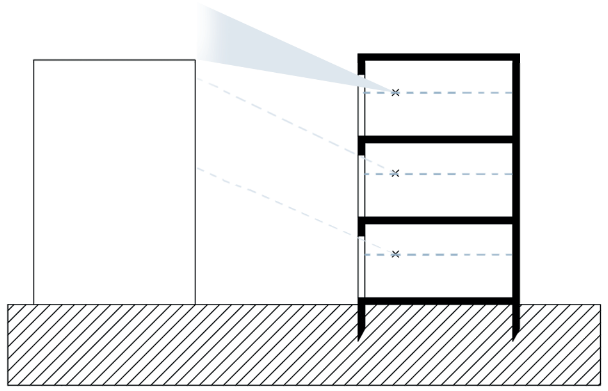
15) 5m between the buildings, front building being 2 story high



16) 5m between the buildings, front building being 3 story high

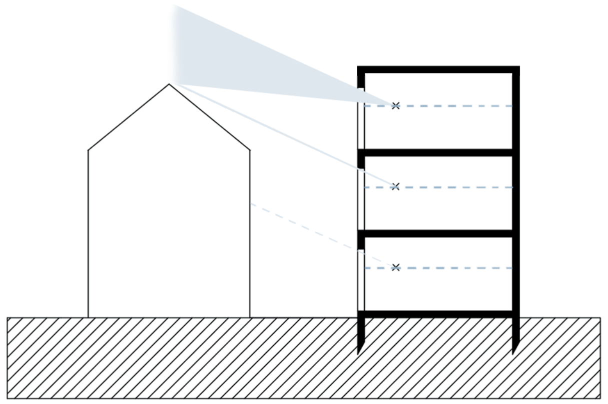


17) 6m between the buildings, front building being 2 story high

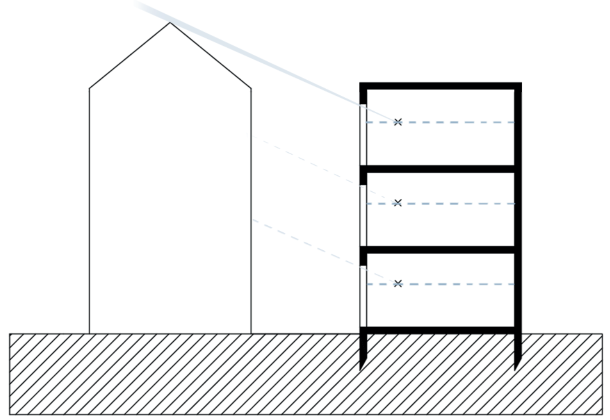


18) 6m between the buildings, front building being 3 story high

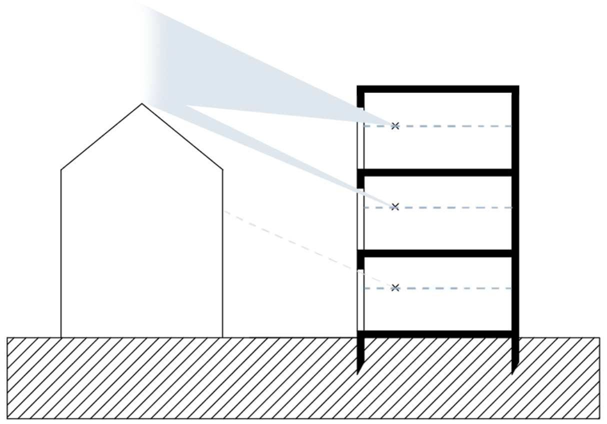
Sky component people can get (pitched roof)



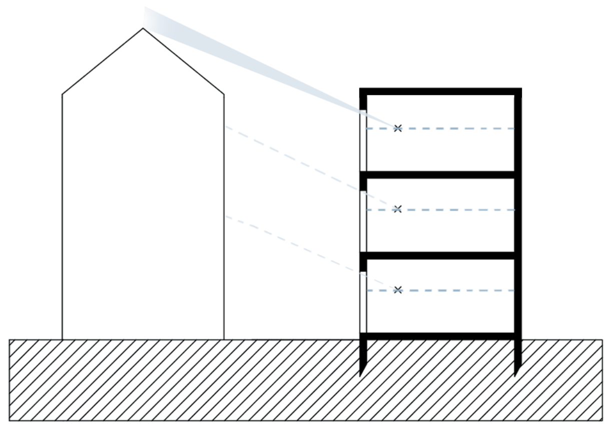
19) 4m between the buildings, front building being 2 story high



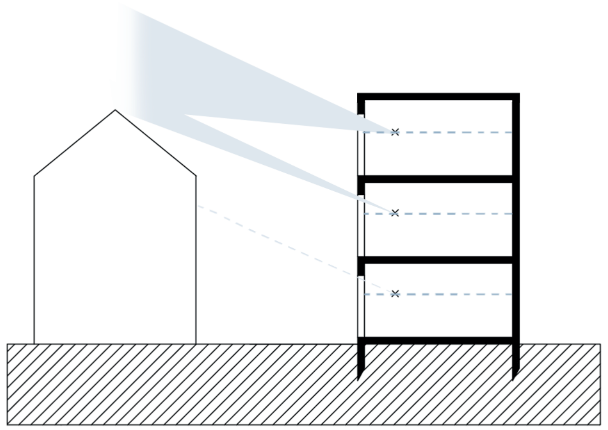
20) 4m between the buildings, front building being 3 story high



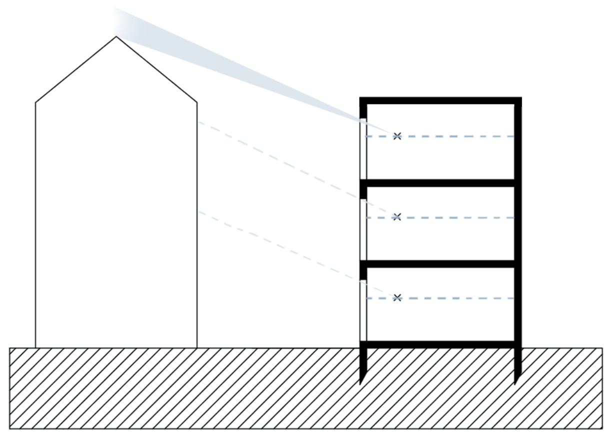
21) 5m between the buildings, front building being 2 story high



22) 5m between the buildings, front building being 3 story high



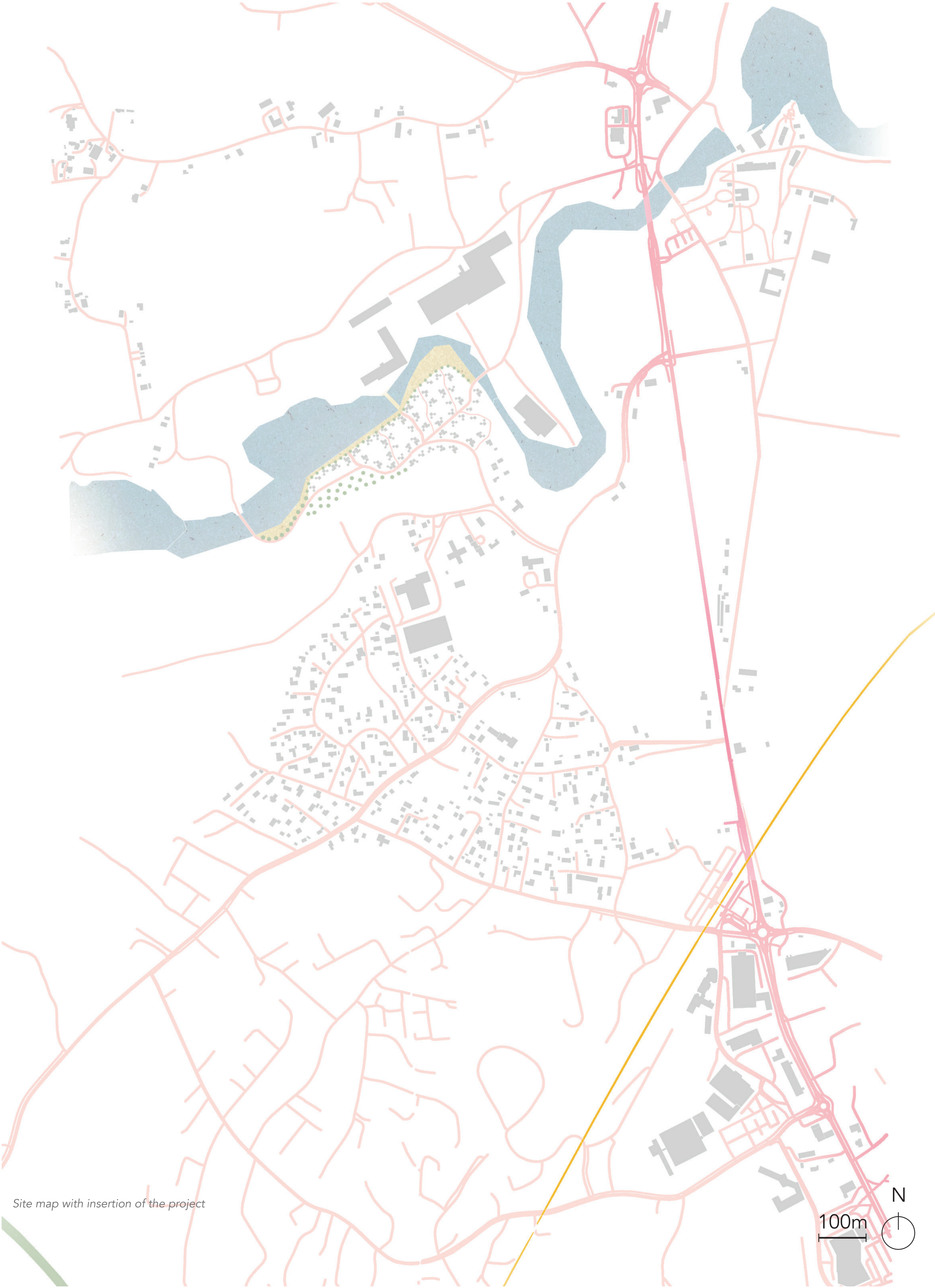
23) 6m between the buildings, front building being 2 story high



24) 6m between the buildings, front building being 3 story high

IV. THE PROJECT

ORGANISATION OF THE SITE
DIMENSIONING AND FLEXIBILITY OF THE DESIGN
STRUCTURE, MATERIALS AND QUALITY OF WOOD
THE APPARTMENTS: DAYLIGHT FACTOR AND INDOOR QUALITIES



Site map with insertion of the project

ORGANISATION OF THE SITE

On the north of Sagmoen, isa road leading to our site. On our site, the road splits in three different directions. One direction goes towards a new bridge and gives access to the other side of the river. Our site is residential, the buildings on the other side of the river will have other functions, such as offices, sportshall or cafés. The two other directions this road takes are a part of a loop around the area, where people can walk and even get to the Constitution building that is in the continuity of that loop. On our site, cars are able to drive on that road but not park. As it is a neighborhood mostly for pedestrians, cars have to drive with a limited speed. Having a road where cars can drive was necessary to allow people to move in and out, pack or unpack heavy things from and to their houses, or even for the garbage collection trucks.

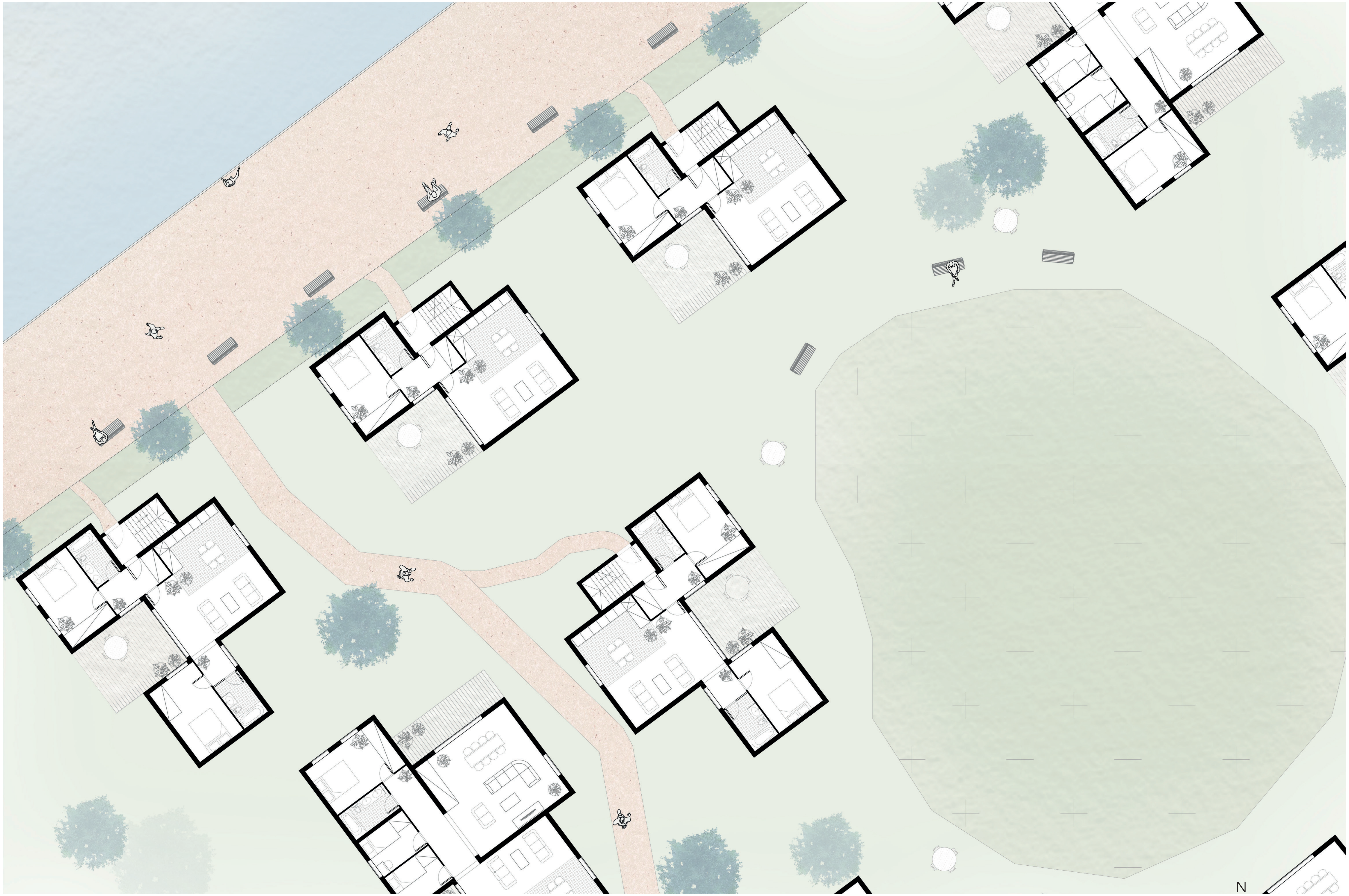
From that main road, some smaller paths are leading to the appartment buildings. Some planted areas separate the paths from the housing, to give more privacy to the appartments located on the ground floor. The building appartments are 2 or 3 stories high, and most of the rooves are terrasses. Solar panels are located on the highest rooves to provide electricity to the buildings.

Each entrance is facing the paths and when entering the appartments, each living space is facing the common gardens. This enhances the aspect of a community and creates small sub-neighborhoods within our neighborhood. Every appartment building is placed in a way so that there is a gap of at least 6m in front of living areas (living rooms and dining rooms) and 4m in front of bedroom windows. This was a ground rule that was set up after the direct sun light and Sky Component analyses.

Along the riverside, an area of 12m wide is dedicated to pedestrians, cyclists, and joggers to enjoy the riverside. On this bank are located some outdoor sport equipements and benches. Further north at the top point of our site, the pedestrian walk gets wider with some benches and tables to allow people to sit down and relax whilst enjoying the view. Also, this area is located between the two bridges, which is easily accessible for the rest of the people living or working on the other side of the river. Planted trees separate the pedestrians with the appartment buildings and create a green belt around the site.

On the site, 54 buildings containing about 130 appartments can host about 505 people. This gives us a density of 505 / 42 000 = 0,012. Sagmoen, the residential neighborhood at the border of our site, for a same amount of m2, hosts 36 houses. We then have a higher density, although the ground space index stays about the same, and doesn't look out of scale on the site map.

Mass plan 1:1000



Ground floor plan, showing a part of the site

1:200

Site façade, looking from the riverside towards the buildings

DIMENSIONING AND FLEXIBILITY OF THE DESIGN

When it comes to dimensioning the appartments, the goal is first to be the most compact as possible. This is in order to densify the site as much as possible. Once everything is densified, we can rearrange the positions and the dimensions in order to give more quality to the site and the appartments.

Using modular design

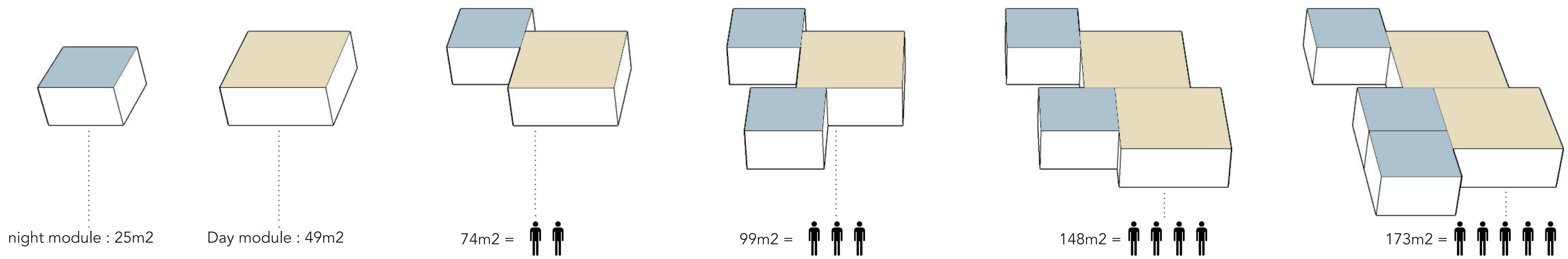
The use of modules dictates the shape of the appartments and the design. This approach allows to separate appartments into different parts and add modules or remove them according to the number of people living in one appartment. By using a modular design, every module can be built off site and assembled (or disassembled) on site. This permits fast assembly, design flexibility and cost reduction. Using modularity in the design can have many advantages as well as disadvantages. Often the advantages are the same as the disadvantages, if they are designed in a bad way. For exemple, modularity can give a lot of flexibility in the design, adding or removing modules, or combining different dimensions of modules according to different functions. But it can also lead to a bad design, bad performances or excess costs if it is badly dimensionned.

In an interview of Hermann Koffmann in 2018 (by architect Mihkel Urmet, TEMPT architects) : «*About wooden architecture and timber construction*», the architect explains that more and more nowadays we can observe a renaissance of wooden constructions in architecture. This is mainly due to new techniques and regulations, like the use of CLT in buildings for exemple. Regarding the question of prefabricated modules, Hermann Koffmann explains that it is the challenge of the architect today to be able to design good modules, and as long as the modules are designed properly, the result will follow.

Dimensioning the modules

Two different types of modules are being used. A «night module» of 25m2 (5x5) includes one big bedroom (or 2 small, depending on the number of people living in every appartment), one bathroom and some space for storage. A «day module» of 49m2 (7x7) contains space for an open kitchen and dining area, and a living room. The entrance is positioned in between the two modules, it is part of both and link them together. Every module is arranged in a way that the living area opens onto a private terrace.

According to the modules, 4 different typologies are designed. As the neighborhood is a residential neighborhood for families, the 4 typologies adapt to 4 different familly types. A «night module» and a «day module» are enough for a couple, and results in a 74m2 appartment with a terrace on the ground floor and balcony on the top floors. For a familly of three, a «night module» is added. This can also suit a couple wanting to have an extra room, such as an office or a guest room. A «day module» is added for a familly of four, and one of the «night modules» contains two small bedrooms. The added «day module» will host a second livingroom that can be parted in a study place and a play room, or just a living room for exemple. Finally, a familly of five have two day modules and three «night modules», hosting two big bedrooms and two smaller ones, two bathrooms and two living spaces.



Dimensions of modules and appartments

STRUCTURE, MATERIALS AND QUALITY OF WOOD

Wooden buildings are deeply connected to the Norwegian tradition. By using different techniques, from the log houses to the stave churches, Norwegians have developped knowledge and craftmanship in the wood construction along the history of building.

Today, in Norway, the wood industry is on the move and thanks to new techniques we can now use this material on a bigger scale. In the 90s, Cross Laminated Timber (CLT) constructions were developped, allowing to build higher, faster and influencing this change of scale in the wood constructions (*Tracing a timber breakthrough*, Marius Nygaard, Catherine Sunter and Ona Katrina Flindall, 18 Dec 2016).

CLT prefabricated modules also took part in this change of scale, and allowed to build faster and in a more economical and ecological way. On this project, CLT prefabricated modules are used for appartments, and brickwall constructions are used for the staircases leading to the second and third floor appartments. Having a different type of construction for the staircases allows an increase of the thermal mass and a variation in the design of the façade.

Each module will be assembled on site. Floor and roof slabs, and loadbearing wall panels will be made of CLT. Some non-loadbearing partition walls (for bathrooms and bedrooms, for exemple) are added according to the design plan. A rockwool insulation, rain shield and vapor shield are used between the CLT pannels and the wood cladding of the façade. By locating the CLT panels on the inside of the insulation layers, the structure is protected from the outdoor climate. A small amount of concrete is used for a pile foundation system with concrete posts.

In the night modules, for the rooves and floors slabs, CLT panels of 500x250cm each are used. For vertical panels, 290x250cm panels are used for walls. On the day modules, three different panels dimensions will be used for the rooves and floors slabs: 500x250cm; 500x200cm and 200x200cm. For the walls, panels of 290x250cm and 290x200cm will be used. On open elements, or where two panels are linked, beams are required to support the assembly.

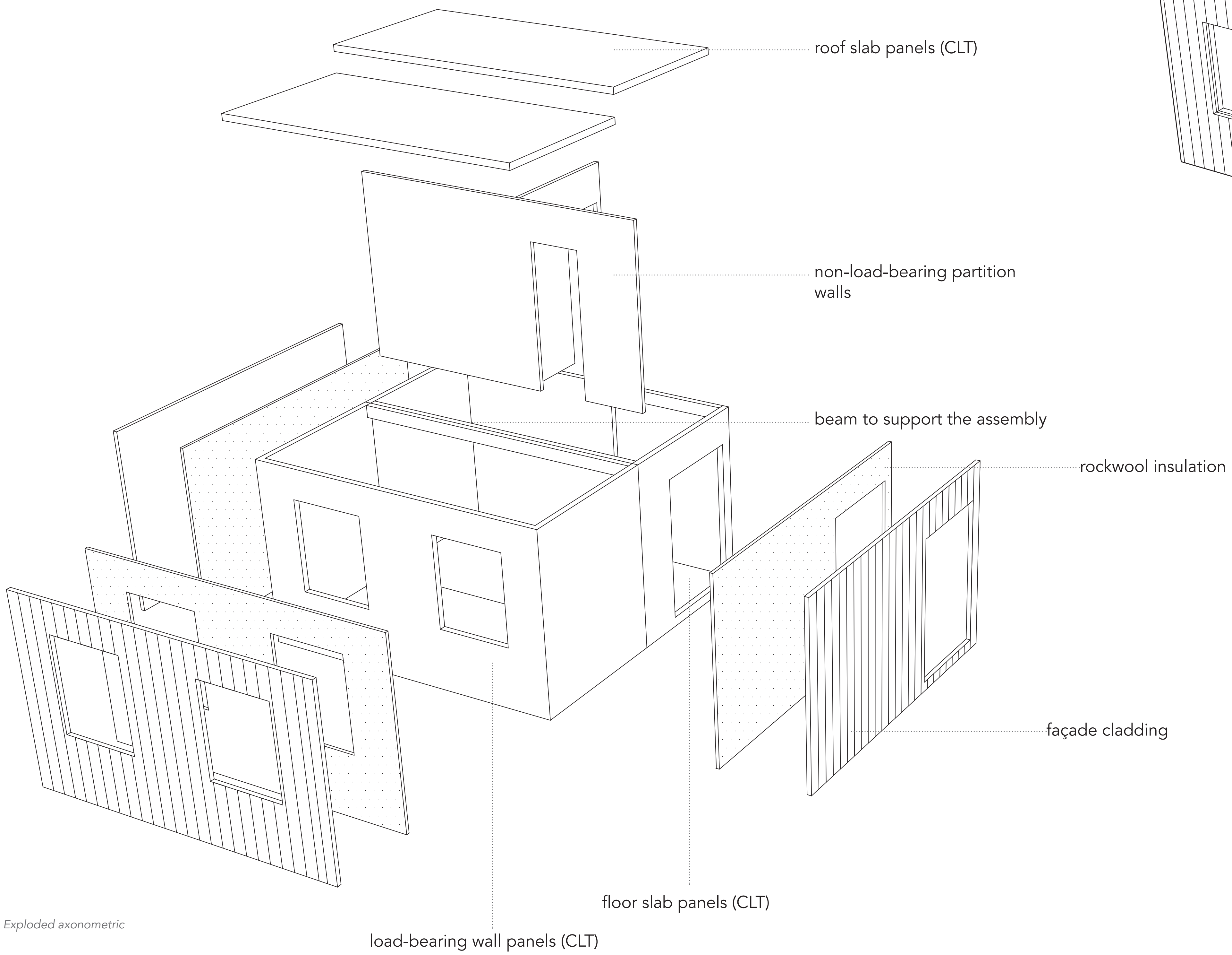
On a Life Cycle Assessement perspective, working with the Moelven company ensures a use of local wood materials. Also, every module being assembled on site, they can be disassembled and transported to an other site easily. At the end of the life cyle of a module, the wood can be reused for other purposes or recycled. At the end, the waste coming from the CLT can also be chopped in woodchip or burnt and converted to energy.

Finally, wood is known as a warm material and using CLT in the design will provide a better thermal sensation as well as a good athmosphere for the people living there.

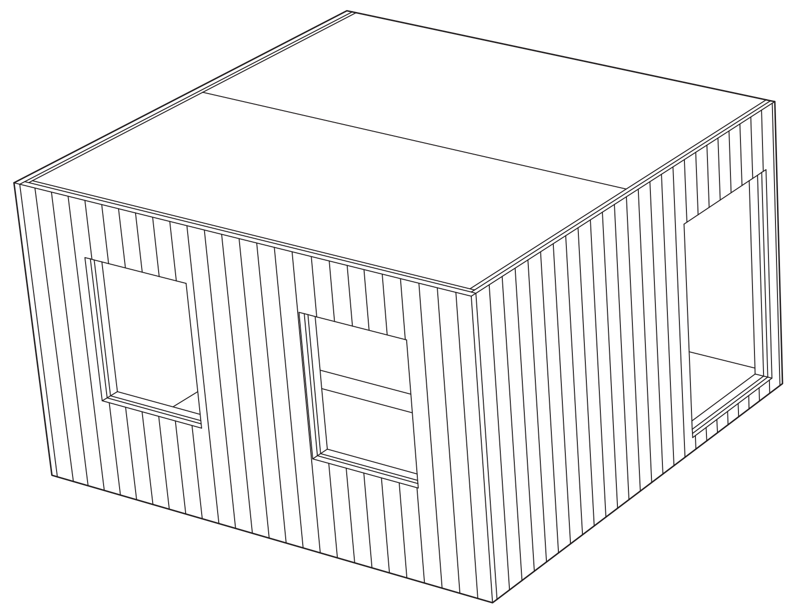
Façade of one of the buildings, showing variety of materials

1m

Axonometric of a module (night module)

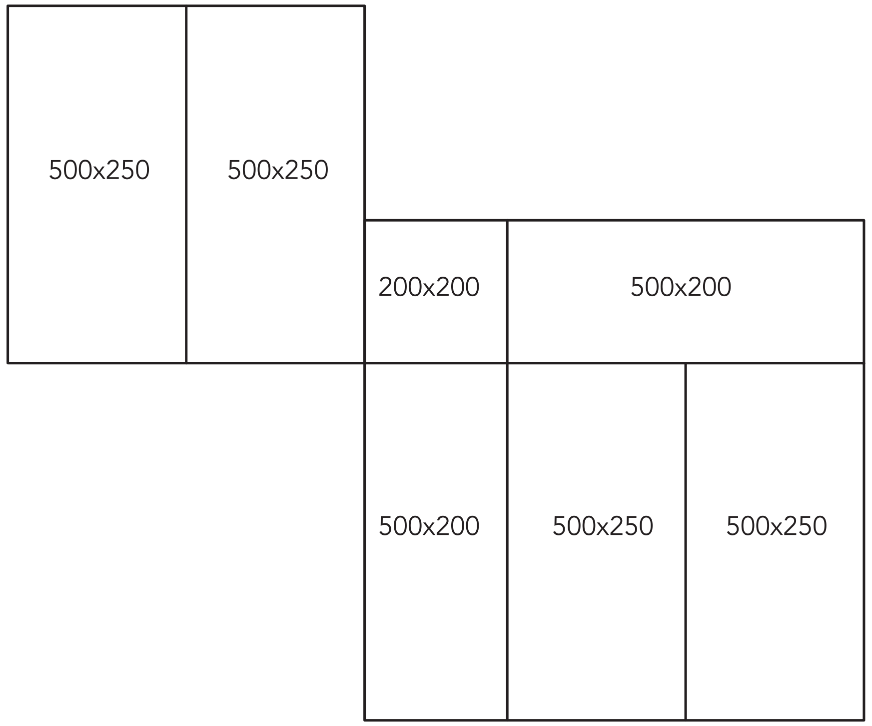


Exploded axonometric

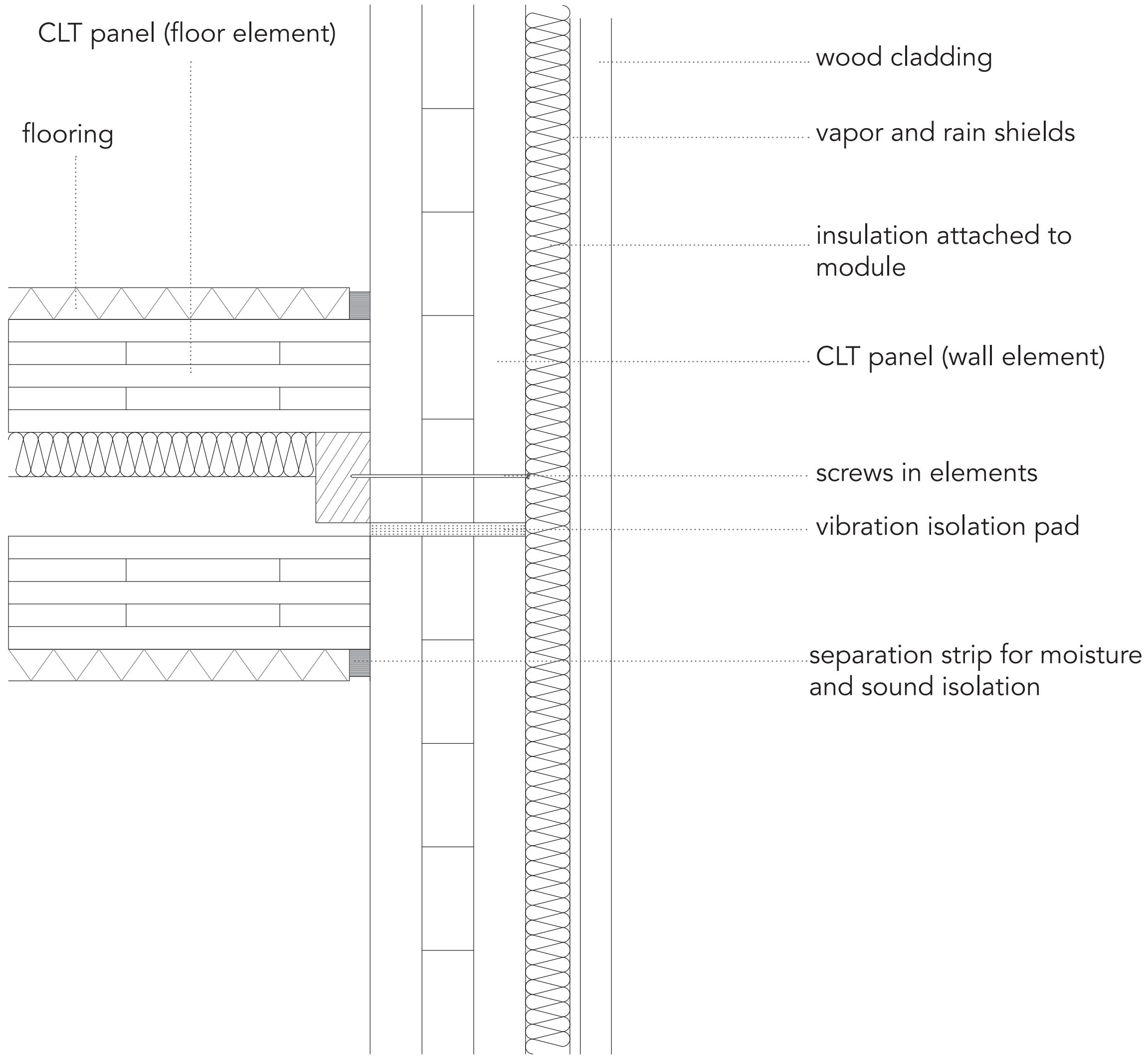


Completed element

CLT panels assembly and stacked modules detail



CLT panels assembly for floors and roofs slabs (dimensions in cm)



Stacked modules detail floor/ceiling/walls (1:5)

THE APPARTMENTS, DAYLIGHT FACTOR AND INDOOR QUALITY

Working with daylight in the appartments was a constant back and forth between the design and the simulations. Every changes of dimensions affected the results of the simulations, and a lot of time has been spent on trying to find the right proportions so that the modular system would be possible and that the people would get enough space and enough daylight.

When calculating the Average Daylight Factor (ADF), the european recommendation is a minimum of 2% in living area, and 1,8% in bedrooms or working spaces. Although, in this project, a minimum of 2% in every room (except bathrooms and entrances) is set.

A first series of simulations were made (see annexe) but after reflection, the dimension of the rooms were too small and it was necessary to rethink the design. This resulted in a less dense neighborhood, but with better indoor and outdoor qualities. In this first series of simulations, after several variations, 3 different sizes of window were chosen. For bedrooms: 120x150cm windows are being used, placed 90cm above the floor. For living rooms, glass doors and large windows are being used: 345x230cm, placed 5cm above the floor. This allows to get more daylight in living spaces, where people spend most of their time. An intermediate size window was set: 150x230cm, 5cm above the ground. This size of window is for spaces such as end of hallways or kitchens.

After redimensionning the appartments, a second series of simulations were made with the same window sizes. However, because the rooms are bigger, the first ADF results were lower. Sometimes, the ADF was even too low. One option was to increase the window size again, but another option was to add windows in rooms with too low ADF. It was prefered to keep to same window size in order to have a standardized size of window, which makes it easier and more efficient when preparing the modules and building the appartments.

Every simulation was done considering surrounding buildings around with an average height of 2 story, located 4m away from bedrooms and 6m away from living spaces. Some appartments on the site have better conditions, but it was more relevant to simulate the worst case scenarios on our plot, to make sure that even the worse case scenario would be good enough. The orientation of the rooms doesn't affect those simulations since an overcast sky is set in order to get the average daylight factor.

The first appartment (fig.1) is for two person. The entrance links the «day module» and the «night module» together. The entrance is lit by an intermediate sized window (150x230cm) and the room gets an ADF of 3,1%. The living area is very well lit by two windows, giving an ADF of 4,2%. Having the intermediate sized window by the kitchen was not necessary, but has been placed there in order to provide a variaty of views in the room and a more uniform light in the room. The bedroom was first lit by one window and was getting too little amount of daylight (1,5%). Another window has been added and the ADF went up to 3,3%. Every room from the first appartment is now well lit.

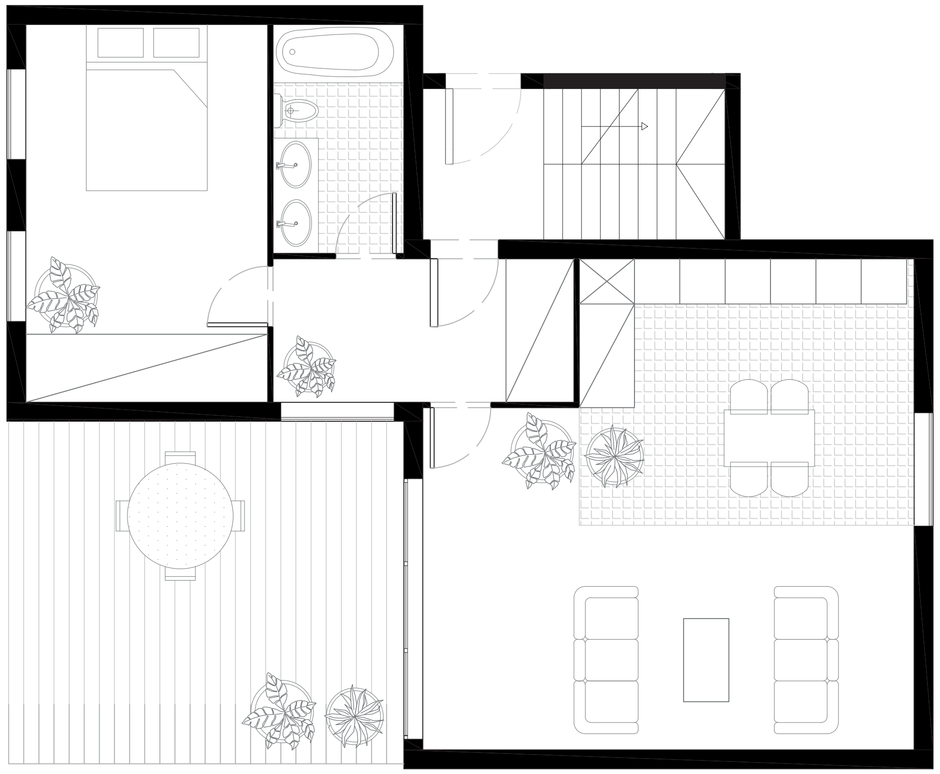
The second appartment (fig.2) is an appartment for three people. One «night module» has been added with one bedroom. The average daylight factor in the two first rooms is the same as for figure one. In the added module, a buffer space is lit by an intermediate sized window and gets an average of 6,4%. The bedroom is also lit by an intermediate sized window and gets an ADF of 2,5%. A second window in this bedroom is not needed. The reason why this bedroom is lit by a bigger window is because the bedroom opens towards the private terrace.

The third appartment (fig.3) is for four people. One «day module» has been added. The two smaller bedrooms located in a «night module» need one bedroom sized window each to get a sufficient amount of daylight. The small bedrooms then get an ADF of 3,1%.The day module that has been added gets an ADF of 3,2%, being lit by a big sized window and an intermediate sized window.

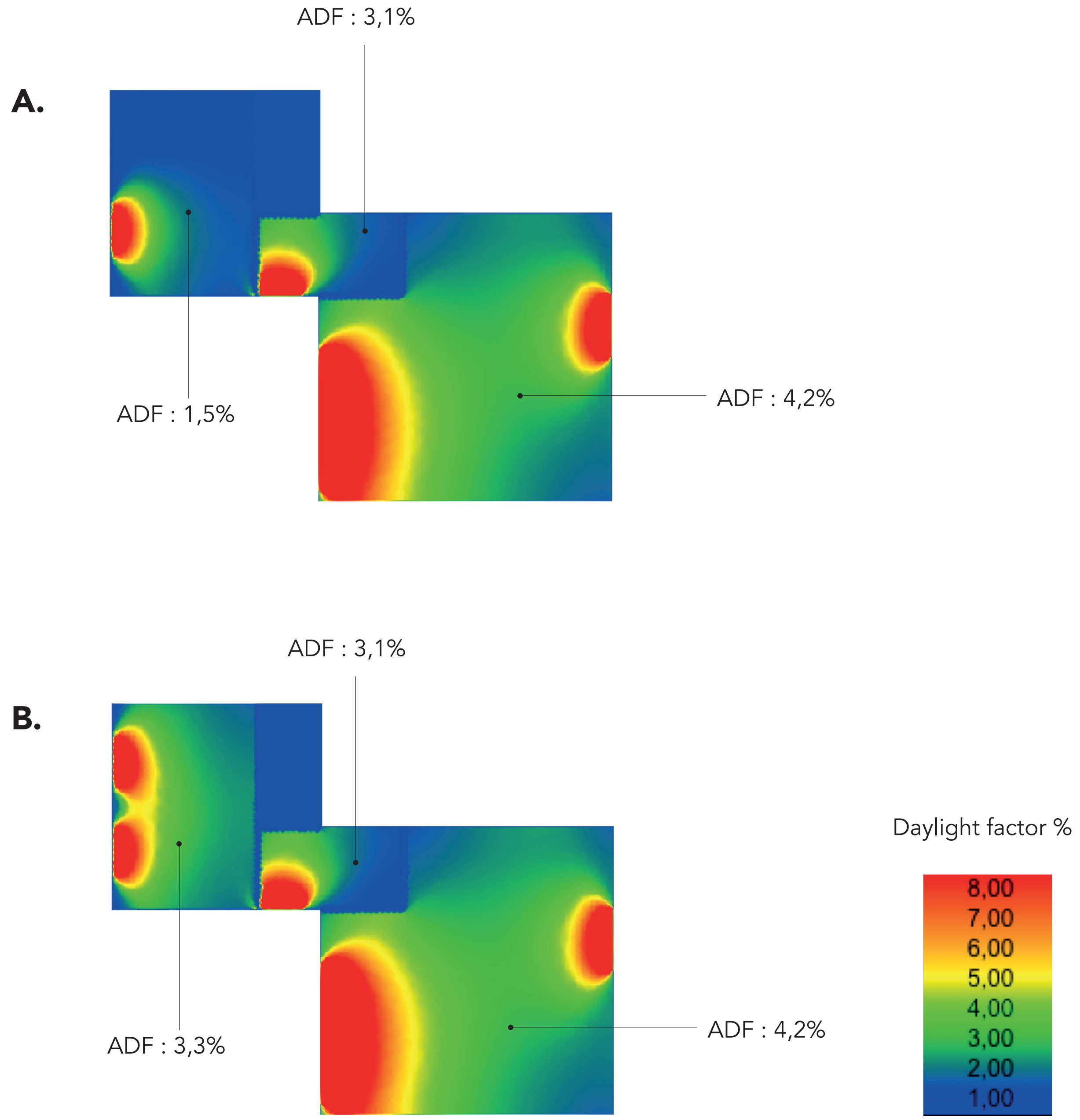
The fourth appartment (fig.4) is for five people, and one «night module» has been added. The bedroom in that last module has the same dimensions of the one in the first module, and is lit by two bedroom sized windows. The room gets an ADF of 3,4%.

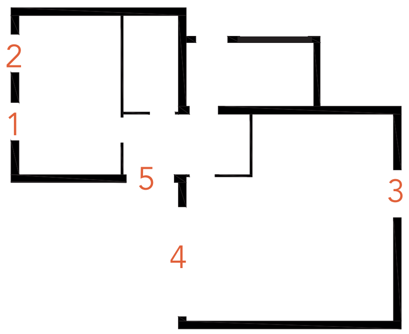
After the last simulations, every appartment are well lit. In addition to the use of wood in the buildings, daylight also has a positive effect on people living in the building. It also reduces the need for electric lighting and saves energy as well as electricity cost. Having a good amount of daylight in the appartment is necessary, although sometimes it can produce discomfort such as glare or sunlight patches. To solve this problem, louvers are placed in front of the windows.

Average Daylight Factor - 2 modules appartment



floor plan 1:100



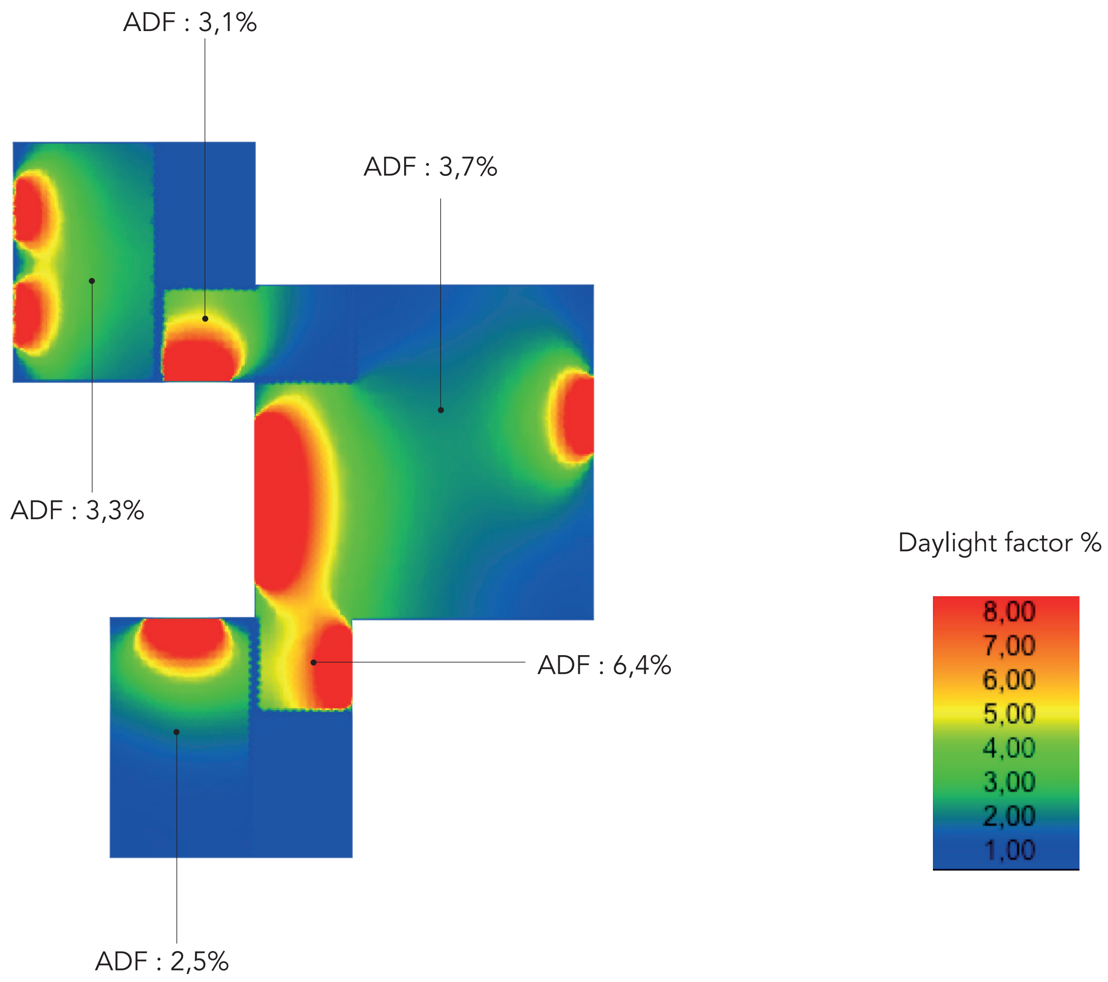


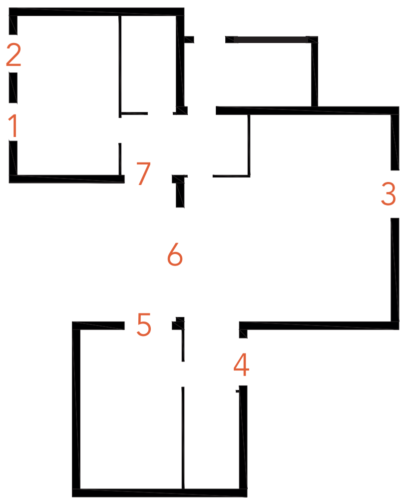
1. 120x150; 90cm above ground
2. 120x150; 90cm above ground
3. 150x230; 05cm above ground
4. 345x230; 05cm above ground
5. 150x230; 05cm above ground

scheme showing window openings and windows size (cm)

Average Daylight Factor - 3 modules appartment

floor plan 1:100



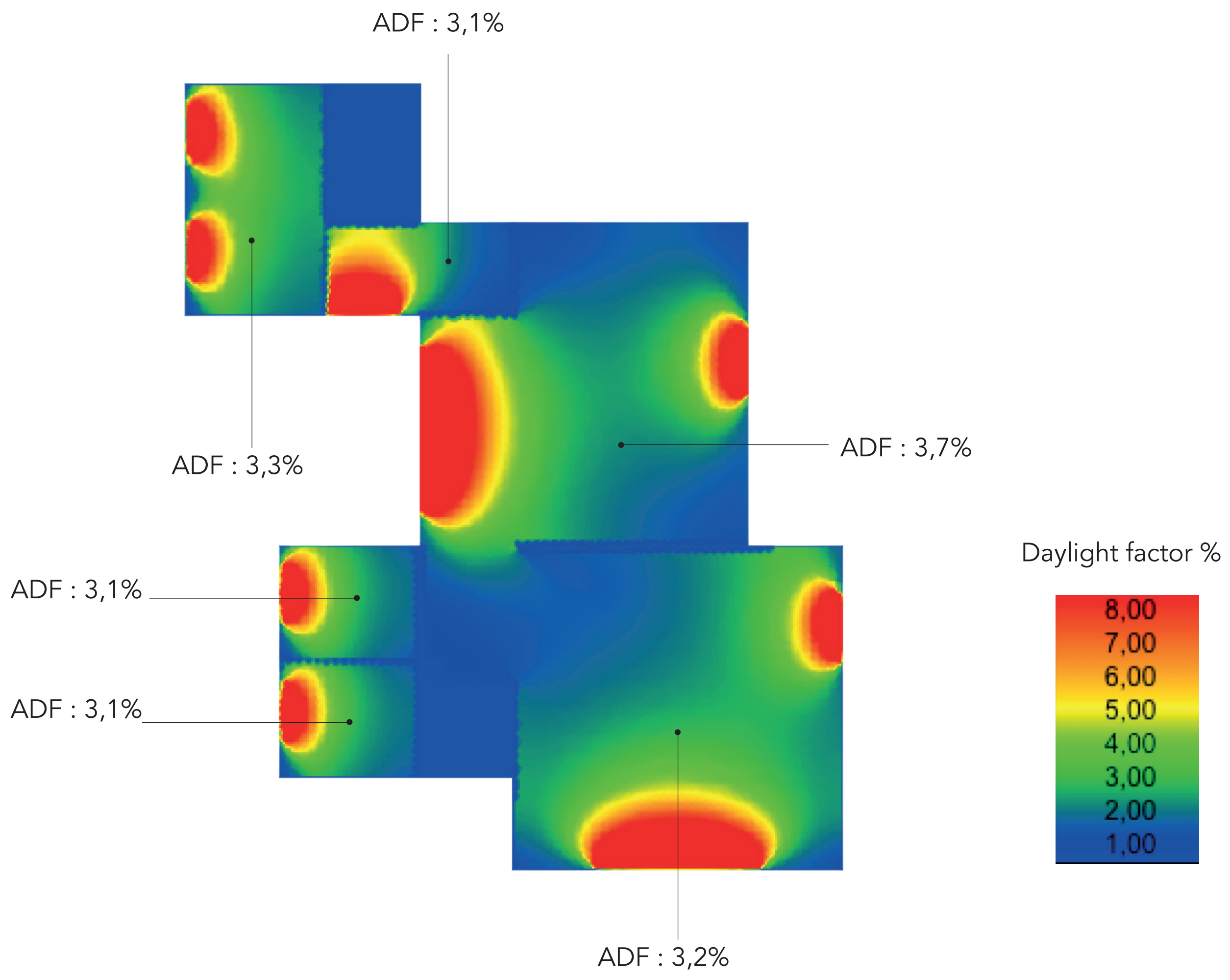


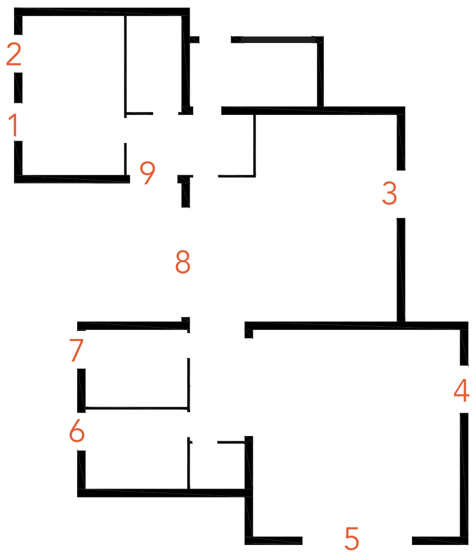
1. 120x150; 90cm above ground
2. 120x150; 90cm above ground
3. 150x230; 05cm above ground
4. 150x230; 05cm above ground
5. 150x230; 05cm above ground
6. 345x230; 05cm above ground
7. 150x230; 05cm above ground

scheme showing window openings and windows size (cm)

Average Daylight Factor - 4 modules appartment

floor plan 1:100



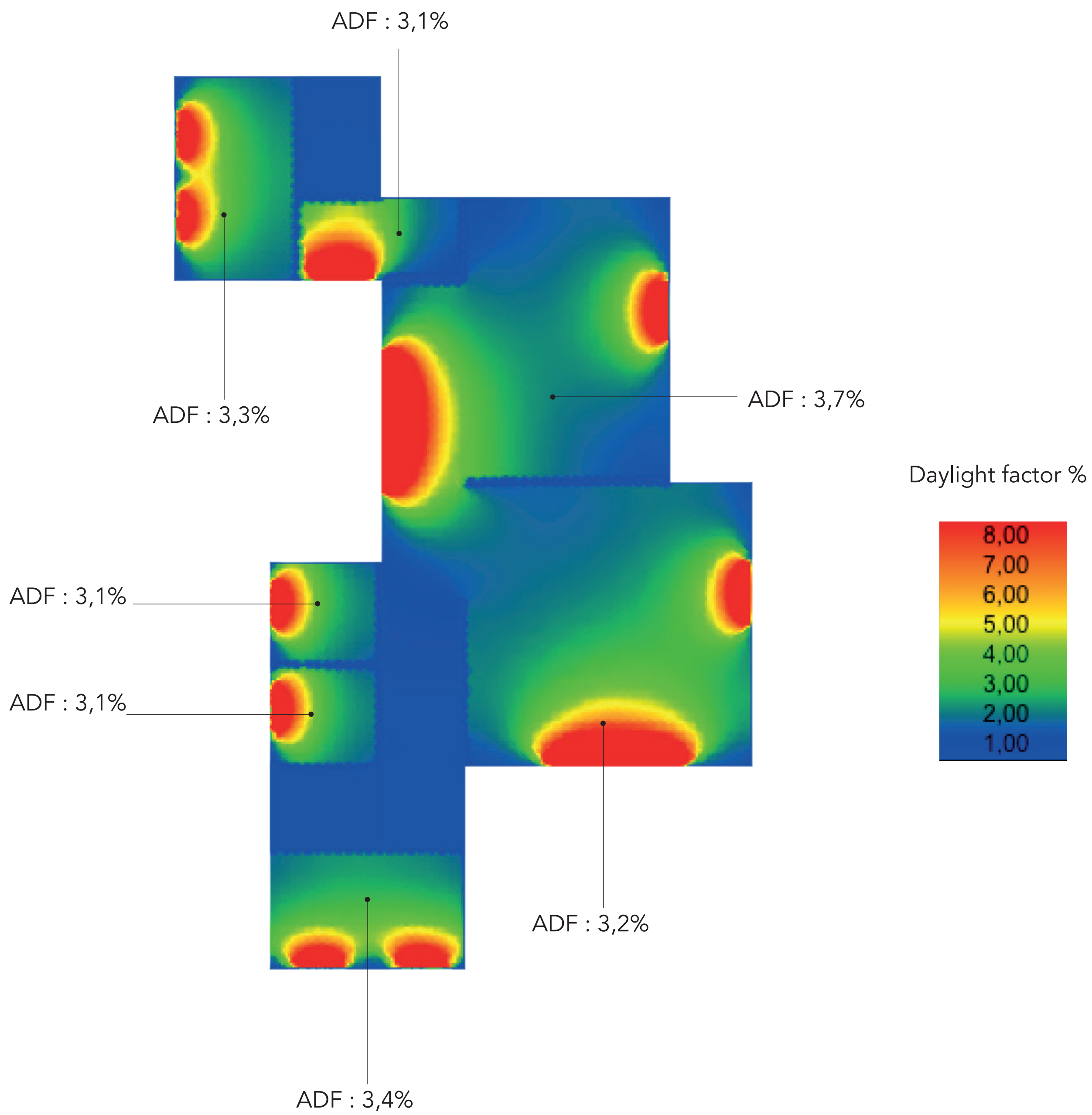


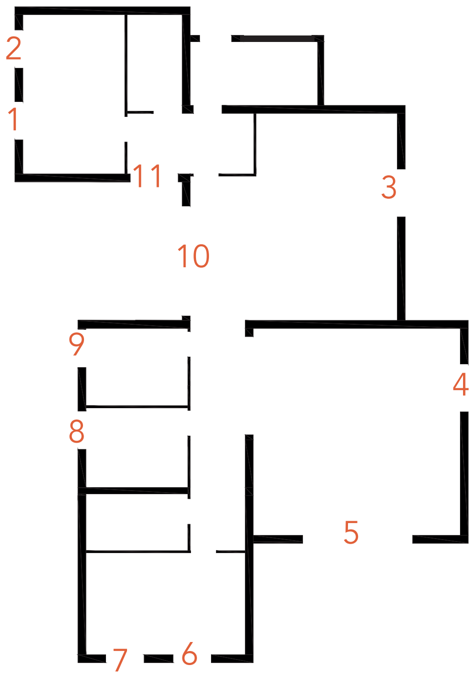
1. 120x150; 90cm above ground
2. 120x150; 90cm above ground
3. 150x230; 05cm above ground
4. 150x230; 05cm above ground
5. 345x230; 05cm above ground
6. 120x150; 90cm above ground
7. 120x150; 90cm above ground
8. 345x230; 05cm above ground
9. 150x230; 05cm above ground

scheme showing window openings and windows size (cm)

Average Daylight Factor - 5 modules appartment

floor plan 1:100





1. 120x150; 90cm above ground
2. 120x150; 90cm above ground
3. 150x230; 05cm above ground
4. 150x230; 05cm above ground
5. 345x230; 05cm above ground
6. 120x150; 90cm above ground
7. 120x150; 90cm above ground
8. 120x150; 90cm above ground
9. 120x150; 90cm above ground
10. 345x230; 05cm above ground
11. 150x230; 05cm above ground

scheme showing window openings and windows size (cm)

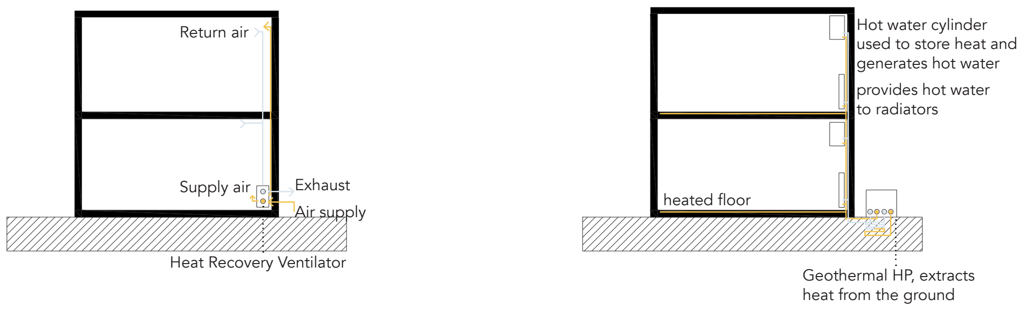
PASSIVE AND ACTIVE STRATEGIES

In this project, the buildings have different orientations, the goal of the design being to place the buildings around common gardens, although most of the appartments have their living spaces facing South, West, or South-West. Having big windows oriented in this direction allows solar heat gain and reduces the heating demand on the buildings. Windows in the livingrooms and bedrooms are operable and provide cross ventilation in the appartments, through windows and doors. As the brick is a dense material with a high thermal mass, having the staircase exposed to sun will increase the thermal mass of the building, absorbing heat during the day and releasing it at night, allowing for a higher thermal comfort.

A ventilation system with heat recovery ventilator (HRV) is used in every building.This improves indoor air quality and reduces energy consumption. Indeed, this preheats the cold air from the outside in the winter, which reduces the amount of energy needed to heat up the appartments. In the summer, it works in reverse and cools the air from the outside before it gets in. Whilst providing the appartments with fresh air, it also releases the exhaust air from the inside.

A geothermal heat pump with boreholes is used to heat up every building. This allows a constant temperature all year around. The heat pump is connected to the underground, which has a constant temperature all year around of 14,9° (*NASA*, 2018). A geothermal system absords heat from the ground through a series of vertical or horizontal loop pipes (vertical in our case, because of limited space). Then, it releases the heat in the appartments, through a duct system. In summer, when the temperatures outside are higher than underground, it works in reverse and captures heat from the building to release it in the cool ground. It will provide the appartments with heating, cooling and hot water. Also, this will avoid burning fossil fuel for heating and reduce energy use.

On the rooves of our buildings, PV panels will provide electricity to the appartments.



Schemes of HRV system and GHP system

Perspective section presenting active and passive strategies

V. CONCLUSION

CONCLUSION

Moelven Eidsvoll Verk is a site that has had a strong wood history for centuries. Indeed, the area was already a wood processing area long before Moelven bought the site. Now, Moelven is moving elsewhere and wants to see a new potential for the use of their site. In this terrain it made sense to envisage new housings, knowing that the comune is expecting to see its population grow in the coming years. In addition, building the neighborhood with wood as a main material sounded like an obvious solution, considering the implaction of Moelven, and the history of the site.

Adapting to the challenges of today, trying to create a low CO2 emissions neighborhood was necessary. On an urban scale, reducing the use of the car in the neighborhood was an initial thought. At the scale of the neighborhood, being consious about the density issues was another step toward a sustainable neighborhood. Those two issues are connected. Indeed, being a big country with a small population, the Norwegian population is quite spread-out compared to the rest of Europe. Being more spread-out means that people commute more, and as the car is the easiest way of transportation, people tend to use it more. That is why an infrastructure and transportation study was relevant, and helped to realize that most amenities are accessible by public transport, walking and cycling.

On a building scale, trying to find solutions to build in a sustainable way, time efficient and cost efficient was the answer of CLT modules. Using a modular design permitted to get flexibility in the design according to the demand and to experiment with the assembly and create nice appartments. In these appartments, a daylight study was necessary to ensure a good indoor comfort and quality. Finally, thinking about passive and active strategies, especially systems such as heating/cooling system and ventilation system allowed to enhance the indoor quality in the appartments.

The limitations on this project were mostly time related. For a further research, the density aspect should be pushed forward, so the position of the buildings on site could continue to evolve until they reach a maximum efficiency.

Finally, building a sustainable neighborhood is complex and requires a lot of knowledge. In a multitude of techniques and answers for a better environement, there are no good or bad solutions. However, the right one is the one that will adapt best to a site, according to the location, the climate and the context.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Per K. Monsen for his big support on the project, his constant enthousiasm, his precious informations and disponibility at any time.

I would also like to thank my second supervisor, Tommy Kleiven, that took over Per, and has been extremely comprehensiv and helpfull during the second part of my project.

Thanks to Pasi Aalto, my co-supervisor, who was able to give me great input on many subjects, especially about density and transportation.

Thanks to the Moelven company for their trust along the way to their site as a base for the project, welcoming us on the site and providing us with precious information.

Thanks to Barbara S. Matusiak, for the light and lighting classes that she gave last semester, wich pushed my interest more and more toward the necessity of good lighting in architecture.

Finally, thank you to the teaching team for all the very interesting classes and help along these two years of master.

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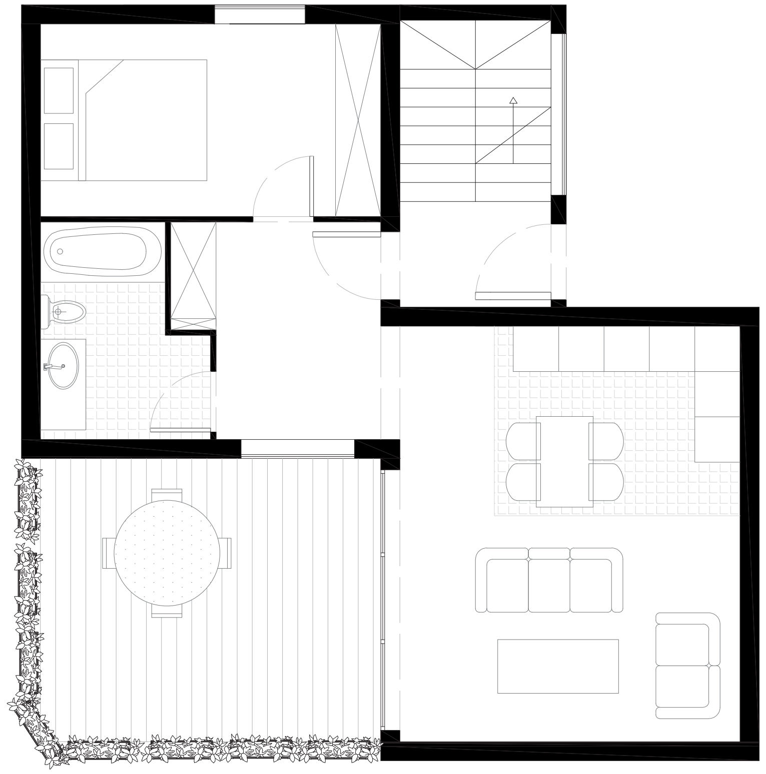
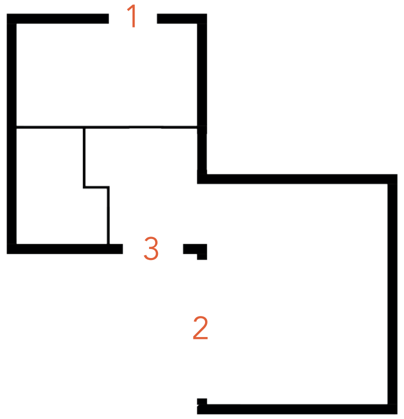
ANNEXES

Daylight analysis - scenario 1

Goal : average daylight factor (ADF) of minimum 2% in every room except bathrooms

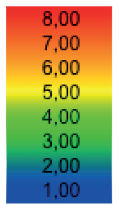


floor plan 1:100

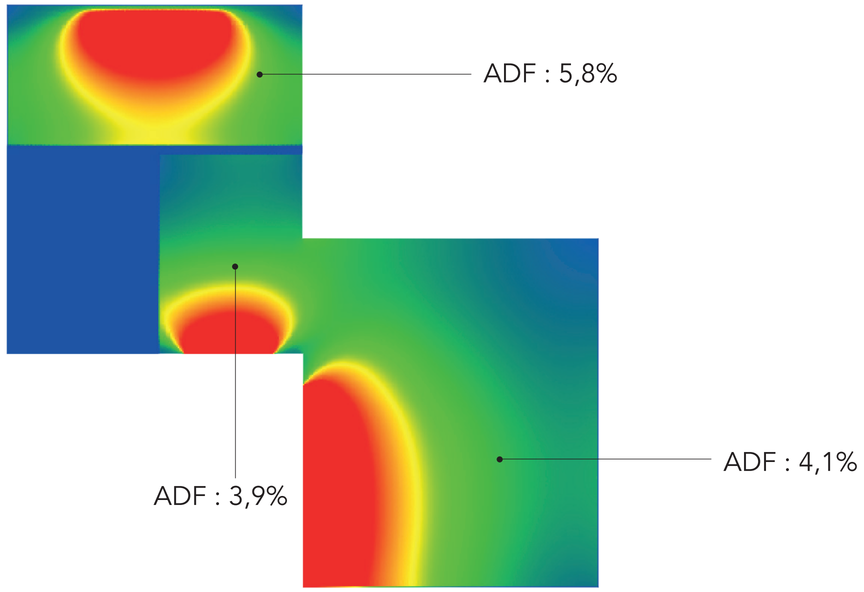


scheme showing openings

Daylight factor %



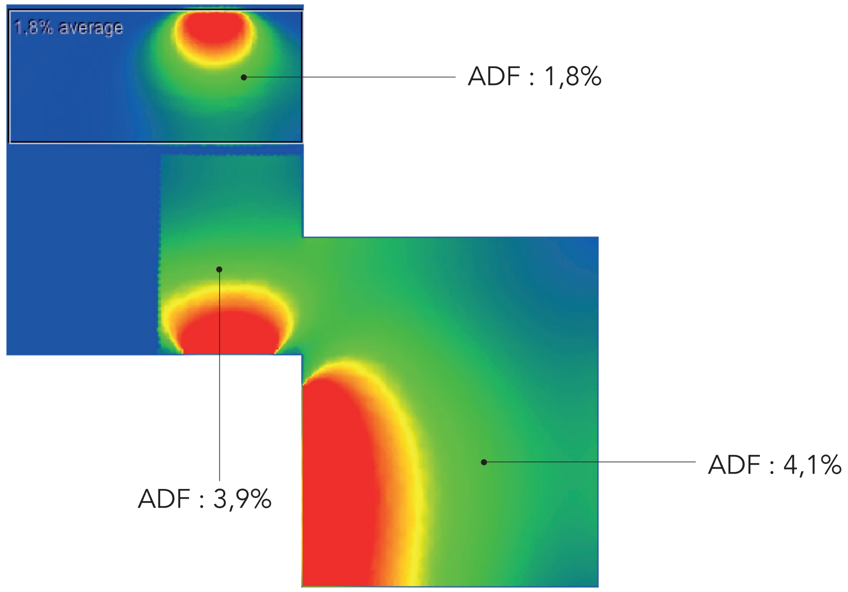
A.



1. 240x120; 80cm above ground
2. 150x230; 00cm above ground
3. 345x230; 00cm above ground

The ADF in the bedroom is very high. We can reduce the size of the window, so there is not so much thermal loss (window facing North).

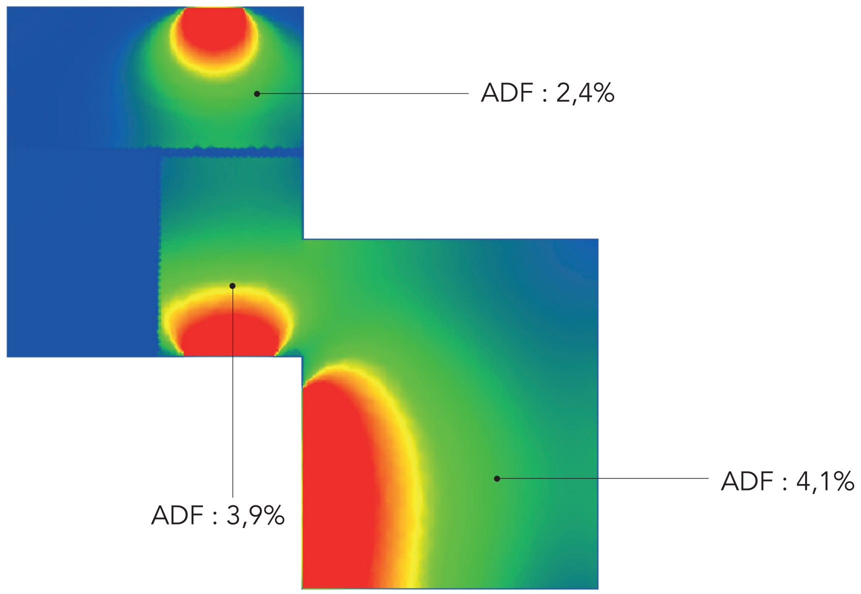
B.



1. 100x120; 80cm above ground
2. 150x230; 00cm above ground
3. 345x230; 00cm above ground

After reducing the window, the ADF is of 1,8%. According to regulation, it is ok to have a percentage of 1% minimum in bedrooms,but for this project we established a minimum of 2%.

C.



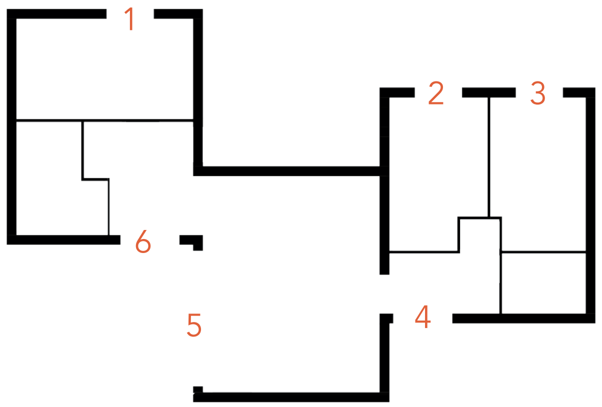
1. 100x150; 80cm above ground
2. 150x230; 00cm above ground
3. 345x230; 00cm above ground

We expended the size a little bit to reach our goal. The ADF is now 2,4%, which is above our goal.

Daylight analysis - scenario 2 (custom objects around, 6m high, 4m in front of windows)

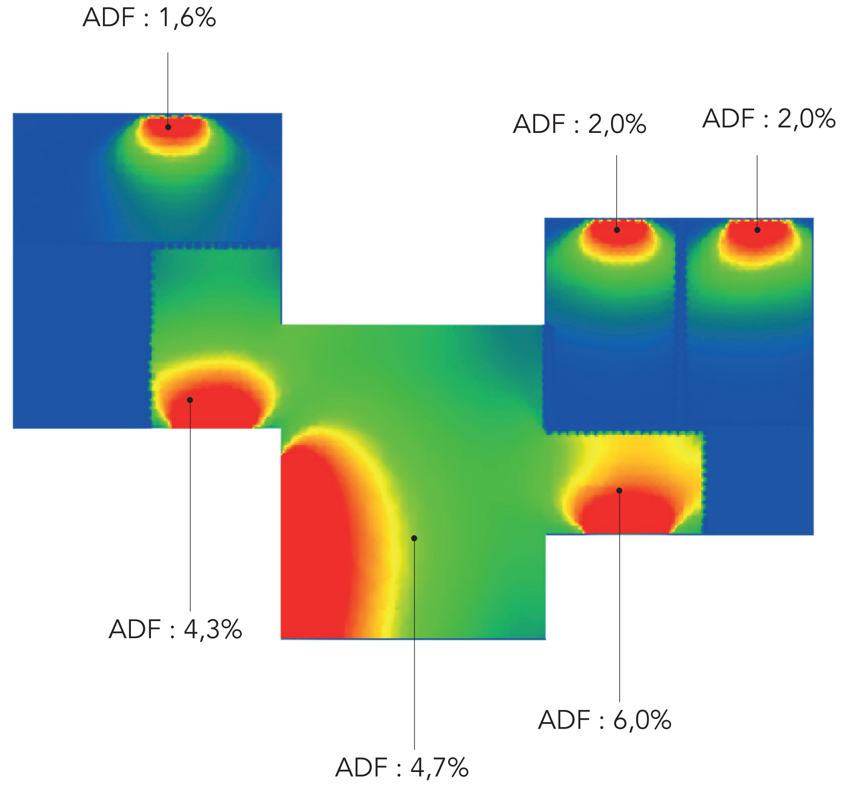
Goal : average daylight factor (ADF) of minimum 2% in every room except bathrooms

floor plan 1:100



scheme showing openings

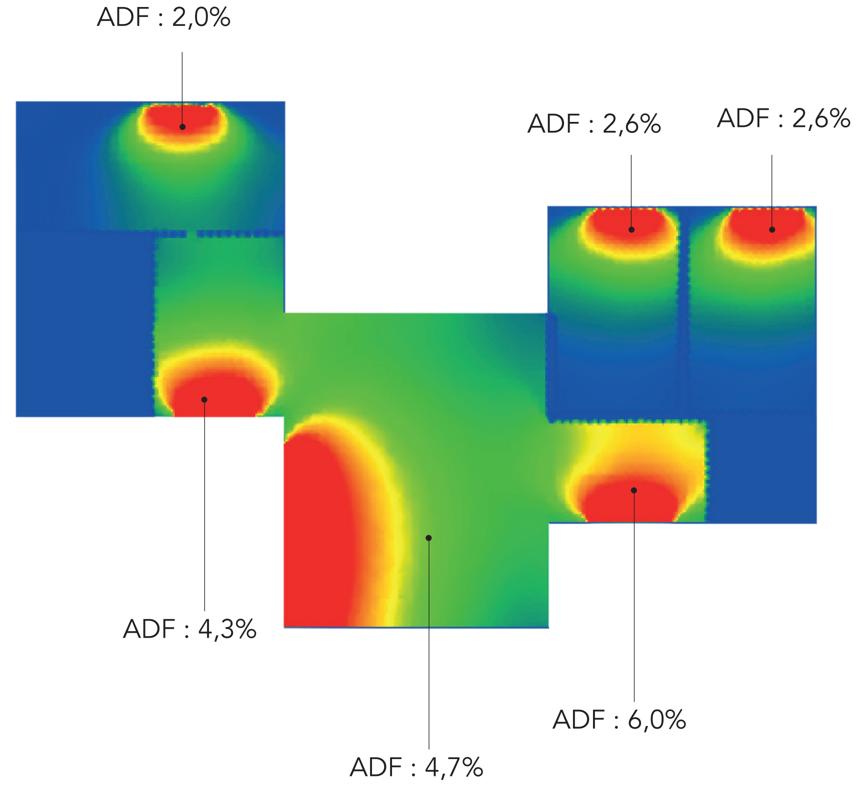
A.



1. 100x150; 80cm above ground
2. 100x150; 80cm above ground
3. 100x150; 80cm above ground
4. 150x230; 00cm above ground
5. 345x230; 00cm above ground
6. 150x230; 00cm above ground

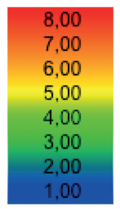
The ADF in the 1st bedroom is a bit low. We can expend the size of this window, and window 2 and 3 as well to have a standardized size for bedroom windows.

B.



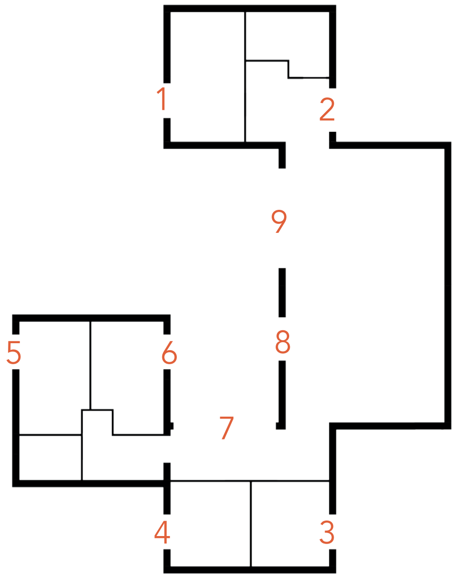
1. 120x150; 80cm above ground
2. 120x150; 80cm above ground
3. 120x150; 80cm above ground
4. 150x230; 00cm above ground
5. 345x230; 00cm above ground
6. 150x230; 00cm above ground

Daylight factor %

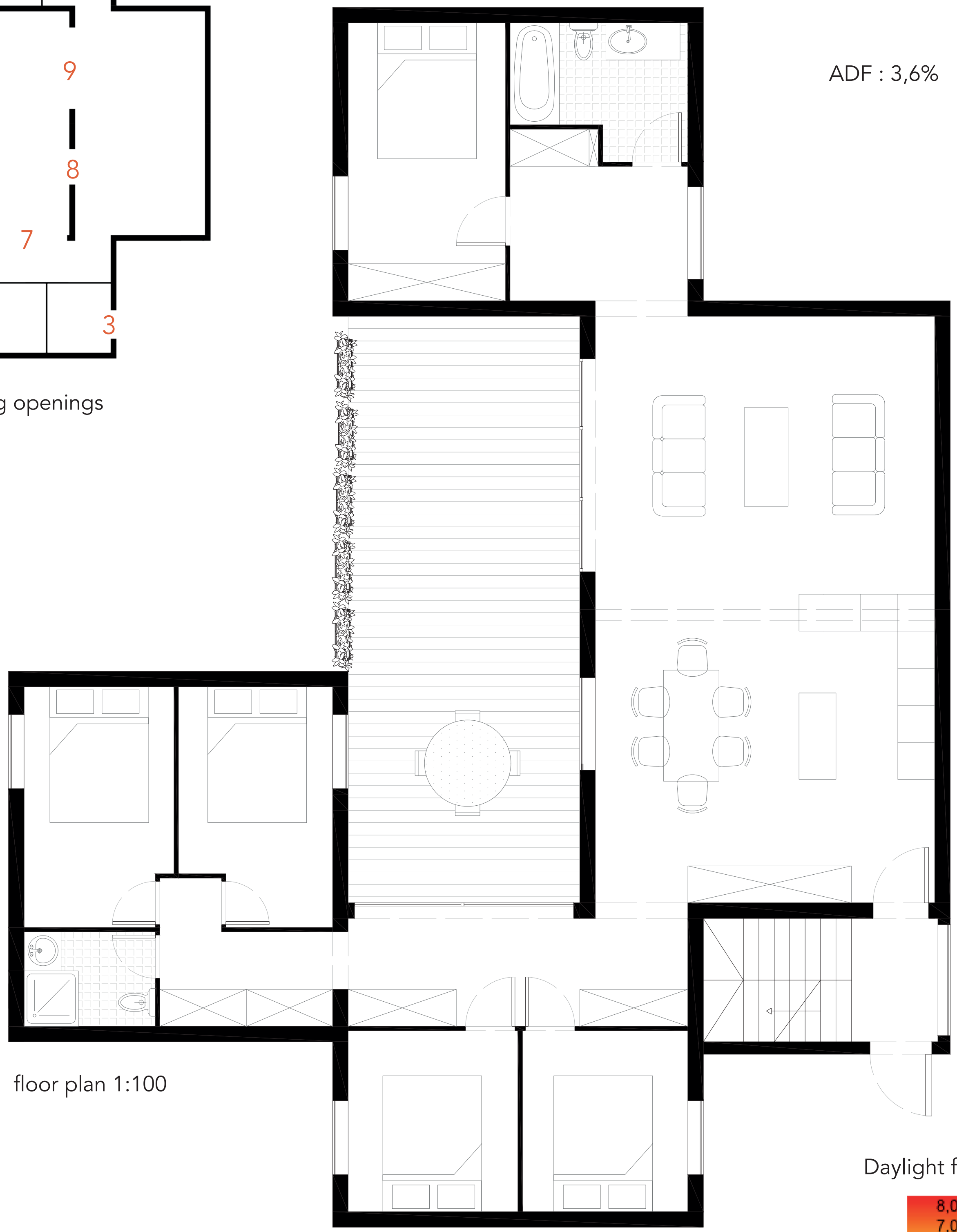


Daylight analysis - scenario 3 (custom objects around, 6m high, 4m in front of windows)

Goal : average daylight factor (ADF) of minimum 2% in every room except bathrooms

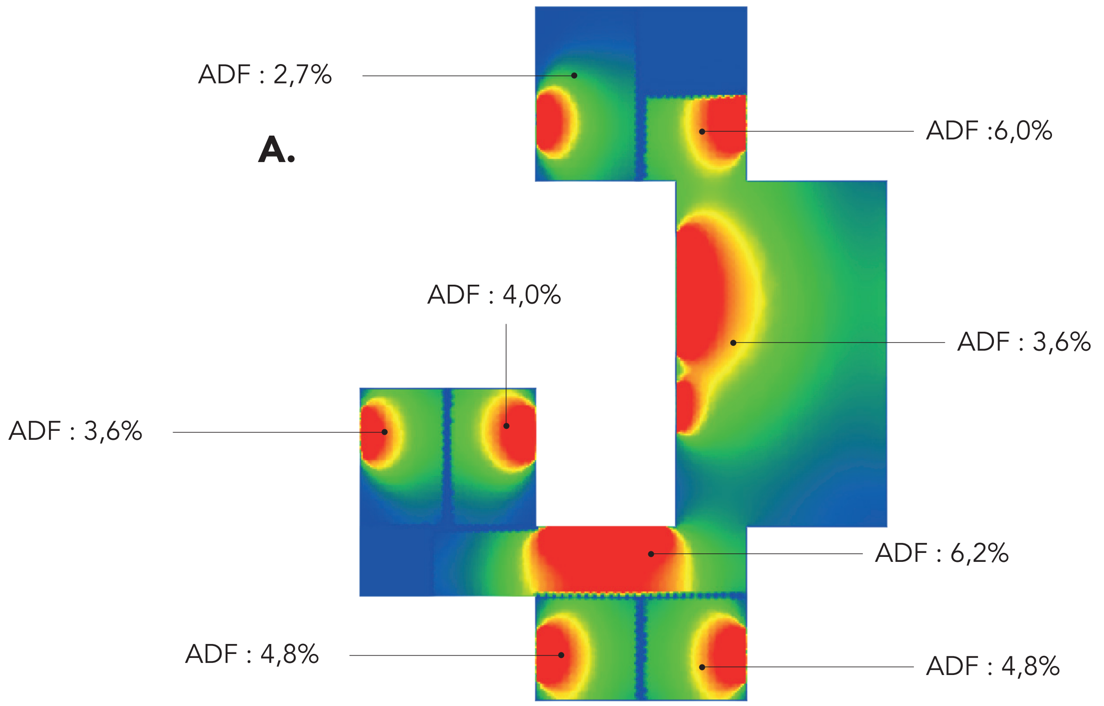


scheme showing openings



floor plan 1:100

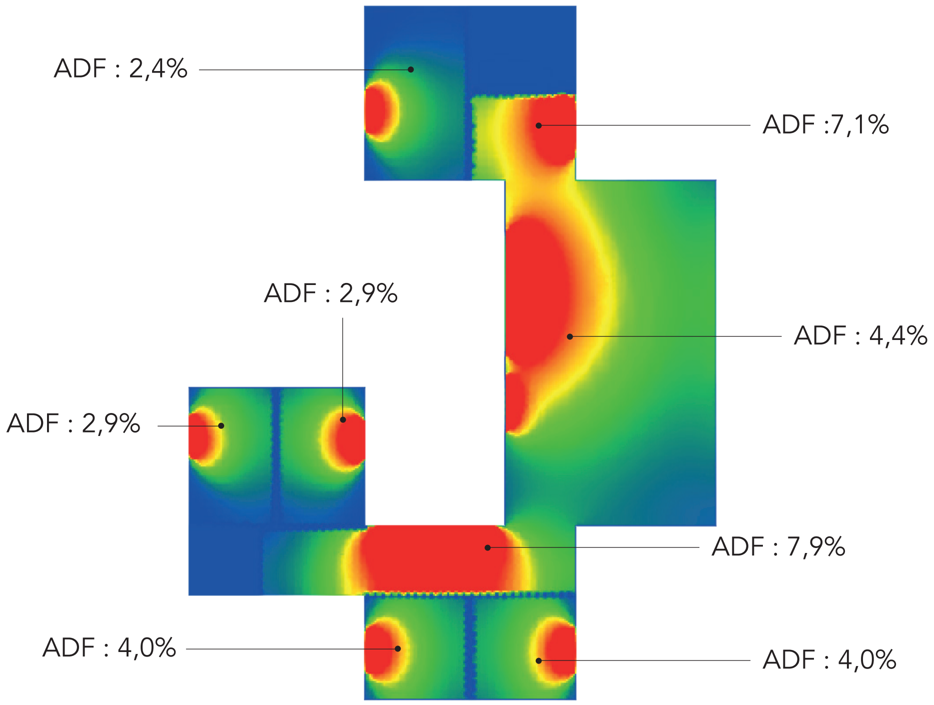
A.



1. 140x150; 80cm above ground
2. 140x150; 80cm above ground
3. 140x150; 80cm above ground
4. 140x150; 80cm above ground
5. 140x150; 80cm above ground
6. 140x150; 80cm above ground
7. 350x200; 00cm above ground
8. 140x150; 80cm above ground
9. 350x200; 00cm above ground

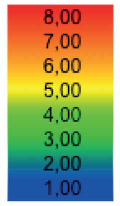
The ADF is sufficient in every room. Although, we want to uniformize the size of the windows like in the other scenarios, in order to have a standard size for bedrooms, glass doors and other windows.

B.



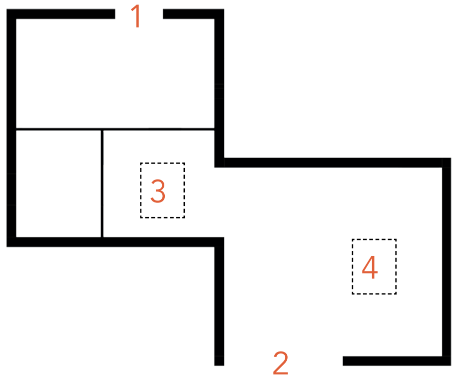
1. 120x150; 80cm above ground
2. 120x150; 80cm above ground
3. 120x150; 80cm above ground
4. 120x150; 80cm above ground
5. 120x150; 80cm above ground
6. 120x150; 80cm above ground
7. 350x230; 00cm above ground
8. 150x150; 80cm above ground
9. 350x230; 00cm above ground

Daylight factor %

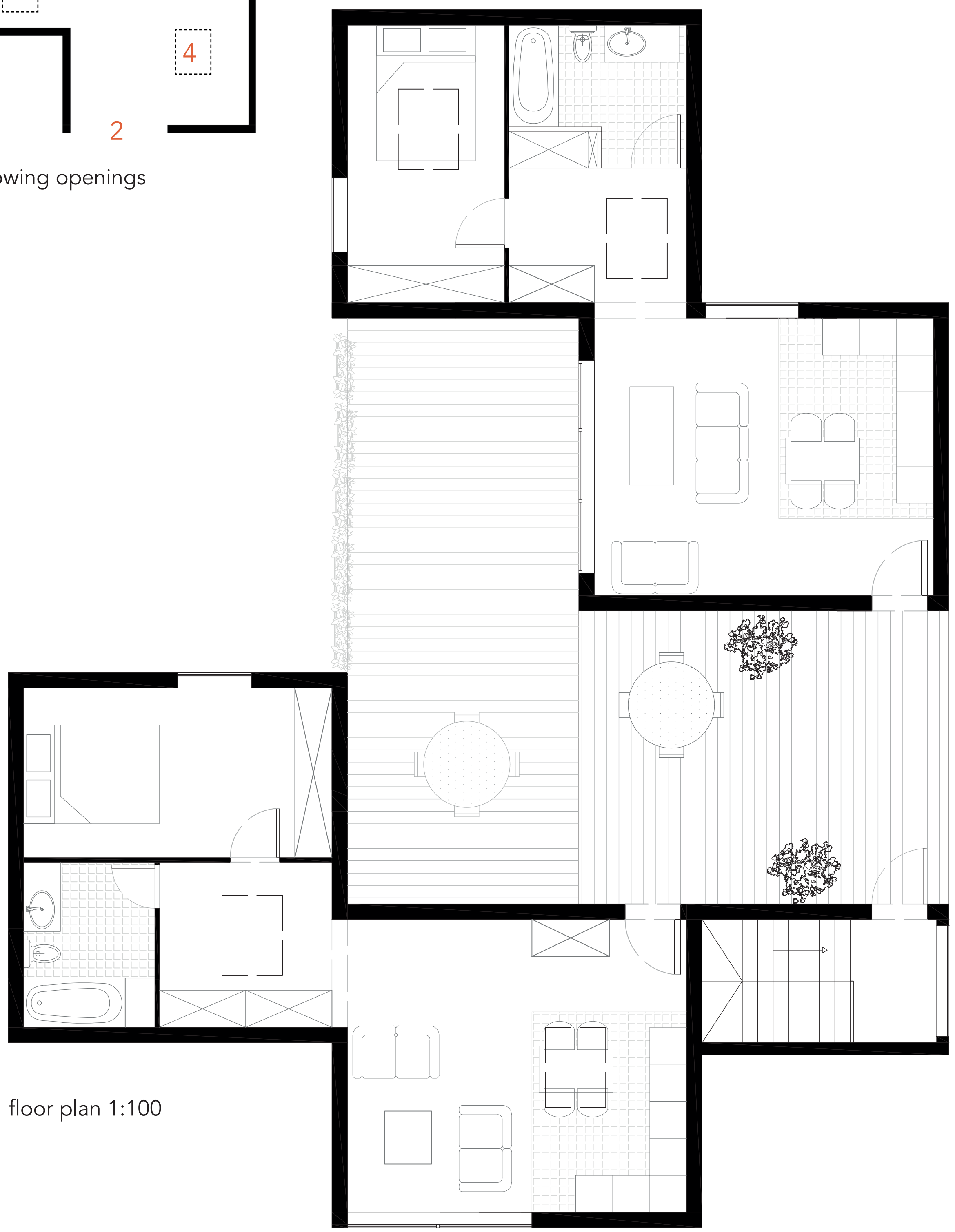


Daylight analysis - scenario 4 (pitched roof, custom objects around, 3m high, 4m in front of windows)

Goal : average daylight factor (ADF) of minimum 2% in every room except bathrooms

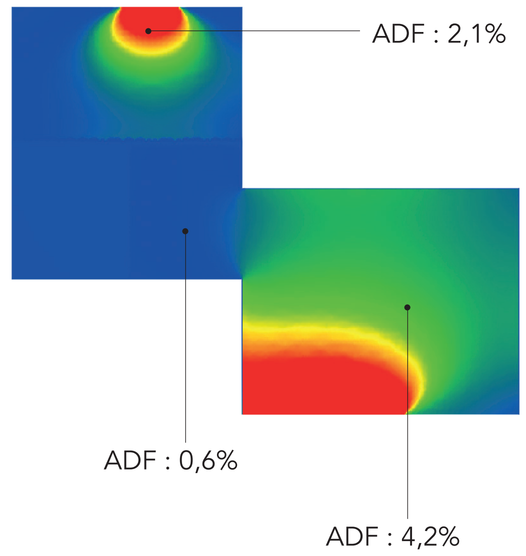


scheme showing openings



floor plan 1:100

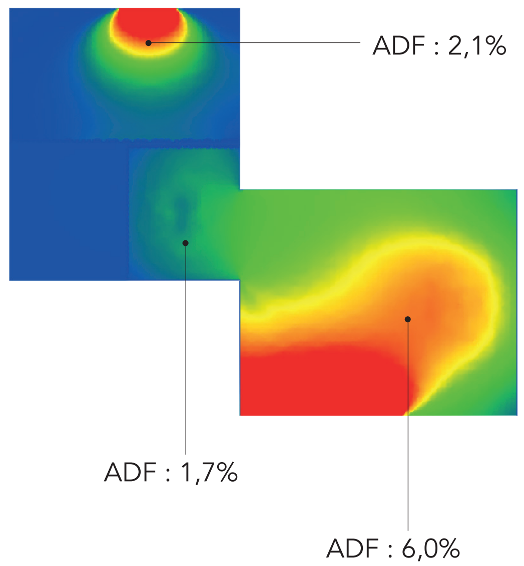
A.



1. 120x150; 80cm above ground
2. 350x230; 00cm above ground

Here we only have two windows. The ADF in the bedroom is sufficient, but not in the hallway. We can add a rooflight in the hallway. The ADF in the living room is sufficient but we can add a rooflight as well for cross ventilation and natural stack ventilation.

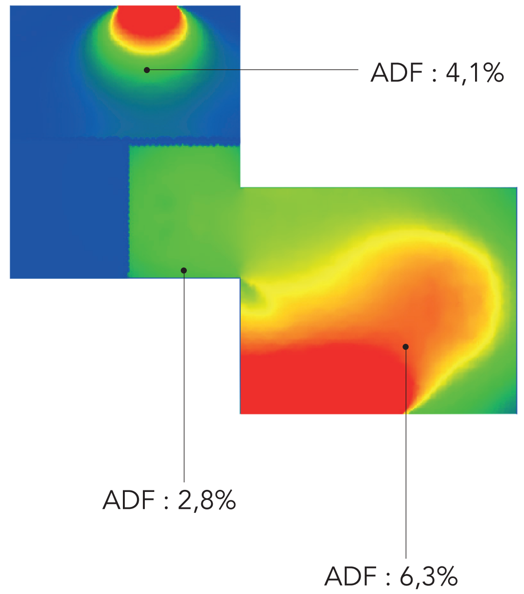
B.



1. 120x150; 80cm above ground
2. 350x230; 00cm above ground
3. 120x70; roof window
4. 130x98; roof window

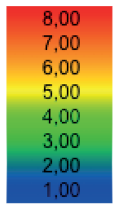
The ADF is still too low in the hallway. We can expend the size of the roof window.

C.



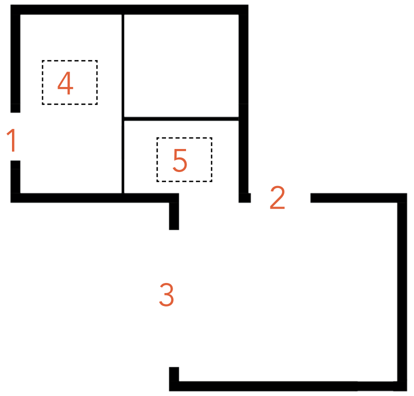
1. 120x150; 80cm above ground
2. 350x230; 00cm above ground
3. 130x98; roof window
4. 130x98; roof window

Daylight factor %

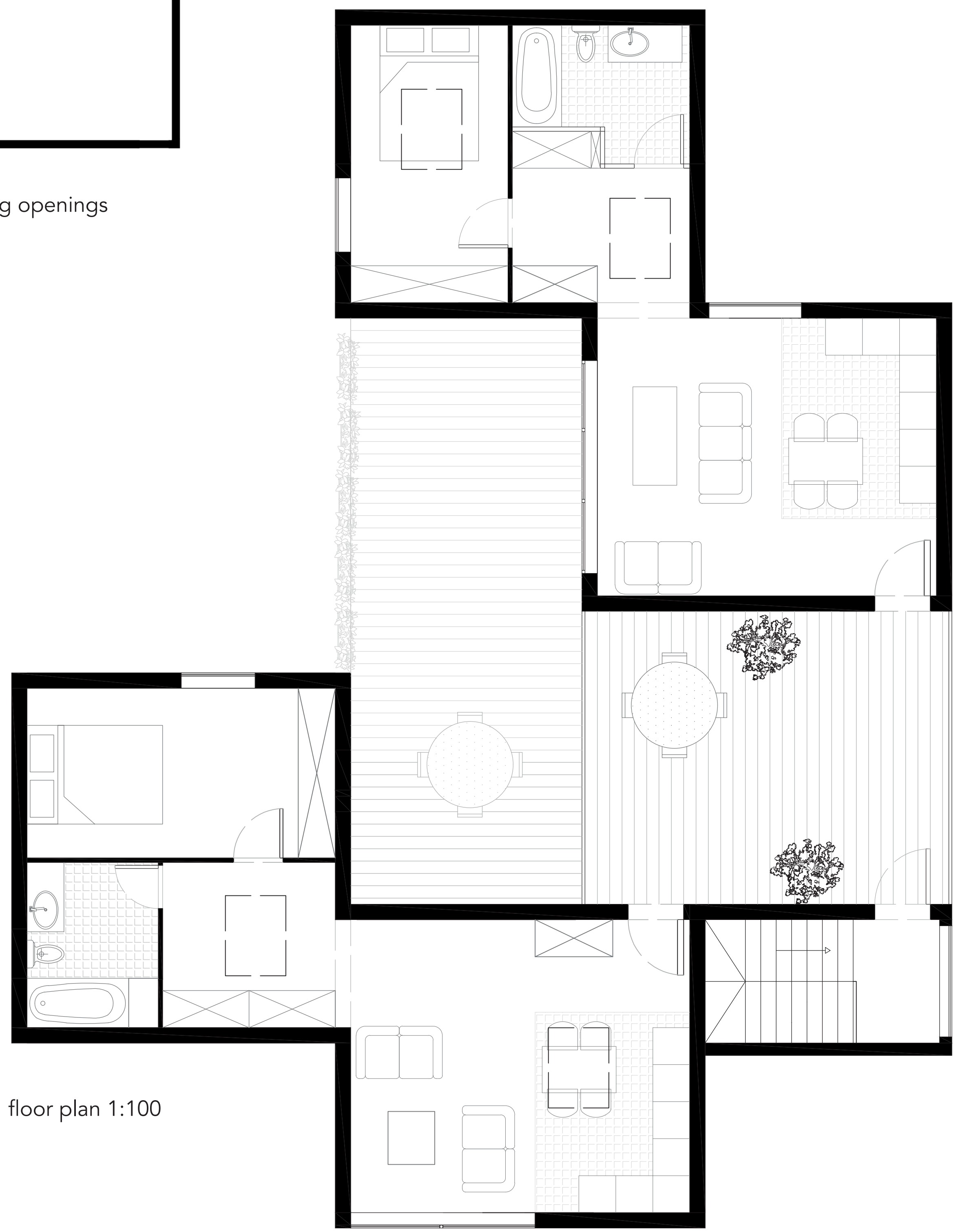


Daylight analysis - scenario 5 (pitched roof, custom objects around, 6m high, 4m in front of windows)

Goal : average daylight factor (ADF) of minimum 2% in every room except bathrooms

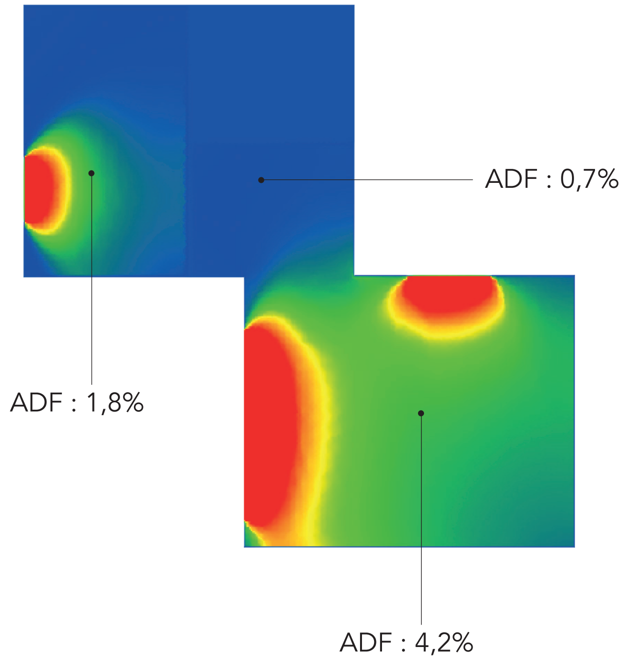


scheme showing openings



floor plan 1:100

A.

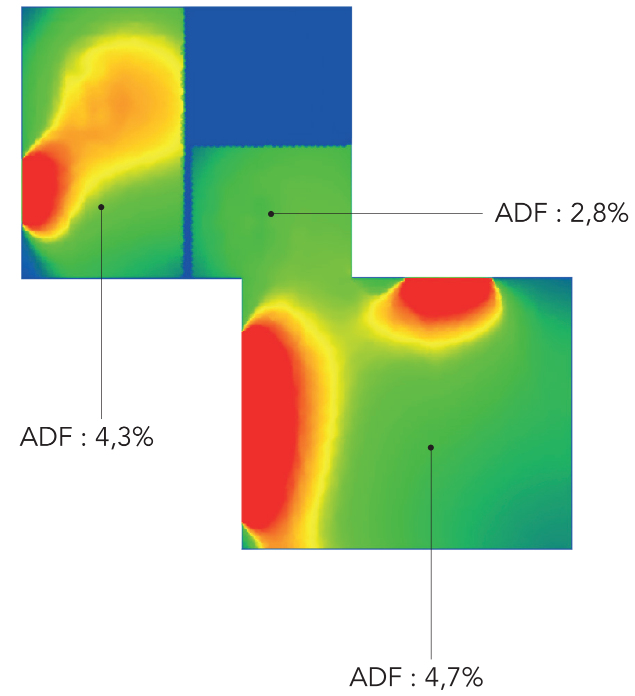


1. 120x150; 80cm above ground
2. 150x150; 80cm above ground
3. 350x230; 00cm above ground

Here the ADF in the bedroom and the hallway are rather low. Probably because of the pitched roof ans the higher ceiling?

We can add roof windows in the bedroom and hallway.

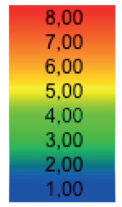
B.



1. 120x150; 80cm above ground
2. 150x150; 80cm above ground
3. 350x230; 00cm above ground
4. 130x98; roof window
5. 130x98; roof window

The ADF is more than enough in every room. The living has more daylight, probably because of the room window in the hallway. We could reduce the size of roof windows to put more PVs but I want a standard size of windows.

Daylight factor %



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