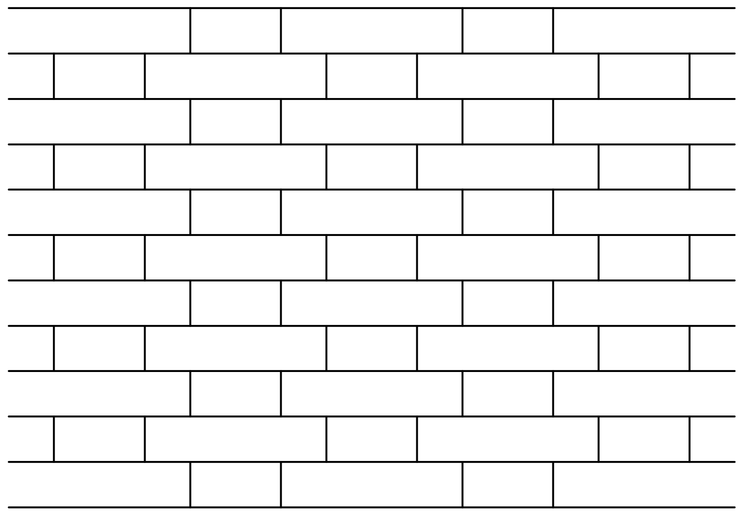


STIGSBORG PARK CONTEMPORARY STUDENT HOUSING

COLOPHON

Title: Stigsborg Park Contemporary Student Housing

Theme: Sustainability

Group: MSc04 ARC - Group 8

Project Period: February 1st 2018 - May 23rd 2018

Main Supervisor: Mads Dines Petersen

Technical Supervisor: Anders Hornum Møllerskov

Field of Studies Architecture & Design

University: Aalborg University

Members: Hussein Nedal Abohamida

Mathias Nordtorp Hyldig

Patrycja Ewa Lyszczyk

ABSTRACT

This Master Thesis report presents the work and outcome of designing a sustainable building for contemporary student housing. The work is conducted as the final part of the Master's education in Architecture from the Department of Architecture & Design at the Aalborg University.

The building site is located in the Stigsborg Harbourfront area, which is being redeveloped as a new urban neighbourhood after laying fallow for many years. The framework of the project is based on the development strategy for area made by the Aalborg municipality.

The aim of the project is to design a building for contemporary student housing that balances private and social human needs, based on the research conducted by Ingrid Gehl and published in her 1971 book "Bo-Miljø" (Living Environment) (Gehl, 1971). To meet the demands of the Danish Building Regulations, the energy frame and indoor environment of the building has been evaluated through static and dynamic simulations made with BE15 and BSim.

MOTIVATION

This introductory text presents the motivation and reasoning for choosing contemporary student housing as the topic for the Master Thesis.

As the project concludes our academic education, it brings us to the cusp of our professional careers. It was, therefore, our desire to work with a theme that reflects a realistic solution to a real problem. The additional desire to build the framework of the project on a realistic situation drove us to base the site location and initial design criteria on the development strategy for the new Stigsborg Harbourfront area developed by the Aalborg municipality.

As young adults, students, and aspiring architects we know that our living environment is an important foundation for our well-being. It is therefore paramount that this environment supports human needs such as privacy and social life. Humans are naturally social beings who, since the dawn of time, have lived and thrived in communities and social institutions, but in contemporary, urban societies, these communities or social institutions are crumbling, as people increasingly value autonomy over social relations and dependency. Through research, we have found that intimate social relationships play an important role in both the physical and psychological well-being of people. As dormitories or student housing environments naturally support social interaction and thereby formation of intimate social relations between the inhabitants, we find that it, in fact, reflects a realistic solution to a real problem.

Sincerely,

Hussein Nedal Abohameda
Mathias Nordtorp Hyldig
Patrycja Ewa Lyszczyk

READING GUIDE

The report is structured in a way that follows the Integrated Design Process (IDP) methodology. The chapters of the report represent the Problem Based Learning (PBL) phases: problem, analysis, sketching, synthesis, and presentation. The report ends with a conclusion and a reflection, followed by a bibliography and figure list. Accompanying the report, an appendix with additional information about the project is provided.

TABLE OF CONTENT

INITIAL GOALS

ARCHITECTURE

The vision is to create a building for student housing that welcomes a diverse group of people, studying at the higher educational facilities in Aalborg. The design should be driven by natural, social interaction between the residents and at the same time respect and understand their need for privacy and intimate space.

From the outside, the goal is to create a building that respects the history of Stigsborg but also fits into the contemporary context of the new neighbourhood. The ground floor should be a window to the public functions of the residence hall that binds together the residents and the people of the city.

ENERGY

Contemporary architecture should facilitate sustainability as a natural extension of our way of life, and as such, the energy goal for the building is respect the 2020 Danish Building Regulations. This can be seen both as an obligation but also as a conscious choice, as it is the architect's way to contribute to a more sustainable society.

LIGHT

Lastly, it is the vision to create a building whose architecture has as much quality lit by natural light. Natural daylight is a scarce resource during much of the winter in northern countries such as Denmark. As such, it should be regarded as an important feature in the architecture.

METHODOLOGY

This project follows the Integrated Design Process (IDP) working method, which is defined by Mary-Ann Knudstrup and practiced at the Architecture & Design education at the Aalborg University. The underlying thought of the IDP is to take into consideration all different aspects of abuilding, to achieve a more holistic end result (Knudstrup, 2004). The method consists of five iterative processes: problem, analysis, sketching, synthesis, and presentation.

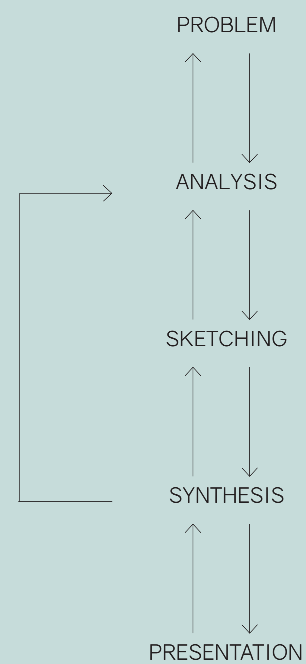
The aim of the problem phase is to become familiar with the problem that is sought to be solved. At this point, a general plan of action is developed, which will serve as a basis for the project.

The analysis phase consists of researching and analysing chosen topics such as site, climate, sun exposure, and historical situation, etc. This process should provide a deeper understanding of the problems and possibilities related to the project.

In the sketching phase, the design is begun with drawings and models that develop the concept of the design proposal. Additionally, architectural, structural, and technical goals of the project should be formulated. All of the work done in this process should be based on results and findings of the analysis phase.

In the synthesis phase, the design concept is detailed. At this point, the project should find its form and expression based on the adjustments and calculations of the considered solutions and parameters that were uncovered in the previous phase. Before moving on to the final phase, it should be ensured that the project relates to the analysis and research of the second phase.

The last phase is the presentation where both the design process and final product is presented. This phase aims to compare the problem statement and vision with the final iteration of the project to justify the outcome. The presentation is concluded by a reflection upon the overall process as well as the final result (Knudstrup, 2004).



Ill.1 Integrated Design Process Diagram

PROBLEM STATEMENT

How is a building for contemporary student housing designed with social interaction, energy consumption, and light as leading design drivers?

RESEARCH

HISTORY
STATISTICS
CASE STUDIES
BENEFITS OF COHOUSING
SÆTTEDAMMEN TODAY
USERS
CASE STUDY ANALYSIS
SUSTAINABILITY
SOCIAL SUSTAINABILITY
HUMAN NEEDS
AUTONOMY-WITHDRAWAL SYNDROME
ZERO ENERGY BUILDINGS
PASSIVE AND ACTIVE STRATEGIES
DGNB
LIGHT

HISTORY

The Stigsborg area is named after an old Viking fortress that once stood on a hill in the area. It belonged to a nobleman, marshal Sti Hvide, who subsequently became a lawless pirate and fled the area. Today, the area borders a residential neighbourhood with single-family houses and apartment buildings from the 1950's.

In 1913, the fortress and the hill were demolished, and Dansk Svovlsyre- & Superphosphat-Fabrik (Danish Sulfuric Acid and Superphosphate Factory) was erected by The East Asiatic Company. The factory continued to operate and expand on the site for many years, eventually changing name to Superfos in 1971. In 1989, the factory was bought by the Finnish fertilizer factory, Kemira, who finally stopped production in 1998.

Popularly, the nickname for the factory was "Syren" ("The Acid") and this name has since become synonymous with the site itself.

Over the years, several environmental cases were brought against the factory and in the end of the 1900's, the factory received numerous fines for environmental failure, inadequate cleaning of production facilities, and nuisance regarding gas and dust from mixers. Moreover, there were strong odours from the production.

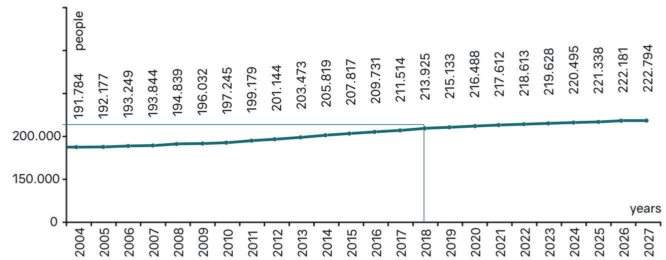
In 2001, the Aalborg Municipality bought the area, and in 2002, the department for City and Landscape Management moved into a newly constructed building by the wharf. The planning of the rest of the area started slowly in 2003, and in 2013, official work began on the area, which has since then been known as Stigsborg Harbourfront (Jensen, 2016).

The last building of the factory, nicknamed "The Kathedral" was torn down in 2011 (kingo.biz, 2018). Now, the only structure that is left is a large, spherical tank, which has rusted over the years.

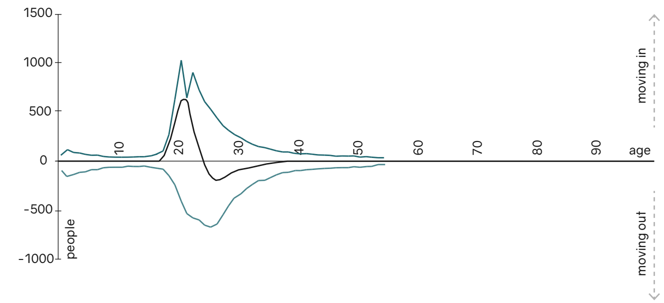
Ill.2 Existing dome

Ill.3 Historic photo of the old factory

STATISTICS



Ill.4 Growth of population in Aalborg



Ill.5 Amount of people moving in and out

This research shows the population growth in Aalborg following the transformation from industrial to modern city. Aalborg is third largest municipality in Denmark with over 210.000 inhabitants. The expansion is continuous - municipality expects to reach 222 000 inhabitants within next 10 years.

Aalborg University is an important driver in the development of the city, and this statistic shows that the age group of 17-29 years is most interested in arriving to Aalborg. This means increased amount of investments in student housing sector.

CASE STUDIES

SOCIAL ASPECT

Tietgenkollegiet (The Tietgen Residence Hall) located in the Ørestad district of Copenhagen is an example of good approach to social aspect of living.

The design of the residence hall is heavily centred around community spaces and all residence floors are equipped with kitchens, common rooms, and utility rooms. The entire ground floor is dedicated solely to common rooms and social functions and houses assembly hall, bike storage, gym, laundry, library, study rooms, and workshops.

The main design feature of the residence hall is the round shape of the building that is derived from a long continuous corridor with access to all private and common rooms: "The house itself says what the idea behind it is: community. You can walk all the way round on all floors. No hallways are a dead end; no doors are locked. The house does not turn its back on anyone. Across the round square in the middle, the residents can see what the others are doing in their kitchens, on the terraces, and in the lounges. And if it looks interesting, they can go over there." ~Pernille Steensgard, writer (Steensgard, 2018).

ZERO ENERGY

Beddington Zero Energy Development (bedZED) is the UK's largest environmentally friendly-housing and sustainability mixed used building. It is designed to meet very high environmental standards, with a strong emphasis on roof gardens, sunlight, solar energy, reduction of energy consumption, and waste water recycling.

Passive strategies are strongly represented in the design. South facing terraces combined with three glazed layers to maximize the solar heat gain which reduce the energy demands. The wind cowls rise on the roof are designed to catch the low velocity wind which will delivered to the home afterwards. The materials used in the complex were selected from renewable sources within 50 miles of the site, to minimize the energy required for transportation as much as possible. Refuse-collection facilities are designed to support recycling.

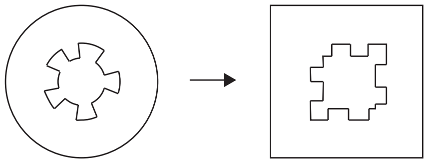
Photovoltaic panels are installed on the roof and integrated in the windows design on the south façade. The electricity they produced is used to charge the electric cars batteries while the rest of the electricity demands is gained from the grid (zedfactory.com, 2018).

LIGHT APPROACH

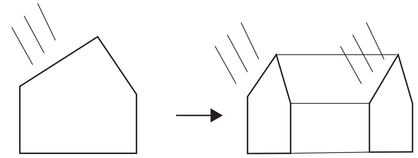
Student Learning Centre in Toronto designed by Snøhetta is an outstanding example of good light environment for studying. The glazing skin design creates different light qualities in the interior spaces of the building. Special pattern is applied on the surface of the glass not only to avoid over heating during the summer time period and to improve the energy demand of the building but also it considers carefully behavior of the sun and uses it in sufficient way (Archdaily.com, 2015).

The research done by Maryline Andersen shows that in terms of vitality, emotion and comfort, the building represents high quality of design. Special care about daylight intent within common areas creates exclusive environment for students. In terms of vitality, the health potential of each view is measured. The emotion describes the potential impact of daylight on people. The comfort takes into account quality of the daylight to provide adequate brightness while avoiding glare discomfort (Andersen, 2018).

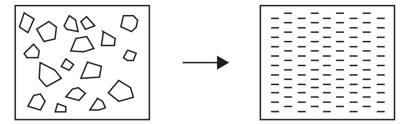
These examples represent interesting approach to the topics that were developed in the Master Thesis Project.



Ill.9 Case study design interpretation - internal common areas



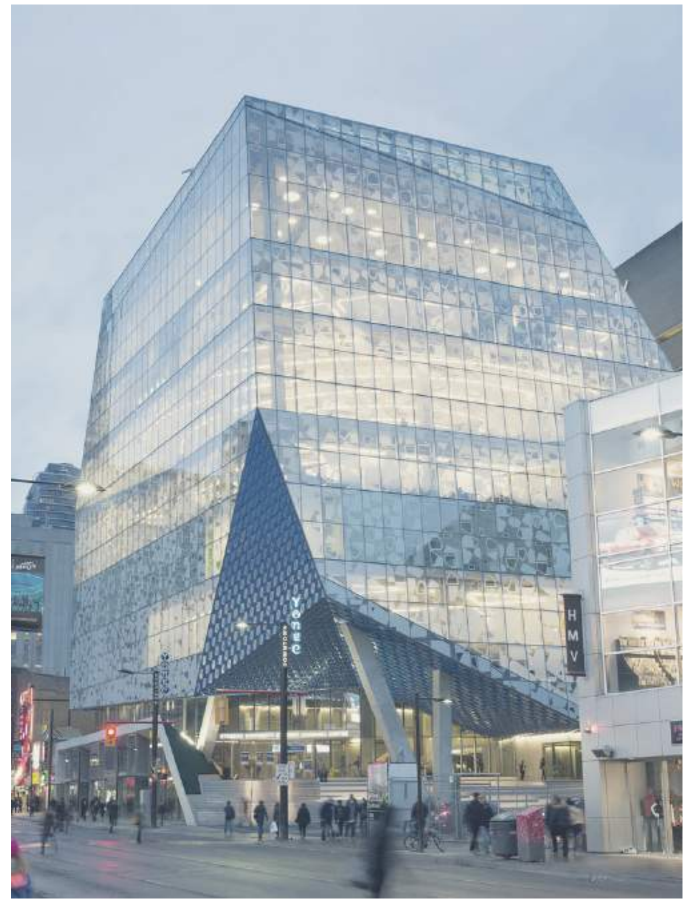
Ill.10 Case study design interpretation - passive solar gain



Ill.11 Case study design interpretation - facade expression

Ill.6 Tietgen Kollegiet, Copenhagen

Ill.7 BED ZED Housing, London



Ill.8 Student Learning Centre, Toronto

BENEFITS OF COHOUSING

Cohousing is a form of communal living that come in many different variations. The communities can range in size, from fitting in a single apartment to encompassing multiple houses. Most communities have shared amenities such as kitchen, dining area, and common spaces, and some even have shared recreational spaces like gardens or gyms. Primarily, cohousing communities are structured to encourage frequent interactions and the formation of close relationships between members.

The modern understanding of cohousing developed in Denmark in the 1960s, among groups of families who were dissatisfied with the general concept of nuclear family lifestyle. It was first described in the newspaper article “Børn Skal Have 100 Forældre” (Children Should Have 100 Parents) by Bodil Graae in 1967. She encouraged readers to contact her if they were interested in the concept, and this subsequently led to the development of the cohousing project “Sættedammen”, which is the oldest cohousing community in the world (Graae, 1967).

According to the online survey “One Shared House 2030”, answered by almost 60 thousand people, the main motivations for living in a cohousing situation is splitting costs and having more ways to socialize (Pereya and Repponen, 2018).

In the 21st century, living in a big city can be expensive, and many cohousing communities are founded on a basis of problems with affordable housing. The members receive the benefit of shared rent, which makes their situation more economically sustainable.
Even though more people than ever live in dense, urban areas, loneliness and social isolation is a serious, public health risk of our time (Holt-Lunstad, 2015). Luckily, the core of cohousing is living with other people and intentional communities are optimal environments for creating and sustaining intimate, social relationships.

Sustaining intimate, social relationships are beneficial for one’s psychological health but research also shows that it has an even greater physical effect than clean air, regular exercise, and diet, including not smoking or drinking (Pinker, 2017). Evidence from Blue Zones from around the world connects intimate social relationships with longer than average lifespans. The communities of Loma Linda in the United States, Okinawa in Japan, and the island of Sardinia in Italy all have in common high amounts of social contact.

Cohousing can not only prove to be a financially sound way of living; it may well be the healthiest way of living in the 21st century (Kim, 2017).

Ill.12 Example of cohousing

SÆTTEDAMMEN TODAY

Sættedammen is the oldest exapmle of cohousing in the world. It consists of 27 houses with a large common area and a common house for social gatherings such as communal dinners and parties. The community is inhabited by 70 people of which two-thirds were original inhabitants in 1997 (Illeris, 1997).

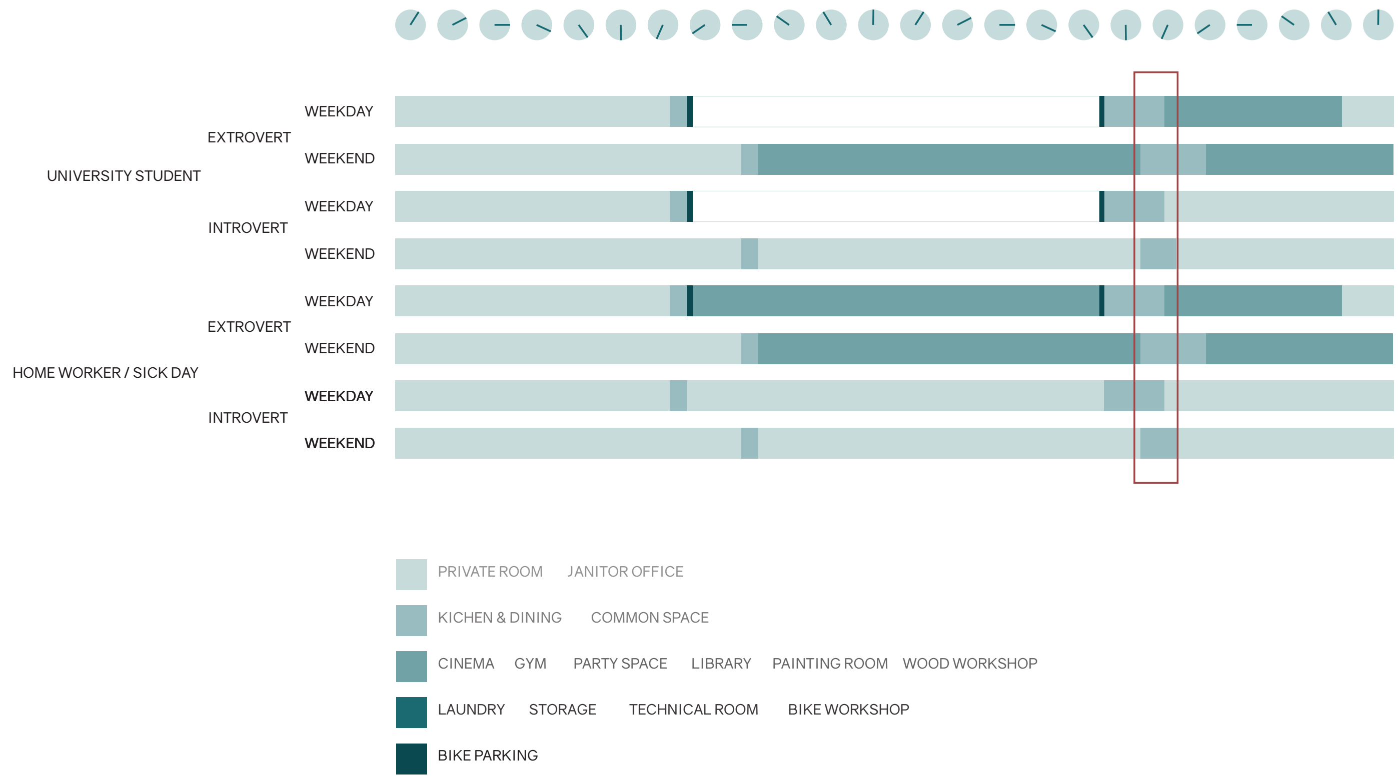
Since the community began in 1972, both the buildings and the life has seen some change. The inner walls of the houses are not loadbearing, which enables the buildings to adapt to the resident's changing needs. Consequently, many of the houses have changed over the years. The community still has a relatively high number of social activities, but they have decreased slightly. Naturally, more communal activities were necessary to make Sættedammen function as a community in the first years, but time has also resulted in more diversity among the inhabitants, namely a bigger age gap, which in turns means that there are fewer coincidences of shared needs. Lastly, the inhabitants have become more individualistic and have a bigger focus on their own family. According to the inhabitants of Sættedammen, it is very important that social activities are voluntary.

In a dormitory environment, the inhabitants have a tighter age gap than a community with children, adults, and retirees. This can mean that there is a bigger basis for shared needs and interests, which can result in more social activities.

Sættedammen has a very flat organizational structure with many groups and comities, which has given an overall stronger sense of shared ownership of the community. For the community to thrive, a balance must exist between providing and receiving services, and when the individual has a strong sense of ownership, there is a more natural sense of responsibility and eagerness to contribute to the community. Mutual trust and respect, amongst other things, manifested in the performance of individual duties, is an important basis for good social relations.

Even though Sættedammen is a cohousing community and not a dormitory, the values regarding private life and community, giving and receiving, and the respect for voluntary participation are applicable in both environments (Illeris, 1997).

Ill.13 Sættedammen



Ill.14 Analyse of usage of the building by different user type in different hours

USERS

The main user focus of the project are students. One of the features of this group is their mix of different backgrounds. There is a big challenge to make a universal place to live for people from all over the world, where everybody can feel at home.

The building will be used also by a janitor of the building who will come once a while to maintain the building. For him special storage has to be designed to keep all the tools he operates with.

Additionally, cleaning company would come occasionally and that demands extra cleaning room storage to keep their accessories placed.

One of the main aspects that is interesting to look at is the relationships between our residents. There is a need to provide facilities that allow people one-to-one connections. The access to those amenities shall not be forced but enhanced by its own function. Contact with other people is most often caused by the action that is done together (like cooking or eating together).

Regardless race, ethnic, nationality, religion, socioeconomic group, marital status or gender people have similar needs for social interaction. The research shows that the face to face contact can make us happier and healthier (Pinker, 2015). In the past people used to be more dependent on each other. They would spend more time together on daily-life routines like doing a laundry or cooking together. Nowadays, together with a development of the technology people became completely independent units. However, it does not mean the man do not need a contact with other people.

Physically humans differ a lot from each other. Two extremes of personalities are introverts and extroverts. Introvert gain energy when they are alone and use it while spending time with other people, whereas extrovert has it opposite way round. Therefore, it is extremely important to be aware of this phenomenon while designing a building.

CASE STUDY ANALYSIS

The analysis on different case study student housing built in Denmark were made. There were several different indicators to compare them. Mainly, the research was done to investigate what is the optimal number of students that would share the kitchen. The analysis were based on Dormitory in Herlev, Tietgen Residency Hall in Copenhagen and SDU Campus Dormitory in Odense. All three examples are completely different from each other, but what makes them comparable is that in all cases students share the kitchen between each other. As the illustation shows on the previous page, the focus time of a day is around evening dinner hours. That is why design of the kitchen and proper amount of people in it are very important.

	Herlev Dormitory	Tietgen Residency Hall	SDU Campus Dormitory
Floor area	4000 m²	26500 m²	15000 m²
Amount of rooms	140	360	250
Average room size	17,5 m²	26 m²	19 m²
Amount of rooms per 5000 m²	175	58	80
Amount of rooms per kitchen	14	12	21
Amount of kitchens per floor	2	5	1

Ill.15 Comparison of different case study dormitories

Ill.16 Herlev Dormitory, Herlev

Ill.17 Tietgen Residency Hall, Copenhagen

Ill.18 SDU Campus Dormitory, Odense

SUSTAINABILITY

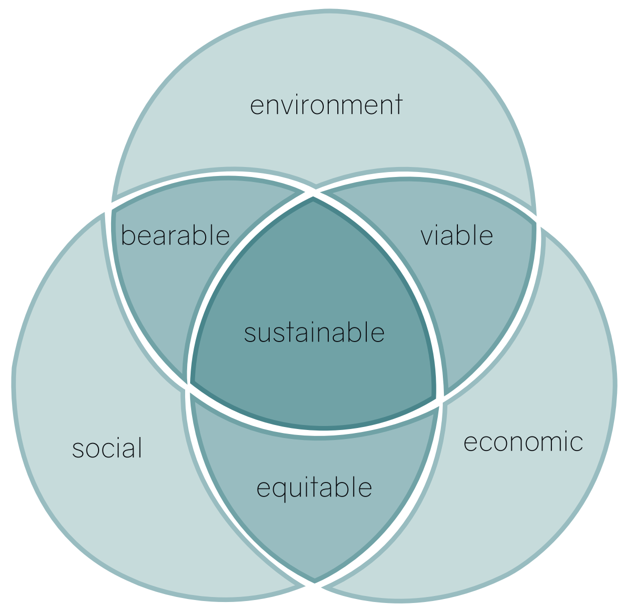
Sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN Commission, 1987).

The environment, the social and the economic sustainability aspects are the primarily components that shaped the concept of sustainability (Bejder, Knudstrup, Jensen, 2014).

In architecture, environmental sustainability concerns about different aspects. A major factor is the CO_2 emissions, and with over than 40% of the emissions comes from the building sector, designers have an important role into changing that by having a better understanding of the different aspects that play a role of choosing materials for example the lifespan and the possibility of reuse as well as the energy consumption of the production and the transportation. Reducing the energy consumption is another factor; to achieve it there need to be integrated three steps in the design process. The first step is to minimize the energy consumption by applying passive strategies. The next step is to optimize the results by integrating the mechanical strategies and the last step is to integrate active solutions that produce power from renewable resources to supply the building with its corresponding needs.

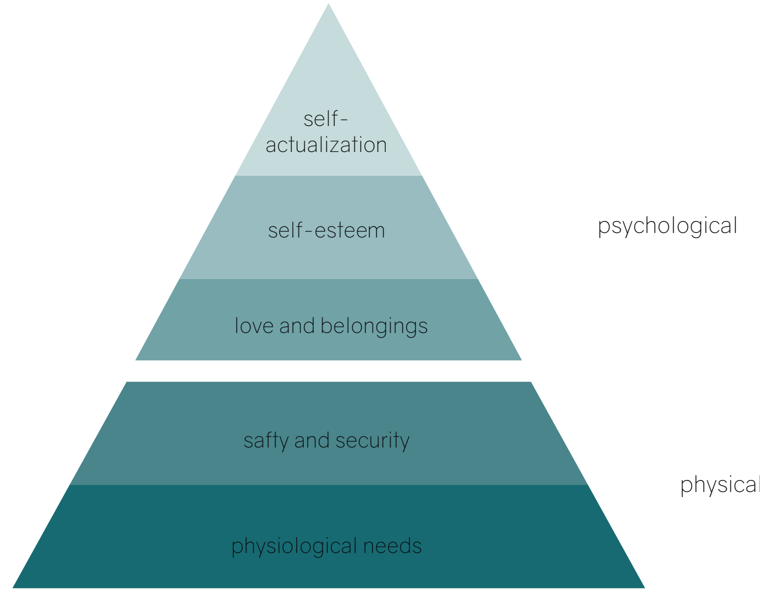
Social sustainability inherently has two aspects: Physical and psychological. Research has shown the significance of both. It is therefore the job of the architect to create an environment that considers both and so the subject is detailed further in the following chapter.

The economic sustainability is about looking into project delivery, increased profitability and productivity to improve productivity through different lines, such as employee, supplier and client satisfaction; minimizing defects; shorter and more predictable completion time; lower cost projects with increased cost predictability; delivering services that provide best value to clients (Akadiri, Chinyio, Olomolaiye, 2012).



Ill.19 Sustainability principles

SOCIAL SUSTAINABILITY



Ill.20 Maslow's hierachy of needs

Within the concept of architectural sustainability, social sustainability is concerned about the aspects of architecture that affects human beings physically and psychologically. The fundamental difference between the two is that the physical aspect is measurable and objective, whereas the psychological aspect is abstract and subjective. To create a holistic, socially sustainable design, both aspects must be considered.

According to Maslow's Hierarchy of Needs, the physical needs of a human being is the basis for the psychological needs, hence physiological and safety needs must be satisfied, before one can cater to the need for love/belonging, esteem, and self-actualization (Maslow, 1943).

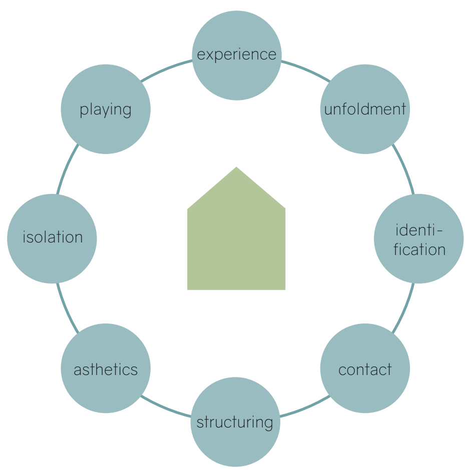
The psychical environment is perceived through the sensory apparatus of the somatic environment (i.e. the body) and to do this, it must be in a state of homeostasis. If the somatic environment is injuriously stimulated, it can lead to a cessation of the metabolic functions that sustain the human body. Metabolic disturbances only occur, when the external environment rises or drops above or below the maximal or minimal limits of the somatic environment. Consequently, if the natural environment does not possess satisfactory conditions to sustain the human body, the architectural or designed environment must intervene (Fitch, 1965).

Regarding the physiological and safety needs, they are in whole satisfied by rules and regulations such as The Danish Building Regulations, which detail a set of minimum requirements that all new buildings must comply with. To further assess the social quality of the physical environment of a piece of architecture it can be measured against the DGNB criteria. These look at the areas of thermal comfort, indoor air quality, visual comfort, safety, and security, etc. (see the chapter about DGNB).

When the physical needs are satisfied, the psychological needs can be tackled. As mentioned however, one must accept that these needs are more abstract and intangible, and it is therefore in a sense impossible to objectively determine, whether they will be met or not. All that can be done is to design a living environment that takes into consideration the different psychological needs of human beings.

In 1971, the psychologist Ingrid Gehl wrote the book "Bo-miljø" (Living Environment) in which she describes the relationship between human needs and their living environment. Each need is discussed in relation to contemporary society and put into perspective to four components of the physical environment: The dimension of, arrangement of, location of, and sensory stimuli from the environment. The needs are described in the next chapter.

HUMAN NEEDS



III.21 Human needs

CONTACT

To look at, listen to, speak with, and do something together with others. The need has varying degrees of involvement such as one-way or two-ways, mediate or immediate contact (Gehl, 1972).
There should be audible and visual contact between people and common spaces where they can congregate. An example could be visual contact between different kitchens.

ISOLATION

To reduce or exclude influences from the surrounding environment. An essential thing is that the obtained isolation is a result of a voluntary action and not a situation from which one cannot escape (Gehl, 1972).
The personal rooms should be quiet and comfortable places for the inhabitants to retreat to, if they need privacy. They should be amply lit, and preferably have a nice view that does not compromise the privacy of the room. I.e. the inhabitants should not feel exposed through the window in their room.

EXPERIENCING

To see, hear, perceive, realize, and receive varying stimuli. The source of the stimuli should be both the surrounding physical environment (houses, trees, plants) and the social environment (people and their activities) (Gehl, 1972).
There should be different sources of sensual stimuli in and surrounding the building. Places with varying degrees of activity or character, such as a quiet court yard that contrasts the busy main street. Filling the courtyard with plants and trees can also provide something to look at and from a window and smell when walking through it.

ACTIVITY

To be active, to create something, to do, to accomplish, to carry through something difficult. This can be realized through hobbies and spare time activities both in the home and in clubs (Gehl, 1972).
Rooms with space or tools for hobbies should be incorporated in the design. These rooms provide a dedicated place for personal expression outside of the private rooms where people can create things themselves or together.

PLAY

This is a multifaceted need, which is comprised of several other needs relevant to the living environment. Play relates motor activity, sensory perception, and to being together socially. Thus, it demands a sufficiently many-sided living environment (Gehl, 1972).
The design should incorporate one or more spaces where people can be active together. This could be a dedicated room such as a gym or exist in the form of furniture such as a simple foosball table.

STRUCTURE

To be capable of orientation, and to be able to place objects in the environment in relation to oneself. Being able to navigate in an environment results in a feeling of safety or emotional security (Gehl, 1972).
The layout of the building should be easy to understand and relate to the surrounding context. This can be achieved by providing distinct views from different parts of the building but also by having distinct functions or materials strategically organized in the plan.

IDENTIFICATION

Being able to identify with parts of one's environment and to project oneself into it. This applies both to the physical and social environment. Physically, to leave a mark in or alter one's living environment. Socially, to make decisions regarding the function and management of the living environment (Gehl, 1972).
Architecturally, the need for identification relates mostly to the possibility of decorating or organising one's own room and to a certain extend also common and social spaces. This can naturally manifest itself in the shared kitchens, where the users should have a possibility to leave a personal mark.

AESTHETIC

Lastly, the desire to receive stimuli that one find aesthetically pleasing or beautiful. Regarding the physical environment, this often manifests itself in artistic order, variation, and harmony. This need is relevant to all perceivable senses (Gehl, 1972).
As a dormitory inherently consist of many repeating units and distinct functions it can advantageously be used in the architectural design of the building. A dormitory is also fundamentally human and social, which should be expressed in the design, layout, and materials of the building.

AUTONOMY-WITHDRAWAL SYNDROME

In pre-industrial societies the two institutions that sustained intimate contact between people were the extended family and the local neighbourhood community. These two primary groups have almost entirely disappeared in contemporary society, in which there now is a tendency to maximize isolation in the living environment. In rural areas individual houses are divided by fields and pastures, and in the suburbs, they are divided by gardens with fences and hedges. In the city, even though it is dense, there is little space for social interaction in common areas of the living environments.

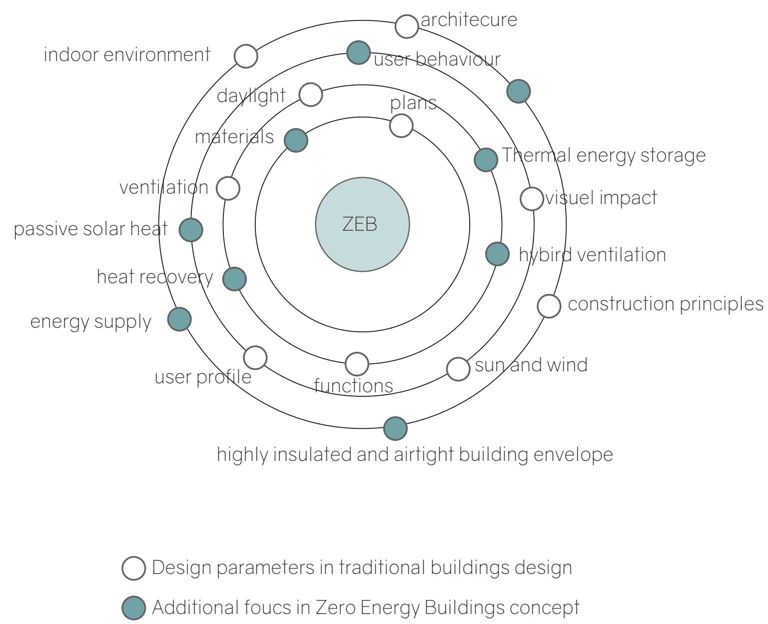
Christopher Alexander calls this phenomenon 'autonomy-withdrawal syndrome'. According to him, the stress of modern society forces people to withdraw into themselves. Wanting to escape stress such as danger, noise, strangers, and too much information, they seek independency or autonomy from society, and idealize self-sufficiency. This behaviour manifests itself in the built environment, where dwellings become increasingly private and isolated, limiting social interaction.

The problem can only be solved, when people change their way of life, but in turn they can only do so if their efforts are supported by their physical environment. This environment must make it possible for people to create and sustain informal, daily contact between each other, either in reinvented primary groups or in another configuration that performs the same way (Alexander, 1965).

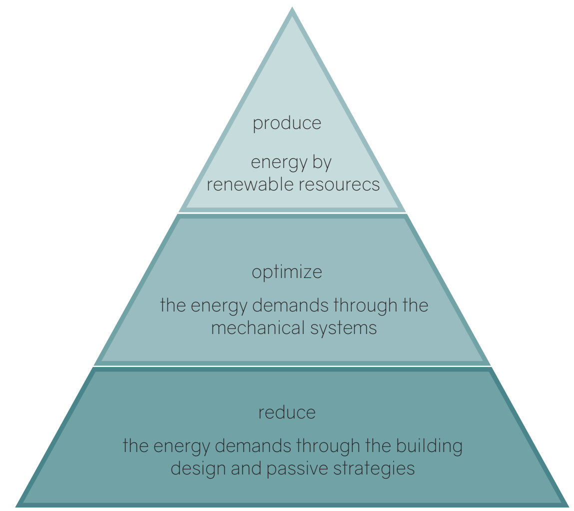
To cope with autonomy-withdrawal syndrome, it is the role of architecture to support the human needs in the living environment as described in the previous chapter.

Ill.22 Suburb area in Denmark

ZERO ENERGY BUILDINGS



Ill.24 Integrated design parameter (Basedon, Kundstrup, 2004)



Ill.23 Overall strategy for designing ZEB

The increased levels of energy consumption around the globe emerged the need of aiming the building industry more towards Zero Energy Building (Thomsen, 2014). Therefore, the Danish Government plans to make Denmark dependent only on renewable energy by 2050 (Ens.dk, 2013).

The Zero Energy Buildings (ZEB) are designed as low demand energy buildings, that energy is produced by renewable energy sources (Thomsen, 2014).

The process of achieving ZEB consists of series of steps. The first step is reducing the energy needs of the building through the design of the building shape, orientation, and climate screen. As well as integrating different passive strategies in the design like the natural ventilation and shading. The second step is to install the mechanical systems to optimize the energy performance when the passive approaches are inadequate. The third step is to produce energy from renewable sources that cover the demands of the building for example using the solar cells to cover the energy consumption of the building (Bejder, Knudstrup, Jensen, 2014).

While designing ZEBs it is important to make a holistic solution that concern not only the energy performance aspects but extends to care about the users' conditions and create a proper indoor environment regarding daylight, functionality, atmosphere and acoustics comfort along with much more aspects which known as ZEBs design parameters (Bejder, Knudstrup, Jensen, 2014).

In order to achieve zero-energy standards, the energy demands of the building must follow the 2020 building regulations. Where the overall supplied energy for heating, ventilation, cooling and domestic hot water is 20 kWh per year per m^2.

The building envelope has to be airtight and infiltration case set to 0,5 l/s m2 at 50 Pa Pressure. Thermal indoor climate should be calculated in the most critical rooms. According to the regulations it allows only 100 hours above 27 degrees a year and 25 hours per year above 28 degrees. The windows area should be a minimum of 10 percent of the net floor area to achieve a proper indoor air quality, the outdoor air supply should be a minimum 0,3 l/s per m^2 heated floor area (BR18, 2018).

Once these specifications are met, a renewable energy source can be implemented in order to supply the building with the energy it demands through renewable sources of energy such as solar cells, thermal heating and windmills.

When it is hard to produce all energy demands from renewable energy sources all around the year, most of the ZEBs are still connected to what is known as the grid. It supplies the building with energy produced from traditional sources when the renewable energy sources are insufficient and when the renewable sources are generating more than the building demands, the extra produced energy will be exported to the grid. (Buildings.com, 2007)

PASSIVE AND ACTIVE STRATEGIES

There is full range of passive and active strategies that can be applied in be building to be holistic Zero Energy Building. The sustainable development demands taking into consideration those solutions.

The natural ventilation is driven by the wind pressure and thermal buoyancy. There are three types of ventilation: single-sided ventilation where the openings are placed on one face of the building, cross ventilation in which the openings are on two sided of the room and stack ventilation where openings are located both low and high level. Therefore, thermal buoyancy is the main driving force (Heiselberg, 2006).

Passive solar heating can be used either directly, when the windows are facing the sun or indirectly when a solid black wall is located behind the glazed façade. The heat is then stored in the mass of the wall and the thermal mass of the building is used as a storage of the heat.

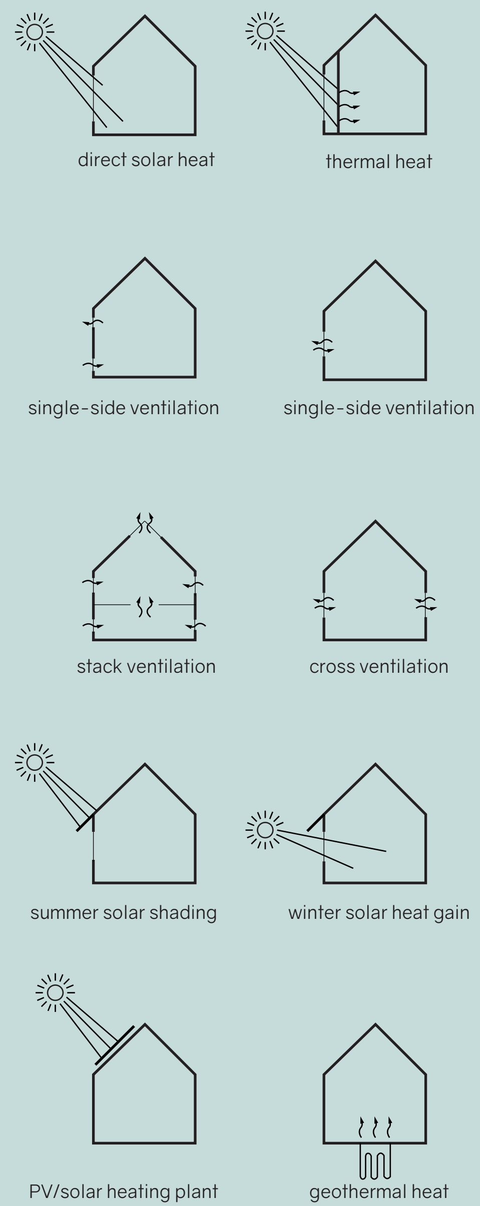
In order to lower the energy consumption of the building, the windows should perform low transmission coefficience. To avoid overheating during the summer period but allow the winter sun to reach to the interior, a solar shading system need to be installed (Bejder, Knudstrup, Jensen, 2014).

Proper building envelope with sufficient amount of insulation decreases the energy demand of the building. There are full variety of different kinds of materials used as insulation material, for example: mineral wool, extruded polystyrene foam, expanded polystyrene foam or natural fibers. U-value has to be kept as low as possible to keep heat inside.
Unlike using passive strategies, the active solutions are needed to use to achieve high performance housing with a low energy consumption. The important aspect is that the source of our technologies is renewable.

Solar panels convert sun light to energy that can be used as electricity or heating in the building. Although it is extremely good source of energy, it is not enough solar radiation in long winter period to generate consistent power (Bejder, Knudstrup, Jensen, 2014).

Therefore, other solutions must be applied. Solar heating plant uses solar radiation to heat the water in the building. They are most efficient when located on the roof in order to gain the maximum solar radiation without shading and using gravity in the circulation of the water.

Geothermal heating uses the ground temperature which is stable on a certain depth. The water in the tubes absorbs the ground heat and transfer it to the house. Unlike the rest of the solutions, the geothermal heating is very expensive solution, therefore very rarely used.



Ill.25 Passive and active strategies

DGNB

Due to integrated design process the DGNB criteria were considered. Special attention had few criteria in the project. Special choice of materials takes into account life cycle impact assessment. Additionally, primary energy solutions were used – solar panels. In terms of economy project discuss the flexibility and adaptability of the building. During the lifetime of the building, the function might change. The project considers good social conditions, both in the aspect of thermal comfort, indoor air quality and visual comfort. There is a big focus on designing high quality common space that enhance communication with inhabitants (DK-GBC, 2016).

Environmental Quality	**ENV1.1 Life Cycle Impact Assessment** ENV1.2 Local Environmental Impact ENV1.3 Responsible Procurement ENV2.1 Life Cycle Assessment Primary Energy ENV2.2 Drinking water and waste water ENV2.3 Land Use
Economic Quality	ECO1.1 Life Cycle Cost **ECO2.1 Flexibility and Adaptability** ECO2.2 Commercial Viability
Social Quality	**SOC1.1 Thermal comfort** **SOC1.2 Indoor Air Quality** **SOC1.4 Visual Comfort** **SOC1.5 User Control** **SOC1.6 Quality of Outdoor Spaces** **SOC1.7 Safety and Security** SOC2.1 Design for All SOC2.2 Public Access SOC2.3 Cyclist Facilities SOC3.1 Design and Urban Planning SOC3.2 Integrated Public Art SOC3.3 Layout Quality
Technical Quality	TEC1.1 Fire Safety **TEC1.2 Sound Insulation** **TEC1.3 Building Envelope Quality** TEC1.4 Adaptability of Technical Systems TEC1.5 Cleaning and Maintenance TEC1.6 Deconstruction and Disassembly TEC1.7 Commissioning TEC1.8 Documentation with environmental product declarations (EPD)
Process Quality	PRO1.1 Comprehensive Project Brief **PRO1.2 Integrated Design** PRO1.3 Design Concept PRO1.4 Sustainability Aspects in Tender Phase PRO1.5 Documentation for Facility Management PRO2.1 Environmental Impact of Construction PRO2.2 Constuction Quality Assurance
Site quality	SITE1.1 Local Environment SITE1.2 Public Image and Social Conditions SITE1.3 Transport Access SITE1.4 Access to Amenities

LIGHT

The daylight is an important asset for designing building with good indoor environment. Not only has its impact on health and comfort of the residents but has an active impact on reducing energy used in the building. It can be beneficial for both heating and cooling loads.

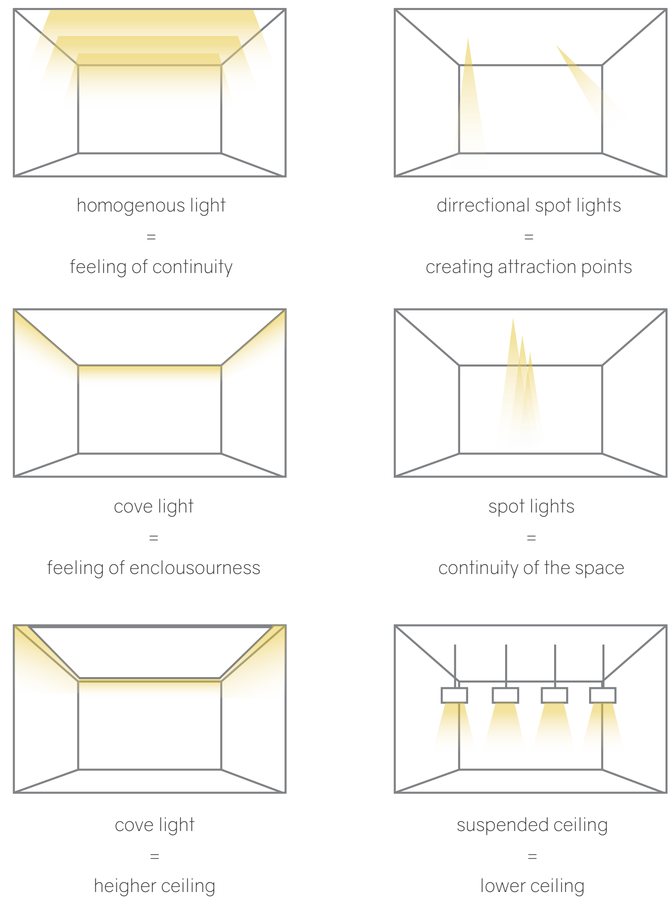
The most common measurement of the light is illuminance (lux). It represents the total luminous flux that falls on a surface, per unit area. The other assessment is daylight factor (DF), which describes ratio between indoor and outdoor illuminance under certain sky conditions (Andersen, 2013).

According to new Building Regulations 2018 in housing buildings the glass area must correspond to 10% or more of the entire indoor floor area. The glass area must take into consideration any shadow-producing obstacles, lowered light transmittance, etc. Alternatively, it must be documented that there is 300 lux or more on at least half of the given floor area for at least half of the day (BR18, 2018).

The sunlight is a dynamic and highly variable source of illumination that affects our vitality, emotions, comfort and compliance in a place. The research made by Maryline Andersen shows that there is wide range of coefficients that together makes whole picture of personal behavior in the building Unlike any other visual aspect, the quality of the light has its effect on human perception (Andersen, 2013).

Humans perception of the space takes into observation whole surroundings and adapts to any changes very fast. The attention is automatically drawn towards bright areas. It is therefore important to design appropriate distribution of brightness. Need for orientation is basic psychological demands. It refers to well distributed escape routes or location of main entrances of houses. It is important that those areas are sufficiently visible (Ganslandt, 1992).

Because of the location of the project in Northern Denmark, sunlight is highly precious asset for most of the year. Being aware of different results in management of the light is crucial. One of the effects that can be achieved is either homogenous illumination with uniform diffuse lighting in the contrast with directional spot lighting which would direct the focus and create attraction points for users of the space. When the light is located on the whole length of the walls it creates feeling of enclosures, while spot lights create continuity of the room. The light can create also an effect of higher of higher ceiling when the lighting is in the cove around the walls, or it can seem lower when lamps are suspended (Negrão, 2013).



Ill.26 Principles of artificial lighting

PARTIAL CONCLUSION

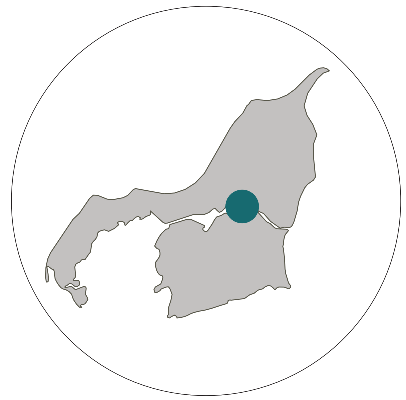
Due to the integrated design process a wide range of topics were researched. Being aware of the history and current trend in the city of Aalborg was important. Essential focus of the project was on the social and interpersonal contact of inhabitants. Unlike social aspects, there was focus on the technical fields as well.

ANALYSIS

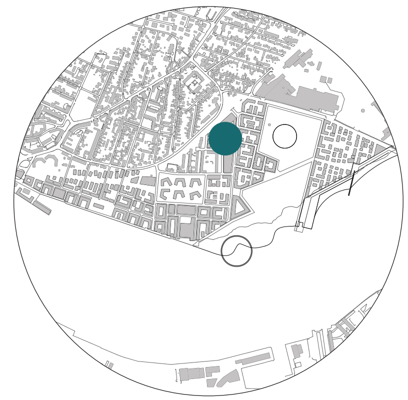
LOCATION

The project is located in Nørresundby, in North Jutland, the northern region of Denmark. The area where the design proposal will be placed is a new mixed-use area in Stigsborg. The surrounding of the project is residential houses. The big area is newly developed in the master-plan made by Vandkunsten together with Aalborg municipality. From south part of the area there is the fjord located together with beautiful panorama of city of Aalborg.

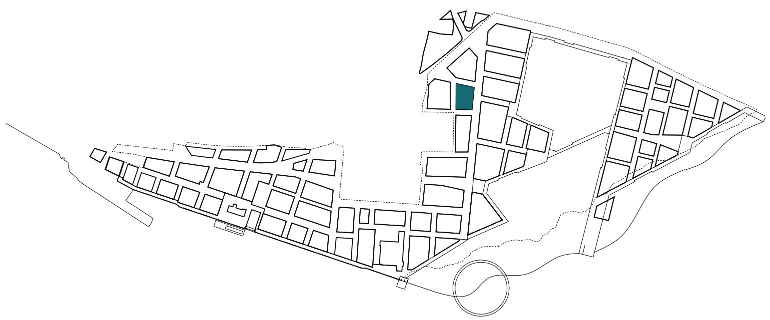
Ill.27 Denmark



Ill.28 North Jutland



Ill.29 Norresundby



Ill.30 Location of the plot

STIGSBORG

Stigsborg is a newly developed area in Nørresundby. It is meant to be mixed-use space in the neighbourhood of existing residential and industrial area. It has good bus connection with the city of Aalborg. For the building with the function of student housing it is one of very good locations as both it is reachable by bike but also can be more affordable than the apartments and dormitories located in the city centre.

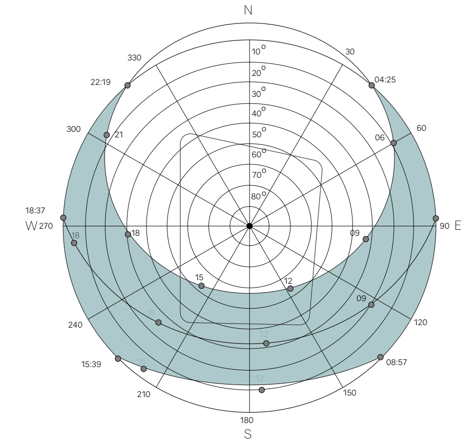
Based on the masterplan made for this area the choice of the specific plot was clearly pragmatic. It is designed to be a housing. It has suitable dimensions for this function and is located close to existing bus stop (around 300 m). It has direct visual connection with Fjord and newly developed park. Finally, it has 3rd class of economy in this area which means that the housing will not be that expensive there (Stigsborghavnefront.dk, 2018).

CLIMATE

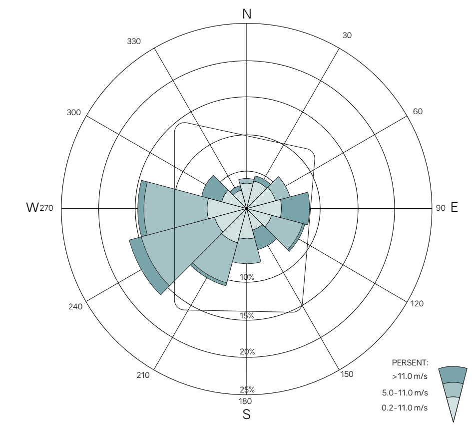
In the winter solstice the sun rises at 8:57 and sets at 15:39 giving the day a length of only 6 hours and 42 minutes and reaching a top angle at only 12 degrees. In the spring or fall equinox the sun rises at 6:35 and sets at 18:37. The length of the day is then 12 hours and 2 minutes and the sun has a top angle at 32 degrees. In the summer equinox the sunrise is at 4:25 and the sunset is at 22:19 with this the longest day of the year reaching to 17 hours and 54 minutes and the top angle at 57 degrees. On the site there is an enormous span between the winter- and summer solstice sun angles and this can have a great influence on the shading coefficients in the architecture (Suncalc.org, 2018).

The majority of rain falls on the site during September, October and November – around 75 mm. The smallest amount of rain falls is in April – around 35 mm.

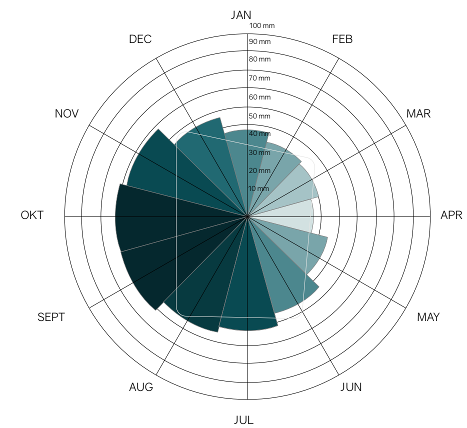
The main wind direction on the site is from the south-west and west. Mostly these winds have a speed ranging from 5 m/s to over 11 m/s. The strong winds can be used positively during the design process for calculations of natural ventilation (DMI, 1999).



Ill.31 Sun

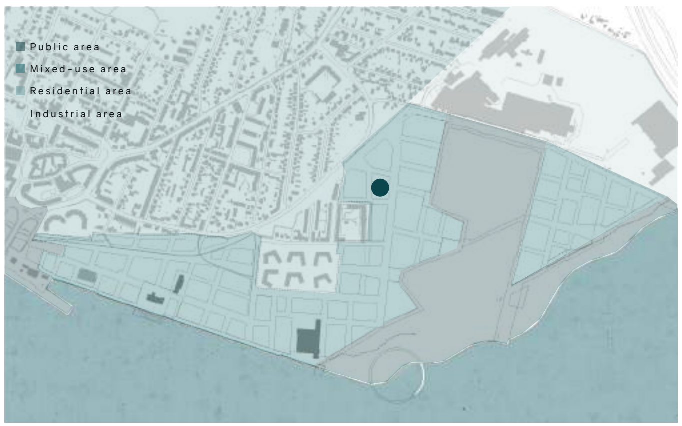


Ill.32 Wind



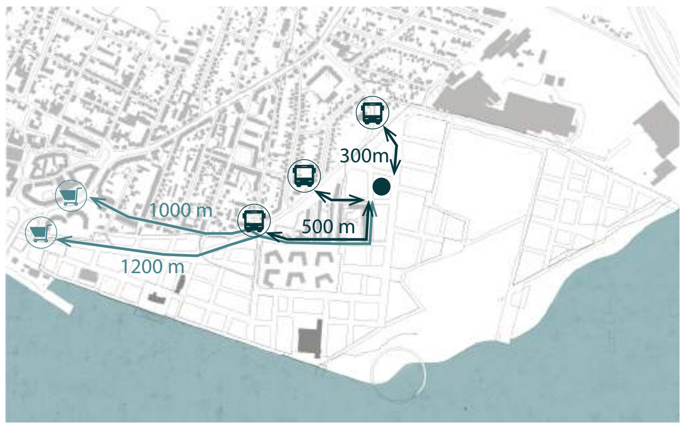
Ill.33 Percipitation

SITE ANALYSIS



Ill.34 Different areas

From north side of Stigsborg area there is mainly residential function located. In the west side there is an industry placed. Next to the Fjord, the public areas are positioned.



Ill.35 Distances to nearest bus stops and shops

Distances to existing bus stops are very short. Although the frequency of transportation is rare, it will change in the future. Nearest shops are located around 1km away from the plot but according to the master-plan new retail shops are planned in Stigsborg area.

Ill.36 Student housing in Aalborg

There are over 20 student houses around Aalborg. Darker dot shows the location of designed student housing. Since buildings of Universities are spreaded around Aalborg there is noticable tendency to locate dorms as well in different locations in the city.

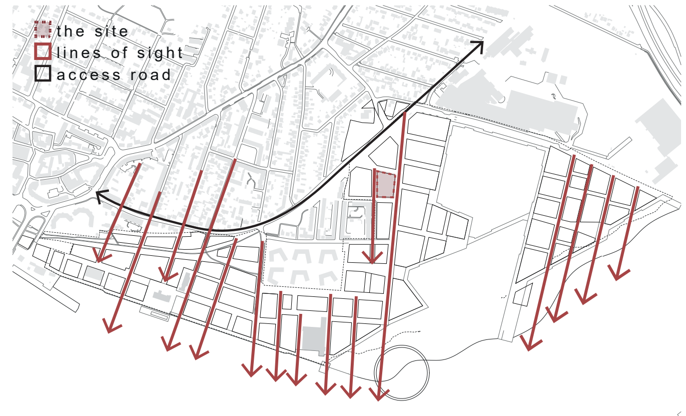
MASTER PLAN

The terrain of the Stigsborg area slopes approx. 5.5 m to sea level from north to south. The entire Park District will be raised to deal with soil pollution and direct excess rain water to the fjord. The project site is located in the northern part of the Park District and slopes approx. 5.0 to 4.5 m from north to south (Aalborg Kommune, 2017).

The plot distribution the Stigsborg area is dictated in large by pre-existing view axis from the suburban area to the Limfjorden. These lines are kept and respected in the new masterplan (Aalborg Kommune, 2017).

The new Stigsborg area will be subdivided into three districts. The Harbour District is the westernmost part of the area and is by location closest to the city centre of Aalborg. Sitting in the middle of Stigsborg is The Park District, which will act as a local centre as well as a link to the new park. Lastly is The Beach District to the west, which is mostly defined by residential buildings (Aalborg Kommune, 2017).

Ill.37 Heights in the area

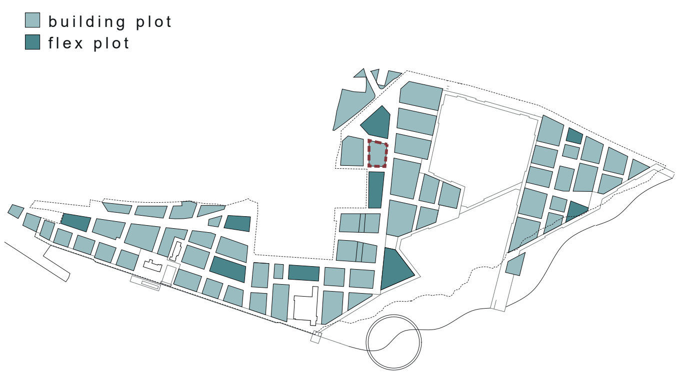


Ill.38 View axises

Ill.39 Districts

Ill.40 Heights of the buildings

Ill.41 Strategy of rain water



Ill.42 Location of flex plots

DENSITY

The building heights in Stigsborg will be tallest by the harbour, facing the city centre of Aalborg across the fjord, and taller generally facing local hubs. Towards north and east, the height will gradually become lower to meet the existing suburban neighbourhood (Aalborg Kommune, 2017).

Excess rainwater is primarily handled on the surfaces of buildings and urban spaces, turning it into an active, experiential part of the cityscape. Everyday rain is handled via evaporation on each plot and excess water is led along the streets in open canals to the fjord (Aalborg Kommune, 2017).

As the Stigsborg area will be under construction for many years, the market is expected to change before the entire neighbourhood is finished. Therefore, so-called "flex plots" are incorporated into the masterplan to allow for possible changes in market demand (Aalborg Kommune, 2017).

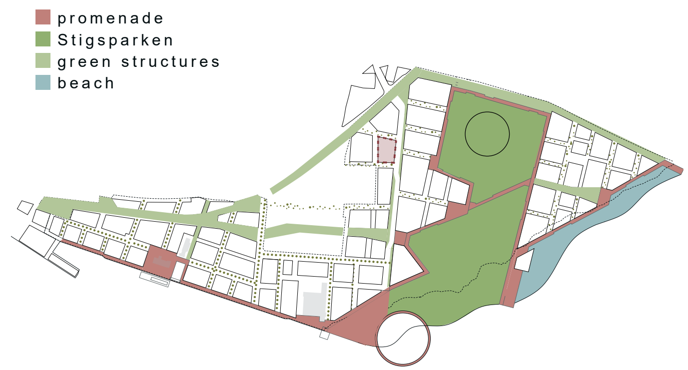
FUNCTIONS

The Stigsborg area is expected to be upwards of 90% residential, while the remaining part is distributed as seen in the diagram. The Park District will see a concentration of institutions, retail, and liberal business, while restaurants/cafés, and other cultural functions will be located in The Harbour District (Vandkunsten, 2017).

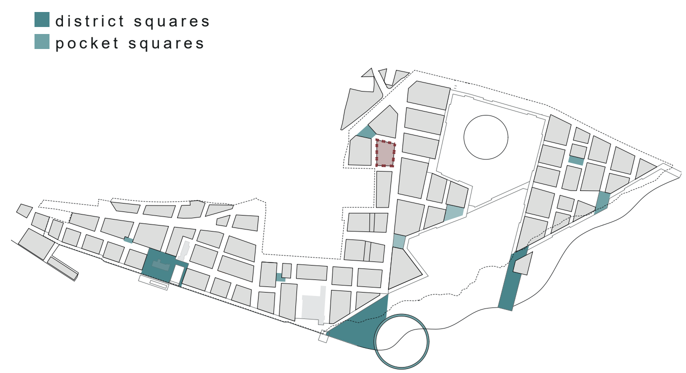
A wide promenade will run along the harbourfront in The Park District and all along the perimeter of 'Stigsparken' in The Park District. Green elements will penetrate the urban landscape and also run along the northern edge of the entire neighbourhood. Lastly, a beach will run along the entire southern edge of The Beach District (Vandkunsten, 2017).

Each district will have a main square and several 'pocket squares' to facilitate urban life. Furthermore, the circular pier in middle of the southern border will become a hub for year-round different cultural activities (Vandkunsten, 2017).

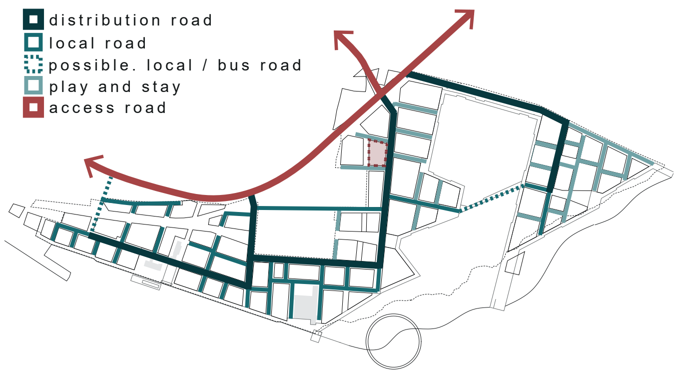
Ill.43 Designed building functions



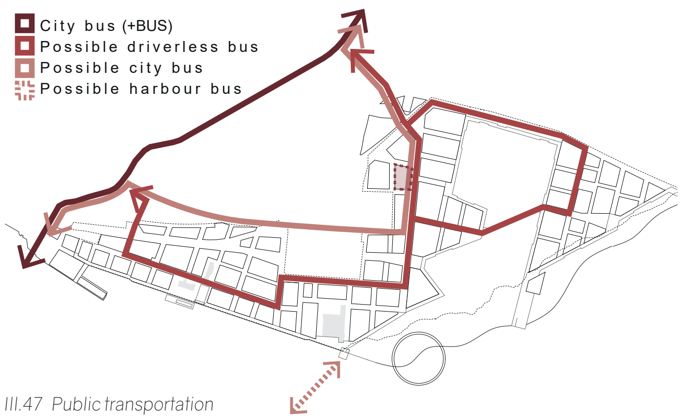
Ill.44 Designed public functions



Ill.45 Location of public squares



Ill.46 Types of roads



Ill.47 Public transportation

Ill.48 Bicycle paths

TRANSPORTATION

Each district will have a main distribution road to which local roads will be connected. The 'play and stay' roads will be shared space, to encourage slower speeds and increase safety. A main access road runs along the northern border of the neighbourhood (Vandkunsten, 2017).

It is the goal for the Stigsborg area to have less than 400 m to the nearest bus stop for all plots. In the future, new public transportation routes will run through the area as seen in the diagram. A possible harbour bus route will create a direct connection between the Stigsborg area and the city centre of Aalborg (Aalborg Kommune, 2017).

The Stigsborg area will be widely accessible by car via select main roads and shared spaces, but car free, dedicated bike paths will also connect east and west (Aalborg Kommune, 2017).

PARTIAL CONCLUSION

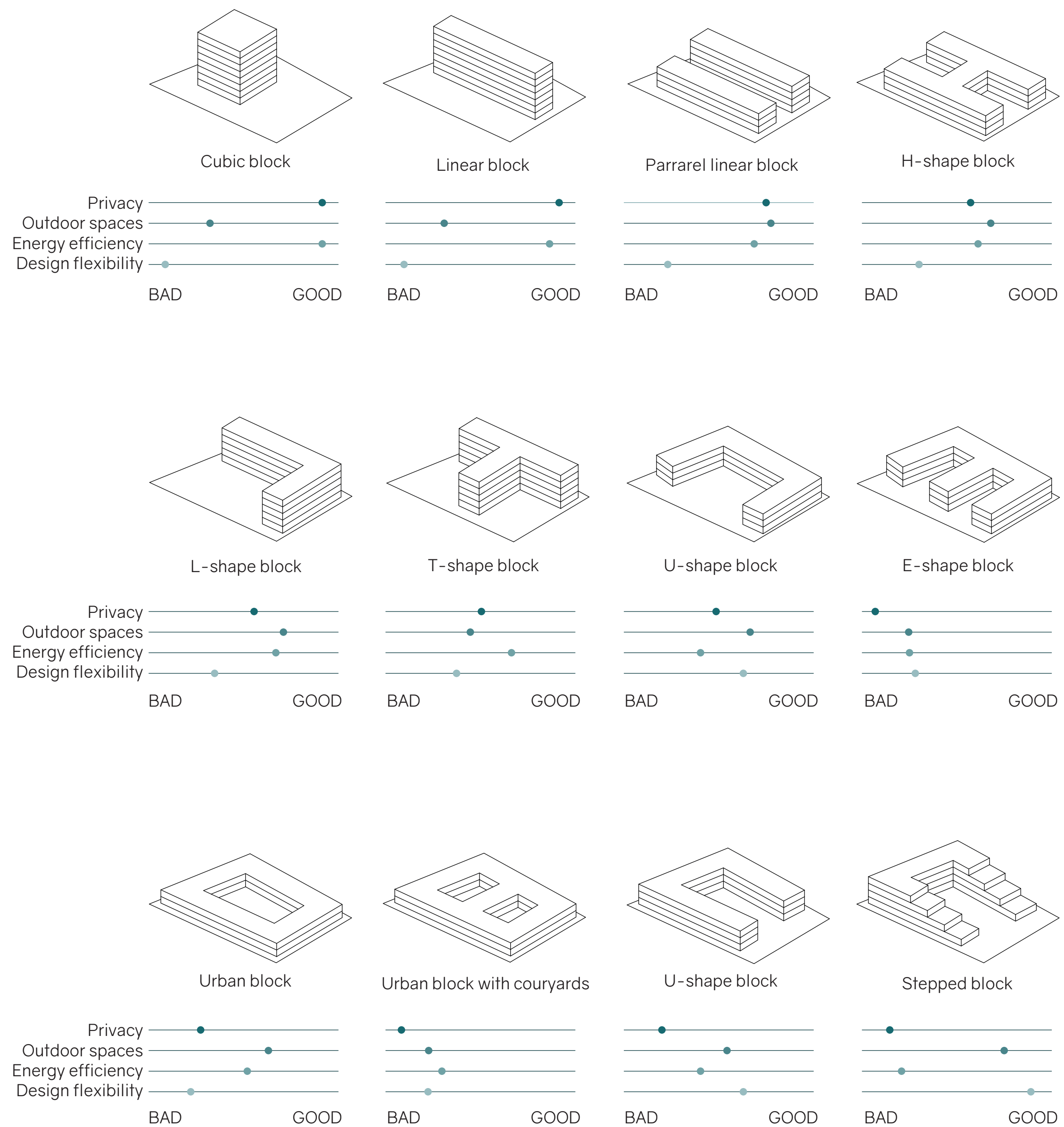
The analysis of the location and climate was crucial foudation for the following sketching phase. The framework of the project is based on the development strategy for area made by the Aalborg municipality.

DESIGN PROCESS

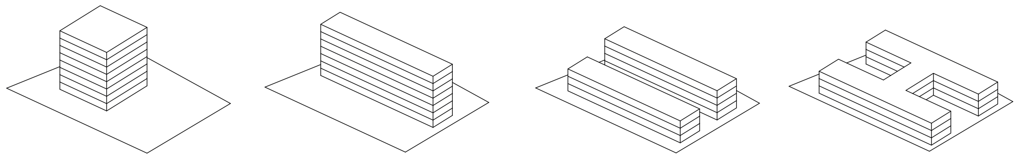
BUILDING TYPOLOGIES
VOLUME STUDIES
ITERATIONS
ITERATION DEVELOPMENT
PLAN DEVELOPMENT
INTERIOR CATALOGUE
INTERIOR CONSIDERATIONS

BUILDING TYPOLOGIES

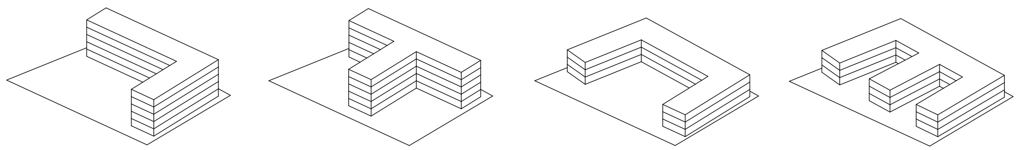
Typology is a way of classification categories of architectural forms with different degrees of density. Distinctly, there are 5 groups: houses, blocks, city blocks, high-rise buildings and mixed solutions. The focus in the project is specifically in the group of blocks and city blocks. That represents group of individual apartments combined. The height varies from 2 to 5 storeys. Within those, there can be differentiated several iterations that are shown on the diagram (Baldea, 2013). The analysis were made to investigate both subjective and objective qualities of each typology. Subjectivly they were analysed in terms of privacy of the apartments, the safety, quantity and quality of outdoor spaces, the ratio between surface area and volume regarding energy efficiency and possible design flexibility.



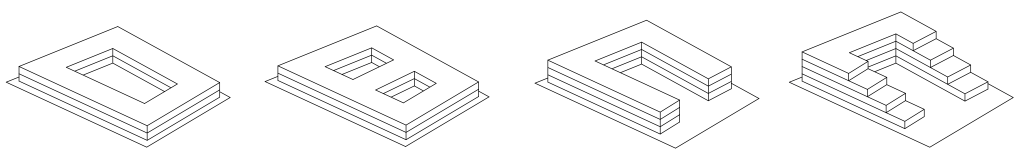
Ill.49 Typologies of the buildings



	Cubic block	Linear block	Parrarel linear block	H-shape block
Roof area [m^2]	625	720	1440	1644
Floors area [m^2]	5000	5040	5040	4932
Walls area excl. windows [m^2]	1960	2469,6	2469,6	2190,3
Transmission loss [W]	17521	19009	20672	20249



	L-shape block	T-shape block	U-shape block	E-shape block
Roof area [m^2]	1056	1056	1459	1787
Floors area [m^2]	5280	5280	4377	5361
Walls area excl. windows [m^2]	2450	2450	1903,65	2315,25
Transmission loss [W]	20295	20295	20304	21859



	Urban block	Urban block with couryards	U-shape block	Stepped block
Roof area [m^2]	2110	2369	1641	1597
Floors area [m^2]	4220	4738	4923	4892
Walls area excl. windows [m^2]	1680,7	1773,8	2138,85	2192,75
Transmission loss [W]	18503	20512	20101	20053

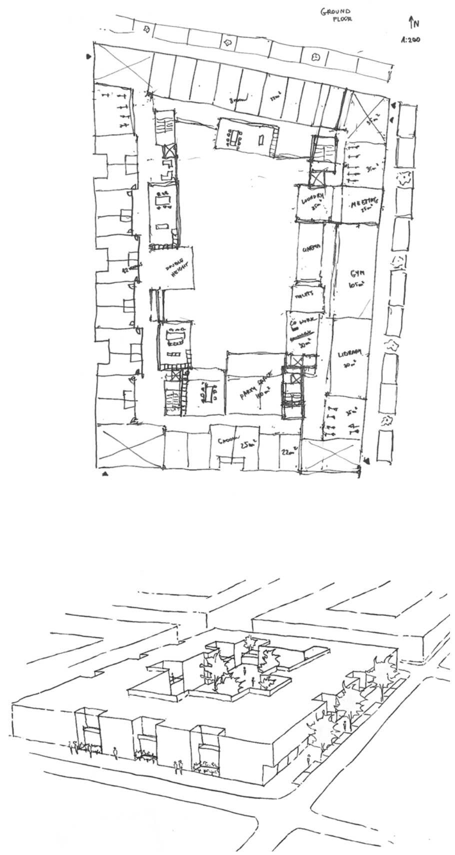
III.50 Transmission loss of different typologies of the buildings

VOLUME STUDIES

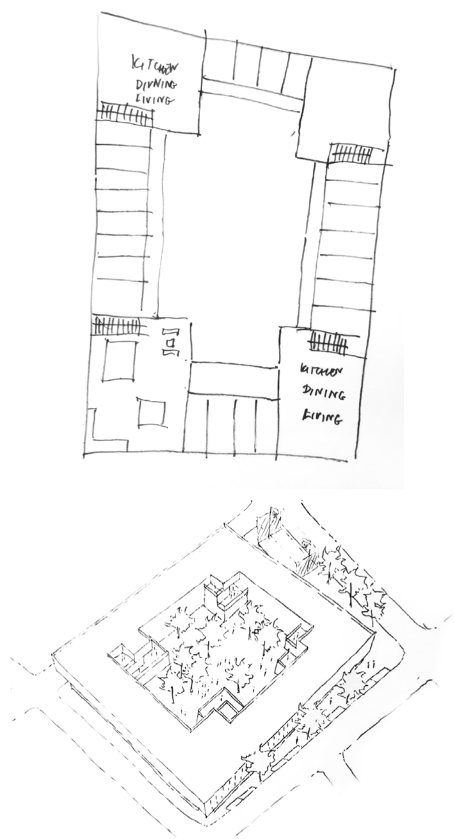
Objectlively, all of the typologies were analysed in terms of transmission loss through the building envelope. The calculations prove that the most optimal volume in terms of area to volume ratio is the cube.

Volume	5000 m^2
Glass area	30 %
Av. U-value build. envelope excl. windows	0.11 W/m^2C
Average outdoor temperature	1°C
Average indoor temperature	22°C

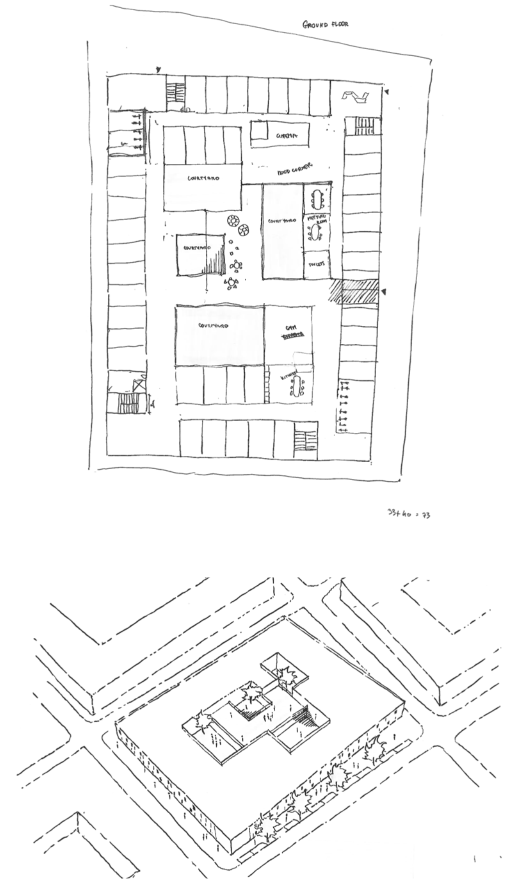
ITERATIONS



Ill.51 Block iteration plan and perspective drawing



Ill.52 Block iteration plan and perspective drawing

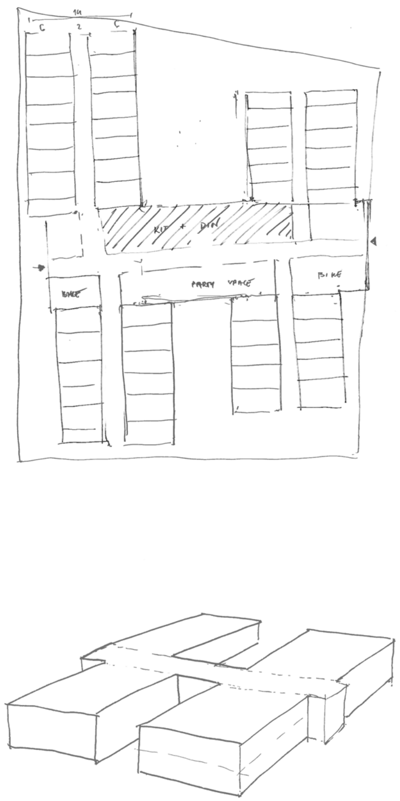


Ill.53 Open ground floor iteration plan perspective drawing

Typology of block was a starting point for the sketching phase of the project. Naturally coming from the masterplan of the Stigsborg area gave a base for several different iterations. The building follows the shape of the plot. Since the initial version seemed to be effortless, next steps were taken in order to challenge the classical idea of one building with internal courtyard.

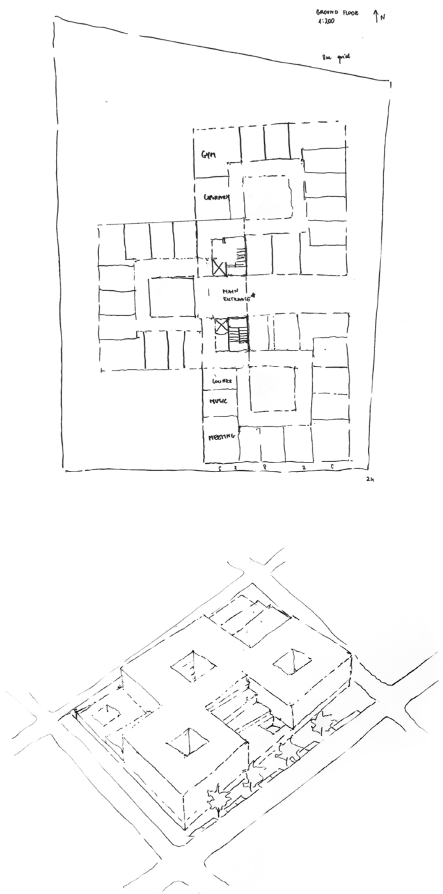
More strict and rigid variant of the building, where the shape is constraint to the rectangle. Private functions are located along the corridors while common kitchens are placed in the corners of the building, but still with connection with internal courtyard in order to give the inhabitants possibility to have visual contact with each other.

Open ground floor plan gives a lot of flexibility in terms of placing different functions but leads directly to problems with not sufficient amount of light. The scale of the building does not allow small courtyards to be comfortable to sit in and have only aesthetical function. The idea was dropped because of light and noise reasons.



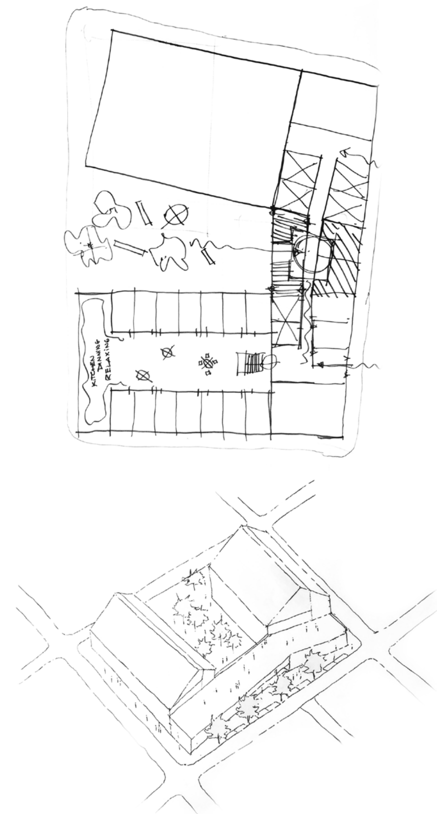
III.54 H-shape iteration plan and perspective drawing

Based on different references of existing dormitories, the other version was drawn. The common functions connecting four different wings of the building. Together with east-west localisation of the rooms came the problem of the privacy which caused moving to another iteration.



III.55 Three volume iteration plan and perspective drawing

Starting all over from the beginning and trying new ideas accompanied the whole sketching process. Totally different approach where rooms would be combined into 3 different buildings with small light court-yards combined with bottom floor for common functions. This version was facing the problem of privacy and lack of light.

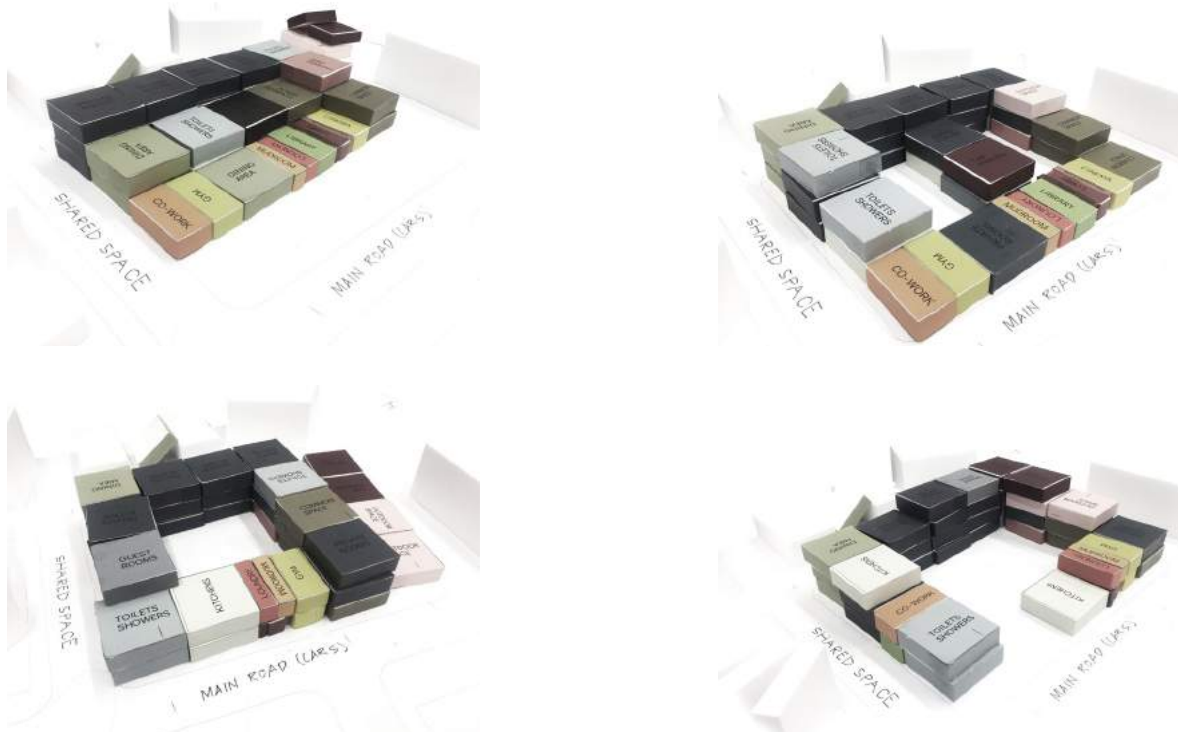


III.56 Two wings plan and perspective drawing

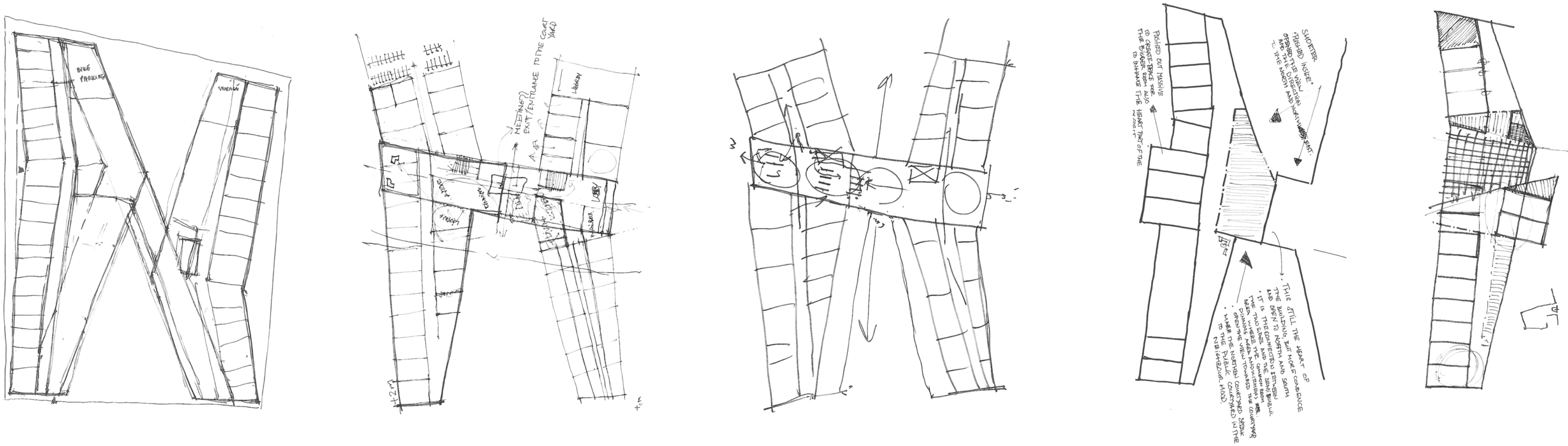
Another iteration shows investigation into different orientation of the rooms and common areas. Two separate wings with private rooms connected with eastern corridor of common functions. Unfortunate placement of the rooms towards the north prevented from further de-velopment of this version.

PHYSICAL VOLUME STUDIES

Together with sketches, the physical volume model was made. It consisted of different functions that were programmed in the building. The model was created in scale 1:200. Each box was 12 x 12 m which related to dimensions from Strategy of the Stigsborg area. There were several iterations of volumes that were modeled. Among the other block, open block and block with two courtyards. It helped in understanding the scale of the project.



Ill.57 Photos of different iterations on physical model



Ill.58 Plan development hand sketches

PLAN DEVELOPMENT

Starting from diagrammatic sketches of the plan, it was developed further with full variety of options. One of the most important features of this concept was a direct visual connection with nearby park. This needed to be respected through whole design process. The sort of transparency in this element was natural and came from the sketch where people from outside could see the vivid life in the building while walking on the street. The other aspect was location of the rooms. They were located in west-east orientation which is the best for the daylight and does not cause any privacy issues. Additionally, in order to avoid so called "dead ends" of the building, at the end of each corridor some working spaces for students were designed.

ITERATION DEVELOPMENT

The iteration that was chosen to be developed began with simple concept sketch diagram in which two parrarrel buildings with the connector were transformed into the configuration where the internal common spaces are the heart of the building. In this stage of the process, the wind, shadow and light analyses were made which are presented in following chapters.

Ill.59 Perspective street view from fjord

Ill.60 Perspective street view from public square

Ill.61 Perspective street view from courtyard

Ill.62 Perspective street view from the park

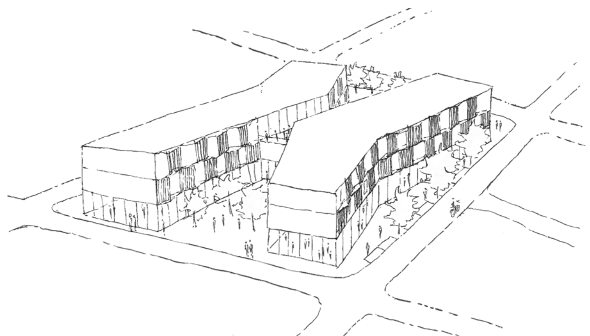
MIDTERM PRESENTATION

The concept was presented during the midterm seminar and has met a positive feedback. The idea was to place the common areas on the ground floor towards the main street and the private rooms towards the west. The rest of the floors consisted only of the private rooms. Inspired by the path coming from the park transparent connection was made. At that point all of the common spaces were located in this area.

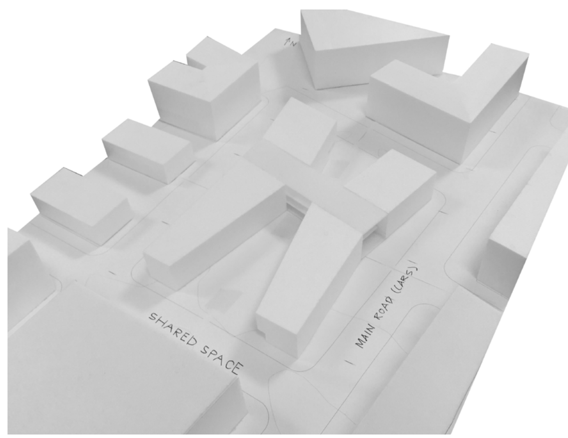
The layout of the private room area had rooms on both sides of the corridor. This created the problem with privacy in those rooms and not enough light in the courtyar. Additionally, internal rooms had odd angles which resulted in uncomfortable spaces to be furnished.

Moreover, the gigantic common space did not represent an intemate atmosphere that was aimed for. There was some criticism about those spaces which resulted in scattered common spaces around the whole complex.

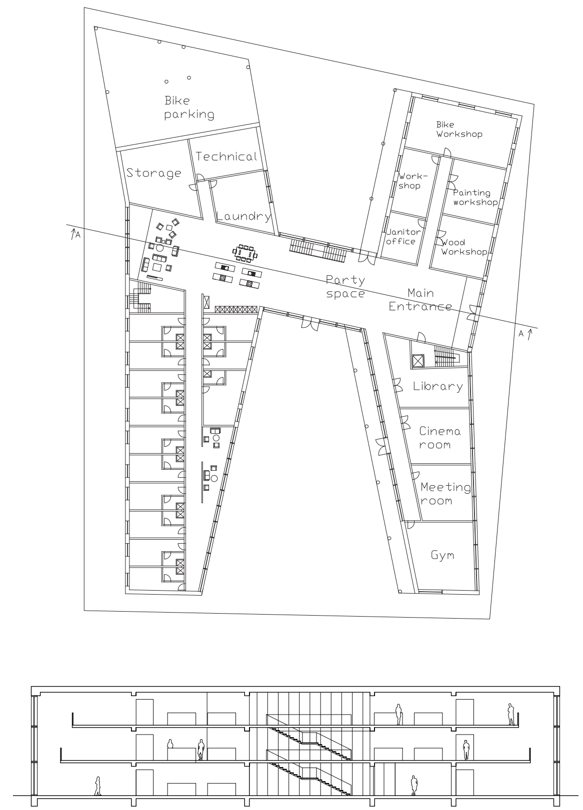
This iteration of the building was a fundament for further elaboration of the project.



Ill.63 Bird view of midterm concept



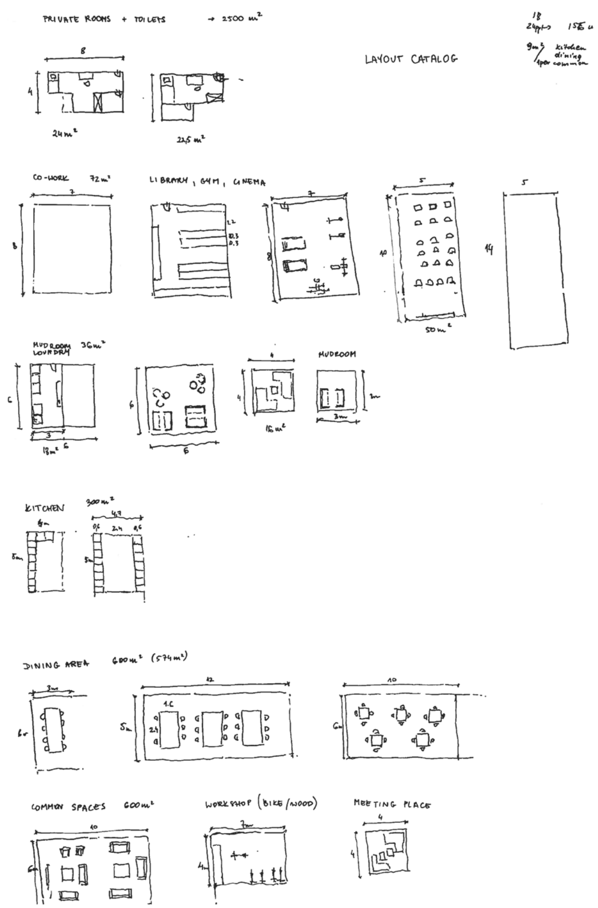
Ill.64 Model presented on the midterm



Ill.65 Plan and section presented on the midterm

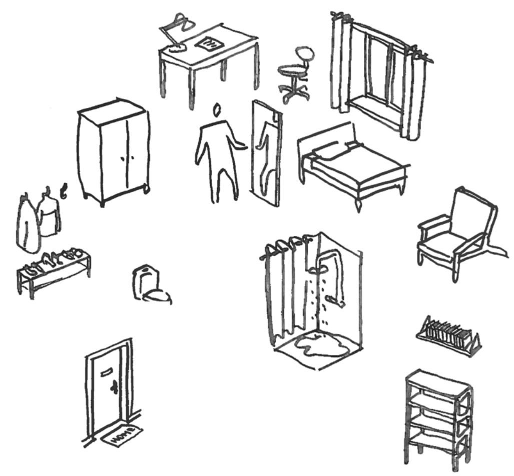
INTERIOR CATALOGUE

Thinking about the users of the building, which mainly were students, the catalogue of interior spaces was developed. At the same time during the process the common spaces and the private rooms were designed. The concept was to provide the basic needs within the private room of the student and then provide him/her with possibility of using common spaces. Very important aspect was that the choice of joining other people was optional and not forced. In this way both intro- and extrovert students would feel comfortable in the building.



Ill.66 Common areas interior plan catalogue

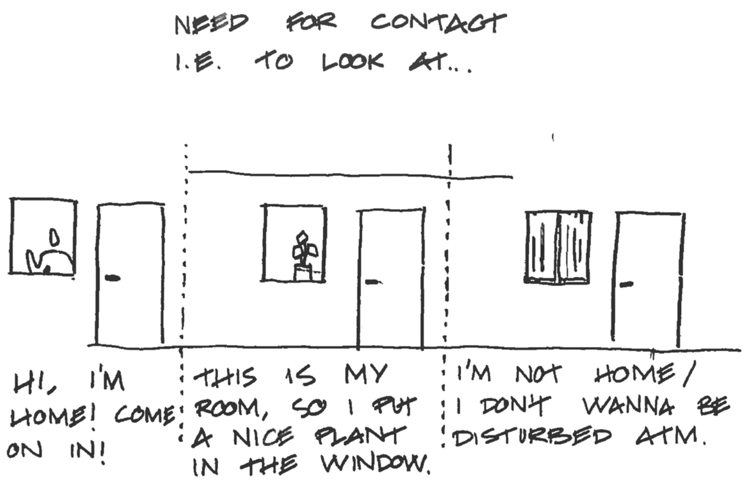
Ill.67 Concept of connection between private and common spaces



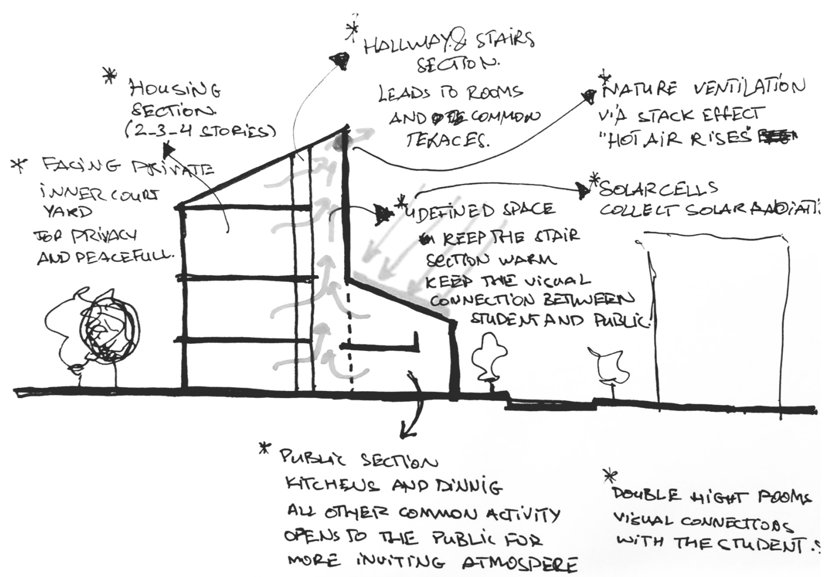
Ill.68 Private room furniture catalogue

INTERIOR CONSIDERATIONS

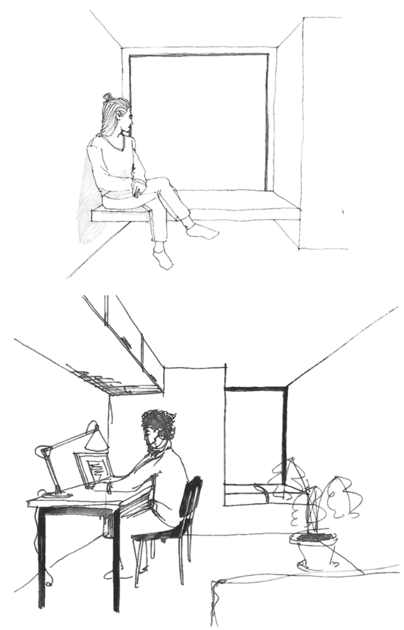
Together with drawing the plans of the interiors, supporting 3D sketches appeared as well. Integrated design process allowed to have full overview on the project all the time. Different passive solutions for the building were also considered during the growth of the project. Among the others passive solar gain and orientation of the building were main drivers for the design.



III.69 Need for contact sketch



III.71 Passive energy initial section



III.70 Private room interior perspective

PARTIAL CONCLUSION

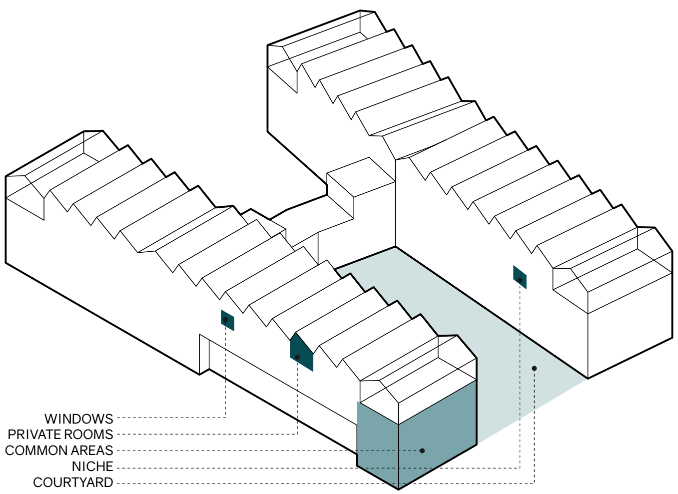
During the design process several iterations of the building were made, supported with working models that narrowed down the design to the final iteration.

SYNTHESIS

REFERENCES
CROSS LAMINATED TIMBER
BRICK
WIND
LIGHT
SHADOW
ENERGY PERFORMANCE
INDOOR ENVIRONMENT

REFERENCES

Different elements of the design have references from other existing buildings that were inspiration during the design process. That allows to communicate the ideas without redundant renderings. Main focus of the design were among the others niche, private rooms, common spaces, windows and courtyard.



Ill.72 Localisation of references

NICHE


Ill.73


Ill.74


Ill.75

PRIVATE ROOMS


Ill.76


Ill.77


Ill.78

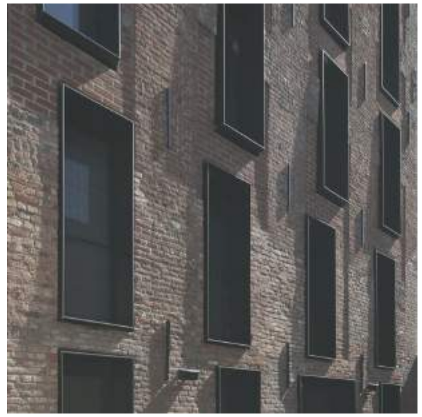
COMMON SPACES


Ill.79


Ill.80


Ill.81

FACADE EXPRESSION


Ill.82


Ill.83


Ill.84

COURTYARD


Ill.85


Ill.86


Ill.87

CROSS LAMINATED TIMBER

CLT is the abbreviation of the term "cross-laminated timber". CLT panels consist of dimensional lumber boards that are stacked side by side and glued together in layers. Every layer is oriented perpendicularly to the grain direction of the previous layer, which makes the panel resilient to forces acting along both axis of its plane. Most CLT panels are made of spruce or fir. The glue is typically a solvent- and formaldehyde-free polyurethane adhesive that has no risk of emissions through its lifetime.

CLT panels are manufactured in full size sheets 4 x 15 m called "master panels" and individual elements are cut from the master panel using a CNC machine (GreenSpec, 2018). This process optimizes the yield of each master panel and is fittingly called "panel optimization". Cut-offs created during the panel optimization are fastened together and used for panels with non-exposed surfaces. Off-site manufacturing like this greatly reduces waste compared to regular on-site construction (Timberfirst, 2012).

The simple selling point of CLT is that it is a sustainable alternative to concrete. It is a renewable construction material with one of the lowest embodied energy consumptions of any building material across its lifecycle; and because the panels are manufactured off-site, building with CLT can also provide time and cost savings during construction (Timberfirst, 2012).

Through their entire growth time, trees will capture CO_2 from the atmosphere and keep it locked in their mass until the wood is burned or left to naturally decompose, so compared to other building materials, timber can therefore be considered "CO_2 negative" - 1 m3 of wood can store 300 kg of CO2 in their mass compared to of concrete, which emits up to 800 kg of CO2 per m3 into the atmosphere (McCaffrey, 2002). FSC certified panels will also ensure that the wood is sourced from sustainably managed forests.

Wood has a higher strength-to-mass ratio than concrete, which leads to a lower total weight of the building's structural element compared with a concrete equivalent. This means that the building needs a smaller concrete foundation, which decreases the building's total carbon footprint.

CLT can be used for all elements of a building and due to their cross-laminated composition the panels are very dimensionally stable. The high plane stiffness allows CLT elements to span great lengths, similarly to beams.

The CLT panels are delivered by truck and assembled on-site. The panels are joined with self-tapping screws and brackets making the construction process is fast and easy. As the panels come prefabricated, there is minimal on-site waste, and construction of the building's superstructure is quiet and clean compared to other building methods.

Ill.88 CLT texture

A big concern with CLT panels is fire safety. Naturally, wood will burn but the composition of CLT panels ensures that it will not experience structural failure too early. Initially, the outer layer of the panel will catch fire, burn it eventually it turns into a protective, charred layer that insulates the rest of the panel. By adding a layer of plaster boards, the fire safety increases even more - from REI 60 up to REI 90 (Storaenso, 2016).

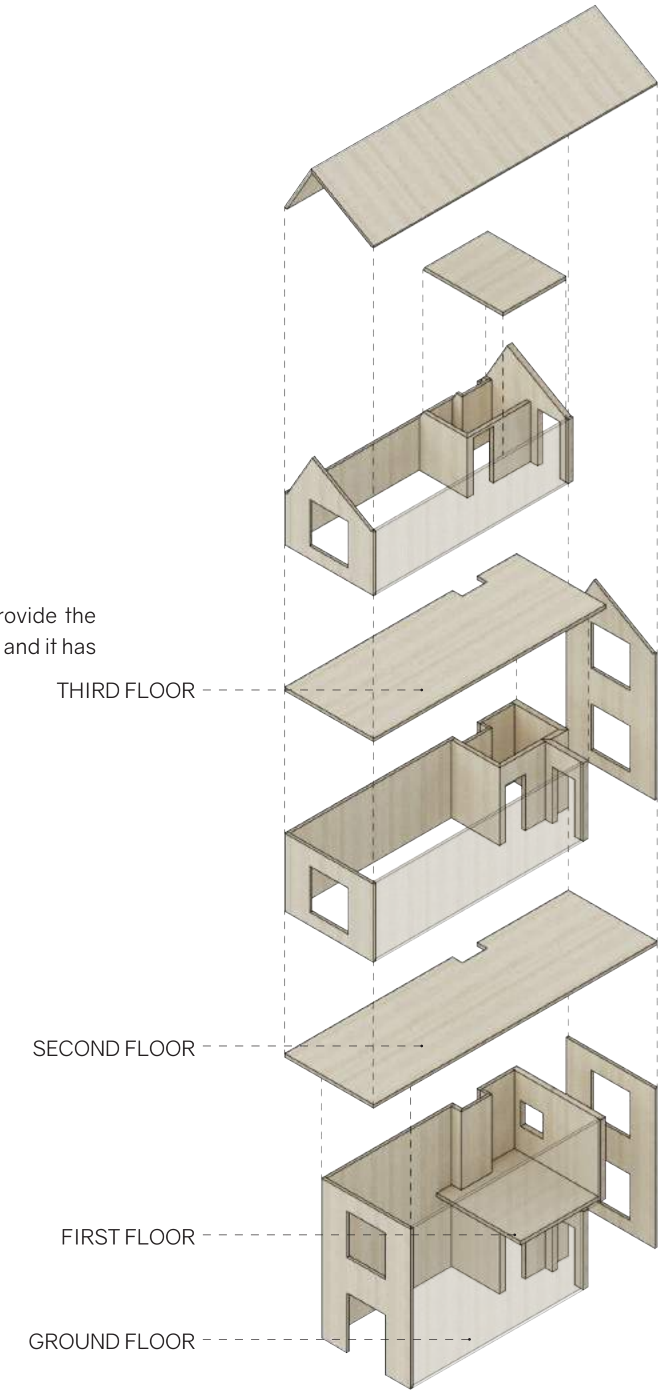
Wood is a naturally hygroscopic material that help to passively regulate the moisture content of the indoor environment (Malmquist, 2017). Since CLT panels are massive elements they have a high thermal mass, which will limit internal temperature fluctuations. When the air is hot, the heat will be absorbed by the panels and released again, when it is cold. The mass of the panels also gives them good soundproofing properties. Limiting stress factors such as excessive heat, cold, or noise pollution is important to achieve a comfortable living environment.

Wood is a natural and organic material with occasional knots and imperfections. This makes the surface visually lively and interesting, while the tactile texture is soft and warm to the touch. The surface of the CLT panels are left exposed on the walls and floor of the building to show the building material and structural system. A rail is attached along the top edge of the walls from which the users can hang pictures, etc.

Conclusively, CLT is a passive indoor environment regulator, it is fast and easy to assemble with minimal onsite waste, it can provide the same strength and structural stability as steel and concrete, and it has a smaller negative impact on the environment.

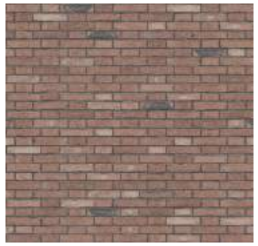
PROS
+ Renewable material
+ Little to no on-site material waste
+ Fast and easy construction
+ Passive indoor environment regulator
+ High strength-to-mass ratio
+ Positive carbon footprint

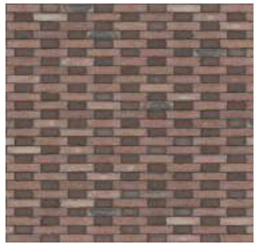
CONS
- Relatively new building material compared to concrete
- Expensive to build with

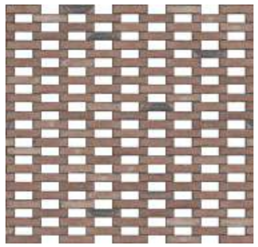


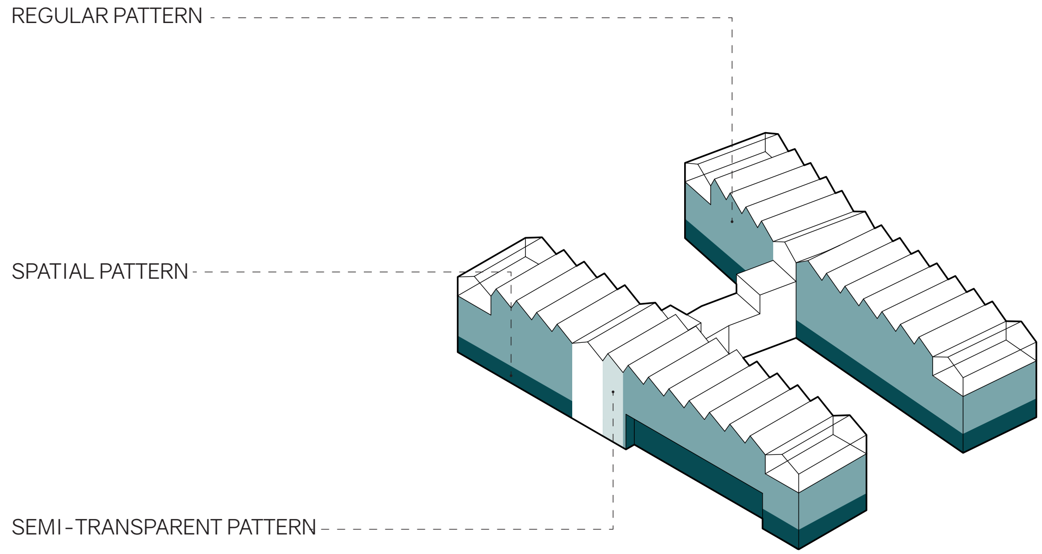
Ill.89 Construction and materiality diagram

BRICK









Ill.90 Brick diagram - localisation of the different Flemmish patterns

Bricks are an aesthetically timeless and sustainable building material. The inherently modular format (228 x 108 x 54 mm) is a perfect canvas with detail and light.

Brick is a very Danish building material. It has been used since the 11th century and is therefore deeply rooted in the country's architectural heritage. For new buildings, it is the most popular façade material and 95 % of all single-family houses are built with bricks (Danske BoligaAkitekter, 2018). In the building site's context, the only pre-existing structure is a typical, Danish apartment building from the 1950's, built with a red brick façade. As such, brick is both historically, contemporarily, and contextually appropriate.

Brick is a natural, long-lasting, and reusable building material. Bricks are made from sand, water, and clay, which are natural materials. The raw materials can be sourced and manufactured locally, which lowers the environmental impact from transportation during production. To remove organic matter and harden the bricks, they must be fired, which requires a relatively high amount of energy. On average, 2.400 kJ of energy is needed to fire one kg of bricks. Darker colours of brick require higher temperatures and therefore more energy. Comparably, red bricks only require one firing. Once the bricks have been fired, they require almost no maintenance and have an expected lifespan of over 100 years. Compared to wood cladding with a life expectancy of about 40 years, brick is cheaper on a long-term basis even though it is more expensive to put up (Byg i Tegn, 2018). Bricks are also highly reusable. If a brick wall is dismantled, all the bricks can be rinsed and reused for other projects. This is especially desirable for restorations where an old or weathered patina is needed. For every 2.000 reused bricks, the environment is spared one ton of CO_2. (GamleMursten, 2018). Bricks have a high thermal mass, which allows them to absorb and expel heat and reduce temperature fluctuations. As the exterior layer of a building envelope, bricks can keep out rainwater, but they are permeable enough to let excess moisture escape from the inner structure minimizing risks of rot. In the sustainable perspective, brick is natural, robust, and reusable as well as passively beneficial.

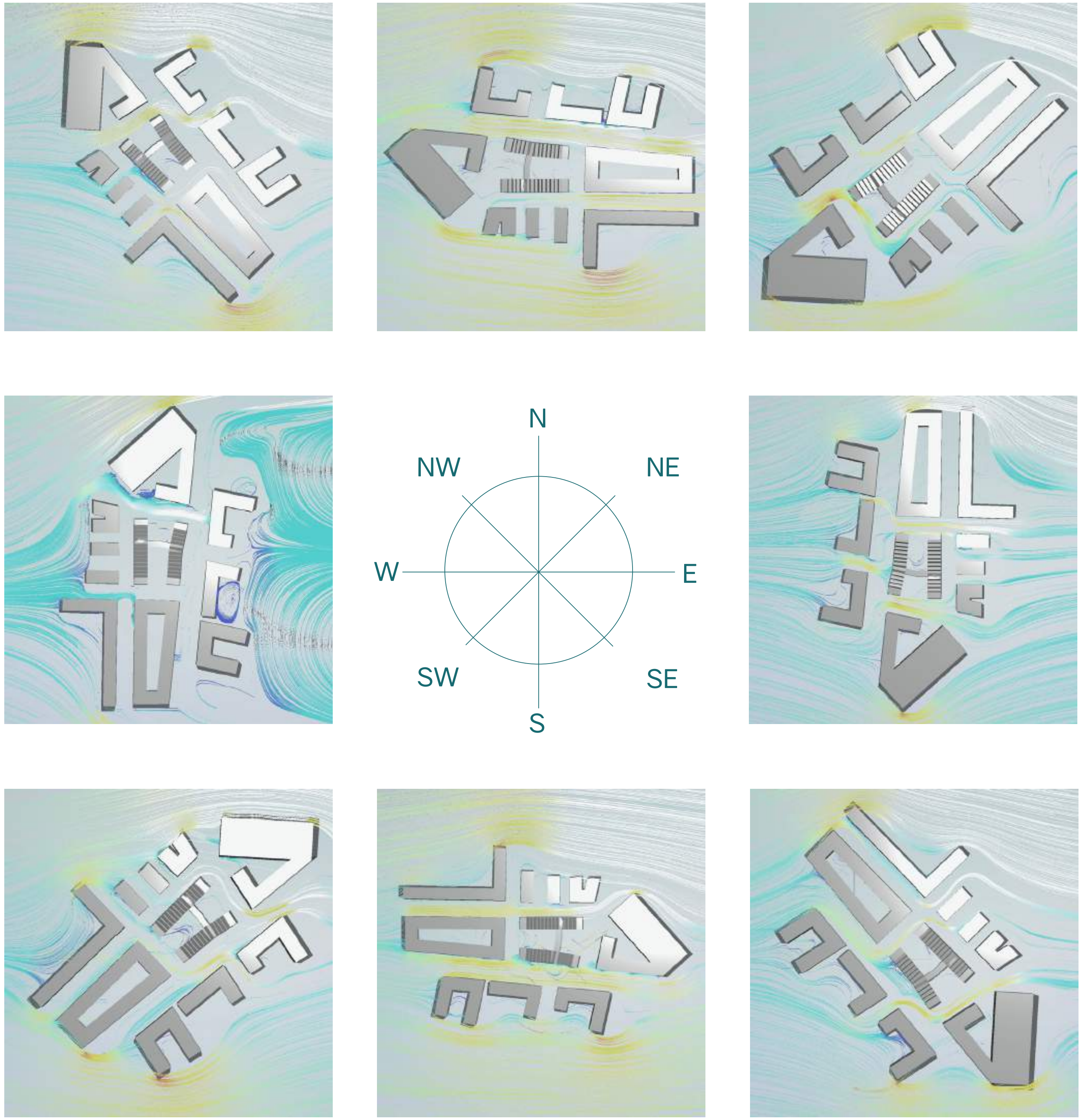
Bricks are building blocks that can be stacked in many ways, producing a wide variety of planar and spatial patterns. Historically, bricks have been laid in loadbearing bonds that could tie the opposing faces of the wall to each other. However, this way of connecting the faces inherently produces a lot of cold-bridges. Hence, modern masons use wall ties to fasten the brick face to the loadbearing structure. This also constrains the brickwork less giving way for more playful brick patterns. With the rising need for high performing building envelopes in contemporary Danish architecture, it is no longer viable to build exterior walls solely out of brick due to their poor heat insulating properties. Therefore, the role of bricks can now be considered more as the skin rather than the skeleton of a building.

The surface of a brick wall has the interesting trait that it will appear differently, depending on the distance from which the spectator observes it. From afar, it will appear to have one, solid colour, but when the spectator moves closer, the bricks and mortar will become distinguishable from each other thereby revealing the pattern of the brickwork. The façade of the building divided into different areas, using different variations of the same brick pattern. Using the method of gesture and principle, this relates the scale of the building to the scale of the human by utilizing spatial offsets in the brickwork.

The diagram above shows the location of three different impressions that are based on classic Flemish patern.

WIND

Wind analysis were made in order to research speed of air around designed building. They were run from all different directions of the world. From the analysis phase of the design, it was known that the strongest and most often wind direction is south-west. It was very important to take it into account while designing the building in order to provide the inhabitants with covered from wind and pleasure outside area. Due to closeness of big Stigsborg park, the idea is that the purpose of the courtyard would be more perceived as place to look and smell at rather than to be in. Naturally, inhabitants are provided with elaborated wooden benches and big terrace on the ground floor which can be used anytime, but the main purpose of that space is to bring the nature closer to the users and make the courtyard pleasant to smell and see all year round.



Ill.91 Wind analysis on the plot

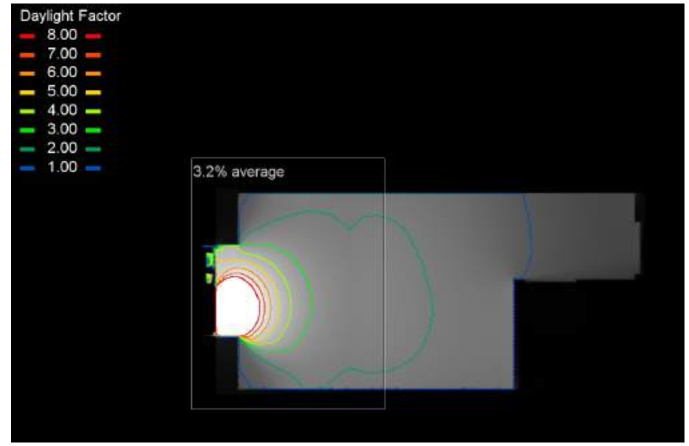
LIGHT

Daylight was an important asset while designing the building. Since the building takes advantage of renewable source of energy which is sun, the size, location and type of windows were meaningful for the project. Trying to reconcile both energy demand of the building and at the same time prevent overheating during the summer period was a big challenge. Additionally, window needed to represent high aesthetic architecture value without going for compromise of its technical performance.

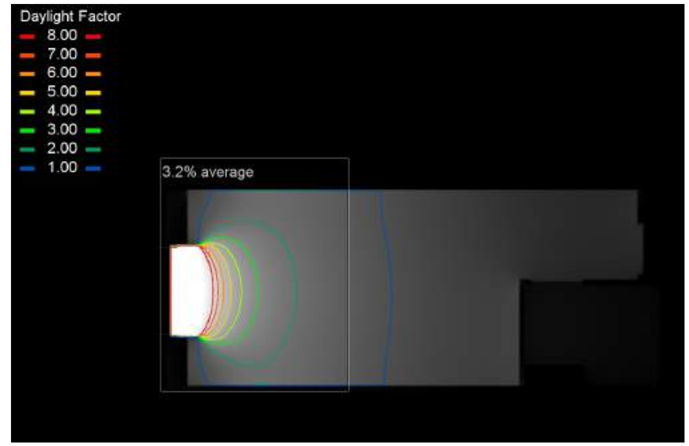
There are several ways to calculate the indoors sunlight but there is no specific indication how to document that there is 300 lux or more on at least half of the given floor area for at least half of the day (BR18, 2018). Because of that, there is plenty ways to interpret the results. During the design process Revit model were made in order to simulate an indoor illuminance. The simulations were made in Insight, which is a plug in to Revit.

However, Revit does not use relevant whether .epw data file, which means that it does not follow the Danish guidance for calculations daylight . Additionally, the results were not accurate for this project because Revit takes LEED certification way of calculating the illuminance. What happened instead, was that with 4m^2 of windows, the room still did not pass the level of proper illuminance.
That is why after several tries, the decision about the size of the windows was made according to new Building Regulations 2018 in housing buildings the glass area must correspond to 10 % or more of the entire indoor floor area. The glass area must take into consideration any shadow-producing obstacles, lowered light transmittance, etc. (BR18, 2018).

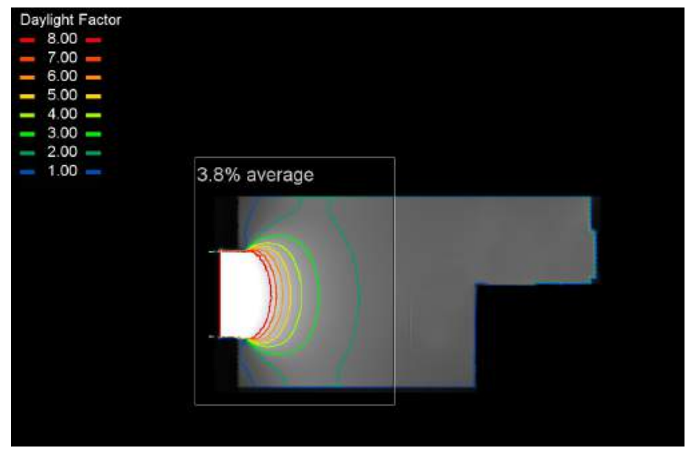
The final design of the regular room window is in size 1600x1600 mm with g-value of 0,5. The daylight factor was simulated in Velux in order to check that there is more than 3 % on at least half of the given floor area for at least half of the day. They were used in 3 different room types that are designed in the building. Three types of rooms will be described in following chapters.



Ill.92 Daylight factor in room type A



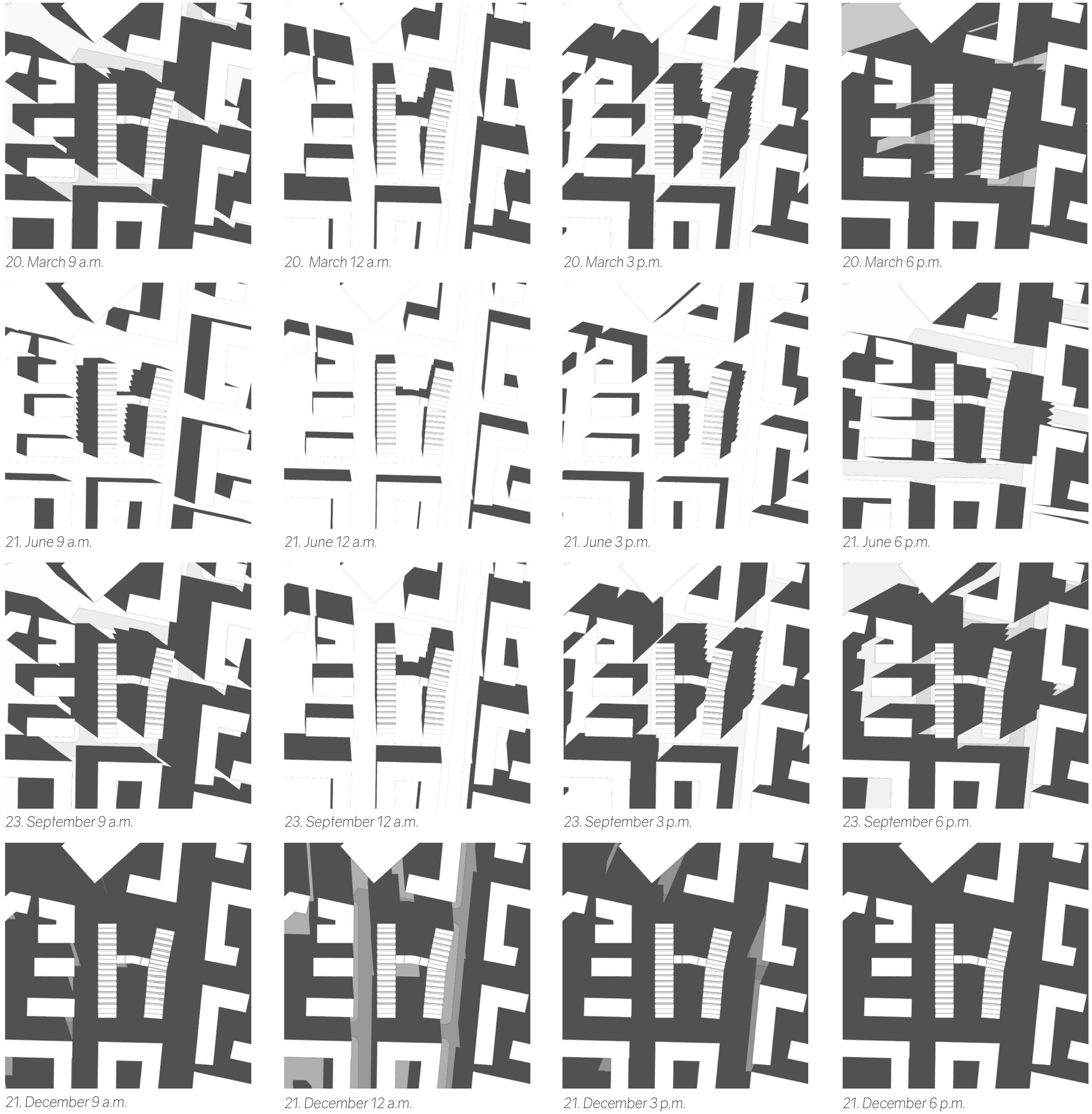
Ill.93 Daylight factor in room type B



Ill.94 Daylight factor in room type C

SHADOW

Together with daylight, to elaborate the need of sun on the plot, the shadow analyses were made. The results show the shadows on the plot during four solstice days of a year (March 20., June 21., September 23. and December 21.) at four different hours (9 a.m., 12 a.m., 3 p.m., 6 p.m.). The main purpose of this analyses were to investigate amount of sunlight hours on the courtyard. More specific simulations to measure this were made in Ladybug. Based on shadow analysis the rooms were located from east and west side of the building to provide students with soft morning and evening sun when they are home and at the same time avoid overheating during the day.



Ill.95 Shadow analysis on the plot

ENERGY PERFORMANCE

The design of the building takes the experience and knowledge from previous phases regarding technical solutions. Since the building is located in Denmark, it has to follow and fulfil among the others all the requirements from Danish Building Regulation 2020 (BR18, 2018). The energy frame and indoor climate were analysed and calculated in order to reach category B criterias from European Standard (EN15251, 2007) and CEN Report (CR 1752, 1998).

The energy performance of the building was calculated in Be18. The building comes below the BR20 regulations regarding both transmission loss through building envelope – 2,3 W/m^2 and energy frame –19,6 kWh/m^2 year (BR18, 2018). The results are taking the active solution into account. There are 150m^2 of solar panels applied on the roof with 30° inclination. It was not possible to reach BR2020 energy frame without solar panels because of the shape of the building which comes with big volume to surface area ratio. Optimal shape of the building would be simple cubic block which represents the least transmission loss through the building envelope. However, this form is not the best for the function of residential building because the floors are too deep for apartments to provide them with sufficient amount of light.

In the project there are several passive solutions applied. In order to avoid overheating in rather transparent common area in the middle, external shutters were installed. Additionally, there are trees in the southern courtyard that helps in the summer to shade the space. Orientation of the building is proper for its function – the rooms are oriented east and west to prevent overheating. The inclination of the roof is towards the south to allow optimal angle of the sun rays to reach solar panels. The building takes advantage of renewable energy from the sun.

Regarding the natural ventilation, there are automatic windows in the external facade above the activity zone on the top floor to allow the stack ventilation to happen. The big volume of common spaces containing kitchens, dining rooms and living rooms is fully ventilated. The air goes through the nets installed in the living space which is both playful and technical element.

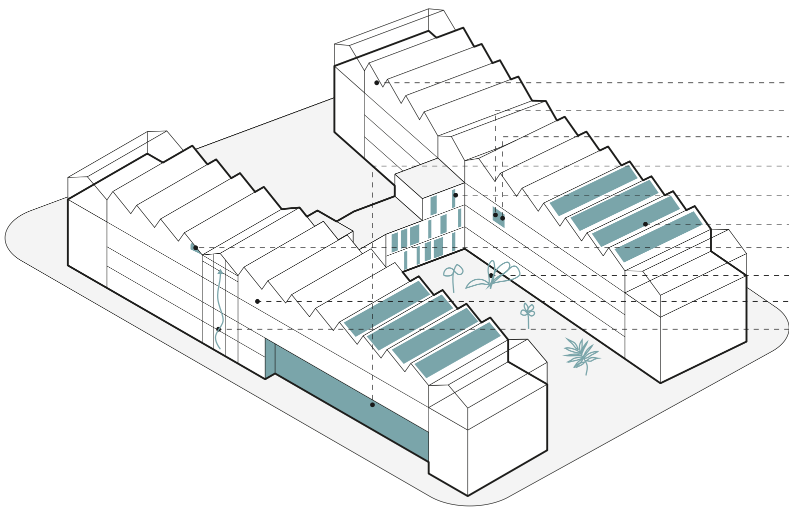
Key numbers, kWh/m^2 year

	Without supplement	Supplement for special conditions	Total energy frame
Renovation class 2	110.9	0.0	110.9
Total energy requirement			34.8
Renovation class 1	52.9	0.0	52.9
Total energy requirement			34.8
Energy frame BR 2015 / 2018	30.3	0.0	30.3
Total energy requirement			25.8
Energy frame Buildings 2020	20.0	0.0	20.0
Total energy requirement			19.7

Contribution to energy requirement		Net requirement	
Heat	44.8	Room heating	21.9
El. for operation of bulding	-4.0	Domestic hot water	22.3
Excessive in rooms	0.0	Cooling	0.0

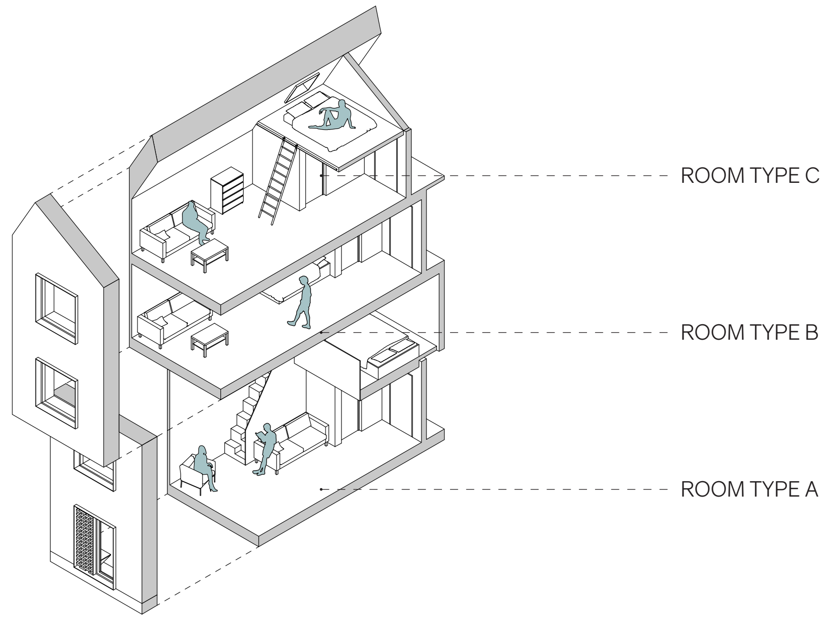
Selected electricity requirements		Heat loss from installations	
Lighting	0.0	Room heating	0.6
Heating of rooms	0.0	Domestic hot water	9.1
Heating of DHW	0.0		
		Output from special sources	
Heat pump	0.0	Solar heat	0.0
Ventilators	2.2	Heat pump	0.0
Pumps	0.2	Solar cells	6.4
Cooling	0.0	Wind mills	0.0
Total el. consumption	17.1		

Ill.96 Key numbers from Be 18



Ill.97 Passive and active strategies diagram

INDOOR ENVIRONMENT



Ill.100 AXO view of three types of rooms

There are three types of rooms that differ in area. Simulations have been made for each room type. Type A is a double height room on the ground floor with two openings on the two levels towards the west and one opening on the upper level towards the hallway. Type B is a room on the 2nd floor and has one opening towards the west face. Type C is a room with a dual pitched roof with a mezzanine and an opening towards the west façade and another on above the mezzanine in the roof. These rooms are chosen because they were critical regarding overheating as it is facing the west and surrounded by the same thermal zone because they are in between the other rooms.

After setting up the model and applying systems of people, equipment, lighting and infiltration, the simulations results proves that the room suffers from overheating at summer season.

To solve this problem, natural ventilation parameters with a set point at 24 C° was applied. Along with the natural ventilation a mechanical ventilation system was also applied to supply the room with 0.015 m^3/s. these two systems helped to reduce the overheating problem but didn't solve it. Therefore, a solar shading system (curtains) applied which helped to reach the thermal comfort requirement (BR18, 2018).

Room type A	TOTAL	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours > 21	7953	457	463	744	720	744	720	744	744	720	744	656	497
Hours > 27	54	0	0	0	0	0	14	11	23	0	6	0	0
Hours > 28	11	0	0	0	0	0	4	2	5	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0

Room type B	TOTAL	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours > 21	8760	744	672	744	720	744	720	744	744	720	744	720	744
Hours > 27	42	0	0	0	0	0	7	18	15	0	0	2	0
Hours > 28	9	0	0	0	0	0	0	0	9	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0

Room type C	TOTAL	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours > 21	8237	525	552	744	720	744	720	744	744	720	744	700	580
Hours > 27	65	0	0	0	26	0	17	13	9	0	0	0	0
Hours > 28	3	0	0	0	0	0	3	0	0	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0

Ill.99 Results from BSim

System	Room type	Description	Regulation	Time indication
People	A	2 people	100%	Week days 01-07/16-24
			100%	Weekends 01-24
	B	2 people	100%	Week days 01-07/16-24
				Weekends 01-24
	C	1 person	100%	Week days 01-07/16-24
				Weekends 01-24

	Room type	Description	Regulation	Time indication
Heating	A	Max power 25 W/m^2	Factor 1	All days from Oct-Apr
		Fixed part 0	Set point 21 C°	
		Part to air 0.6	Design temp -12 C°	
			MinPow 0.5 W/m^2	
			Te Min 18	
	B	Max power 20 W/m^2	Factor 1	All days from Oct-Apr
		Fixed part 0	Set point 21 C°	
		Part to air 0.6	Design temp -12 C°	
			MinPow 0.5 W/m^2	
			Te Min 18	
	C	Max power 20 W/m^2	Factor 1	All days from Oct-Apr
		Fixed part 0	Set point 21 C°	
		Part to air 0.6	Design temp -12 C°	
			MinPow 0.5 W/m^2	
			Te Min 18	

System	Room type	Description	Regulation	Time indication
Infiltration	A	Basic air change 0.065 /h	100%	All the time
		Tem Factor 0		
		Tmp Power 0.5		
		Wind Factor 0		
	B	Basic air change 0.065 /h	100%	All the time
		Tem Factor 0		
		Tmp Power 0.5		
		Wind Factor 0		
	C	Basic air change 0.065 /h	100%	All the time
		Tem Factor 0		
		Tmp Power 0.5		
		Wind Factor 0		

System	Room type	Description	Regulation	Time indication
Venting	A-B-C	Basic air change 2.1 /h	Set point 24 C°	Apr-Sep / 12-20
		TmpFactor 4 /h/K	Set P Co2 0 ppm	
		Tmp Power 0.5	Factor 1	
		Wind factor 0.1 s/m/h		
		Max air change 10 /h		

System	Room type	Description	Regulation	Time indication
Ventilation	A-B-C	Fans: input	Point 1 Te1 -12 C°	Al the time
		Supply 0.015 m^3/s	Tinl1 on line 20 C°	
		Pressure rise 900 Pa	Point2 Te2 -12 C° 8	
		Total eff 0.85	Tinl2 on line 20 C°	
		Part to air 0.5	Slope before 1 0	
		Fans: output	Slope before 2 0	
		Return 0 m^3/s	Air hum 0.07 kg/kg	
		Pressure rise 600 Pa		
		Total eff 0.85		
		Part to air 0.5		
		Recovery unit		
		Max Heat rec 0.9		
		Min heat rec 0		
		Max cool rec 0		
		Max moist rec 0.6		
		Heating coil		
		Max Pow 1 kW		
		Cooling coil		
		Max Pow 0 kW		
		Surf temp 5		
		Humidifier		
		Max output 0 kg/h		

System	Room type	Description	Regulation	Time indication
Equipment	A,B,C	One laptop	100%	Everyday 17-22
		Heatload 0.135 kW		
		Part to air 0.5		
		One LCD tv	100%	Everyday 18-22
		Heatload 0.18 kW		
		Part to air 0.5		
		One cooffe machine	100%	Everyday 20 min
		Heatload 0.7 kW		
		Part to air 0.5		
		Vaccum cleaner	100%	Every week 15 min
		Heatload 0.12 kW		
		Part to air 0.5		

System	Room type	Description	Regulation	Time indication
Lighting	A,B,C	Task lighting 0.013 kW	Factor 1	May-Sep/20-24
		General lighting 0.1 kW	Lower limit 0.05 kW	Oct-Apr, week days/6-8, 16-24
		Gen. lighting level 200 lux	Temp max 25 c°	Oct-Apr, weekends/6-10, 15-24
		Lighting type fluorescent	Solar limit 0	
		Solar limit 0.1 kW		

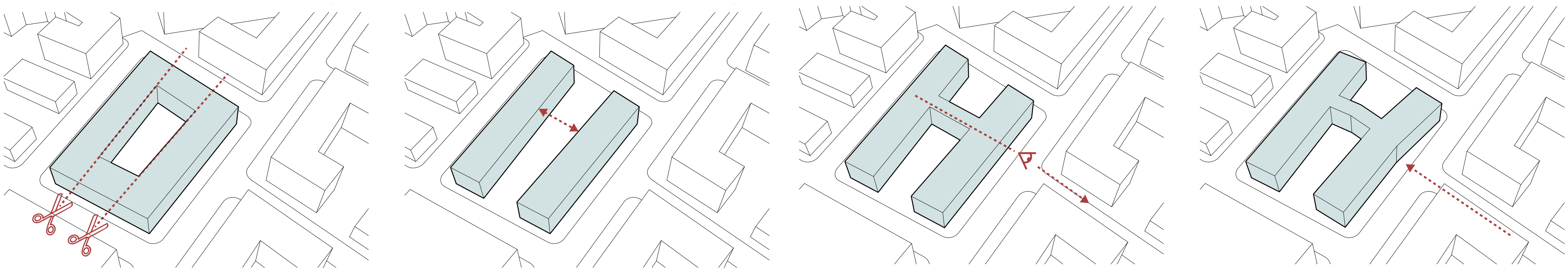
Ill.101 Systems applied in the BSim

PARTIAL CONCLUSION

The technical aspects of the building is an essential part of the design. Supported with light, shadow and wind analyses, it represents fundamental considerations about both energy performance and indoor climate.

PRESENTATION

FORM DEVELOPMENT



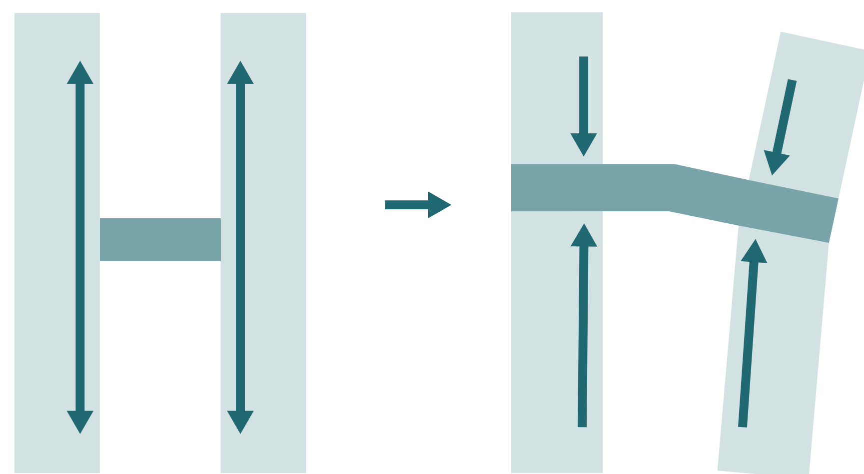
Ill.102 Form development diagram

The development of the concept was a complex process. In very simplified diagram there are 4 steps that were taken to achieve the desired form of the building. The starting point was urban block building with internal courtyard. Because its encosurness the building volume was splitted to two separate volumes. To link two buildings, connector was added. Lastly, the axis view towards the park was respected and with this gesture the eastern volume was tilted.

III.103 Vizualization - bird view

CONCEPT

The basic idea for the project came from the simple drawing that instead of placing the common functions in the connection of the building, they were placed in the whole middle part of the design. In this way inhabitants have enabled visual contact with what is happening in the common areas and be enhanced to join other people. Additionally, transparency of that area strengten axis view to nearby Stigsborg park.

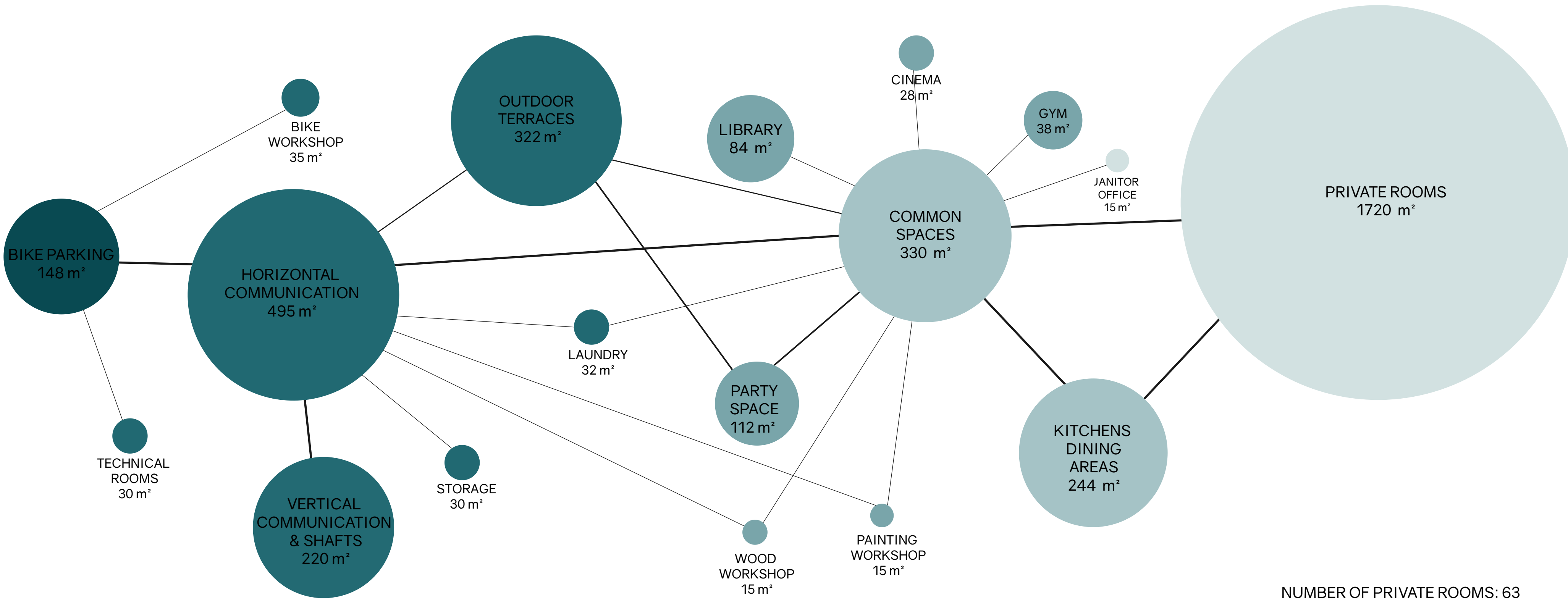


Ill.104 Concept diagram

Ill.105 Vizualization - View from the park

PROGRAM

Due to the function of the building which is student housing, the main program of our building are rooms for students. Besides this, there are full range of supporting functions to this one. The heart of the project is common spaces which act as a main place for social interaction of inhabitants.

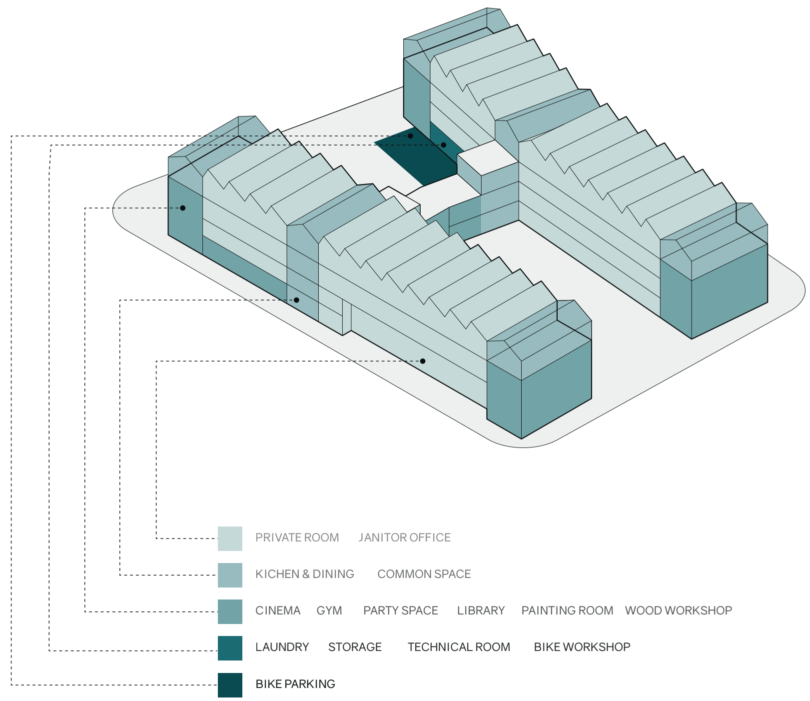


NUMBER OF PRIVATE ROOMS: 63
TOTAL NET AREA: 3720 m²
TOTAL GROSS AREA: 4980 m²

Ill.106 Diagram of connections of the functions

FUNCTIONS

The basic idea of the project is to locate the shared kitchens, living rooms and dining rooms in the center of the building in order to enhance the possibility for the contact within inhabitants. In this way, students have better visual connection with the activities happening in the centre of the building. Furthermore, working spaces and meeting rooms are placed at the end of each wing of the building to give a chance for vertical communication within the each cluster. Additionally, some of the private functions were located on the ground floor in the northern part of the building. The private rooms are facing west and east, both because of privacy issues and to prevent overheating during the summer period.



Ill.107 Function diagram

MASTER PLAN

The project is located in Stigsborg area in Nørresundby. There is 60 m from the plot to the big Stigsborg park. It is part of the strategy of the landscape part of the project where in principle people would go to that park to spend the free time. From the east side, according to the masterplan of this place, there will be busy street located. Other surrounding roads have only local character where only residents will use it.

There will be few retail shops located in the diamiter of 300 m. Other, existing ones are 1 km from the plot. There is a bus stop in a walking distance of 300 m. The city center is in the bike distance of 2 km. Additionally, there is planned a stop of future water bus that will help with communication of the people to the center. The whole new Stigsborg area will be mixed use what makes the place attractive for young people coming to Aalborg.

Ill.108 Masterplan drawing - scale 1:5000

GROUND FLOOR

The main entrance of the building is facing the north courtyard. It is placed in the middle of the connector which links two wings of the building. Next to the entrance, main bike parking is located. There are also entrances from south, east and west side of the building which are provided with additional bike parking places.

The connector is a link between the common facilities section and the private room section. It is important that the connector is a destination itself and not only a passage, where people can meet to relax or play some indoor games like table tennis. In the south part of it, there is a big terrace that provides inhabitants a space to enjoy a sunny day outside.

From the conncector residents can move to different common facilities located in northern part of the building. In the east wing there are different workshops located that are oriented towards the main street which brings the life to the sourrounding area. In the west wing there is a cinema room, a laundry room and a double height library which will be the first to perceived when people approach the site of the public square with the bus stop.

Two southern wings consist of private room sections that include type A - double height rooms accessed from a corridor with a view towards the inner court yard and ends up with the common meeting rooms.

Number	Quantity	Name	Net area (m²)
1	1	Library	84
2	1	Storage	15
3	1	Cinema room	28
4	1	Laundry and drying room	32
5	1	Common toilet	14
6	1	Technical room	14
7	1	Bike workshop	35
8	1	Gym	38
9	1	Common toilet	7
10	1	Handicap toilet	5
11	1	Reused room	15
12	1	Workshop	15
13	1	Storage	15
14	1	Workshop	15
15	1	Technical room	15
16	1	Janitor room	15
17	1	West wing entrance	57
18	1	Common area	40
19	1	Main entrance	33
20	1	Common area	38
21	1	East wing entrance	55
22	1	Vertical connections and technical shaft	25
23	1	Vertical connections and technical shaft	30
24	1	Horizontal connection	187
25	13	Type A Double hight student room (22.5 m² per room)	292,5
26	1	Common room	57
27	1	Common room	57
Total			1176,5

III.110 Table of net interior areas

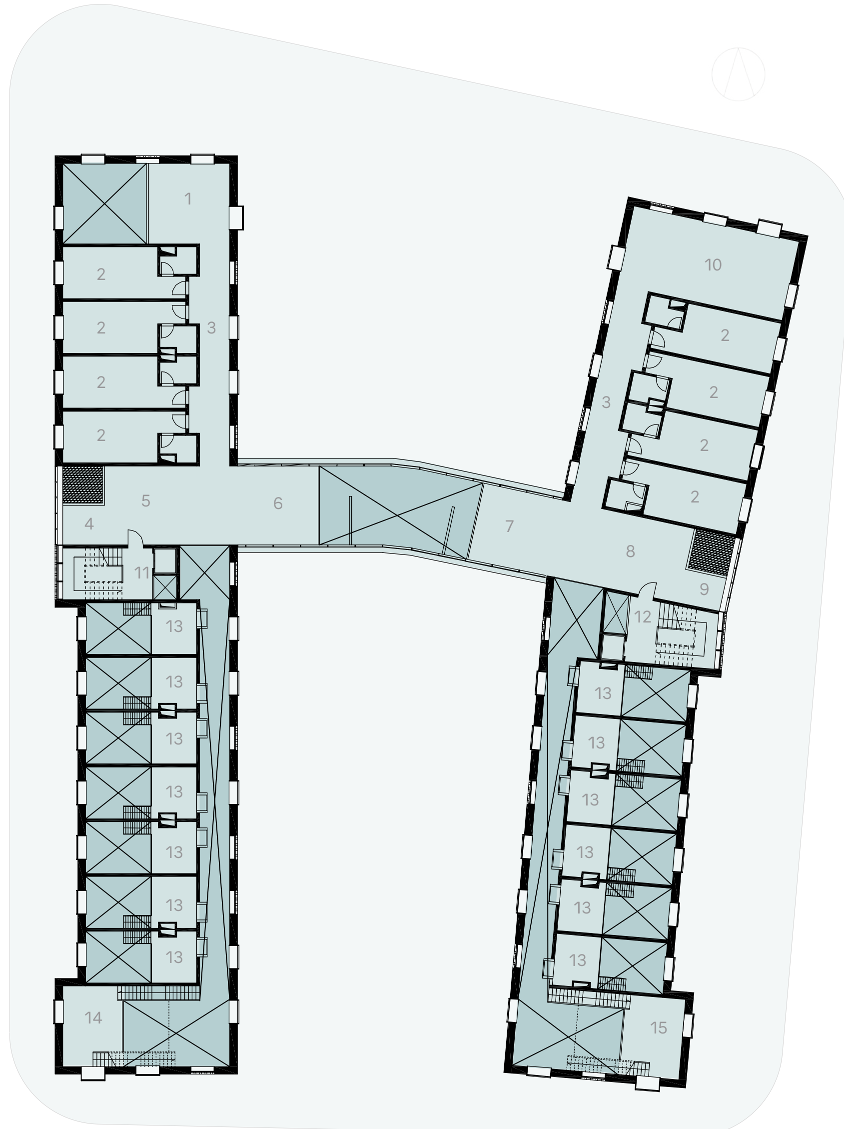
III.109 Ground floor plan - scale 1:500

FIRST FLOOR

On the first floor there are type B rooms located above the common facilities section. They are accessed with a corridor that ends up with the common study rooms. In the connector there are the common kitchens, the dinning areas and the living rooms which are balconies to the area at the ground floor.In the southern part of the building there are mezzanines of rooms type A. There are internal windows installed towards the double height corridor which allows inhabitants to interact with each other.

Number	Quantity	Name	Net area m²
1	1	Studying room	28
2	8	Type B studet room (27.5 m² per room)	220
3	1	Horizontal connection	89
4	1	Dinning area	15
5	1	Kitchen	24
6	1	Living room	30
7	1	living room	30
8	1	Kitchen	24
9	1	Dinning area	15
10	1	Studying room	55
11	1	Vertical connections and technical shaft	25
12	1	Vertical connections and technical shaft	30
13	13	Type A Double hight student room (9.5 m² per room)	123,5
14	1	Common room	18
15	1	Common room	18
Total			744,5

Ill.112 Table of net interior areas



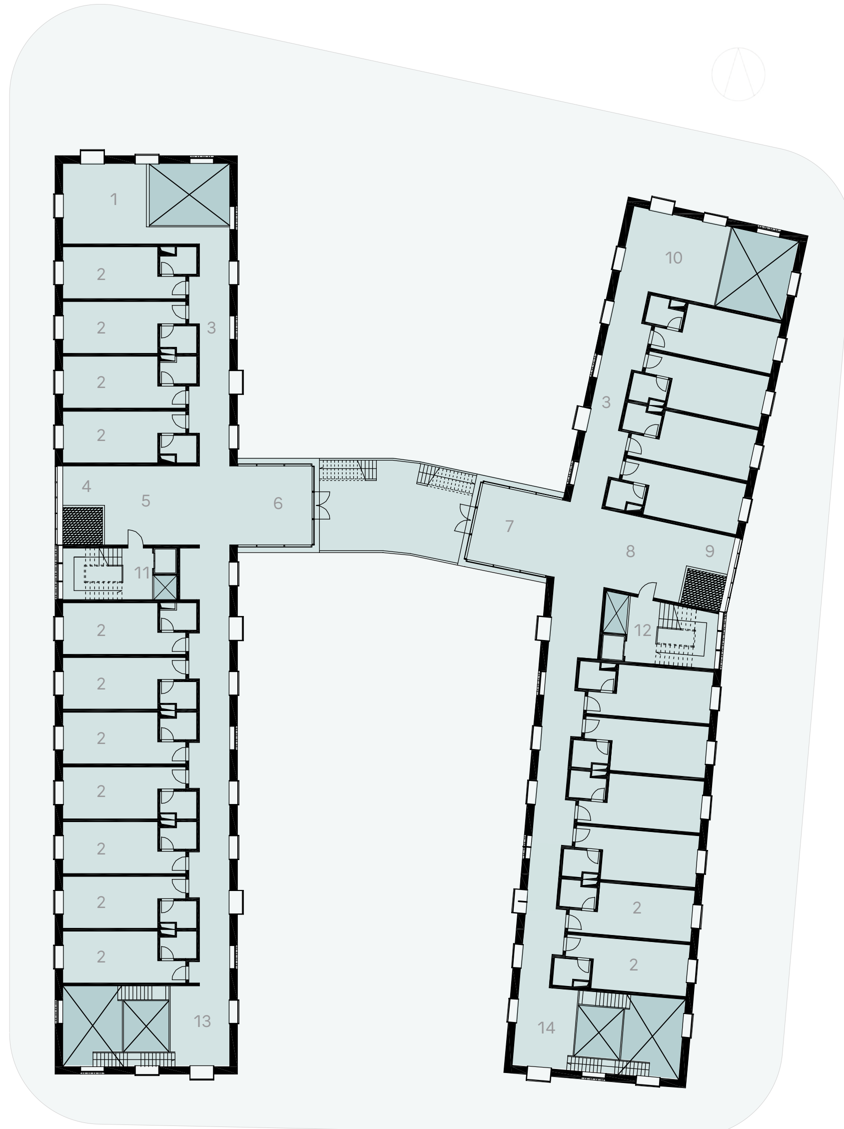
Ill.111 First floor plan - scale 1:500

SECOND FLOOR

The second floor includes type B rooms on the both sides of the connecting path. The rooms are accessed by the corridor and ends up with the common meeting rooms at the south and the common studying room at the north. In the middle, there are the kitchens, dinning areas and the living rooms where it is possible to access the outdoor terrace from them and move between the east and west wing of the building.

Number	Quantity	Name	Net area (m²)
1	1	Studying room	28
2	21	Type B studet room (27.5 m² per room)	577,5
3	1	Horizontal connection	92,5
4	1	Dinning area	15
5	1	Kitchen	24
6	1	Living room	30
7	1	Living room	30
8	1	Kitchen	24
9	1	Dinning area	15
10	1	Studying room	35
11	1	Vertical connections and technical shaft	25
12	1	Vertical connections and technical shaft	30
13	1	Common room	21
14	1	Common room	21
15	1	Outdoor terrace	58
Total			968

Ill.114 Table of net interior areas



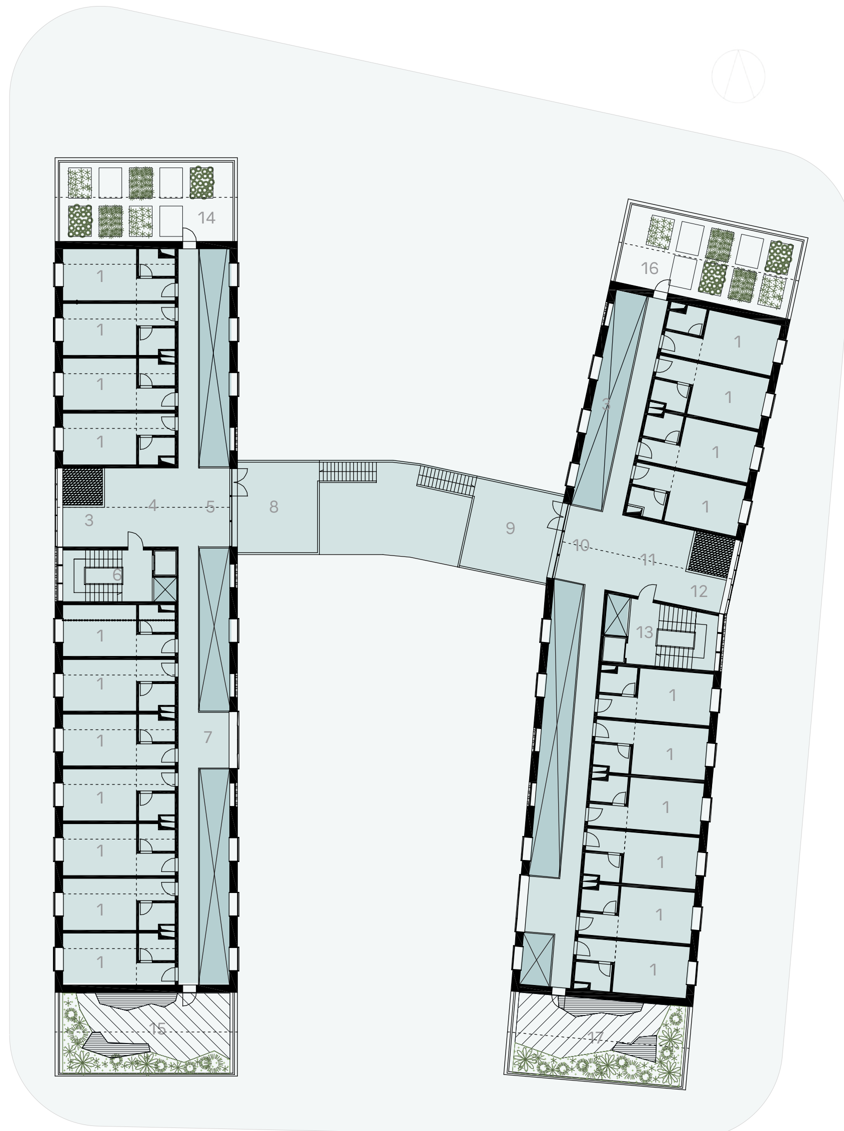
Ill.113 Second floor plan - scale 1:500

THIRD FLOOR

This floor consists of the type C rooms which are smaller than the other types. This feature allowed creaction of a corridor that has a visual connection to the floor below. The combination of various volumes created a special social experience and atmosphere between these two floors. At the same time exposed the shape of the roof. A new indoor balcony is created by connecting the corridor with the external wall which add even more different experiences in this floor.

Number	Quantity	Name	Net area m²
1	21	Type C studet room (23.7 m² per room)	497,7
2	1	Horizontal connection	126
3	1	Dinning area	7
4	1	Kitchen	25
5	1	Living area	10
6	1	Vertical connections and technical shaft	25
7	1	Indoor terrace	7
8	1	Outdoor terrace	31
9	1	Outdoor terrace	31
10	1	Living area	10
11	1	Kitchen	25
12	1	Dinning area	7
13	1	Vertical connections and technical shaft	30
14	1	Outdoor terrace	66
15	1	Outdoor terrace	66
16	1	Outdoor terrace	66
17	1	Outdoor terrace	66
		Total	831,7

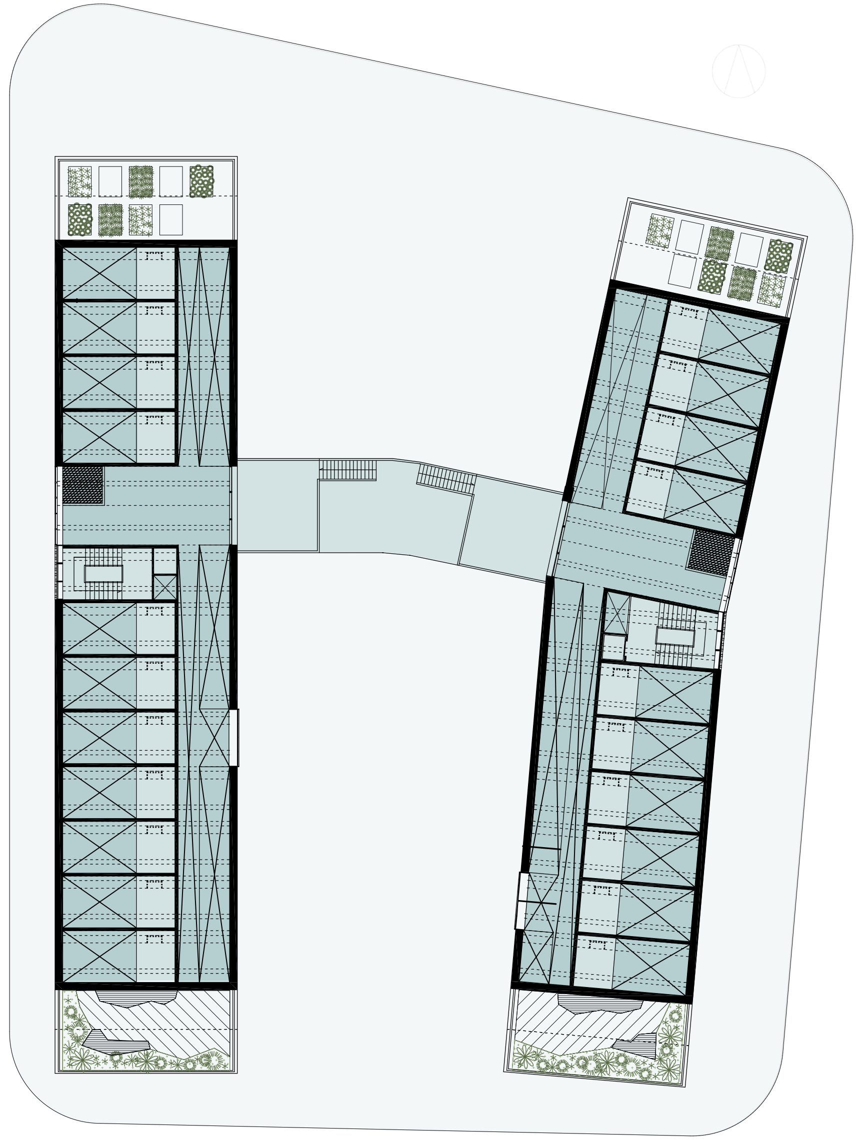
Ill.116 Table of net interior areas



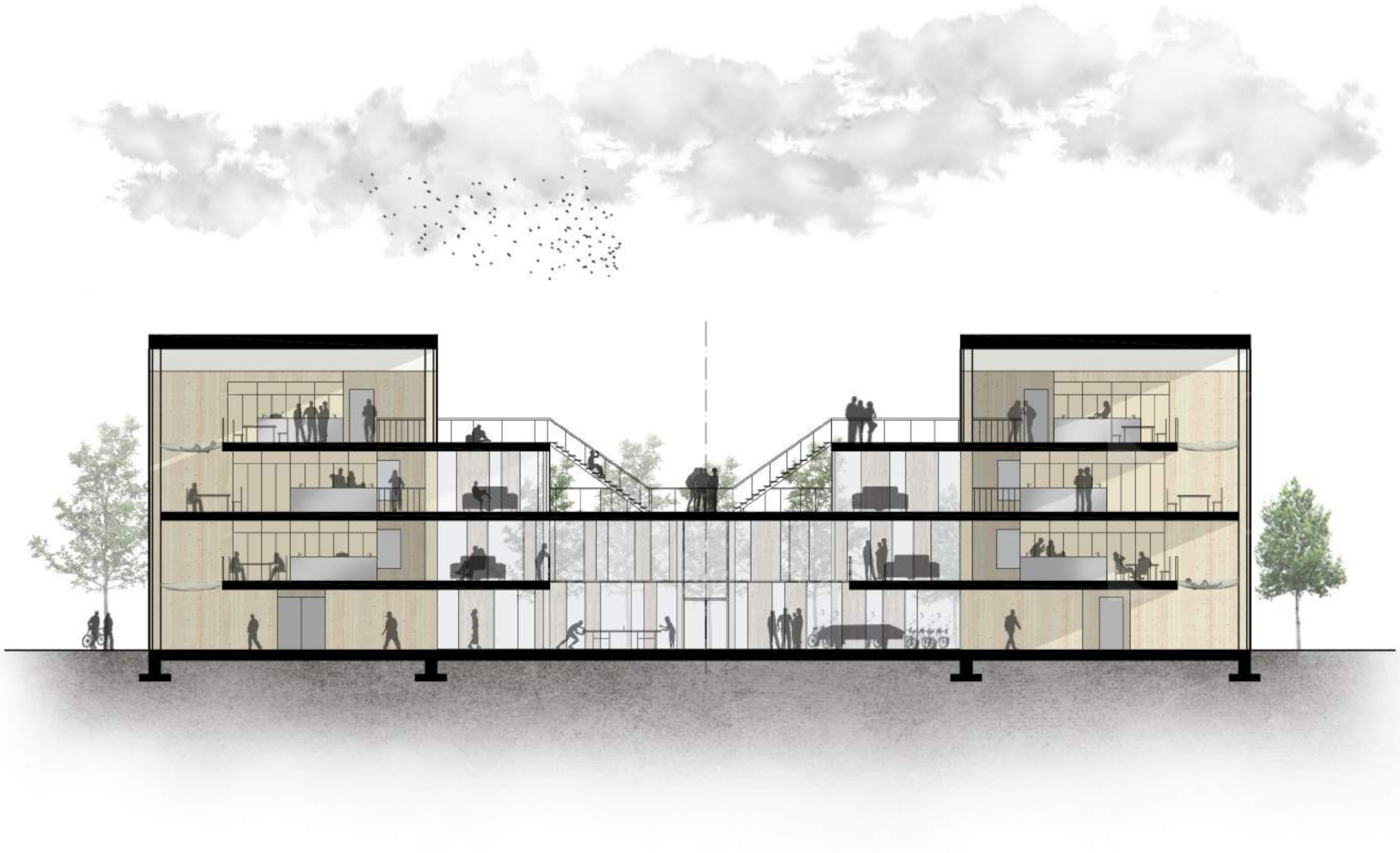
Ill.115 Third floor plan - scale 1:500

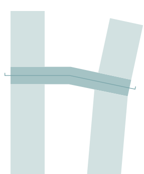
MEZZANINE FLOOR

This floor shows the mezzanine space that belongs to the third floor room type C. Even though it is a small space, the plan shows that it provides enough cozy space for a mattress, and a big window to enjoy watching the stars and the sky from the bed.



Ill.117 Mezzanine floor plan - scale 1:500





III.118 Sestion A-A scale 1:250

Ill.119 Sestion B-B scale 1:250

III.120 Section C-C 1:250

Ill.121 Vizualization - view from the courtyard

Ill.122 Elevation northscale 1:250

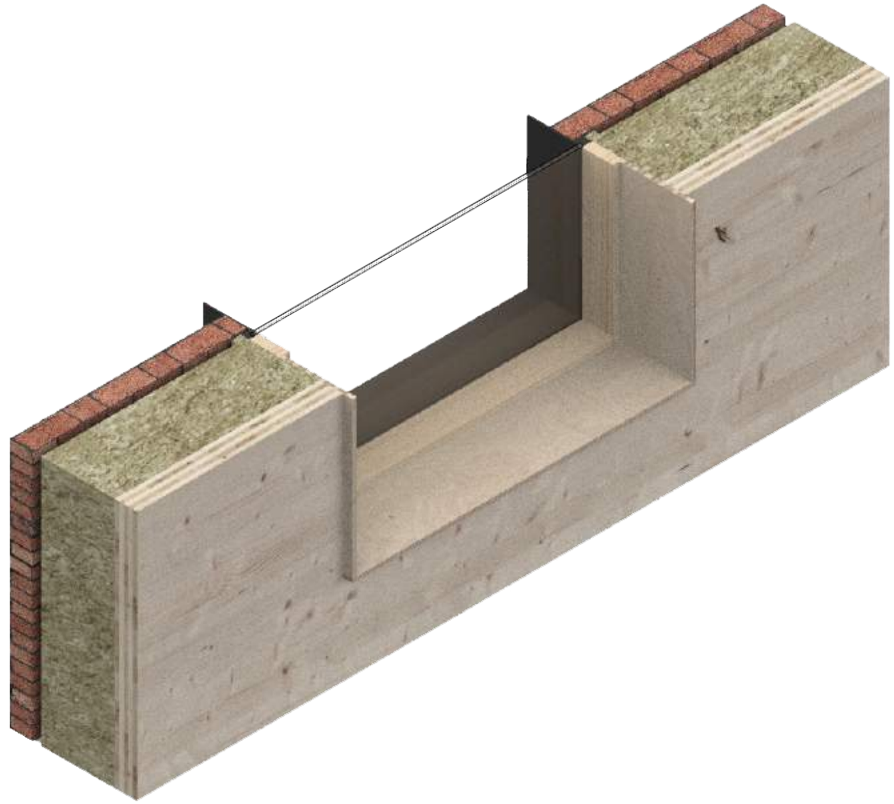
Ill.123 Elevation east scale 1:250

Ill.124 Elevation south scale 1:250

Ill.125 Elevation west scale 1:250

DETAIL

The drawing shows a crucial detail of the building. It is a connection of the window with external wall. The U-value was calculated to ensure that building envelope will have allowable transmission loss (BR18, 2018). Additionally, axonometric render was made to explain the key connection. It has high architectural expression that gently covers the frame of the window and at the same prevent linear loss around the opening (DS 418, 2007).

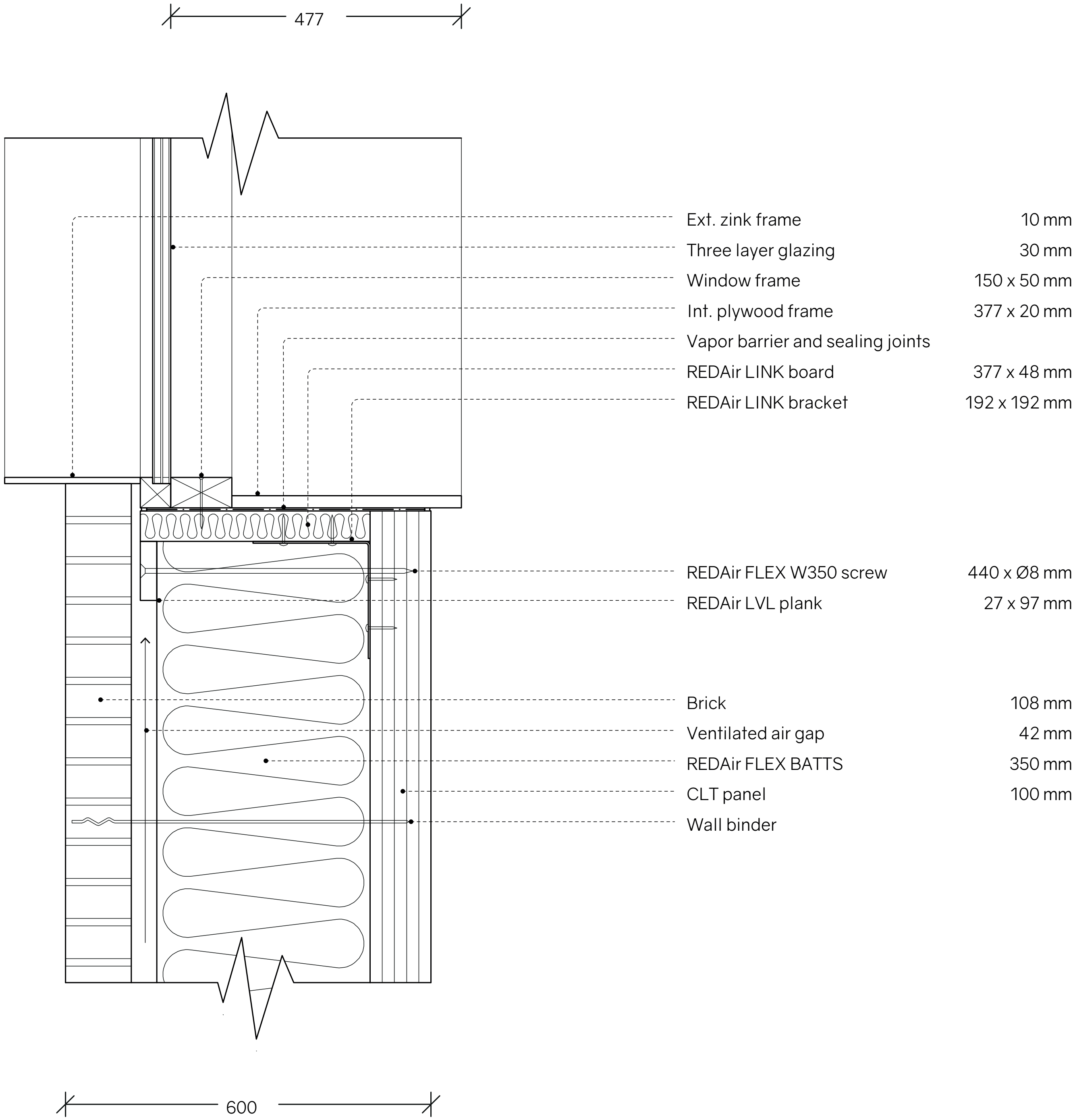


Ill.127 Axonometric view of detail of the wall

	Material	Thickness	Thermal conductivity	Thermal resistance	Transmission coefficient
Notation			λ	R	U
Unit		[mm]	[W/m*K]	[m2*K/W]	[W/m2*K]
	Brick	108			
	Vent. air gap	42			
	R_so			0,060	
	Insulation	350	0,033	10,606	0,086
	CLT panel	100	0,130	0,769	
	R_si			0,120	
	Total	600			

$$U = \frac{1}{R_{si} + \sum R_n + R_{so}}$$

Ill.126 U-value wall calculation



Ill.128 Connection with window detail drawing - scale 1:10

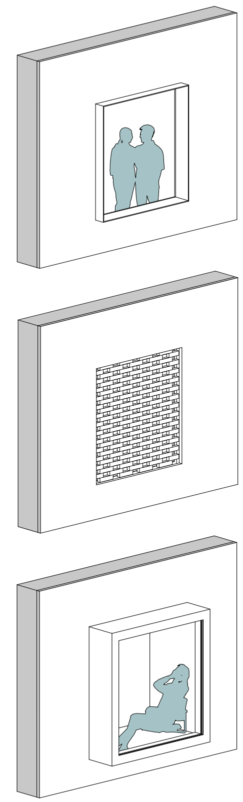
NICHE

The corridors not only perform the basic function of transporting users between different sections within the building, but also create different experience full of life and sensation that will enhance the social life spirit that this project is based on.

To do that, in front of the entrances to the rooms there are niches installed in the exterior wall oriented towards the inner courtyard. It creates interaction between inside and outside. Three types of openings were designed to generate an interesting expression.

The first type is a window provides the clear visual and light experience. The second type is the semi-transparent window which lays behind a special pattern of brick and provides with an interesting shadow experience. The third one is a niche window that provides a small intimate point for two people to sit and talk in a more private space.

The spatial experience is different between the ground floor and the second floor. On the ground floor, there are the room windows on the higher level where people can sit in their rooms and open the window to interact with the others in the corridor. On the second floor there is a different spatial experience with the mezzanine corridor, the indoor balcony and the dual pitched roof.



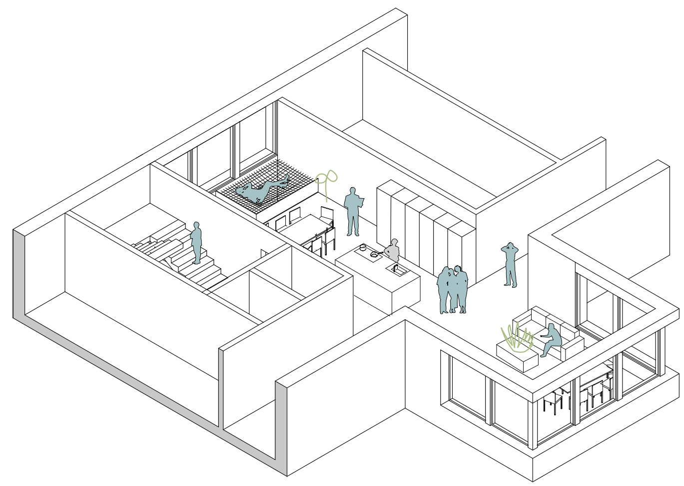
Ill.129 Axonometric view of different types of openings

Ill.130 Vizualization - view from corridor

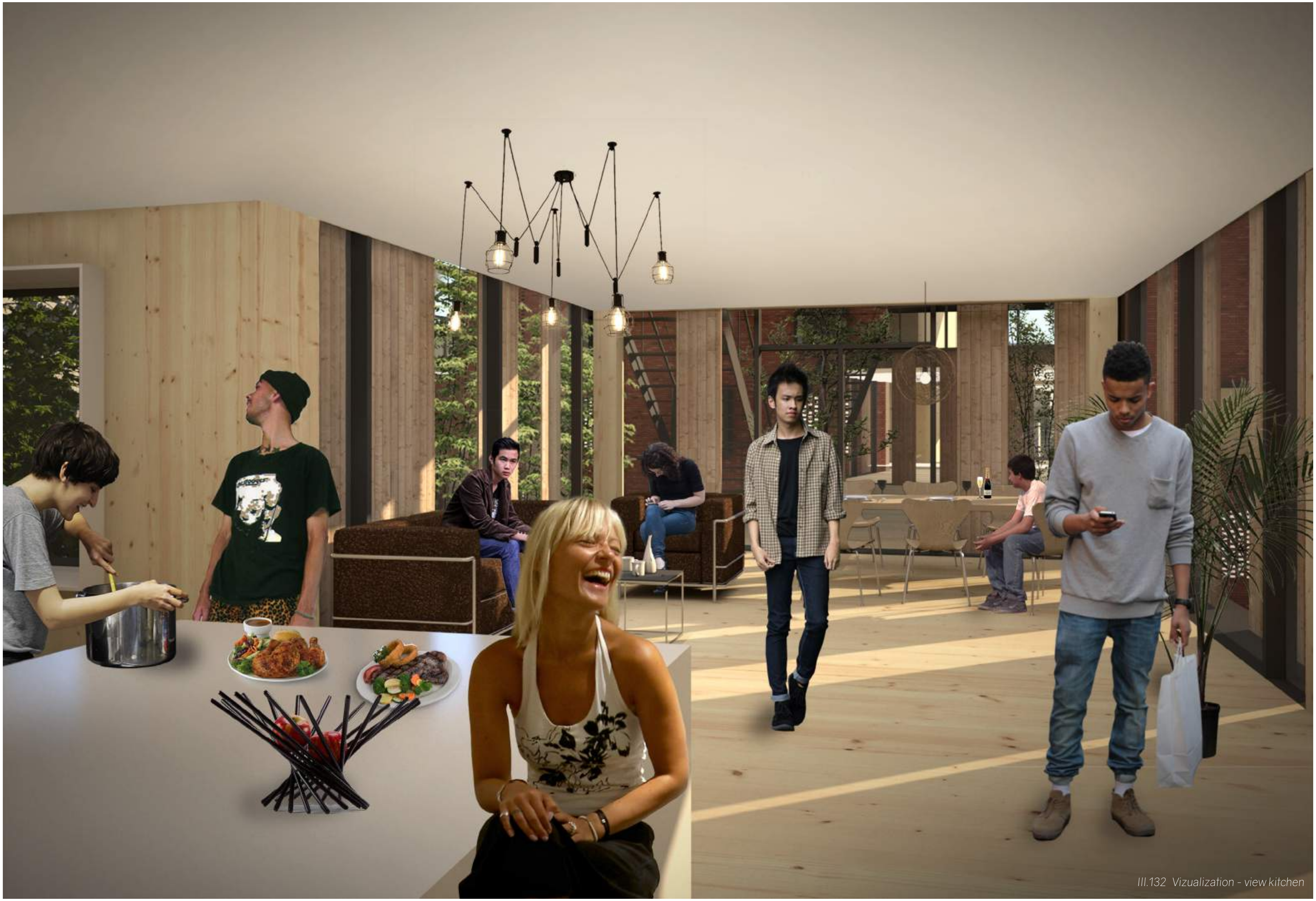
KITCHEN, LIVING, AND DINING SPACE

One of the most important characters of this project is the social life atmosphere. Therefore, a decision from the beginning was made to design only common kitchens on each floor. The kitchens are placed in the middle of each wing to direct the students towards the connection path where the activity and life take a place with the view towards the inner courtyards, the neighbourhood garden and the access to the outdoor terraces.

Each kitchen is equipped with all amenities that are needed for everyday life. Beside the cooking facilities there are spaces towards the outside for dining tables to encourage the student to have their meals together. While towards inside there are the living room spaces where students can gather to meet, watch TV, enjoy the view towards the courtyard and access the outdoor terraces.



Ill.131 Axonometric view of kitchen, dining and living space



Ill.132 Vizualization - view kitchen

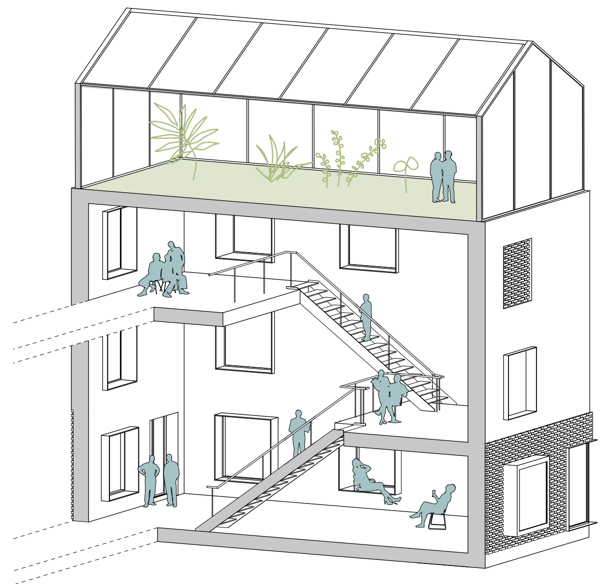
MEETING POINT

To provide more options that encourage the student social life, bigger meeting spaces were designed at the end of each wing. However, they slightly differ in function. The ones towards the south are more for gathering and spending time, having a chat or even play games. While the other ones at the other end of the wing facing the north, provide a better light conditions and quiet atmosphere to create a studying space.

Despite the different functions, these meeting spaces were designed as mezzanine floors. The purpose of that is to create a spacious volume and an atmosphere where everyone feels connected to the rest of the space. That gives more possibilities to interact and socialize.

The gathering spaces to the south on the ground floor have an access from the courtyard that improves the interaction between indoor and outdoor space. That also provide a quick and easy access to the students coming from the fjord road or the future water bus. In addition to that, the meeting spaces are vertically connected which give the possibility for student accessing the building from that entrance to move between floors.

On the other end, the connection between the library and the studying spaces is only visual but it is to strengthen the quietness atmosphere by reducing the number of activities which reduces the noise to make the space only space for reading.



Ill.133 Axonometric view of meeting point

Ill.134 Vizualization - view from the meeting point

ROOM TYPE A

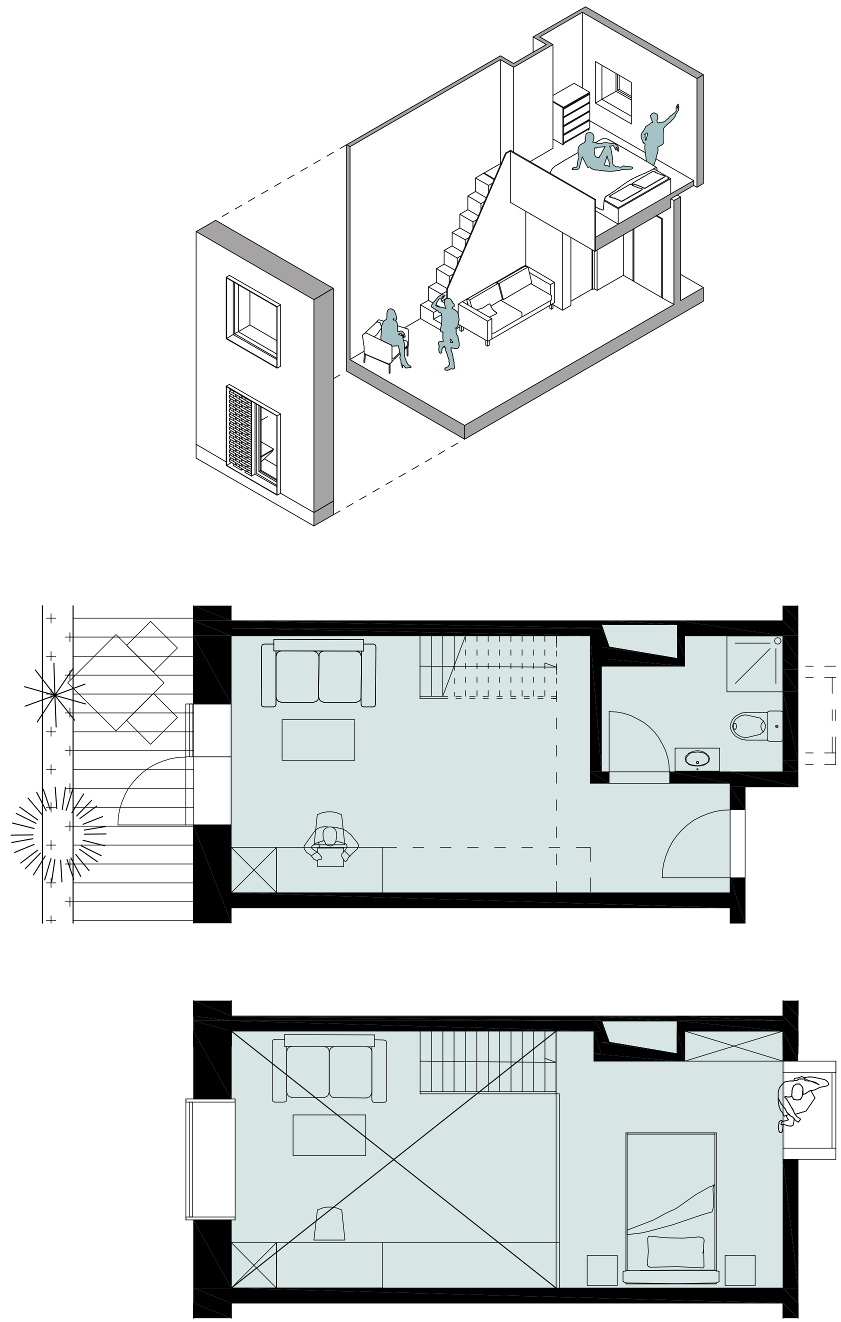
Type A of the student rooms can accommodate up to two people. It is 30 m² divided into two levels: 22 m² on the ground floor providing a space for a bathroom and a double height living room and 8 m² bed-room on the first floor.

The living room is divided into a studying section furnished with an integrated studying wall that provide shelfs, cupboard and a studying table. Along with the living section and an integrated storage area under the stairs.

This type of room has a door that leads to a small outside semi private area which allows to take a chair and site outside to enjoy the interaction with the neighbour. It has also a high window that allows the sunlight to penetrate deep in the room.

The upper level is where the sleeping area is, which provide privacy to this function as the room situated at the ground floor next to a street. Another niche was designed here providing a visual connection to the inner courtyard as well as to the people walking in the hallway.

The floor and the walls are made of the CLT. It is a natural material that creates a warm interior feeling.



Ill.135 Axonometric view and plan of room type A

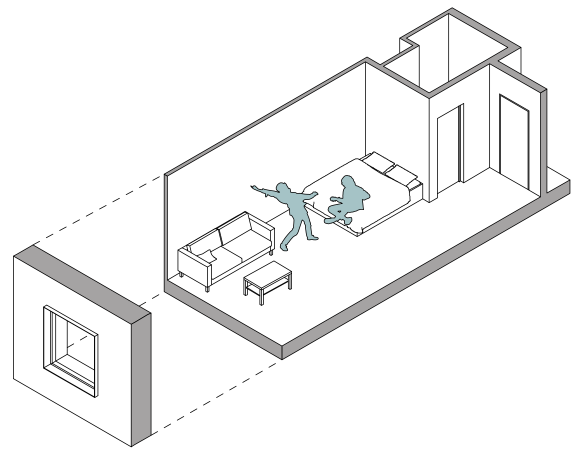
Ill.136. Vizualization – interior view room type A

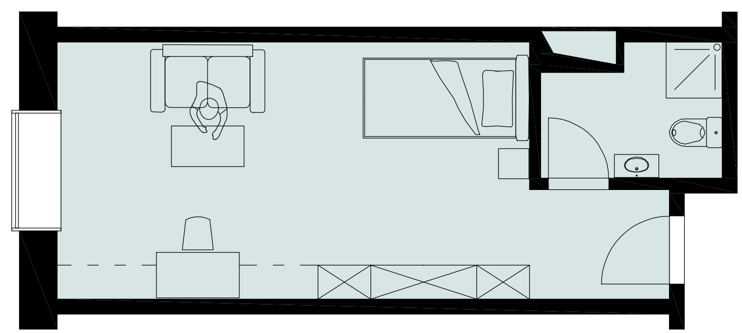
ROOM TYPE B

Type B of the students room can accommodate two people. It is 27 m² that is also divided into the three main areas: studying, living and sleeping.

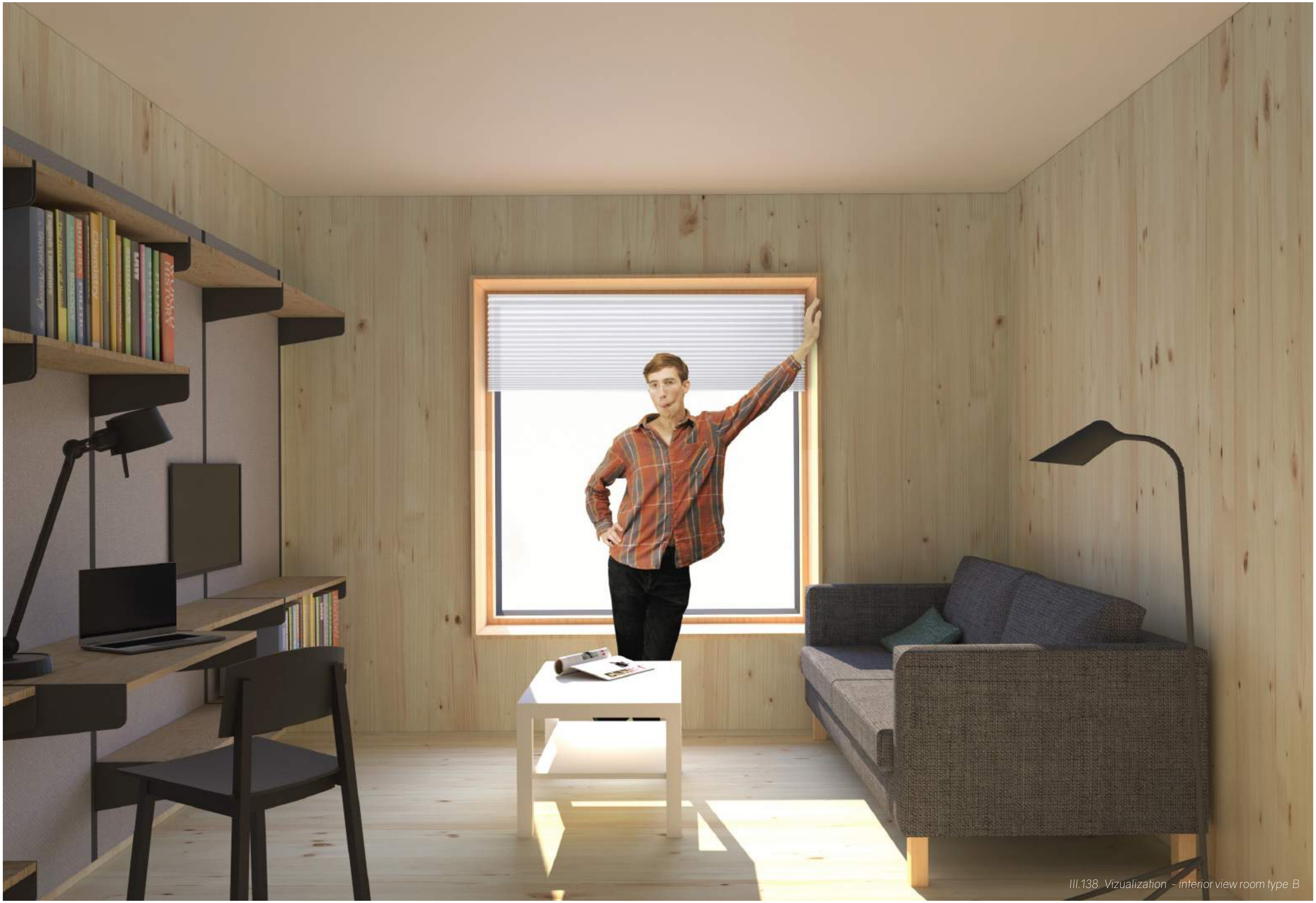
The sleeping area is located deep in the room away from the window to provide the quietness. Provided with a built-in closet for storage. The studying and living area are closer to the window where there is more light which suits these activities.

The window sill of the deep window is placed at sitting height making it an integrated furniture of the architecture of the room. The floor and the walls are made of the same materials as the type A room - the CLT.

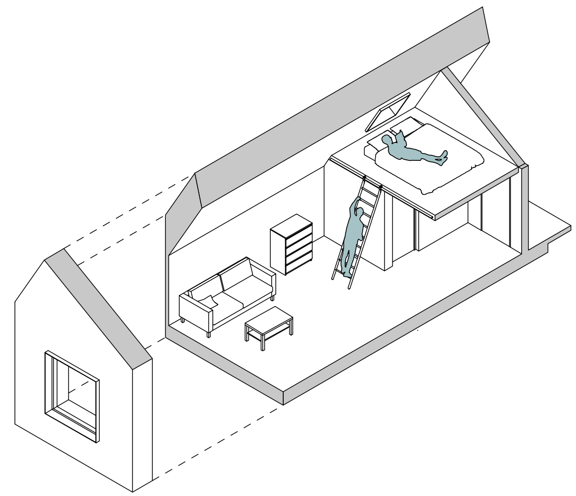




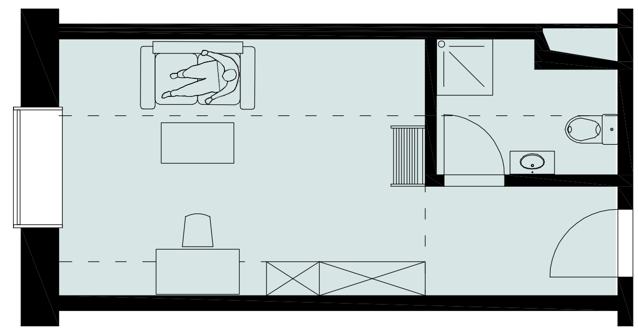
Ill.137 Axonometric view and plan of room type B

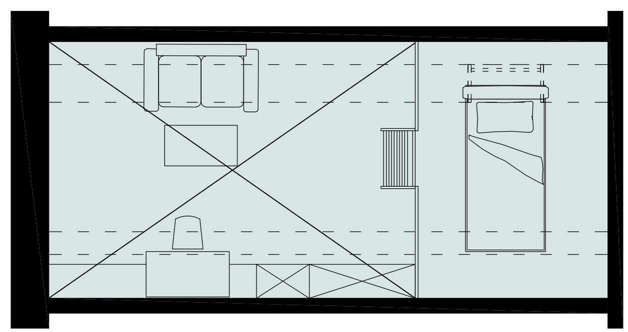


Ill.138 Vizualization - interior view room type B



Ill.140 AXO View of room type C





Ill.139 Axonometric view and plan of room type C

ROOM TYPE C

Type C of the student room can accommodate one person. It is 23 m². The studying area in principle is similar to the other two types where the integrated furniture provides the studying table and storage. The living area is beside the studying, and both of them are close to the window niche. However, because of the shape of the roof, there is enough space created for a mezzanine floor where the sleeping area in this type is. On the top of were the mattress is, there is a roof window installed with a beautiful view to the sky. The floor and the walls are made of the same materials as the other two types.

Ill.141 Vizualization - interior view room type C

EPILOGUE

CONCLUSION
REFLECTIONS
LIST OF LITERATURE
LIST OF FIGURES

CONCLUSION

The project answers realistic problem of city of Aalborg which is lack of accommodation for students arriving to study at Aalborg University and University College Nordjylland. Based on the authors experience and case studies, the essentials of proper and comfortable student housing was created. Integrated design process helped to combine both architectural and technical aspect of the project.

Integrated passive and active solutions exemplify the academic approach of the project. Additionally, three room types were designed with special attention to good indoor quality. It was a big focus during the design process to provide inhabitants with perfect living environment.

The location of the common functions represents initial concept of the project to enhance the axis view to the park located nearby. In this was the project is unique and relates to its neighborhood. It is explicit in the gesture of tilting of the eastern part of the building.The concept works also with social sustainability which takes into consideration both social and private need of inhabitants.

The architecture gives an attention to the human scale which is expressed in tectonic way of use on the façade. Three different patterns were applied to differentiate diverse areas on the elevations.

REFLECTION

In the matter of the climate changes for future elaboration of the project the topic of being a Zero Energy Building would be interesting. One of the disputes was to reach a 2020 energy frame without need of use of solar panels. Even more challenging would be to reach the Zero Energy Building energy performance. This could be achieved by changing the volume of the building which would have smaller surface to volume ratio.

One of the consideration is about using other type PIR insulation which would have better resistance and less embodied energy than RedAir Flex Batts used right now. Although being aware that it comes with fire proof problems because it burns very fast, together with usage of CLT construction it would not be the best choice.

Another topic that would be interesting to evolved is artificial light, which at the beginning was considered as big driver in the project but at the end, along with progress of the design process, it was not developed sufficiently.

In terms of construction, CLT would need to be explored further. It has a lot of positive architectural characteristics like warm interior expression, fast assembly-time and many others, but it also comes with high price of the material.

Furthermore, the room layout could be more elaborated. Some integrated furniture would be designed that would make the project more consistent.

LIST OF LITERATURE

Aalborg Kommune 2017, Udviklingsstrategi Stigsborg Havnefront, Stigsborg Havnefront, Aalborg.

Akadiri, P.O., Chinyio, E.A. & Olomolaiye, P.O. 2012, Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector.

Alexander, C. 1966, The City as a Mechanism for Sustaining Human Contact, Center for Planning and Development Research, University of California, United States.

Andersen, M. (n.d.), Ryerson Student Learning Center. Available: https://portfolio.oculightdynamics.com/detail/ryerson [2018, 02/15].

Andersen, M. & Rockcastle, S. 2013, Annual Dynamics of Daylight Variability and Contrast: A Simulation-Based Approach to Quantifying Visual Effects in Architecture.

Archdaily.com 2015, Ryerson University Student Learning Centre / Zeidler Partnership Architects + Snøhetta. Available: https://www.archdaily.com/771491/ryerson-university-student-learning-centre-zeidler-partnership-architects-plus-snohetta [2018, 02/23].

Bâldea, M. & Dumitrescu, C. 2013, High-Density Forms in Contemporary Architecture.

Bejder, A.K., Jensen, M. & Katic, I. 2014, Zero Energy Buildings - Design Principles and Built Examples for Detached Houses.

BR18 2018, Bygnings Reglementet. Available: http://bygningsreglementet.dk/ [2018, 02/14].

Buildings.com 2007 , Zero Energy Buildings defined. Available: https://www.buildings.com/article-details/articleid/4987/title/zero-energy-buildings-defined; [2018, 02/15].

Byg i Tegn 2018. Available: taenkitegl.dk [2018, 04/14].

CR 1752 1998, “Ventilation for buildings - Design criteria for the indoor environment”.

Ctb.ku.edu 2017, Building relationships with people from different cultures. Available: https://ctb.ku.edu/en/table-of-contents/culture/cultural-competence/building-relationships/main [2018, 02/07].

Danske BoligArkitekter 2018. Available: danskeboligarkitekter.dk [2018, 04/16].

DK-GBC, G. 2016, DGNB system Denmark manual for kontorbygninger 2016. København: Green Building Council Denmark. .

DMI 1999, Vejr, Klima og Hav. Available: http://www.dmi.dk/fileadmin/user_ upload/Rapporter/TR/1999/tr99-13.pdf [2018, 02/09].

DS 418 2011, Calculation of heat loss from buildings.

DS 447 2005, Code of Practice for mechanical ventilation.

DS/EN 15251 2007, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

Ens.dk 2013, The Danish Climate Policy Plan. Available: https://ens.dk/sites/ens.dk/files/Analyser/danishclimatepolicyplan_uk.pdf; [2018, 02/15].

Fitch, J.M. 1965, The Aesthetics of Function, New York Academy of Sciences, United States.

GamleMursten 2018. Available: gamlemursten.dk [2018, 04/16].

Ganslandt, R. & Hofmann, H. 1992, Handbook of Lighting Design.

Gehl, I. 1971, Bo-miljø SBI-rapport 71, Teknisk Forlag, Copenhagen.

Graae, B. 1967, Børn Skal Have 100 Forældre.

GreenSpec 2018. Available: http://www.greenspec.co.uk/building-design/crosslam-timber-introduction/ [2018, 04/12].

Heiselberg, P. 2006, Modelling of Natural and Hybrid Ventilation. Available: http://vbn.aau.dk/files/65753147/Modelling_of_ Natural_and_Hybrid.pdf [2018, 02/20].

Holt-Lunstad, J. 2015, Loneliness and Social Isolation as Risk Factors for Mortality.

Illeris, S. 1997, Sættedammen i 25 år.

Jensen, B. 2016, Stigsborg Historien, Aalborg Stadsarkiv.

Kim, G. 2017, How Cohousing Can Make Us Happier (and Live Longer). Available: https://www.ted.com/talks/grace_kim_how_cohousing_can_make_us_happier_and_live_longer [2018, 02/14].

Kingo.biz 2016, Kemirahallen Aalborg. Available: https://kingo.biz/ydelser/nedbrydning/totalnedbrydning/referencer/kemirahallen-aalborg/ [2018, 02/22].

Knudstrup, M. 2004, Integrated Design Process in PBL.

Malmquist, C. 2017, Benefits of Building with Cross Laminated Timber. Available: http://construction.acppubs.com/trends/benefits-of-building-with-cross-laminated-timber/.

Maslow, A.H. 1943, A Theory of Human Motivation, Psychological Review, United States.

McCaffrey, R. 2002, “Climate Change and the Cement Industry”.

Negrão, A. 2013, The Impact of Artificial Light in Architectural Spaces for a Methodology of Integrated Lighting Design in Architectural Concept.

Pereya, I. & Repponen, A. 2018, One Shared House 2030. Available: http://onesharedhouse2030.com/results/ [2018, 02/10].

Peterson, K., Torcellini, P. & Grant, R. 2015, A Common Definition for Zero Energy Buildings.

Pinker, S. 2017, The Secret to Living Longer May Be Your Social Life. Available: https://www.ted.com/talks/susan_pinker_the_secret_to_living_longer_may_be_your_social_life [2018, 02/14].

Pinker, S. 2015, The Village Effect: How Face-To-Face Contact Can Make Us Healthier and Happier.

Steensgard, P. 2018, The Building. Available: http://tietgenkollegiet.dk/en/the-building/ [2018, 02/16].

Stigsborghavnefront.dk 2018. Available: https://stigsborghavnefront.dk/ [2018, 02/03].

Storaenso 2016, CLT - Documentation on fire protection, Available: http://www.clt.info/wp-content/uploads/2015/10/CLT-Documentation-on-fire-protection-EN.pdf [2018, 05/03].

Suncalc.org 2018, SunCalc sun position- und sun phases calculator. Available: http://www.suncalc.org/#/57.0394,9.9295,16/2016.03.18/13:29/1/0 [2018, 02/09].

The Ministry of Climate, Energy and Building 2013, The Danish Climate Policy Plan Towards a low carbon societ.

Thomsen, K.E. 2014, Danish Plans Towards Zero Energy Buildings. Available: http://www.rehva.eu/publications-and-resources/rehva-journal/2014/032014/danish-plans-towards-nearly-zero-energy-buildings.html [2018, 02/16].

Timberfirst 2012, What are the benefits of building with cross-laminated timber? [Homepage of Timberfirst], [Online]. Available: https://timberfirst.wordpress.com/2012/09/11/what-are-the-benefits-of-building-with-cross-laminated-timber/.

Timberfirst 2012, What is cross-laminated timber (CLT)? [Homepage of Timberfirst], [Online]. Available: https://timberfirst.wordpress.com/2012/07/25/what-is-cross-laminated-timber-clt/.

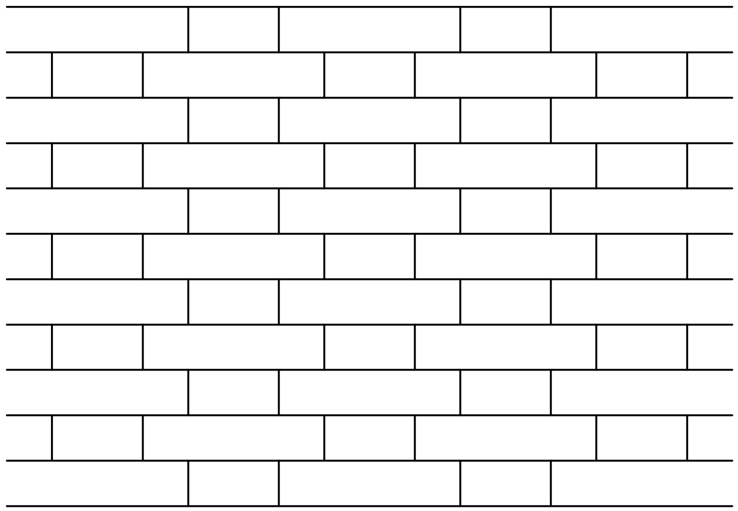
UN Commission 1987, Report of the World Commission on Environment and Development: Our Common Future. Available: https://www.sustain.ucla.edu/about-us/what-is-sustainability/ [2018, 02/15].

Vandkunsten 2017, Stigsborg Vandkunsten Stigsborg Fjordby Udviklingsplan, Aalborg Kommune, Aalborg.

Zedfactory.com (n.d.), BedZED. Available: https://www.zedfactory.com/bedzed [2018, 02/15].

LIST OF FIGURES

Illustration numbers not listed below are illustrations created by the group, either as diagrams, tables, pictures or drawings.



STIGSBORG PARK CONTEMPORARY
STUDENT HOUSING

APPENDIX

COLOPHON

Title:	Stigsborg Park Contemporary Student Housing
Theme:	Sustainability
Group:	MSc04 ARC - Group 8
Project Period:	February 1st 2018 - May 23rd 2018
Main Supervisor:	Mads Dines Petersen
Technical Supervisor:	Anders Hornum Møllerskov
Field of Studies	Architecture & Design
University:	Aalborg University

Members:	Hussein Nedal Abohamida
	Mathias Nordtorp Hyldig
	Patrycja Ewa Lyszczyk

TABLE OF CONTENT

ESCAPE PLANS

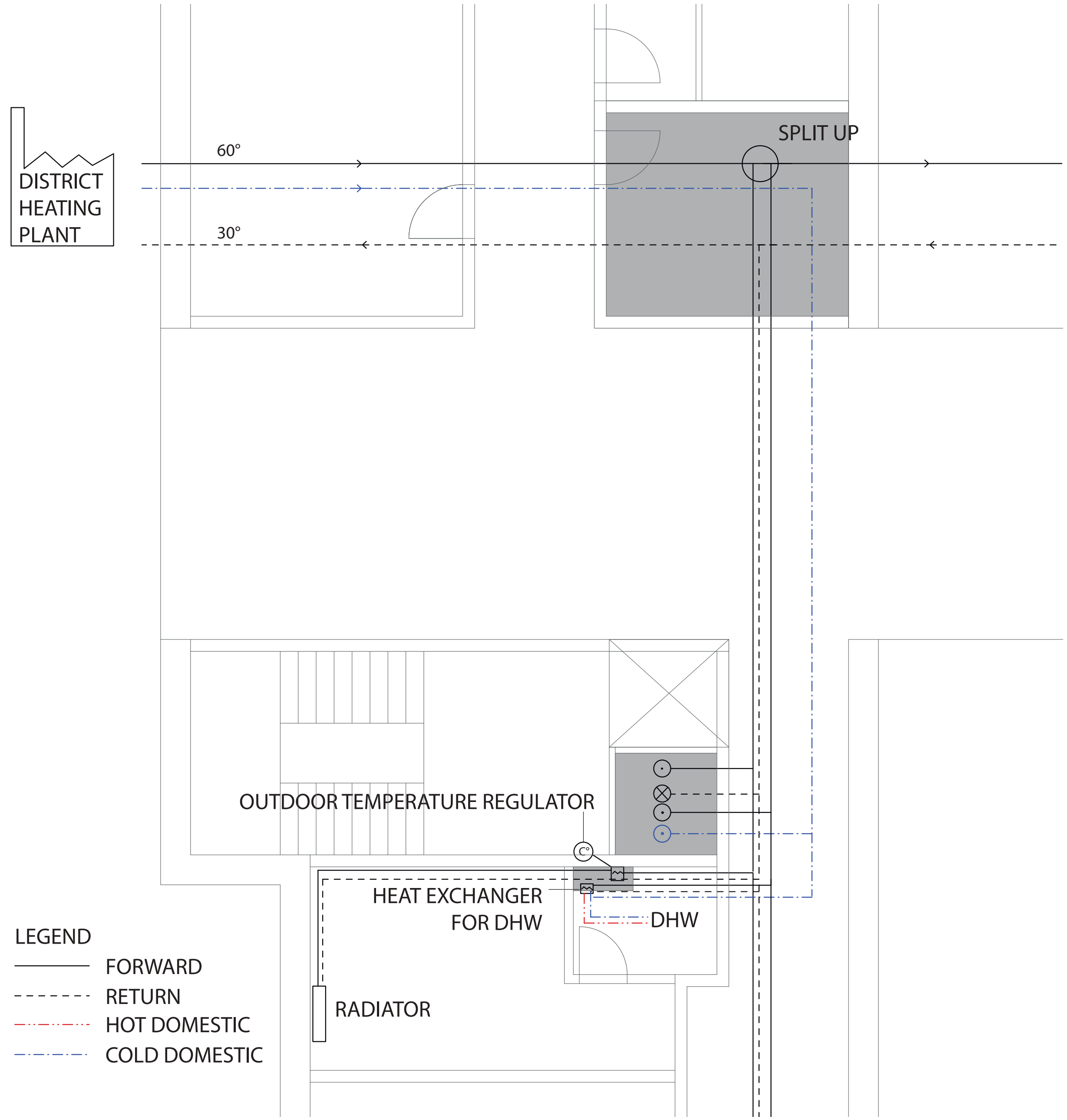
III.1 Ground floor escape plan - scale 1:500

III.2 First floor escape plan - scale 1:500

III.3 Ground floor escape plan - scale 1:500

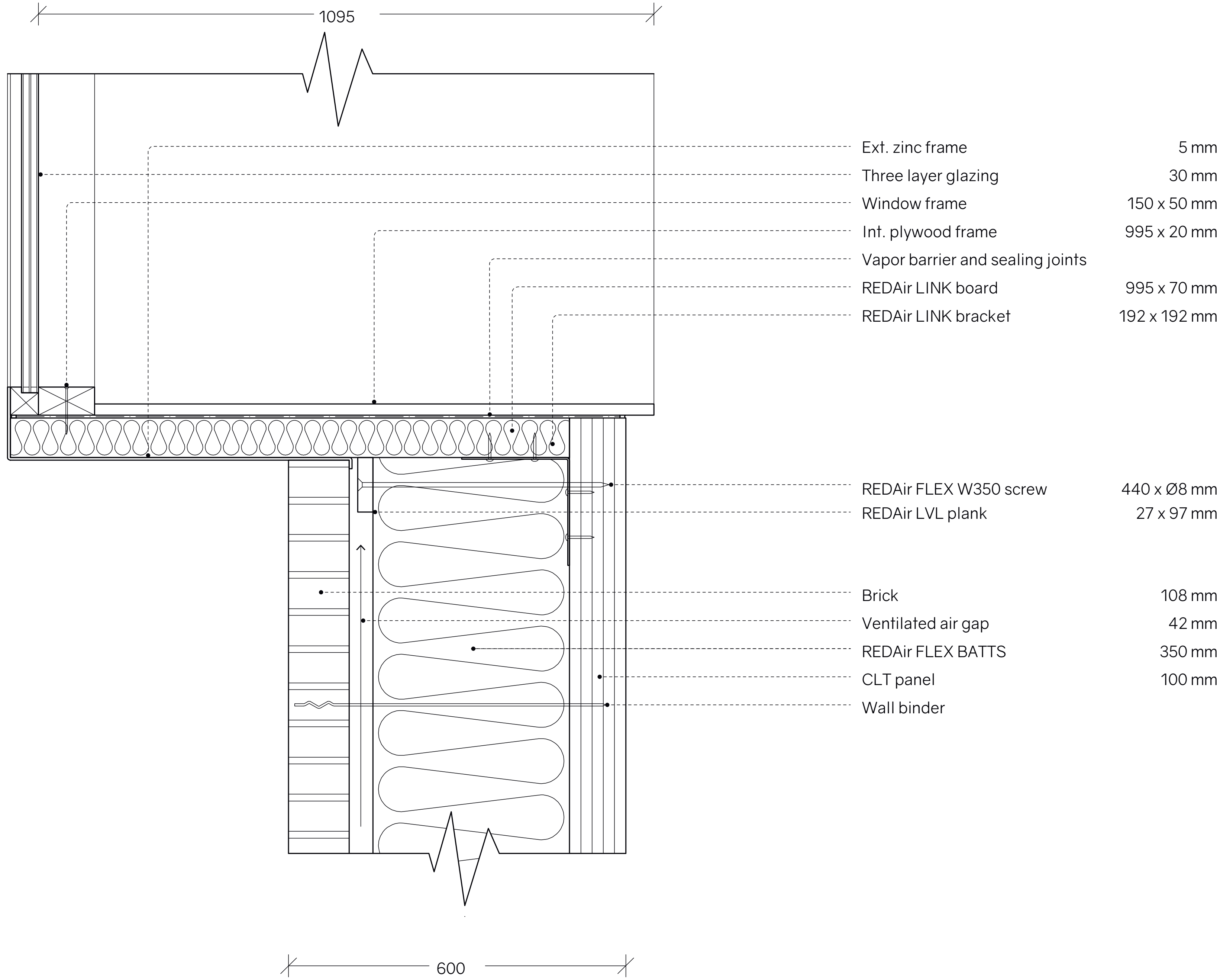
III.4 First floor escape plan - scale 1:500

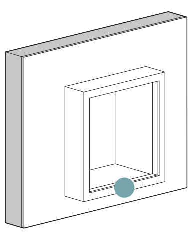
INSTALATION SYSTEM DHW & HEATING



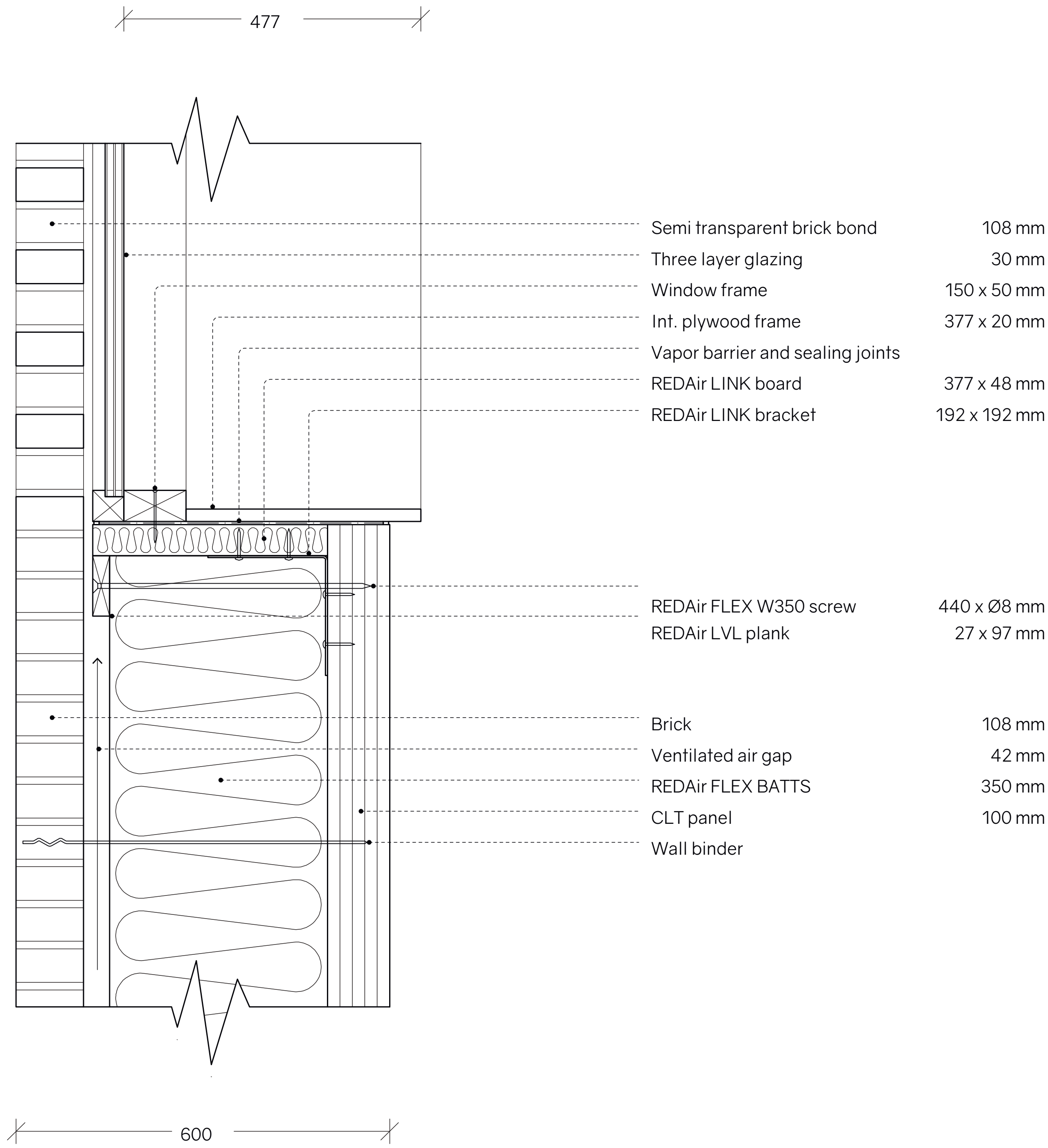
III.5 DWH and heating instalation draft diagram

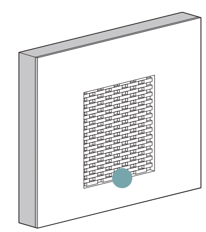
DETAIL DRAWINGS





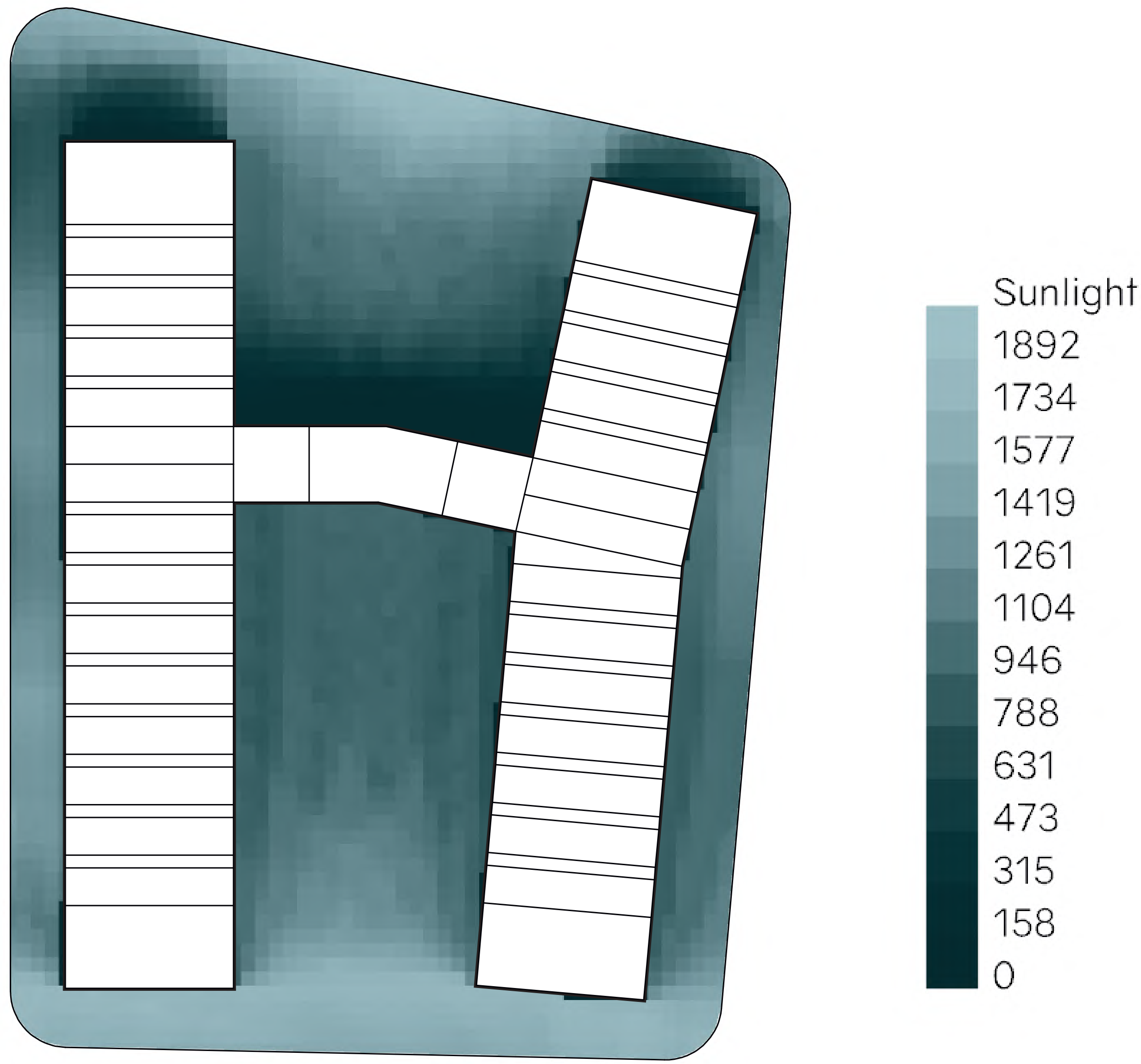
III.6 Detail of niche - scale 1:10





III.7 Detail of semi-transparent window - scale 1:10

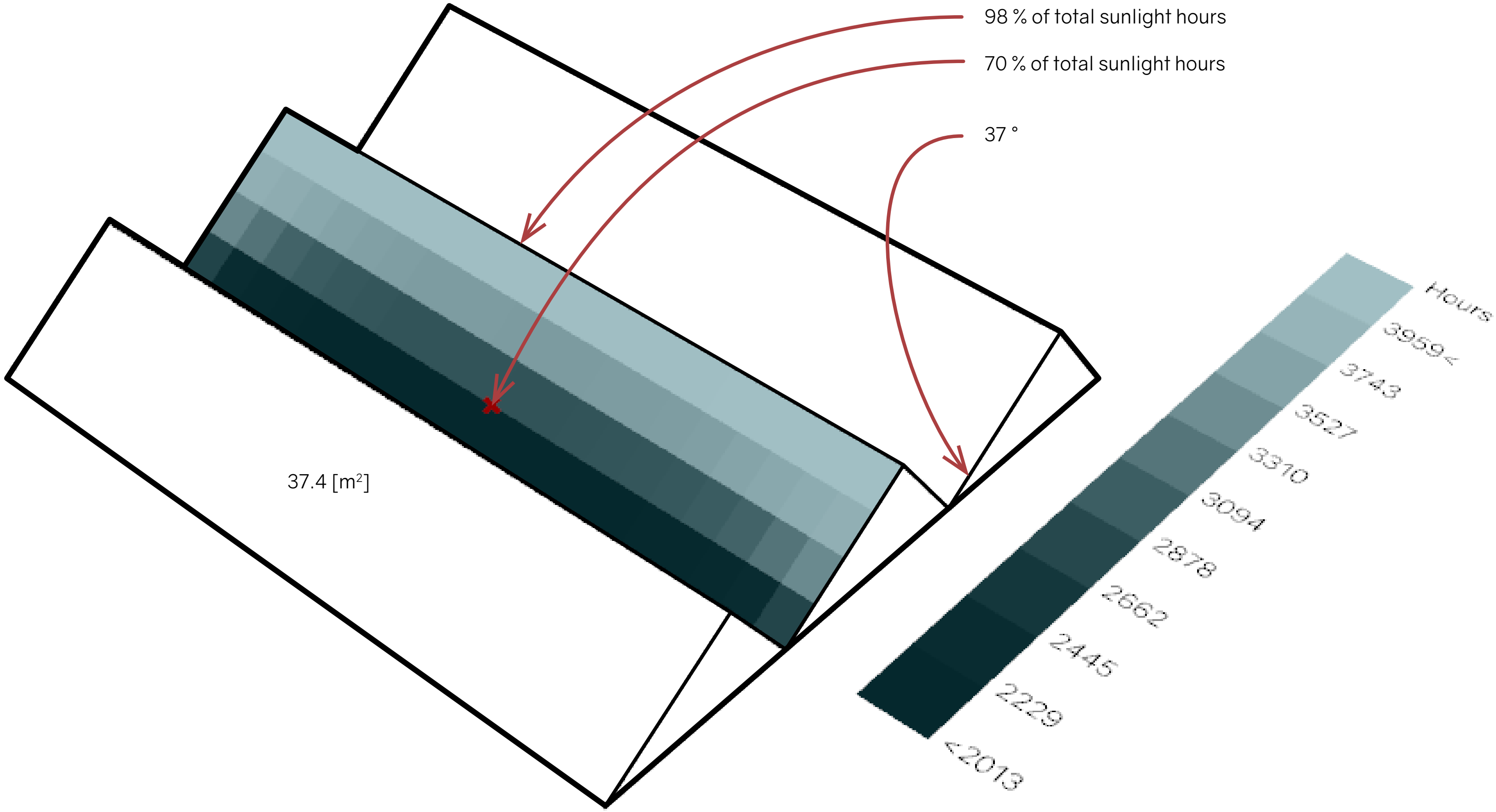
LADYBUG – SUNLIGHT HOURS



III.8 Sunlight hours diagram on the ground

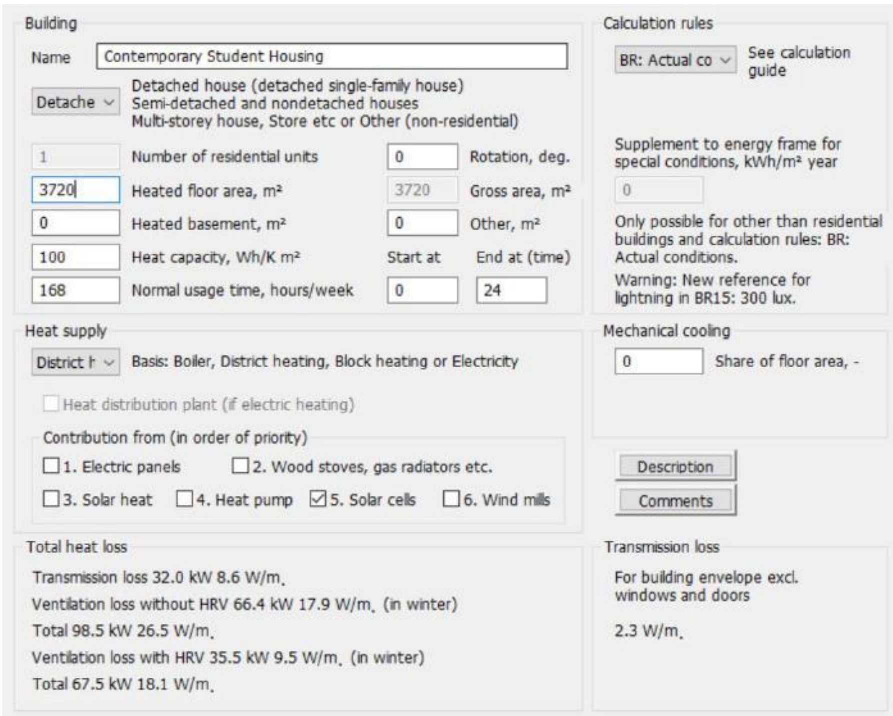
Total roof area: 1.023 [m²]
"Usable" roof area: 798 [m²]

Total sunlight hours: 3.993



III.9 Sunlight hours diagram on the roof

BE 18



Ill.10 Inputs in Be18

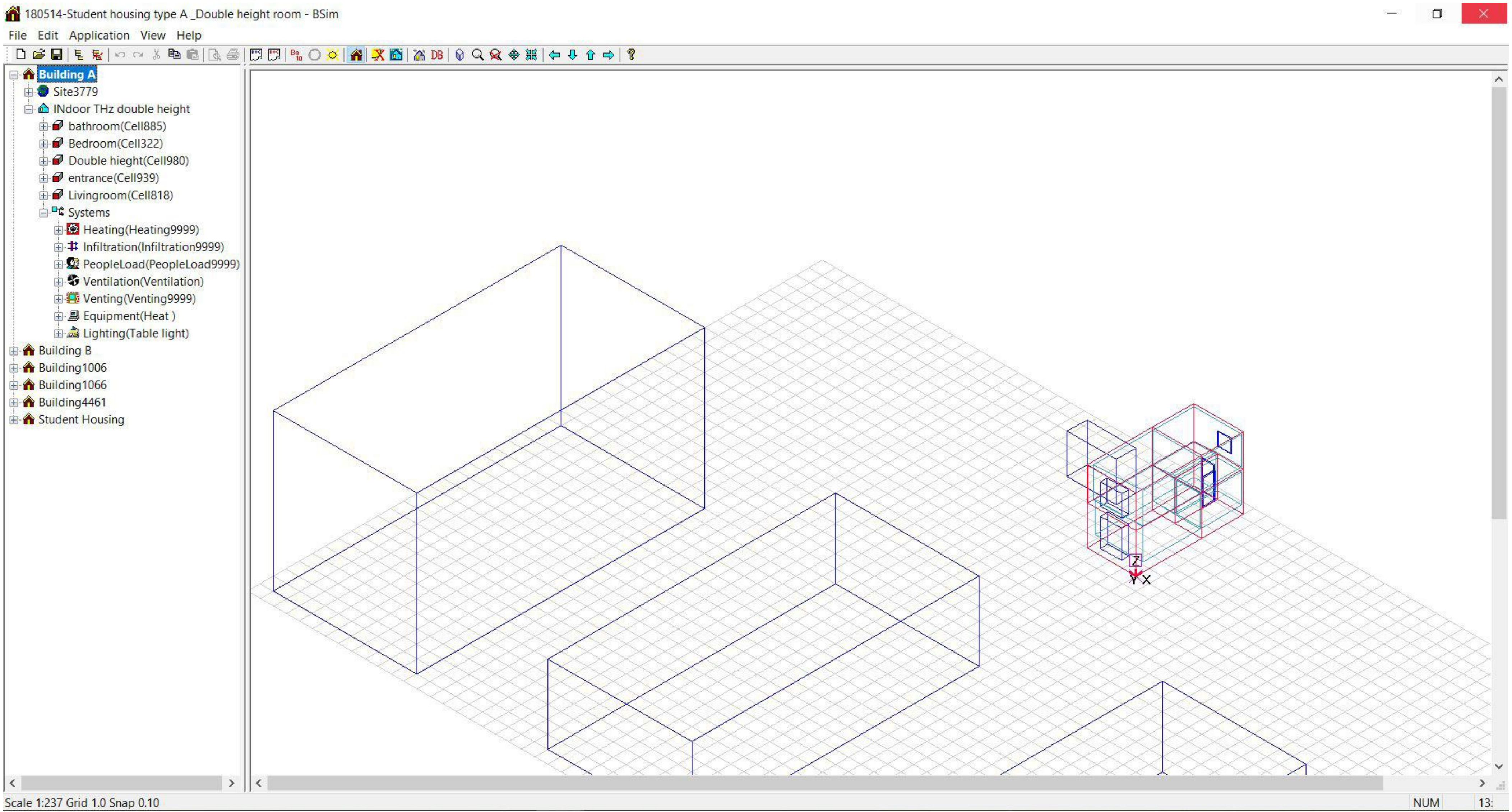
Ill.11 Results from Be18

Calculations are based on equations from

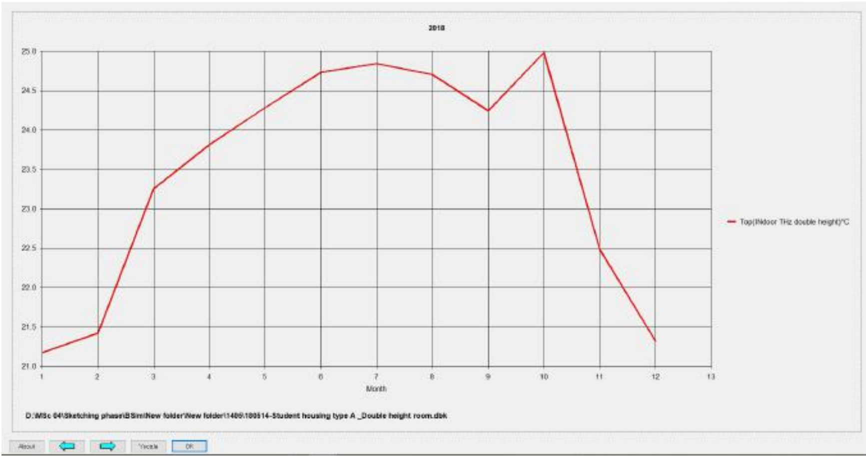
- BR15:2015
- EN 15251:2007
- CR 1752:1998 – Ventilation for buildings – Design criteria for the indoor environment
- Lectures from ZEB course from MSc-02:
    - Lecture 10 - Design of Natural Ventilation
    - Lecture Husbyggeri 2: Hygrotermisk bygningsfysik

According to the function of the building, it is considered as Category 2 building which means "Normal level of expectation and should be used for new buildings and renovations" (EN 15251:2007 Table 1, p.13)

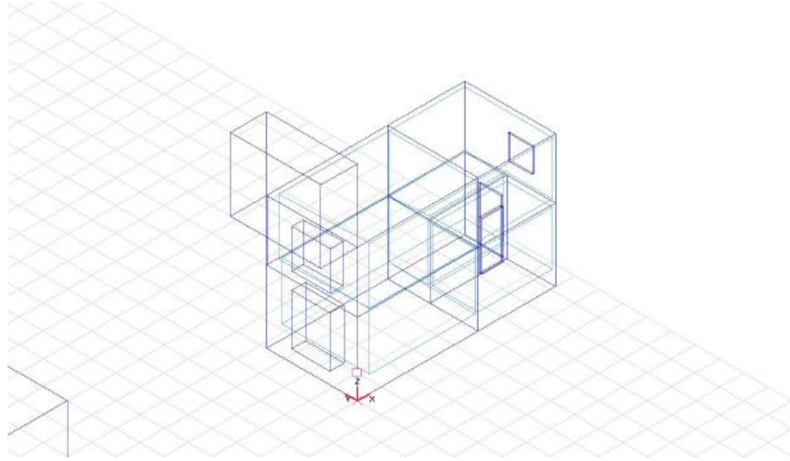
BSIM - ROOM TYPE A



Ill.12 Geometry - room type A with surrounding buildings



Ill.13 Geometry - room type A

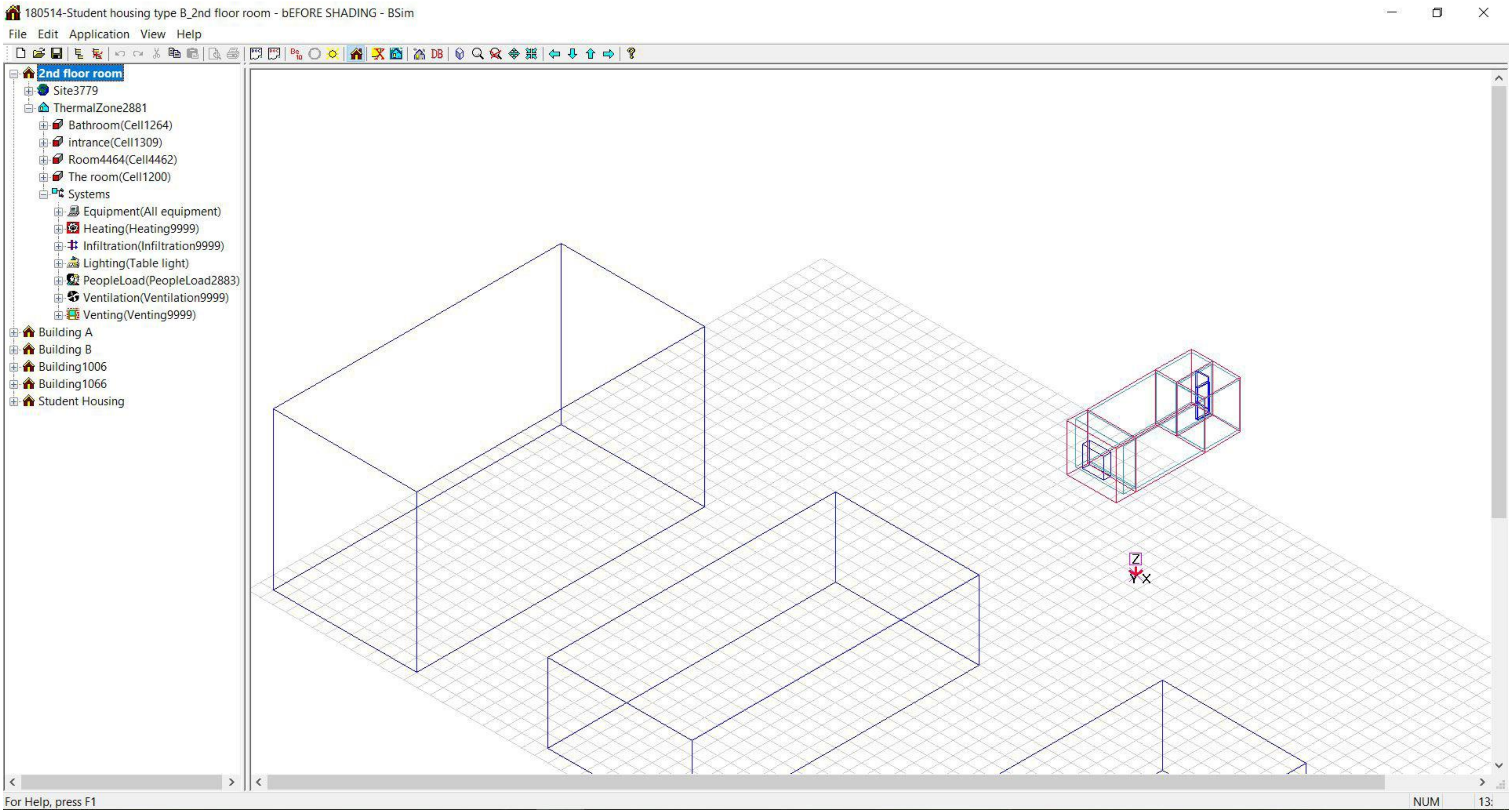


Ill.14 Geometry - room type A

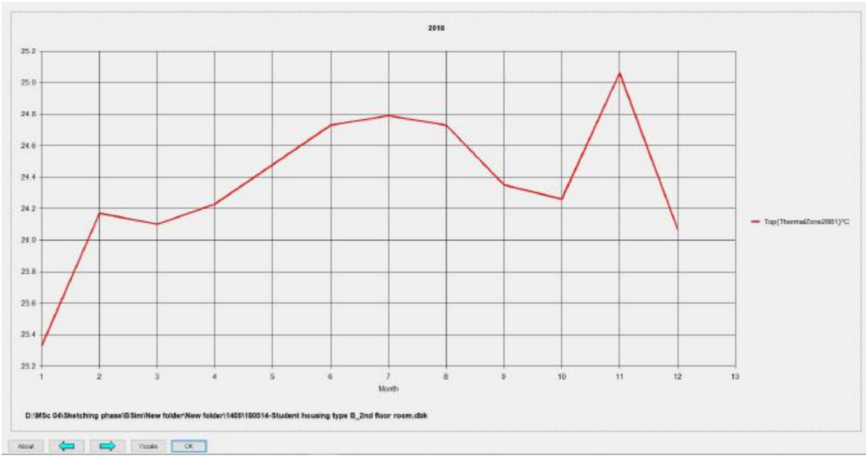
Month	Hours	INdoor THz double											
INdoor THz	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	95.73	37.57	21.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.28	30.14
qCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qInfiltration	-373.86	-44.38	-41.80	-43.90	-35.69	-26.09	-18.79	-16.84	-17.02	-22.79	-32.08	-34.21	-40.28
qVenting	-794.49	0.00	0.00	0.00	-58.05	-131.80	-166.56	-184.22	-155.81	-98.05	0.00	0.00	0.00
qSunRad	1058.09	21.72	45.16	90.60	115.96	142.19	155.49	159.55	129.43	97.54	59.97	25.07	15.43
qPeople	1284.00	111.00	98.40	107.40	106.20	109.20	104.40	111.00	107.40	104.40	111.00	104.40	109.20
qEquipmen	304.18	25.90	23.34	25.79	24.97	25.90	24.97	25.90	25.79	24.97	25.90	24.97	25.79
qLighting	53.12	0.00	0.00	0.00	0.00	10.71	8.71	8.46	11.78	13.46	0.00	0.00	0.00
qTransmiss	-1108.86	-134.93	-128.84	-136.17	-104.36	-75.06	-53.85	-47.53	-46.79	-66.39	-97.49	-95.06	-122.39
qMixing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qVentilation	-517.91	-16.89	-18.00	-43.72	-49.02	-55.06	-54.38	-56.32	-54.78	-53.14	-67.30	-31.44	-17.89
Sum	-0.00	0.00	0.00	0.00	-0.00	0.00	-0.00	0.00	-0.00	-0.00	0.00	-0.00	0.00
tOutdoor me	7.7	-0.5	-1.0	1.7	5.6	11.3	15.0	16.4	16.2	12.5	9.1	4.8	1.5
tOp mean(°(	23.5	21.2	21.5	23.3	23.8	24.3	24.7	24.9	24.7	24.2	25.1	22.5	21.3
AirChange(/	0.9	0.5	0.5	0.5	0.6	1.1	1.7	1.9	1.7	0.9	0.5	0.5	0.5
Rel. Moistur	41.7	37.7	35.0	33.2	34.3	39.6	48.4	52.5	50.6	49.2	39.6	42.4	38.2
Co2(ppm)	772.4	836.1	831.8	820.4	776.3	721.9	695.6	693.6	695.7	726.2	829.5	814.7	826.7
PAQ(-)	0.2	0.5	0.5	0.4	0.3	0.2	0.0	-0.0	0.0	0.1	0.2	0.3	0.4
Hours > 21	7953	457	463	744	720	744	720	744	744	720	744	656	497
Hours > 27	56	0	0	0	0	0	14	11	23	0	8	0	0
Hours > 28	11	0	0	0	0	0	4	2	5	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	139.13	11.82	10.67	11.82	11.44	11.82	11.44	11.82	11.82	11.44	11.82	11.44	11.82
HtRec	1962.09	278.25	261.15	257.53	192.13	116.39	66.12	50.38	53.17	95.10	145.88	196.70	249.28
ClRec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HtCoil	38.27	13.19	11.52	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.27	9.68
ClCoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidif	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorHeat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorCool	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Ill.15 Results from BSim - room type A

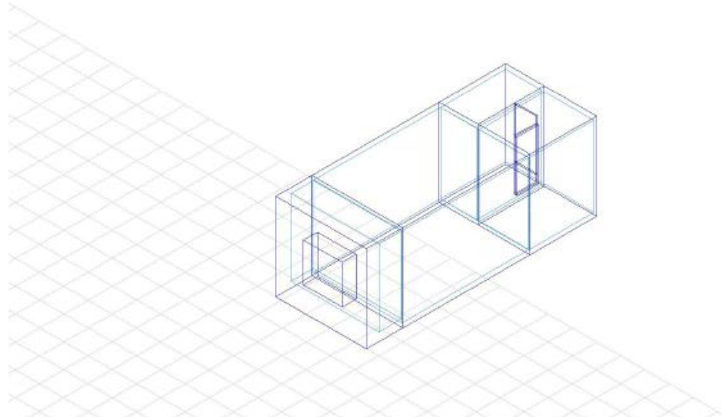
BSIM – ROOM TYPE B



Ill.16 Geometry - room type B with surrounding buildings



Ill.17 Geometry - room type B



Ill.18 Geometry - room type B

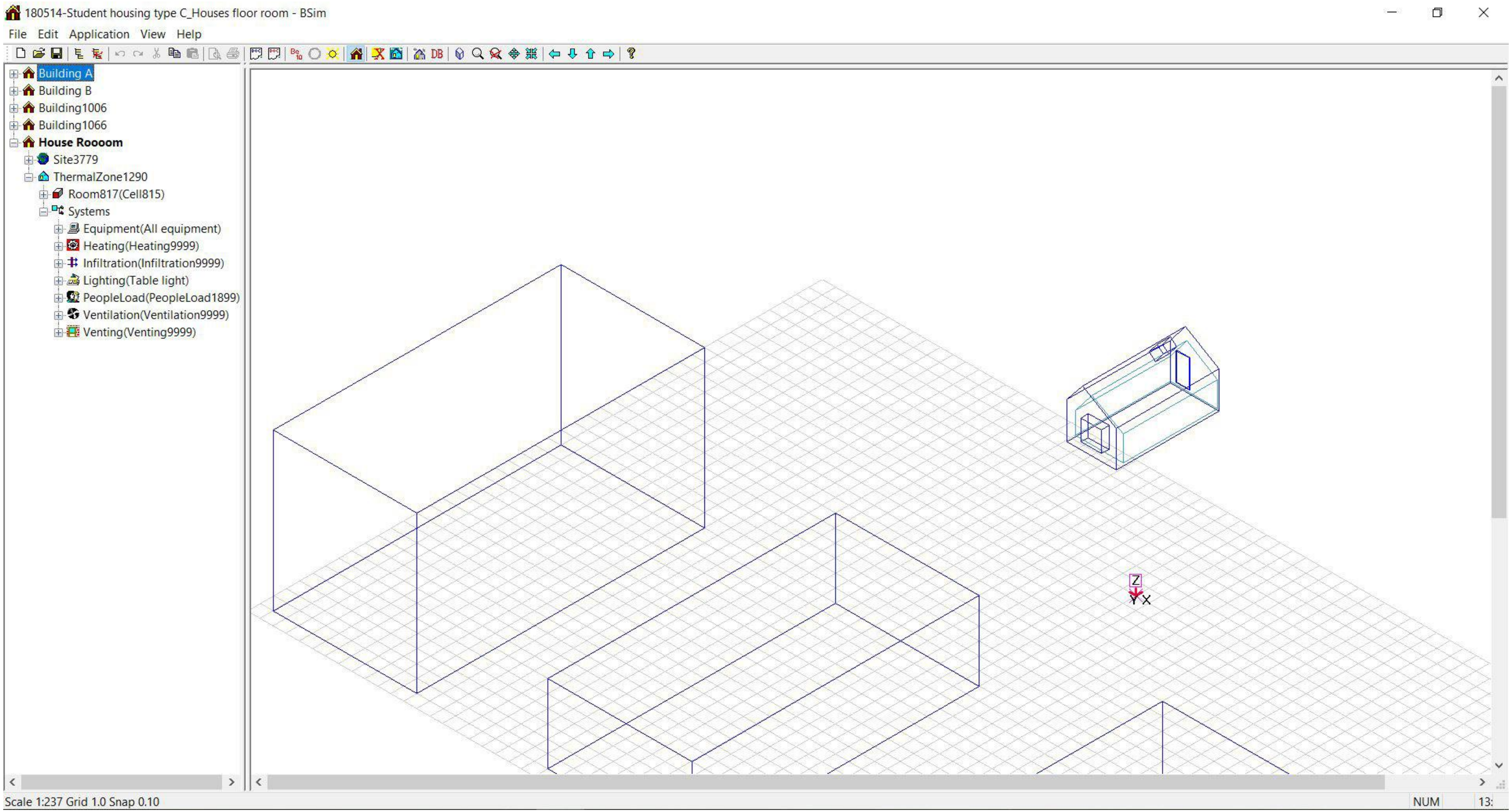
Options | Moisture | Simulation | HeatBalance | Parameters | Tables

Month | Hours | ThermalZone2881

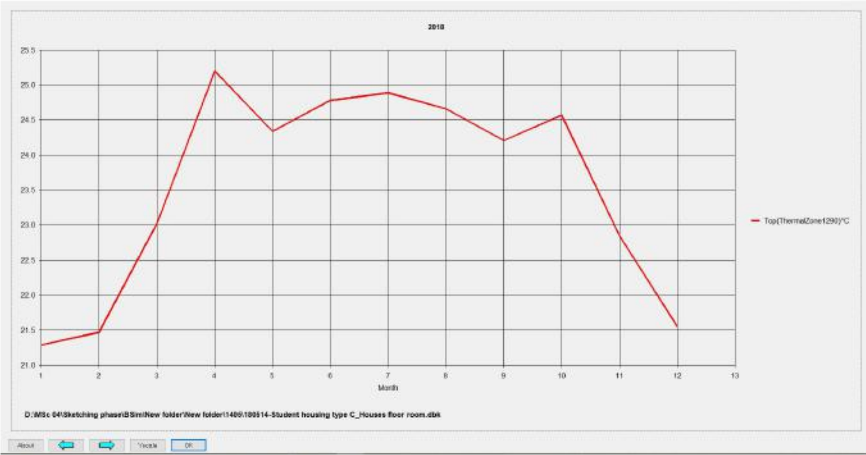
ThermalZor	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qInfiltration	-325.69	-40.44	-38.37	-37.61	-30.13	-21.89	-15.52	-13.84	-14.11	-19.04	-25.16	-32.12	-37.46
qVenting	-709.88	0.00	0.00	-31.33	-66.07	-108.41	-127.09	-138.99	-120.69	-73.68	-43.62	0.00	0.00
qSunRad	523.26	9.24	19.16	37.58	60.54	73.28	82.45	84.67	67.15	46.85	25.14	10.70	6.51
qPeople	1155.60	99.90	88.56	96.66	95.58	98.28	93.96	99.90	96.66	93.96	99.90	93.96	98.28
qEquipmen	304.18	25.90	23.34	25.79	24.97	25.90	24.97	25.90	25.79	24.97	25.90	24.97	25.79
qLighting	44.90	0.00	0.00	0.00	0.00	11.86	9.91	10.26	12.86	0.00	0.00	0.00	0.00
qTransmiss	-336.49	-46.17	-42.42	-36.55	-30.94	-21.47	-14.51	-12.35	-12.69	-18.49	-26.31	-34.24	-40.37
qMixing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qVentilation	-655.86	-48.43	-50.26	-54.53	-53.94	-57.56	-54.16	-55.55	-54.98	-54.57	-55.85	-63.27	-52.75
Sum	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00
tOutdoor me	7.7	-0.5	-1.0	1.7	5.6	11.3	15.0	16.4	16.2	12.5	9.1	4.8	1.5
tOp mean(°(	24.4	23.7	24.2	24.1	24.2	24.5	24.7	24.8	24.7	24.4	24.3	25.0	24.0
AirChange(/	1.0	0.6	0.6	0.6	0.8	1.1	1.6	1.8	1.6	0.9	0.7	0.6	0.6
Rel. Moistur	39.2	32.1	29.4	30.0	32.8	38.9	48.3	52.5	50.4	48.9	40.1	35.7	31.9
Co2(ppm)	722.2	793.9	789.6	747.1	722.0	678.3	655.5	651.3	654.4	688.5	726.1	774.2	785.0
PAQ(-)	0.2	0.4	0.4	0.4	0.3	0.2	0.1	-0.0	0.0	0.1	0.2	0.2	0.4
Hours > 21	8760	744	672	744	720	744	720	744	744	720	744	720	744
Hours > 27	42	0	0	0	0	0	7	18	15	0	0	2	0
Hours > 28	9	0	0	0	0	0	0	0	9	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	139.13	11.82	10.67	11.82	11.44	11.82	11.44	11.82	11.82	11.44	11.82	11.44	11.82
HtRec	1999.07	290.32	272.60	258.13	192.13	116.39	66.12	50.38	53.17	95.10	145.88	199.97	258.88
ClRec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HtCoil	1.29	1.13	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
ClCoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidif	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorHeat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorCool	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Ill.19 Results from BSim - room type B

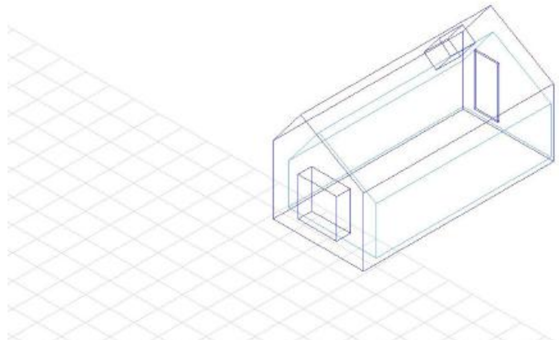
BSIM - ROOM TYPE C



III.20 Geometry - room type C with surrounding buildings



III.21 Geometry - room type C



III.22 Geometry - room type C

Options | Moisture | Simulation | HeatBalance | Parameters | Tables

Month | Hours | ThermalZone1290

ThermalZor	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	33.14	15.58	6.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	10.56
qCooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qInfiltration	-201.24	-23.84	-22.39	-23.23	-20.41	-13.98	-10.08	-9.03	-9.03	-12.15	-16.67	-18.67	-21.75
qVenting	-444.64	0.00	0.00	0.00	0.00	-84.51	-101.40	-111.14	-92.15	-55.44	0.00	0.00	0.00
qSunRad	693.35	12.85	26.19	51.33	74.69	99.08	109.47	111.37	88.77	62.17	33.52	14.82	9.10
qPeople	642.00	55.50	49.20	53.70	53.10	54.60	52.20	55.50	53.70	52.20	55.50	52.20	54.60
qEquipmen	304.18	25.90	23.34	25.79	24.97	25.90	24.97	25.90	25.79	24.97	25.90	24.97	25.79
qLighting	261.70	31.43	26.88	26.98	18.81	11.56	9.46	9.36	12.41	24.01	28.81	30.46	31.53
qTransmiss	-754.31	-99.29	-91.29	-94.11	-85.17	-37.28	-29.87	-25.31	-25.54	-43.16	-65.96	-68.04	-89.30
qMixing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
qVentilation	-534.17	-18.13	-18.45	-40.45	-65.99	-55.38	-54.75	-56.64	-53.95	-52.60	-61.09	-36.21	-20.52
Sum	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	-0.00	-0.00	0.00	-0.00	-0.00	-0.00
tOutdoor me	7.7	-0.5	-1.0	1.7	5.6	11.3	15.0	16.4	16.2	12.5	9.1	4.8	1.5
tOp mean(°(	23.6	21.3	21.5	23.0	25.2	24.3	24.8	24.9	24.7	24.2	24.6	22.9	21.5
AirChange(/	1.3	0.9	0.9	0.9	0.9	1.6	2.2	2.5	2.3	1.3	0.9	0.9	0.9
Rel. Moistur	37.2	30.8	28.4	28.0	28.3	36.6	45.9	50.3	48.5	46.5	36.3	35.7	31.2
Co2(ppm)	583.3	609.0	606.8	601.0	603.9	560.8	549.1	550.1	549.6	562.4	606.0	597.4	603.9
PAQ(-)	0.3	0.5	0.6	0.5	0.4	0.3	0.1	0.0	0.1	0.1	0.3	0.4	0.5
Hours > 21	8237	525	552	744	720	744	720	744	744	720	744	700	580
Hours > 27	65	0	0	0	26	0	17	13	9	0	0	0	0
Hours > 28	3	0	0	0	0	0	3	0	0	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	139.13	11.82	10.67	11.82	11.44	11.82	11.44	11.82	11.82	11.44	11.82	11.44	11.82
HtRec	1967.60	279.30	262.16	257.58	192.13	116.39	66.12	50.38	53.17	95.10	145.88	198.37	251.02
ClRec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HtCoil	32.75	12.14	10.51	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	7.94
ClCoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidif	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorHeat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FloorCool	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentCoolinç	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CentHeatPu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

III.23 Results from BSim - room type C

MSc 08 ARC Hussein Abo Hamida, Mathias Nordtorp Hyldig, Patrycja Ewa Lyszczyk
Architecture & Design, Aalborg University