BIRKELUNDEN

PREFACE

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ABSTRACT

Following an integrated design process, the project presented in this report shows how a sustainable primary school can be designed to create inspiring learning environments that motivates the students and help them learn new things easier, with a good indoor environment, while still having a zero energy building.
Through a range of spatial settings within the building, suchs as niches and flexibile learning areas the school accommodate all the children and their different needs, the same strategies apply for the outdoor area, that encourage the children to play and be more active in their daily life. The school is not only for the children, but is also open after hours for gymnastics and theater, to create a space for the local community to gather.

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INTRODUCTION

The danish schools have had issues with bad indoor environment, which affects the children's learning abilities and health. In 2013 the danish government made a new reform, which demanded longer school days for both the students and the employees, the reform also included more activity during the school hours, but it did not include better conditions for the users.

This project is to design a new school in Haderslev municipality for around 600 children, which will replace the old school. The design will focus on improving the indoor environment, through the air quality, temperatures and learning environments, based on knowledge of children's learning styles.

Besides having focus on the user's needs, the school will also include moderne approaches to sustainability and the DGNB demands, through materials, access, different active and passive strategies etc. Before the beginning of the design phase different analysis will be made to support the choices, which are made to reach the final design.

PROBLEM AREA

How to design a new sustainable school, which meets the environmental demands from 2018 and emphasize a creative and alternative approach to learning through different learning styles and learning environments? While at the same time create a good indoor environment to give the students the best conditions for learning something new.

METHODOLOGY

INTEGRATED DESIGN PROCESS

The integrated design process is a holistic approach to building design and construction, it combines knowledge and methods from both architectural and engineering perspectives (Knudstrup, 2004).

The integrated design process consists of five phases, that is used in an iterative process. The phases are: problem, analysis, sketching, synthesis and presentation.

The **Problem phase** is where the problem is defined or the idea for the project is explained, taking into account possible issues and potential.

In the **Analysis phase** the program and theory is outlined, together with the microclimate, urban development, room program, energy frame, indoor environment and the users.

Different methods like mapping, phenomenology and serial vision are used together with diagrams and pictures to show the results of the different analysis.
There will also be made some case studies to gain knowledge from what others have done before, and learn from it.

At the end of this phase some general design criteria is formed, but being an iterative process, this can be changed during the next phases.

During the **Sketching phase** different architectural ideas are drawn based on the criteria from the prior phases, using different materials, models, diagrams, scales and methods. In this phase new and creative ideas are created, and there must always be an awareness of how the design change influence the buildings energy performance and the effect on the indoor environment for an example.

In the **Synthesis phase** all of the ideas and technical considerations are brought together to one final design. All the considerations from the sketching phase flows together or interact, to make a building that has a high architectural quality and high quality technical solutions.

The Presentation is the last phase, where the design is presented and all the qualities are shown and explained using renderings, floorplans, sections, diagrams and 3D models.
The presentation should also explain how the building meet all the design criteria and the solutions are presented.

The integrated design process allows the design to develop based on both the architectural basis, but also taking the engineering approach into the design, making the final design more whole and thought out. (Knudstrup, 2004)

Ill. 1 - The integrated design process

EVIDENCE BASED DESIGN

Evidence based design (EBD) originated in healthcare design, but has later spread to other fields of building design suchs as schools, office spaces, hotels, restaurants, museums, prisons and even residences. (Whitemyer, D., 2010)

EBD is when a design is created based on a critical integration of credible evidence, practical design expertise and the client population needs, preferences and resources. This means, that evidence-based design is a broad base of evidence sources, that are narrowed used in the design uppeset research-informed design. (Marberry, 2017).

Evidence-based design is based on different levels of evidence, the different gradients of evidence, where the highest level shows some kind of causation. (Peavey, 2017)

EBD helps with a desirable interdisciplinarity between architecture and other fields, such as psychology and philosophy in order to gain a holistic understanding of how humans, and in this case children perceive and respond to their environment, when they need to learn something new.
EBD is used in this report in the sense that all the research and information used, comes from experience from people who worked with education and children.

RESEARCH THEORY

THE DANISH SCHOOL SYSTEM

The first recorded school in Denmark started in 828, when Ansgar bought 12 slaves free to teach them, and later priests began to teach in the Danish monasteries. In 1721 King Frederik 4^{th} orders 240 schools to be built for his soldiers children, these schools are called “Rytterskoler”.

“Rytterskolen” was often a building with the teachers housing areas in one end a schoolroom, witch had its own entrance area and then a stable in the other end of the building. These schools sometimes had a belonging outdoor gymnastic area. The teaching were done on a blackboard, as blackboard teaching and often with lots of rote learning. Slowly the school influence more, because children had to learn to read, this meant that the schools grew and became independent buildings, with two to eight classrooms.

The building where designed with two staircase, one in each end of the building. These staircases were often related to two small classrooms, one on each side and two large classrooms in the middle of the building. (Hansen and Schultz, 1972, pp. 9-14)

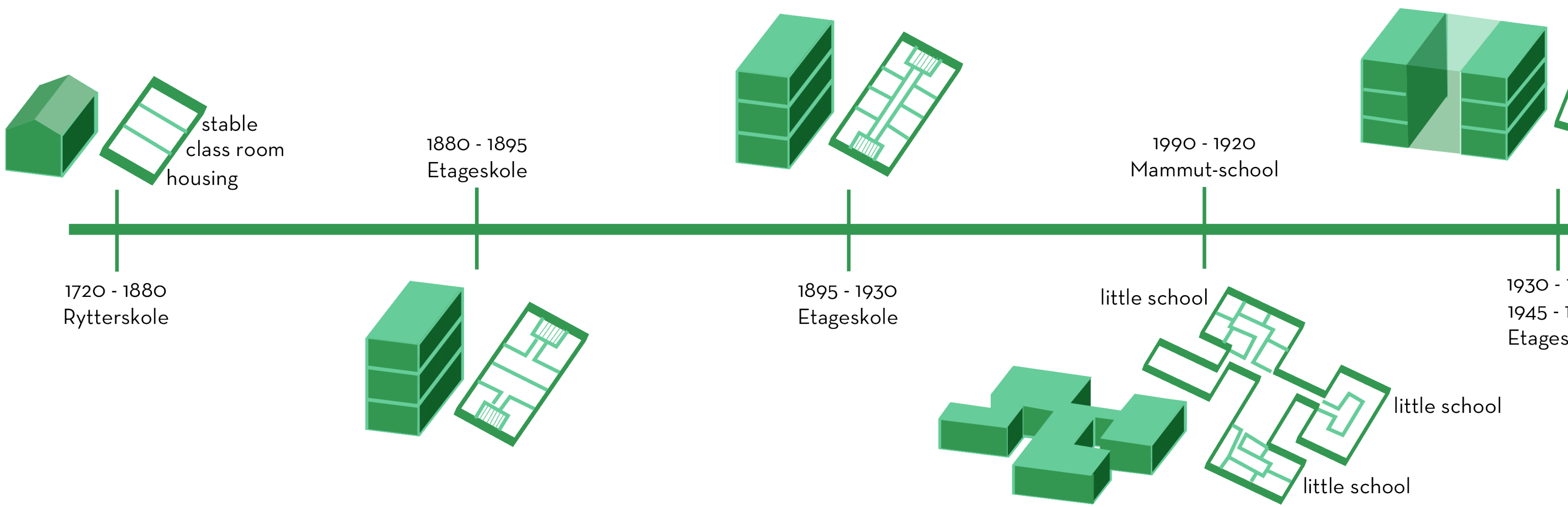
The schools kept growing, and in 1895, the structure of the school changed into a middle-corridor, which connected the two staircases. This structure made it possible to make more classrooms. (Hansen and Schultz, 1972, pp. 9-14)

Around the 1900, middle-school was created, this means that the schools now go from 1^{st} grade to 8^{th} or 9^{th} grade, and not only from 1^{st} grade to 6^{th} grade. Because of this expansion, the schools also expanded into **“mammut-schools”**, which are large, unstructured school plans, where classrooms are placed around a common area, as a “mini school”, but often the schools consist of multiple “mini schools”.

All the partitions were non-bearing elements, which made it possible to tear them down if needed. These schools are also called “the little school in the large”, and because of this unstructured and large plans, they evolved again around the 1920s.

In the 1920s, Denmark was hit by a depression, and they needed to find a cheaper solution for the design of the schools. This was the reason why the school structure changed back into the middle corridor-structure from the 19th century. (Hansen and Schultz, 1972, pp. 9-14)

In the 1930s, the idea of the middle-corridor is further evolved, by letting the middle-corridor breach through the levels and having balcons along the sides in the upper levels, leading into different classrooms. This design had some issues with noise, which was the reason why the school design changed around the 1940s, into “aulaskoler”. **“Aulaskoler”** was a reaction to the noise-problems. To



solve this problem, the large common space was made into an indedenpend room connected to hallways, which lead out to classroom, through middle- or side-corridor. In the same period lots of new large central schools were built (Hansen and Schultz, 1972)

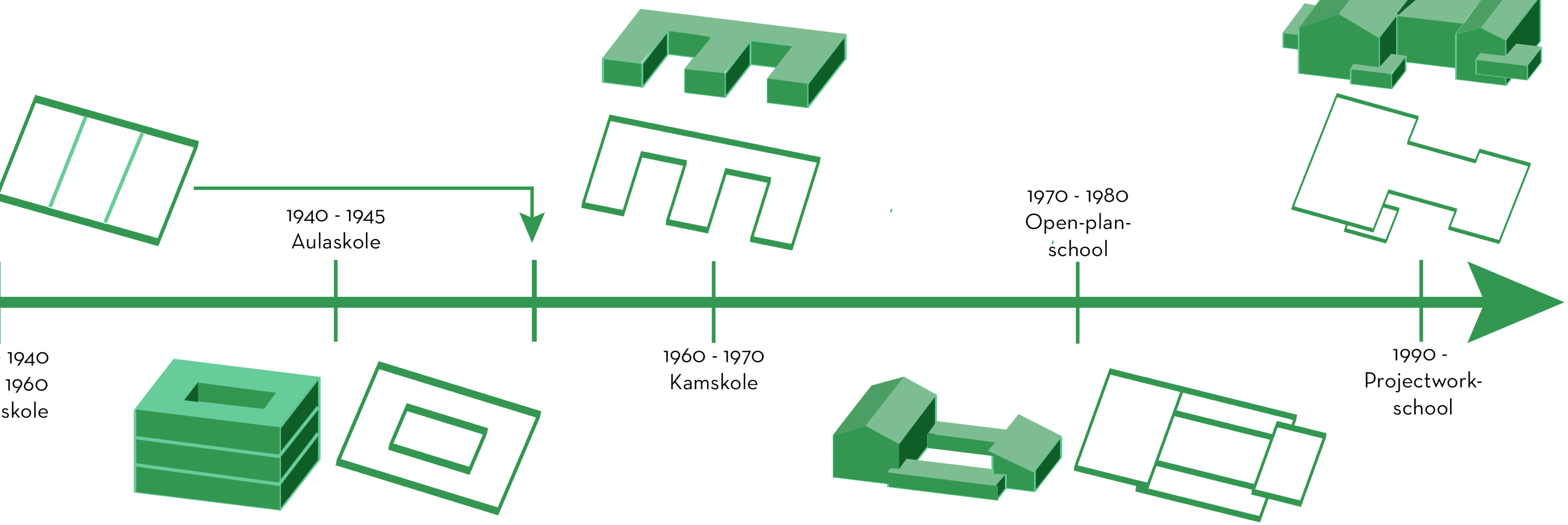
“Den blå Betænkning”, was a result of the new “Folkeskolelov” from 1958, it states that the curriculum committee chose to keep the original classroom as a principle of educational aspect. The classic classrooms should increase in size to 60m² for 24 children. (Hansen and Schultz, 1972, pp. 336-381)

After the new law, the school-design were inspired by the american and english schools, like the **“open door”**-school and the “storrumsskolerne”. The idea of the **“Storrumsskolerne”**, was to make large classroom with around 200 students with four to five teachers. (Hansen and Schultz, 1972, pp. 336-381)

1960s are imprinted by schools, which are separated according to their function, often in the three functions: classrooms, workshops and administration. This approach shows the distribution of roles, and keeps them in the physical environment. This separating by function and sectioning is an expression for the strictly division of lessons and organisation based on sprung. These schools were called **“kamskoler”**, and were often only in one plan. (Static.uvm.dk, 2001)

In the 1970s and 80ts the danish school changed radically into the **“open-plan”**, where mainly all internal walls were flexible, to make a wide range of possible changes in the classroom and working forms. This evolves into the little school in the big school, where classrooms are made into sizes, which make it possible to work in different workforms, like individual- or group work etc. In each building section there is several classrooms placed around a central common area. This period were impacted by lots of experimentation with school buildings. (Static.uvm.dk, 2001)

1990s made a new type of school, a more project-minded school, where moveable, internal walls makes it possible to create rooms, which fits the need space for the concerned workform. In 1993 a new school reform was made, the focus were more on the individual students needs and teaching styles. Which were the reason for the very flexible rooms, from small group rooms to multiple classes. (Dansk Arkitektur Center - DAC, unk)



THE REFORM OF THE SCHOOL SYSTEM

In 2013, one of the largest changes in the Danish school system was made, a new "skolereform", school reform. The new reform referred to improve the professionalism of the children, this meant longer school days for the children. the school days will have an average of 30 hours pr. week from nursery school to 3^{th} grade, 33 hours pr. week for 4^{th} grade to 6^{th} grade and 35 hours pr. week for 7^{th} grade to 9^{th} grade. (Altinget.dk, 2013)

Besides the longer days, the extra hours will be spent on more lessons with exercise and movement, english lessons from 1^{st} grade, german or french from 5^{th} grade, more lessons with math and danish between 4^{th} and 9^{th} grade, craftworks and design becomes a new subject, which replaces craft and handwork. More electives from 7^{th} grade, the final examinations must have larger influence on admission to secondary education, increased parental and stundential influence, more flexible team formation rules, training of teachers, school leadership and pedagogues. (Altinget.dk, 2013)

These were some of the main points of the school reform from 2013, which should increase the learning for all students, and improve the professionalism in the Danish primary school. (Altinget.dk, 2013)

The reform came to force in august 2014, and afterwards a comprehensive evaluation and follow-up of the reform began by SFI, The National Research Center for Welfare. The first measurement, after the reform came into force, was approximately one year after and the second measurement was around two years after. The measurement continued until 2018, were a new reform or adjustments to the reform came. (Nielsen, C. P., Keilow, M. and Jensen, L., 2016)

The reports show, that the relation between the school leaders and the management had become close, besides that, they have more freedom to government regulations. Based on the teachers perception, there have only been a small difference in the teaching and educational practice, from before the reform to after. But the use of exercise has increased and the use of student-plans have decreased, these are the large changes.

The pedagogues have gotten a larger influence on the school day, where they spent more time on homework helping, planning the education and making exercises. The status of the students seems to be the same as before the reform, the only changes are the less joy of going to school and the days are too long, but they have increased their interest in the professionalism. (Undervisningsministeriet, 2016)

In 2018 the government came with at new suggestion to improve the school reform, a link reform, where some of the exercise hours should be spent on traditionnel, professionalism subjects. Simultaneously the school days will be shorter and the school structure should be more autonomous. (Folkeskolen.dk, 2018)

LEARNING STYLES

No one child is the same when it comes to learning something new, some prefer to sit by themselves, others learn better in pairs, some needs to lay on the floor or have dim lights to learn best.

"The way in which each individual learner begins to concentrate on, process, absorb and retain new and difficult information.." (Schmidt, 2001)

This is the definition of learning styles that Rita and Kenneth Dunn provides, it describes very general the idea of people having different approaches to learning something new.

There are many models and approaches to learning styles, the one that will be used in this project is by the professors Rita & Kenneth Dunn, because their model includes a wide range of variables, and it is one of the most well researched methods that specialises in children (Dunn, 2004).

Dunn & Dunn
Dunn & Dunn's model consists of 21 variables (Ill. 2) that all play a role when we have to learn something new.

The variables are divided into physical, emotional, sociological, physiological and psychological elements. Some of these elements are proven to be genetic, whereas others develop through time and experience. A person's learning style will therefore change through his or her lifetime.

The genetic elements are sound, light, temperature, design, time of day, movement and intake. Children adapt to the schools system, which is why many of them even though they start with a holistic approach, they slowly become more analytic, because this is the way they are taught in the current school system. (Dunn, 2004)

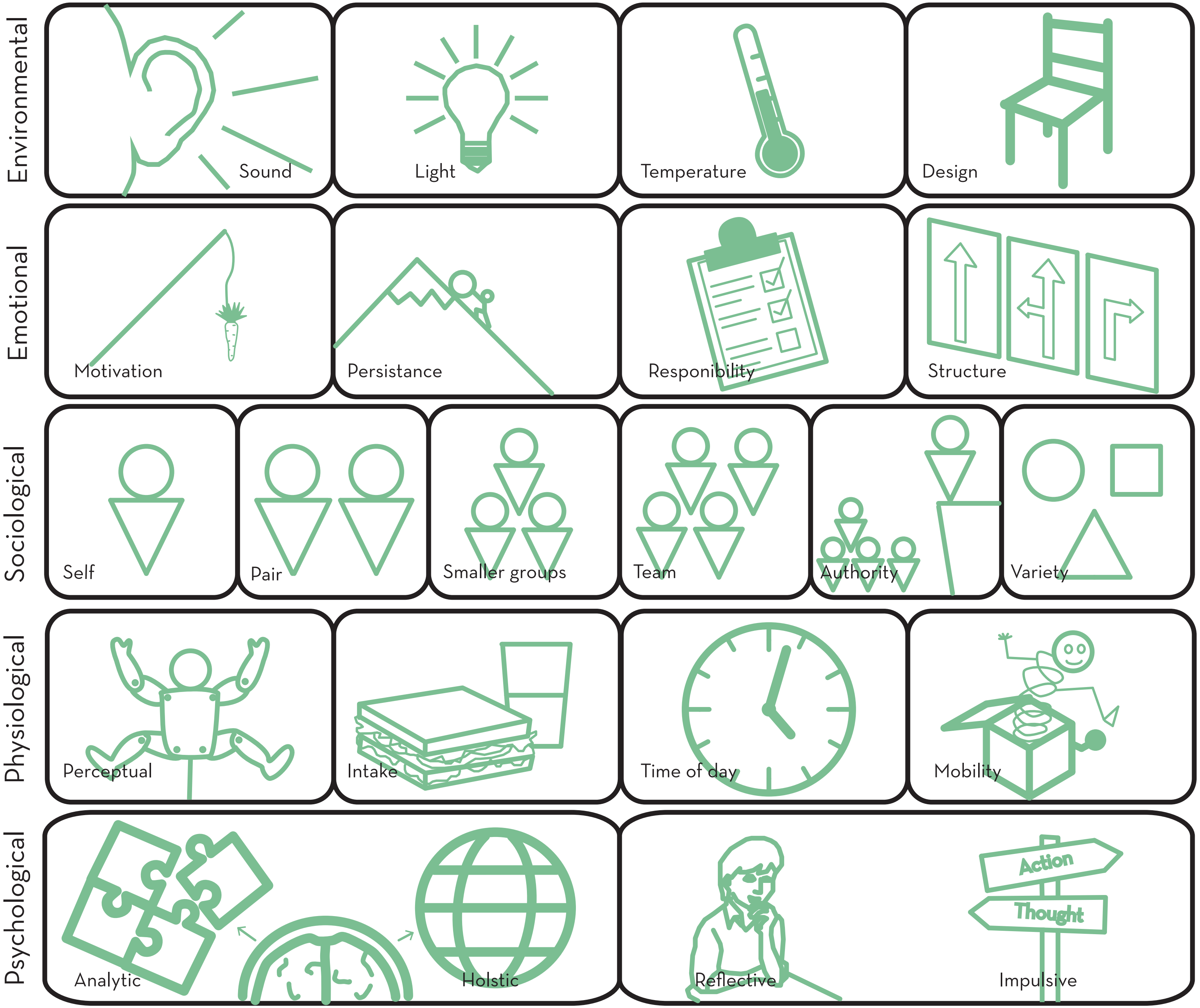
Dunn & Dunn divide children into two main groups: holistic and analytic, where statistically 88% of children are holistic, and only 12% are analytic, but in spite of this today's school system is focused on a teaching approach that benefits the analytic children, which, as mentioned before, is only about 12% of the children. (Dunn, 2004)

Children will typically lean more towards one than the other, but that does not mean that they will have all the preferences from either the holistic or the analytic, even though they will always have more in common with one than the other.

Table 1 shows the strengths and preferences of the holistic and analytic learner.

Holistic	**Analytic**
Visual learners	Auditory learners
needs to move around, informal design	Can sit still and learn
Want choices on what, how and with whom they are going to learn	Works on their own even from the small grades
Learns best between 10 and 15 o'clock	Works best early in the day
Dim lights	Prefers bright light
Prefers tactile and kinesthetic material	Do not care how the room is designed
The right side of the brain is dominant	Self motivating
Works best with an outer motivation	Persistens
Needs authorities	
Works best in pairs or smaller groups	

Table 1 (Dunn, 2004)



Ill. 2 - Dunn & Dunn's learning style variables

Analytic students tend to do better in school, because their learning style is more in line with the traditional teaching style. The holistic students tend to either be at the top or the bottom of the scale. This is because the holistic students either finds the outer motivation they need or they do not, and then they can end up at the bottom of the scale. (Dunn, 2004 p. 49)

A study shows, that the awareness of one's learning style also improves learning (Bhagat, Vyas and Singh, 2015), Teaching the children about the different learning styles will make them aware of their own style and make them understand why somebody is allowed to do something else, and it also makes them more open to try different types of teaching.

How best to address the different learners, will be described later in the repot, where the user is also described.

Dunn and Dunn also explains, why it is important not to use to many different teaching styles, when teaching. Because this will most likely confuse all of the students, but in the small grades it is beneficial to introduce a subject tactile, and then do the repetition auditive. To engage most of the students, whom at that age are most likely to be holistic. Most of all the teacher should be aware of his/her students different learning styles, and try and engage the student by addressing their individual style.

Also at home parents need to remember, that their children not necessarily learns the same way they do, so what worked for them will maybe not work for the child.

One learning style is not better than the other, they are just different (Dunn, 2004), because children learn differently, they need to be taught differently as well.

In this project the learning styles of the children will be used as a design tool for the learning environments around the school. They will be used as guidelines to create different rooms, that the children can use depending on their different learning styles.

SUSTAINABILITY

INDOOR ENVIRONMENT

To ensure a good indoor environment at the school, a comparison between the officiel, Danish set of rules, BR18 and the more sustainable certification, DGNB has been made to investigate what the minimum demands are and how much it is realistic to improve the indoor environment for the students and teachers. On some accounts the DGNB has not yet made any demands for schools, so in that case the BR18 will be used.
The aim of this project is to obtain the category II of the DGNB demands to ensure the children and teachers a healthy environment.

The Danish building regulations are rules set for new buildings in Denmark, which contains certain standards for access, construction, energy use, indoor climate, installations and fire protection. These regulations are set to secure a satisfying standard for every building in Denmark. (Bygningsreglementet.dk, 2018)

DGNB, which stands for Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council). This certification takes the entire lifespan of the building into account, to prevent making an unsustainable process, material use and building method.

The certification is divided into three categories: environmental, economy and social, to include every aspect of sustainability. These categories are furthermore divided into 40 subcategories, which are used to measure the sustainability of the building.

DGNB has three different categories based on different air-quality, which gives different satisfaction among the users, where category 1 is for highly sensitive people, as patients in a hospital. Category 2 is chosen for this project, because it is children, which are not highly sensitive, but still more sensitive than grownups.(DGNB System Denmark, 2017, pp. 227-250 & pp. 341-348)

*IAQ is categories for the indoor air quality, based on the users satisfaction

As Table 2 shows, the demands for DGNB is higher than the BR18, to secure a better indoor environment and a more sustainable building.

	BR18(Bygningsreglementet.dk, 2018)	**DGNB(DGNB System Denmark, 2017**
CO_2	max. CO_2 level: 1000 ppm	DS/EN 15251 Ventilation quotient between category II : IAQ* II: average · 900 ppm
Temperature	DS 474 (DS/EN ISO 7730) The builder owner decide how many hours there should be above 26°C and 27°C. Often the amount of hours is set to: 100 hours above 26°C /year 25 hours above 27°C /year	DS/EN 15251 category 2 Summer: · 26 °C Winter: 20 °C 100 hours above 26 °C and 25 hours above 27 °C
Ventilation	DS/EN ISO 7730 (DS 447) min. 73% heat recovery min. 5,0 l/s pr. person and 0,35 l/s pr. m^3	Category II: 7 l/s pr. pers.
Acoustics	SBi-anvisning 218 External noise exposure: L_{den} · 33 dB (with closed windows) Technical installations: · 30 dB Reverberation (125-4000 Hz): class and crafting T· 0,6s music room (<250m3) 0,8 ·T·1,1s Gym (<3500m3) T· 1,6s Group areas T·0,4s	There are still no acoustics demands for schools
Daylight (DF)	DS/EN 14501 (SBi 264) min. 300 lux for 50% of the room in min. 50% of the daylight- hours. Or the amount of glass-area should be 10% of the floor-area.	Category II: 50% above 2% Permanent workplaces: Category II: DF · 2,5% (min. 80% of the workplaces)

Table 2 - Indoor environment demands from BR18 and DGNB

THE THREE PILLARS OF SUSTAINABILITY

The concept of sustainability has been commonly used for many years, but not clearly defined before The Brundtland report,Our Common Future 1987, which defines sustainability as:

> *"...development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*
> *(Brundtland et al., 1987)*

The Brundtland Report divides sustainability into three pillars, that all have to be addressed for a design to truly be sustainable. The three pillars are economic, environmental and social sustainability.

Environmental sustainability is the most well known of the three pillars. This pillar is concerned with the environmental impact a building has, both in terms of materials and energy use throughout the buildings life-cycle. There is also a focus on indoor climate quality, properties and the embodied energy of the materials used. There is a focus on the Life Cycle Assessment of the building to ensure that the building stays sustainable until it is demolished or reused.

Economic sustainability addresses the financial side of the building, sustainable solutions is often more expensive in the building phase, because the technologies used are either new and still in development or it is produced in small quantities and therefore is more expensive. But when thinking sustainable the focus should not only be on the construction phase of the building, but it includes the whole life cycle cost, which means the costs for the building all the way through its lifetime.(Kibert, 2016, p.58)

Social sustainability is the most neglected of the three pillars compared to environmental and economic sustainability, because there are few practical resources that directly address the problem. The main focus of social sustainability is to create spaces where people feel safe, have a sense of community identity and belonging, respect and engagement with people from different cultures, background and beliefs. It is also important that the crime rates are low, and opportunities for all people to be socially included and have similar life opportunities (Woodcraft, et al., 2011).

A holistic design approach should take all of these aspects into consideration, to make sure the building is sustainable for both the environment, the society, the people living there and the overall economy. The focus in this project will be on the environmental and social sustainability, the economical will be addressed more in terms of the lifetime of materials and flexibility in the building.

Ill. 3

ZERO ENERGY BUILDING

A zero energy building, ZEB, is defined as a building with at low energy demand, which is covered by renewable energy sources. It is also a building with a focus on a good indoor climate, and high architectural quality and a respect for the user.(Bejder, et al., 2014)

The ZEB is based on the optimal combination of low energy demand and the supply of renewable energy sources, such as solar, wind, thermal and biogas from either on site or from the energy infrastructure, grid.

The ZEB has a focus on the indoor environment in relation to temperature, air quality, acoustics and daylight in the building. The building should also be a house of the future, which means that it is sustainable, not only by the energy demand, but also in relation to materials and user needs.

The overall goal for the ZEB is to eliminate the consumption of fossil fuels, by using the renewable energy sources as mentioned before.

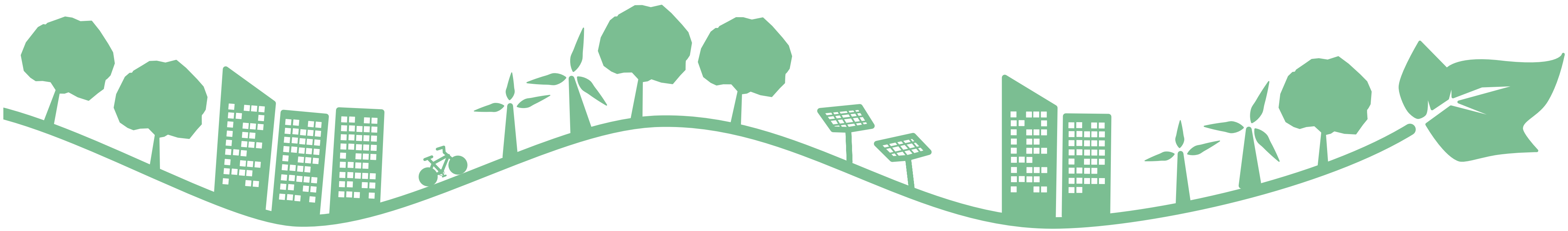
There are different types of zero energy building; net Zero Site, net Zero Source, net Zero cost and off-grid-zero-energy.

The net Zero site produces the renewable energy on site, that is needed to cover the buildings energy demand. The **net Zero Source**, in addition to cover the energy demand of the building, also covers the transportation to the site and the generation of the energy.

The net Zero Cost is where the building owner is paid by the utility for the energy provided to the grid, and this amount is at least equal to the amount the building owner pays for energy services and energy used over the year. (Marszal and Heiselberg, 2009, pp. 1-20)

An **Off-grid-zero-energy** is as the name indicates not on the grid, and therefore needs to produce all the energy needed for the building. This also means storing energy for periods without enough sun and wind, depending on the renewable energy source.

To have the best idea of how sustainable the school actually is, the net Zero Source will be used in this project, because it gives the clearest idea of how much energy the building actually uses, including use, transport and the loss during transport.



PASSIVE AND ACTIVE STRATEGIES

When designing a Zero Energy Building there are different strategies that can be used to keep the energy demand down, while maintaining a good indoor climate. The strategies are divided in passive and active strategies.

To keep a stable indoor climate a **low U-value** of the building envelope protects against overtemperature in the summer and heat loss in the winter, which will cause the building to have a more stable indoor temperature. A low U-value can be obtained by insulation in the building envelope, and also by the materials used for the construction.

Concrete and brick have a heavy themalmass, which means they will retain the heat, and then slowly release it, when the building's ambient air temperature drops. In addition to this passive solar heating, in the winter is very useful to keep the heating demand down.

Likewise will **passive cooling** help keep the temperature down in the summer, and therefore reduce the energy demand for cooling. **Passive heating** and cooling can typically be combined, as some kind of external shading, since the sun is high during the summer, the shading will keep the sun out, but let in the low winter sun.

To keep the energy demand on electrical light down, **natural daylight** is a key strategy to use when designing a zero energy building. When using natural daylight, it is important to remember, that there are different types of daylight depending on the location of the windows.

From north the light is diffuse and optimal as working light, where as the light from the south is more direct and changing during the day, it also brings a lot of heat compared to the light from north.

To prevent overheating from the southern sunlight **external shading** can be applied where it is necessary. When the shading is external, it prevents most of the heat from entering the building.

One of the last passive strategies are **natural ventilation**, to keep the energy demand on the mechanical ventilation low, and making the mechanical ventilation unnecessary during the summer. Natural ventilation helps control the CO_2 level in the rooms, while also keeping the temperature down.

Mechanical ventilation will properly be necessary in the winter, because then the air outside will be too cold to use for natural ventilation, because it will take to much energy to warm up the fresh air. It is more energy saving to use mechanical ventilation with heat recovery.

When using natural ventilation, one has to distinguish between cross ventilation, single sided ventilation and stack ventilation. the efficiency of the different types depends on the room size and height, but also on the type, placement and size of the windows.

Besides from the before mentioned passive strategies, there are numerous of active strategies, but the most useful, concerning zero energy buildings, are renewable energies, such as solar cells, geothermal heating, wind power, hydro power and so on. These active strategies can cover the building's low energy demand.

All of the passive strategies will be used in this project, in different extent, as it is relevant for the design, and the sustainability of the building.

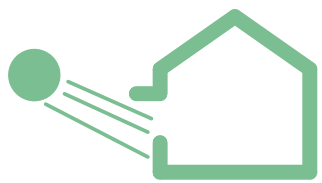
There will also be used some active strategies, most likely **solar cells** and **geothermal heating**, because the area is open, which allows a lot of light onto the site and large area of land also gives the possibility of laying down pipes for geothermal heating.

The **wind power** is harder to use, because of the placement in an dwelling area and the risk of noise. The hydro power cannot be used, because the area as no stream to power it. The solar cells and geothermal power will be used in order to keep the use of fossil fuels down, and rely more on renewable sources.

Ill. 4 - Low u-value

Ill. 5 - Passive cooling

Ill. 6 - Daylight



Ill. 7 - Passive heating

Ill. 8 - Natural ventilation

Ill. 9 - Renewable energy

FIRE REGULATIONS

A school is part of application class two in the danish building regulation, and this means, that the building needs to be five meters from the boundary between properties, roads and paths, unless the building's wall towards the boundary is a fire wall.

Every building must have at least one access directly to terrain, this can be either a door or a door from a staircase.

Escape routes has to be easy to find, reach and use, it has to be noted, that not everybody in the building is familiar with the buildings planning and exits.

From a random point in every room, there must be less than 25 meters to the nearest escape hall or exit. If the room is less than 150 m² and suited for less than 50 people there only has to be one exit.

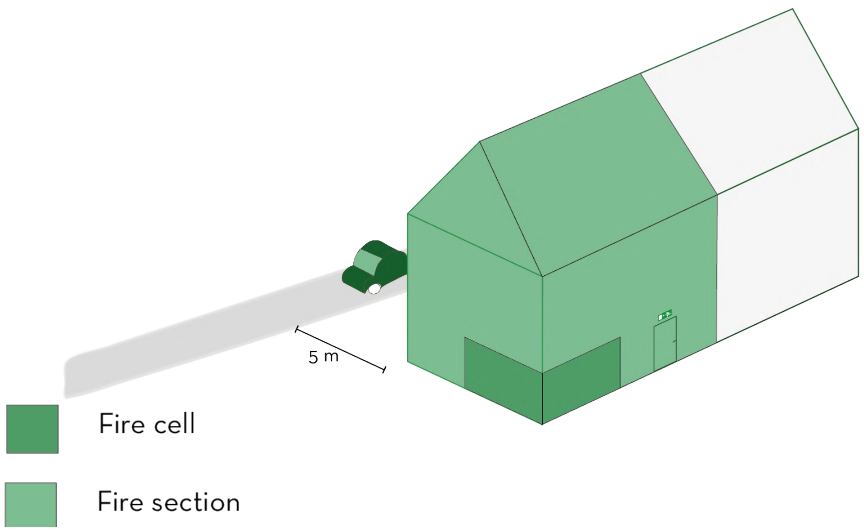
Rooms, that creates a particular fire hazard, needs two fire exits. This could be rooms like physics, crafting, art and school kitchens.

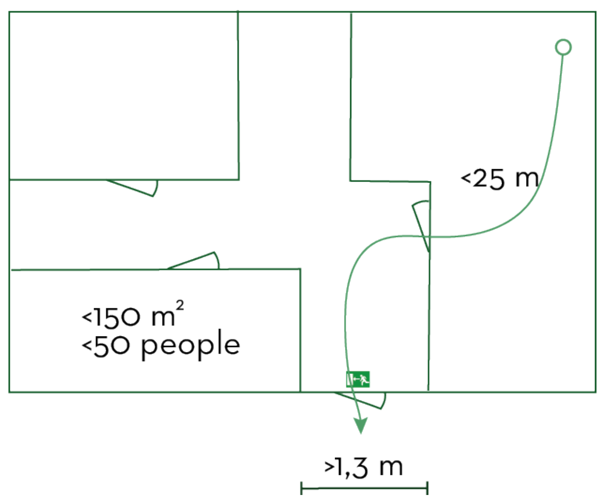
The building can be divided into fire cells and fire sections. Fire cells are usually rooms, or one apartment, where as the fire section is bigger, and can be an entire floor or a section of an apartment block.

Halls, that are used as fire escapes, needs to be at least 1,3 meters wide if it is used by 130 people or less, if it is used by more, there needs to be an addition of 10 mm per person above the 130 people.

A fire unit that is meant for people, need to have one rescue opening per started ten people. So a room for 21 people needs three openings.
Rescue openings less than two meters above the ground, can be placed at a height less than 0,6 meters.

To avoid spreading of the fire to other buildings, there should be at least 10 meters between them, unless one or both of the buildings have fire walls. Two buildings are considered separate in a fire perspective if the distance between them are bigger than both their required distance to the property boundary line. (Knudsen, 2012)



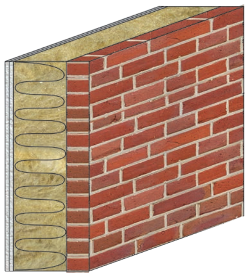


LIFE CYCLE ASSESMENT

Designing a sustainable building also means to use materials that are sustainable in for an example CO_2 outlet in their production. Making an life cycle assessment, LCA, of the materials in a building gives an overview of the different materials impact on the environment. The calculation also put the building up against a DGNB reference, to give an overview of the performance of the building materials.

The most common construction materials are wood, concrete and brick. Brick is already used in the area, but according to the local plan the municipality wants the school to be build in wood with the outdoor columns in steel.

Therefore these materials are the subjects of the initial LCA calculation together with concrete, since it is a very cheap and easy material to work with and it is being used more and more. The steel columns is not included because it does not give a clear idea of the materials, when one is a column and the others are walls, later on there will be made a new LCA to determine the material of potential outdoor columns.

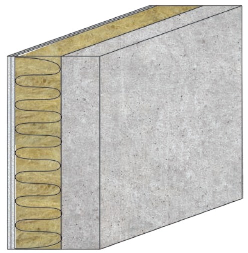


Ill. 10 - Brick wall

Brick has a high thermal mass, and is widely used in danish architecture. Bricks are load bearing so there are no need for extra materials for carrying the load of the
building. Bricks can be cleaned and reused in a new building as they are.(Randerstegl.dk, 2019)

Ill. 11 - Wood wall

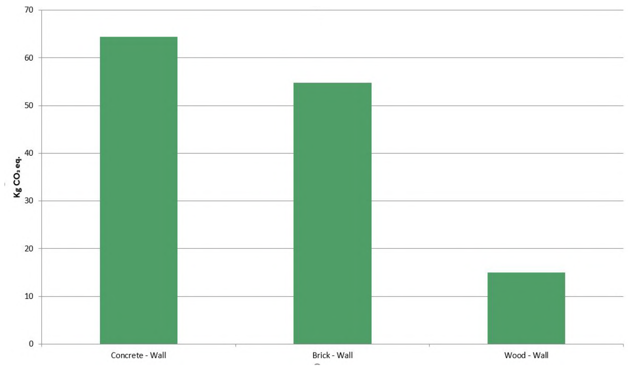
Wood is a light material, and is often used as a facade cladding and not for constructional purposes, but it can be used as a load bearing material as well as cladding. The wood is reusable, but not very easily, because the dimensions of the wood needs to fit with the new building. Because wood has spent its whole lifetime absorbing CO_2, it is still a sustainable material, as the graph also shows.(Ponsaing, R. von Benzon and Auken Beck, 2001)



Ill. 12 Concrete wall

Concrete is also a material with a high thermal mass and is also load bearing.
Concrete is harder to reuse, since it has to be broken down, and then it can be reused in for an example roads, but usually not on a new building. The production of concrete takes a lot of energy. (Herholdt, 1985, pp. 13-31)

Graph 1 shows how one square meter of wall with the different material perform in kg CO_2 emission in LCA, the three walls all have the same U-value, the only difference is the outside cladding and the construction.



Graph 1 - Each walls performance in LCA

As the graph shows the wooden wall has a smaller impact on the environment, than the brick and concrete, but the calculation does not take other properties into consideration, such as thermal mass and load carrying for construction. This conclusion support the municipalities wish for a wooden building, both in cladding and construction. This also supports the idea of the tactility of the school.

SUMMARY OF SUSTAINABILITY

To truly make a sustainable building, there are many different aspects that has to be considered. The three overall categories are economy, social sustainability and the environment.

To address the economy and the environment, there are some very defined things that can be done, and in this project there will be a focus on creating a good indoor climate for the users by following the DGNB demands for schools, and furthermore the use of sustainable materials for the building, measuring this by making an LCA calculation for the building.

An aspect, that is concerned with both economy and the environment are the energy frame, and to keep the use of energy and thereby the cost for energy down, passive and active strategies will be used, also as an aim to make the building a Nearly Zero Energy Building.

Using all of these aspects to create the design of the building so it becomes a natural part of the buildings architecture. The design will include the use of all passive strategies and two active strategies, solar cells and geothermal power.

The main technical focus of this project is the indoor climate and making the building a zero energy building. The other analysis made have been made to give a better understanding for the background of sustainability and to give ideas of how to solve the building in an sustainable way, that is also good for the indoor environment.

ANALYSIS

SITE HISTORY

Today Haderslev is a city with around 21.955 citizens in 2017, it lies close to the German border and approximately 15 km from the east coast. The city is a trade center for the whole area, with mainly metalware companies, but also lots of educations and part of the Danish army.

The city is also influenced by german culture, because it lies in the borderland, which means, that the city has some german schools, church, library and rowing club. (Denstoredanske.dk, 2017)

The city started as a borough back in the middle ages, where some of the original buildings from different periods are preserved. The eastern and western part of the city is mainly residential neighborhoods from the 1960s and beyond. (Denstoredanske.dk, 2017)

Haderslev occurred in the 11^{th} century in the inner part of the fjord, later a Dominican monastery was built. The city gets municipality right in 1292, where king Christian the 3^{rd}, who is at the time the duke of Haderslevhus castle, he also completed the reformation in this part of the country. (Denstoredanske.dk, 2017)

Later on duke Hans the Older built a renaissance castle, called Hansborg, he also builds the pharmacy, the latin school, hospital and exclusive townhouses. The city goes through some violent fires in 1627 and 1759, but recovers and expanses the harbour front during the 18^{th} century and has slowly expanded since. (Denstoredanske.dk, 2017)

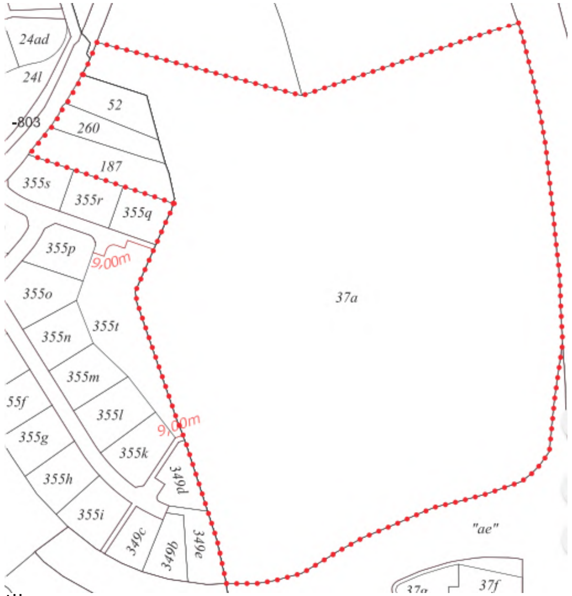
During the 18^{th} century, Haderslev is under german rule after a war in 1864, but after a vote in 1920, the city was once again under Danish rule. (Danmarkshistorien.dk, n.d.)

Ill. 13 Historical map of Haderslev

Ill. 14 The site in 1:5000

DEVELOPMENT OF THE AREA

District plan nr. 10-38, School at Erlev Bjerge and Gammel Hørregårdsvej, Haderslev from december 2018.



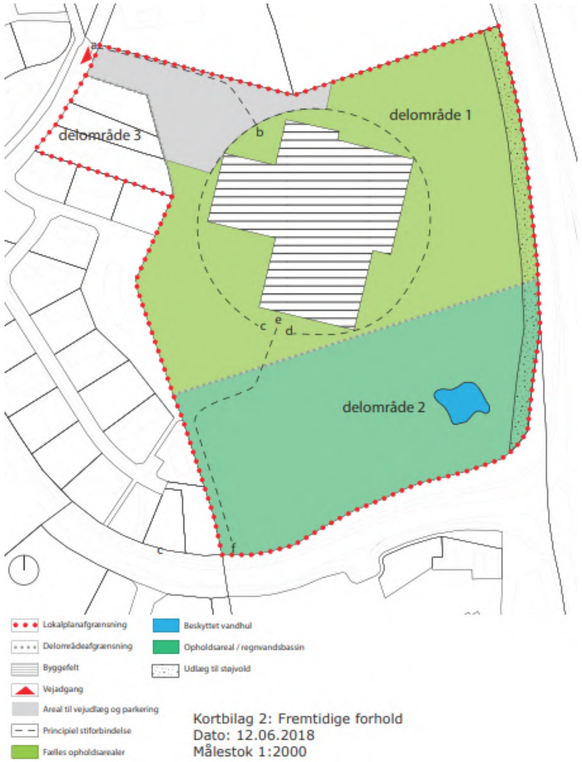
Ill. 15

The area is 6,7 acres and include cadastral 37a under Haderslev and cadastral 52, 260 and 187, Erlev, Gl. Haderslev, which lies in the southern part of Haderslev.

The area is divided in three, as shown on Ill. 16, where the first part of the area should be used to public purpose, as a school, this is the part this assignment will mainly focus upon, because it is also the part, which are closets to the access-road.

The school should be placed in the northern part of the site, with a ground area of around 6.000 m², with access from Gammel Hørregårdsvej og Erlev Bjerge. Part area one, should also have a rainwater basin, roads, paths and parking for the use of the area. The total amount of settlement in the first part of area must not exceed 40%, besides that, the western side of the area is affected by more than 58 dB, which are more than what is allowed for environmental sensitive application. (Haderslev Kommune, 2018)

The outer materials should mainly be wood and glass, the windows and doors should primarily be glass, wood and steel, besides that, the roof should be flat and covered with roofing felt. The construction should be laminated wood and columns, but the outdoor columns should be in steel. (Haderslev Kommune, 2018)



Ill. 16

The empty areas in part area one can be used for building production garden, sports fields, amphi scene, fireplace and forest area. Besides that, it is possible to make a stream, ponds and lakes, as well as rain water basins, which can be used in relation to the teaching. Other unused area should be used for building greenhouses, bike shelters, shelters etc. The terrain can be regulated with -1 to +2 meters on certains places. (Haderslev Kommune, 2018)

The second part should be for rainwater basins or some sort of stay, as well as paths and supply routes. The third part of the area should only be used for open-low settlement. (Haderslev Kommune, 2018)

The area should be the place for a new school for 0th grade till 6th grade, which should replace the old school, Hertug Hans Skole at Buegade and Sønder Ottinggade. Besides a new school, the area should also have recreational, green areas to play-, sport- and outdoor activities, which could be used for school purposes and for the public after school hours. (Haderslev Kommune, 2018)

Some of the demands from the consultation period were to make a parking area with space for loading on and off students and it was a wish during a hearing, that special attention should be paid to the cemetery, meaning that noise should be kept away from the cemetery. The new building should shield the cemetery from possible noise from the school.

The parking should be one parking space pr. 100 m² and five bikespaceses pr. ten students. The new path should be connected to the existing system of paths. (Haderslev Kommune, 2018)

MICROCLIMATE ANALYSIS

SHADOW ANALYSIS

Given the sites size, there are nothing close enough or high enough to give any problems with shadows on the site, the dwellings to the west are two stories and their shadows on a winter afternoon barely touch the site as the illustration shows.

The only consideration, that has to be made is how the new buildings of the school will shade for each other, and eventual new vegetations effect on the buildings, since there is no current vegetation close to the part of the site, where the school will be placed.

Ill. 17 Shadows on winter solstice at 15 o'clock

WIND

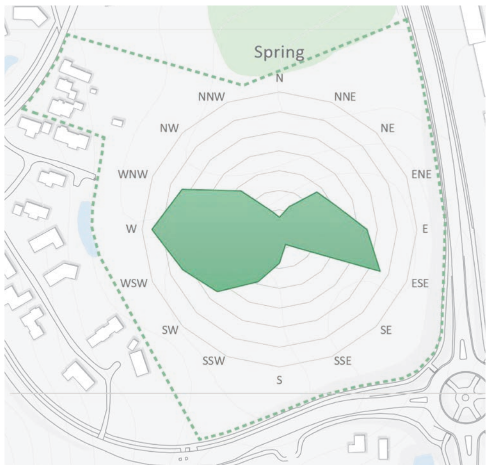
In Haderslev and Denmark in general the wind comes from a south, west and south-western direction.

Especially in spring the wind also has a tendency to come from an eastern direction. The sites topography is very flat, and therefore there is not much to shield from the wind. Towards the bigger roads, there have been made small hills to help with the noise together with vegetation towards east.

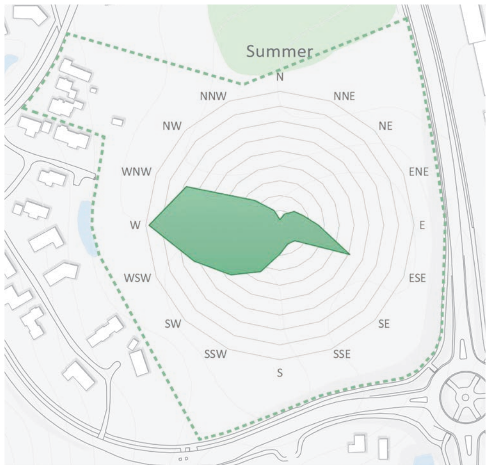
The small hills will not have a big impact on the wind, and there are nothing to shield from the west, where the wind usually comes from during the summer.

To shield of the wind, will be important on the outdoor areas especially from the common directions during fall and spring to make the outdoor areas usable during the colder months, by having covered areas. Also in the summer, the outdoor areas should be usable, but at that time of the year the wind is also desirable to use as natural ventilation inside the building.

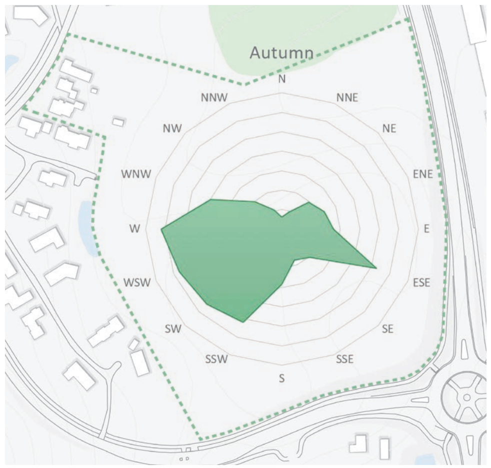
To shield from the wind both the new buildings of the school can be used to shield the outdoor areas and also new vegetation could help to make some comfortable outdoor spaces for the children to play in. The placement of the buildings and their height can help provide good conditions for the natural ventilation, to be used both in the summer, but maybe also in the winter, in some areas of the school.



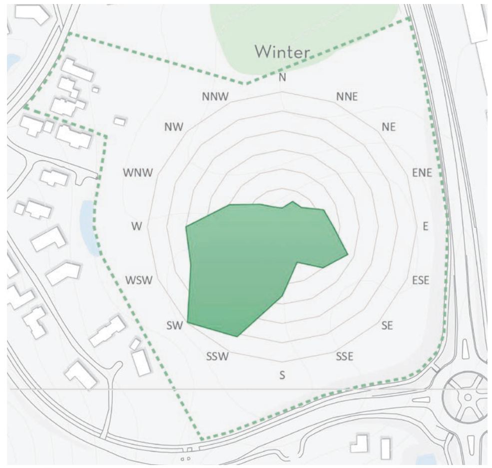
Ill. 18 Average wind direction in spring



Ill. 19 Average wind direction in summer



Ill. 20 Average wind direction in autumn



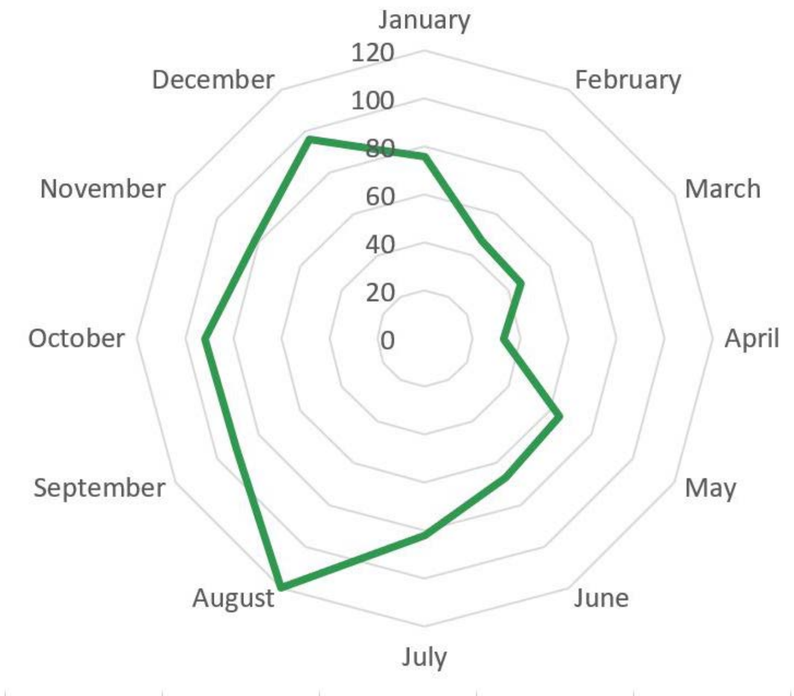
Ill. 21 Average wind direction in winter

PRECIPITATION

The illustration below shows the average rainfall per month from 2006 - 2015 in Haderslev (DMI, 2018). As seen on the graph the most rain falls in August, and during the autumn.

Because the site is located very low, there need to be done something about the precipitation, due to the aim of creating a sustainable school, there will be rainwater collection on the roof, and on the outdoor areas and on the outdoor areas, some of the collected rainwater will be used for watering plants and for flushing the toilet.

Besides from that, there will be integrated LAR, Lokal Afledning af Regnvand, local drainage of rainwater, solutions on the site.



Ill. 22 Average monthly precipitation in mm

SUMMARY OF MICROCLIMATE ANALYSIS

Due to the size of the site and the placement at the edge of the city, there are not many things that have an influence on the microclimate on the site, but there are some conditions which needs to be taken into consideration.

The wind on the site, is not stopped by anything, so there needs to be focus on the wind between the new buildings of the school and on shielding the outdoor areas.

Also the precipitation can become a problem due to the low placement of the site, but this also gives the opportunity to use it in the outdoor area for the school and collecting rainwater from the roof. Some of the outdoor areas should also be covered to be more useful.

URBAN ANALYSIS

GREEN & BLUE AREAS

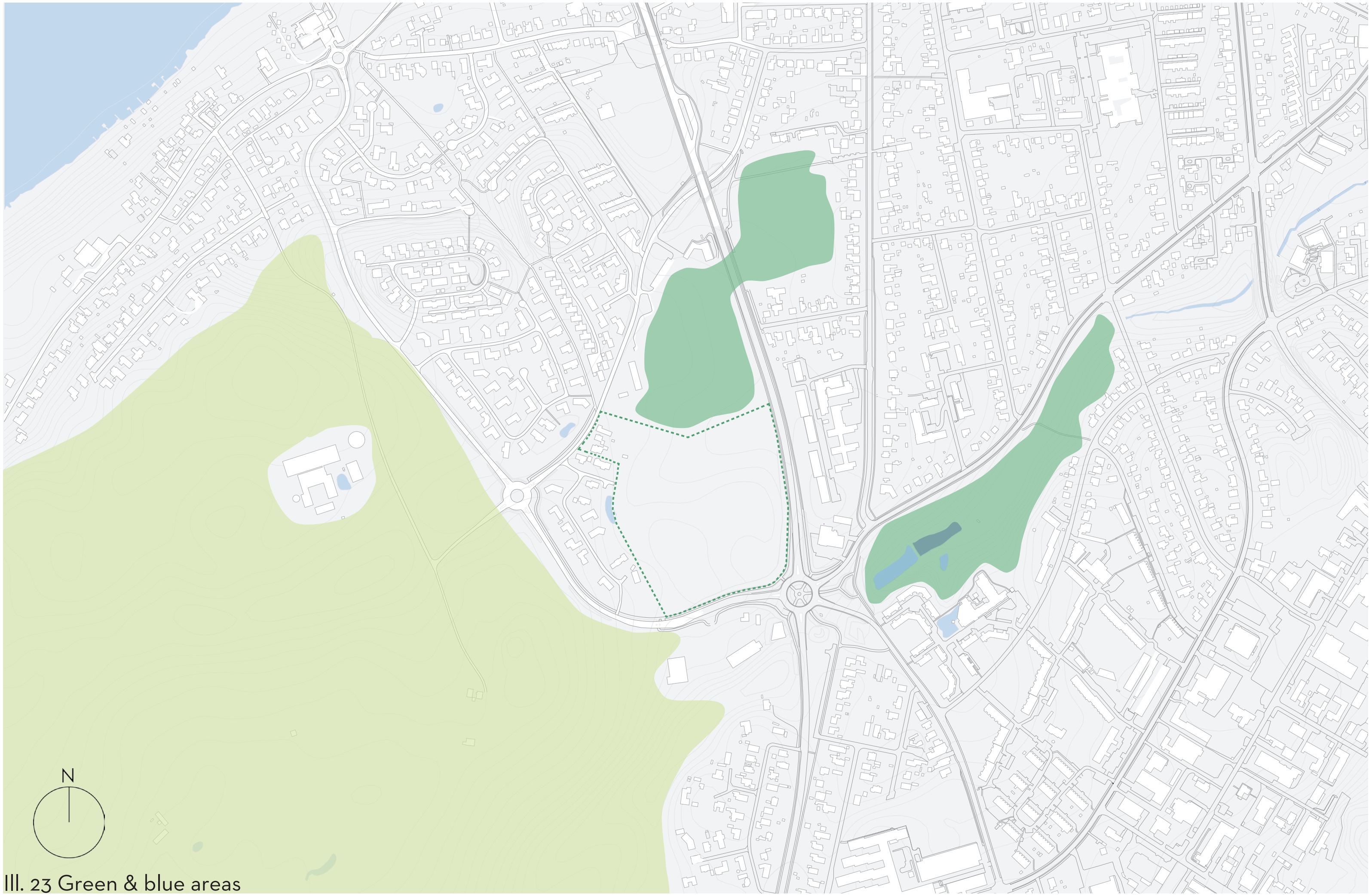
To the north of the site there is the fjord, and beside from a few small ponds, that is the only bodies of water near the site. There are a parkarea to the east of the site, and to the west of the site there are mainly fields.

The chosen site should also have a large, green area in extension of the eastern park-area from the cemetery and down to the southern part, to create a common, green area for this part of Haderslev city.

Green areas (cemetery, park)

Water

Fields



Ill. 23 Green & blue areas

ARRIVAL

The main access road is Gammel Hørregårdsvej, but it would also be possible from Erlev Bjerge, these are two large roads, which connects the site with the farmland and the newer part of the city. Erlev Berge is also connected to the main road, Omkørselsvejen, which runs through the city. It is also possible to arrive from the smaller road, Forsetesvej,

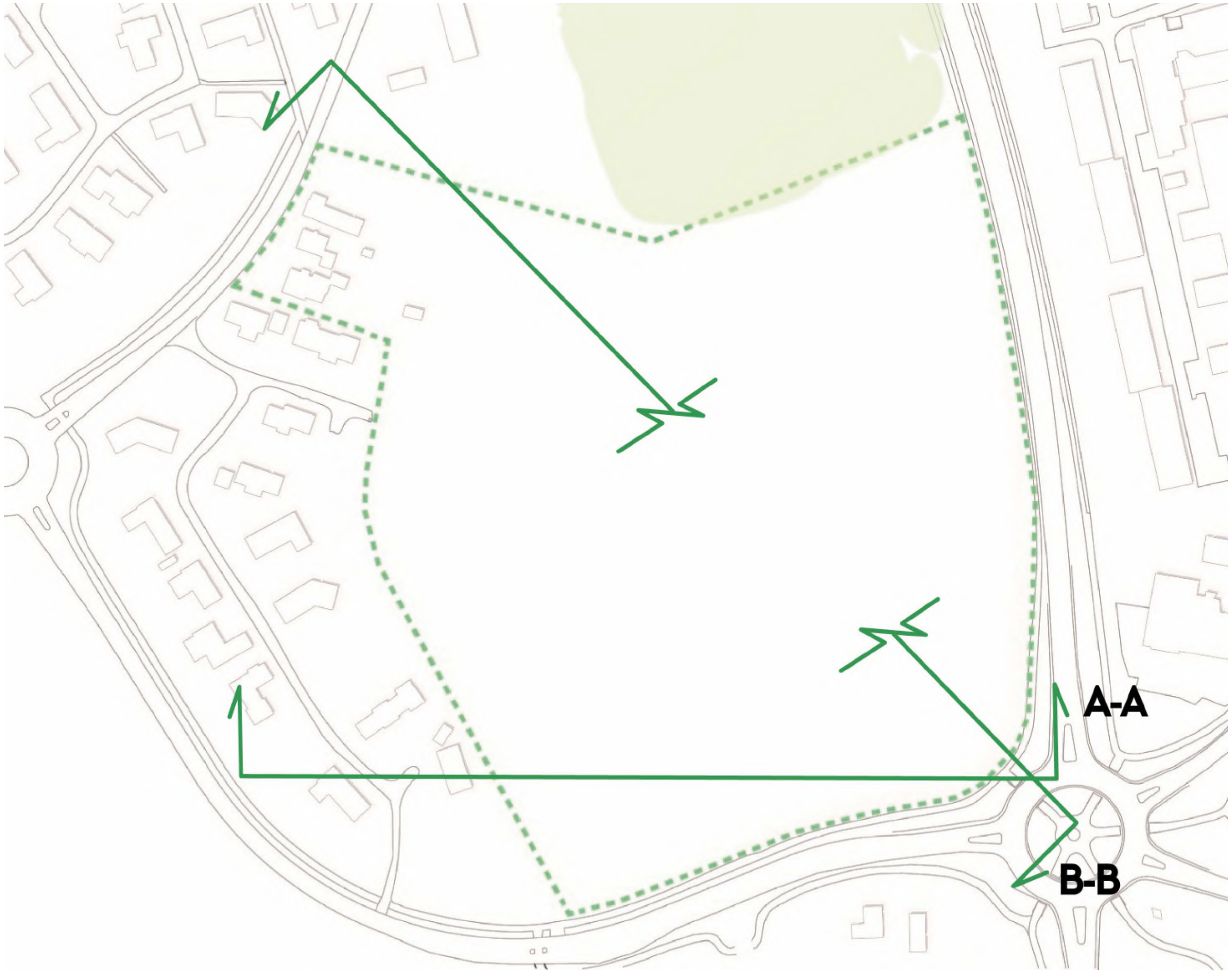
The paths, which leads to the site are mainly connected to the north, west and south. most of the paths come from the dwelling areas, but one path also leads to the bike path in the south end.

This bike path leads to the dwelling area to the east. Two other paths connects the site to the cemetery in the northern end, and a path in the south connects the site to the fields. The path from the southeast, which goes beneath the roundabout, should go through the hill and lead directly to the northwest part of the site, to connect with the access-road.

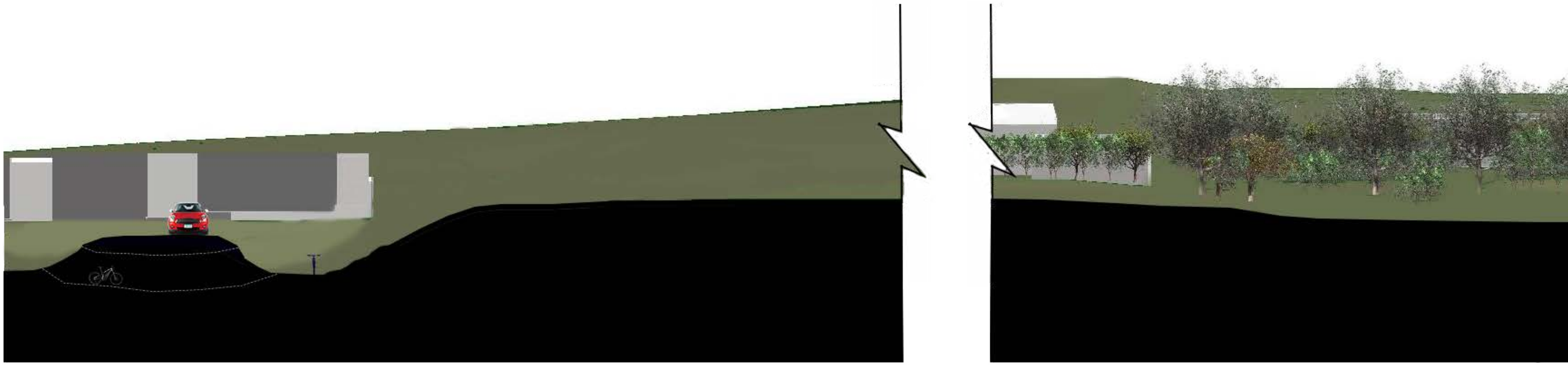
Ill. 24 in scale 1:3000

HEIGHT AND CROSS SECTION

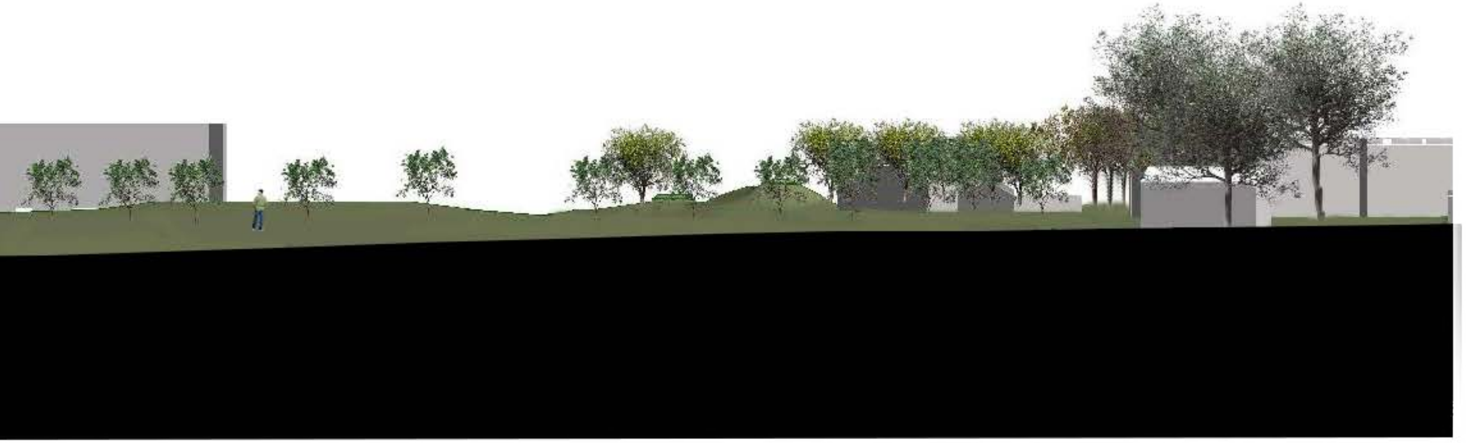
The terrain of the area is a bit hilly. It rises in the southern end, up to the roundabout, where the bike-path is lowered down below the roundabout. The height difference in the area is 8,28 m this means, that the terrain will not have the biggest influence on the design.

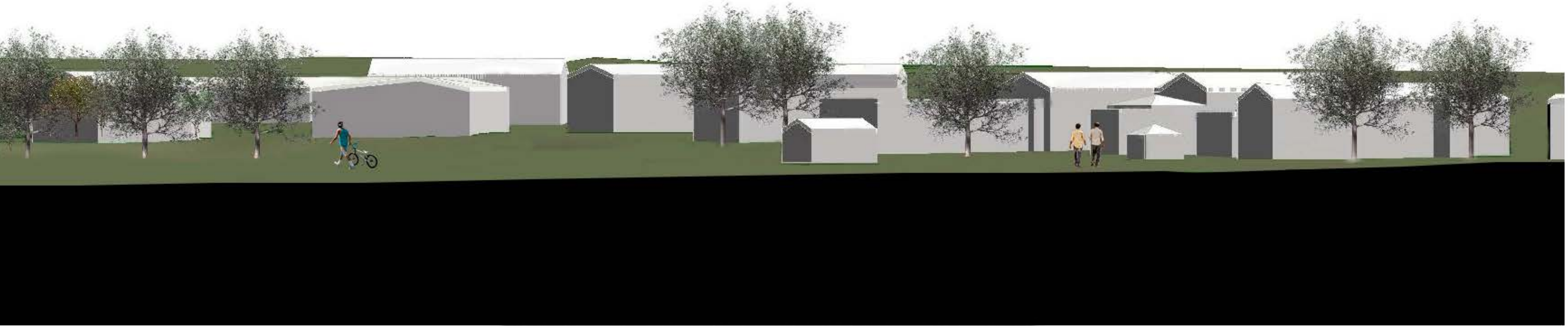


Ill. 25 section A-A 1:500



Ill. 26 section B-B 1:500





MAPPING

Lynch is used to make a mapping of the area around the site in Haderslev, it indicates some of the things, which will influence the design in different ways.

The access to the site, should be from Gammel Hørregårdsvej or Erlev Bjerge, because the terrain is raised in the southeastern end, which creates an edge, that discorrent the site from Omkørselsvejen.

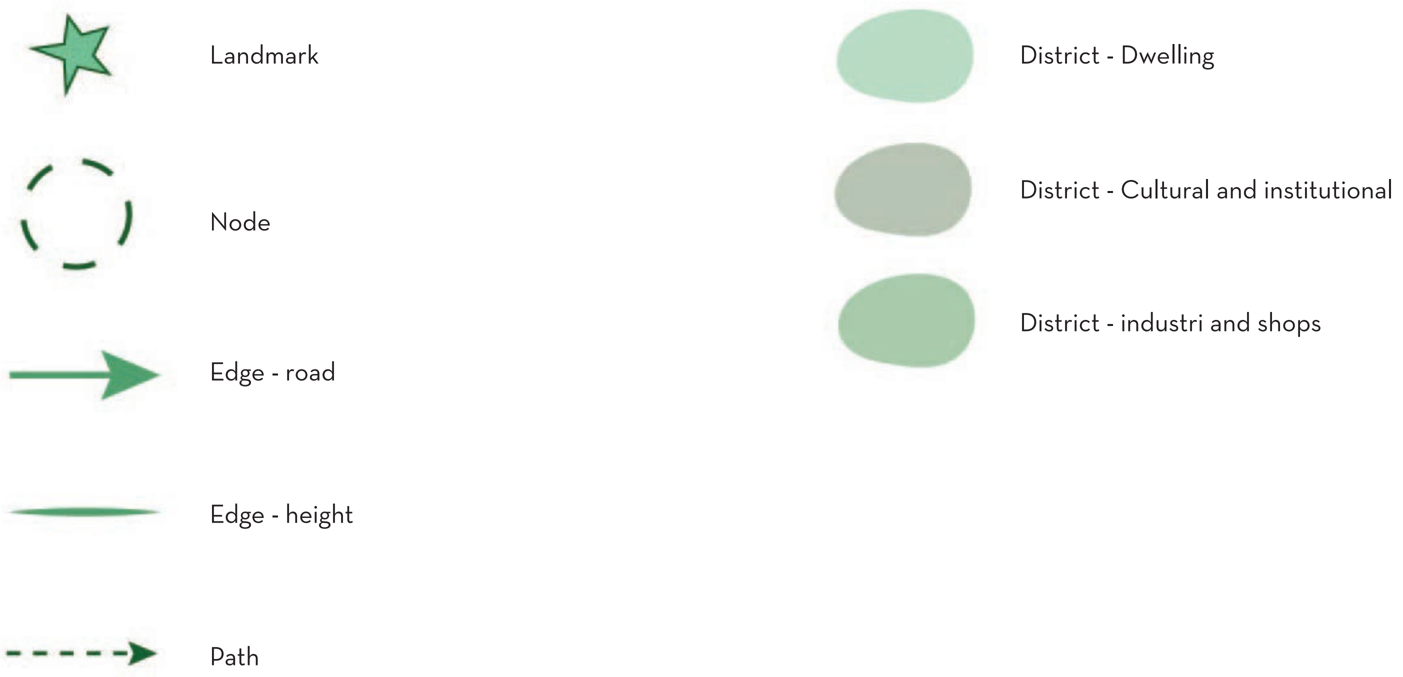
This raise also protects the site from the largest road around the site and the roundabout. The roundabouts, where the large roads meet and the connections to the smaller roads, becomes the nodes and gathering points for the traffic and people, who use the area.

Omkørselsvejen and Erlev Bjerge, as well as the raised hill, frames the site to the south-east. The cemetery lies above the northern part of the site and the western part is limited from the newly, built dwellings.

Various paths from the north-west connects the building site to the large dwelling districts all around, which makes it easier to arrive to the site from the surroundings. The paths go beneath the roundabout in the southeast, one of these paths leads directly into the site, but is blocked by the raised hill. The hill should be lowered, so the path would go through the hill and directly up to the access road from Gammel Hørregårdsvej.

The surrounding area only has a little bit of industry districts, in the form of the gas station and a fire station with the high tower, which also works as a landmark, as well as the cemetery, which are a cultural landmark.

The new school will work as a landmark, due to its function as a school, because the people of the city will know where the local school is.
The node, in the large roundabout, shows that it is possible for people to arrive to the site without crossing the large road, because the paths are beneath the roads, which otherwise works like edges.



Ill. 27 Mapping of the site in 1:5000

VEGETATION

The vegetation on the site various alot, the site is mainly a field, with crops - like rape, high grasses and weed of different kinds, as shown on Ill. 28 and Ill. 29.

The field has a windbreak of trees and bushes on the eastern side of the site. The windbreaker consist of wildly growing trees, both hardwood and softwood.

Ill. 30 and Ill. 31 shows some of the trees, like beech, maple, spruce and chestnut, as well as some of the bushes, especially shrubbery, like elderflowers and rosa canina, called dog-rose. The trees are both deciduous and evergreen, which means that some of the windbreak will still be effective in the winter, but not as effective as when all the trees have leafs during the summer.

The current vegetation will be used as a way of choosing the new vegetation for the site, since the vegetation at the school is going to be trees and bushes, that can live at the site with minimum caretaking.

The existing vegetation will mainly be preserved, and some trees and bushes will be added to the west and south to minimize the wind, as well as the noise and visual connection to the large roads. This will make some comfortable outdoor areas for the school.

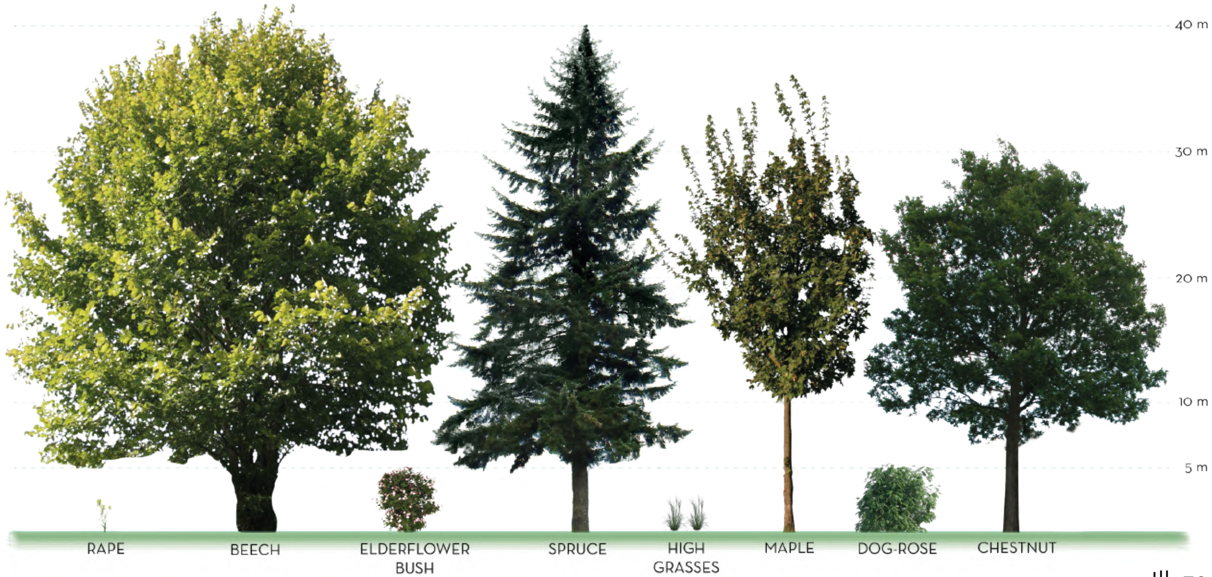
Ill. 32, is a diagram, which are showing the difference between the maximum heights of the vegetation on the site in relation to each other.


Ill. 28


Ill. 29


Ill. 30


Ill. 31



Ill. 32

SUMMARY OF URBAN ANALYSIS

The site is placed in an area, where there are mostly dwellings to one side and fields to the other. The site is shielded from the big road by a small hill, that also works as a noise barrier.

It is safe for people to arrive on the site by bike and food, because of the well organized bike lane, that is kept free of the road. This lowered bike-path should be lead through the hill and directly to the northwest of chosen site, where the access-road will come from Gammel Hørregårdsvej.

The vegetation on the site varies and is mostly wild vegetation and crops, this will mainly be preserved, but trees and bushes will be added to the west and south. The materials in the area are mostly brick, but the municipality wants the school built in wood.

Since this area is placed at the edge of the existing city, the school will help define the architectural style of the area. The function, as a school, will make the building a landmark for the area.

USER ANALYSIS

THE USERS

Children in primary school change a lot in behavior from they begin at 6 years of age and until 6. grade where they are 12-13 years old. To create a school that adapts to the students, the grades are divided into two groups, children universe with children from 6 years to 3th grade, and the junior universe with children from 4th - 6th grade, with a total of around 600 students.

In the school, there are also 55 teachers, four people in management, two people in the administration, five operating staff (cleaning and janitor) and one in technical management.

The next section will describe the needs of the teachers, in relation to how they teach, and the development that children go through during primary school, and how it have an effect on their learning.

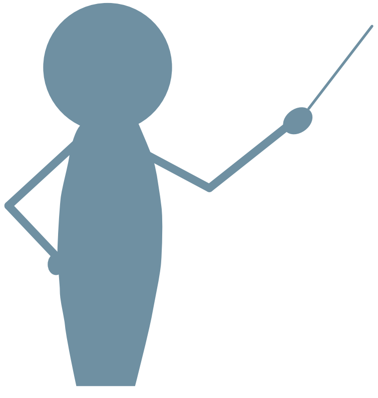
Employees

At a school there are different types of employees, there are the administration, management, technical management, cleaning crew, the janitor and the teachers. The teachers are the biggest employee group, and their needs change over the day.

Before 2013 the working hours of the teacher were managed by the teachers themselves, and they could work when and where they wanted, which gave them freedom to work from home. Now the teachers have a regular 37 hours week in average measured over a period of one year (Retsinformation.dk, 2013), that is managed by the school administration, and all of those hours has to be spent during the day at school, which creates higher demands for the design of the school (Vilsbøll, 2018).

The teachers work schedule is divided into teaching, preparation, grading assignments and other activities at school, like playground duty or counseling, teaching only represents 39% of the teachers time (Vilsbøll, 2018).

The administration and management is also on at the school 37 hours a week, usually in their offices. The janitors working day is never the same, the janitor repairs



Ill. 33 Teacher

Ill. 34 Administration and management

Ill. 35 Support functions - janitor and cleaning

the outdoor areas and keep them clean and well managed.

Child development

Through their time in school children develop with every passing year. In the beginning they learn most by using their hands and body. Which is why learning games and play is a well working teaching approach in the first couple of years. At first attention on the individual child and see how they learn best, will help along the way. (Knudsen, 2008)

From the very first day in school, the child needs to feel like it belongs, it is as simple as their name on the coat rack and a home room, they can feel safe in.

A flexibility in the learning spaces for the younger children help provide room for working in all group sizes or alone, depending on the preference of the child. As described earlier in the report, some children work by themself very well even at a young age.

Especially when the children starts to read, spaces with pillows, blankets and mattresses will benefit their learning, because then they can get comfortable either in smaller groups or by themselves.

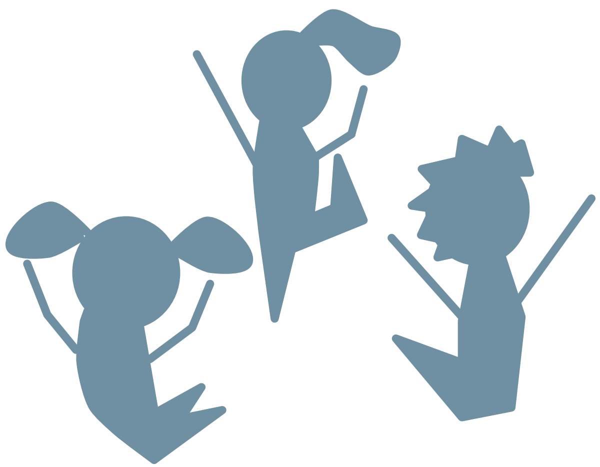
When the children reaches the age of 10-13 years, they are more ready for the more traditional way of learning, sitting at a desk for longer periods of time. This does not mean that they do not benefit from the hands on approach, but now they can be more focused, when taught in class.

Furthermore children at this age become more aware of relations and they need to belong somewhere even more than before. There will usually be more bullying at this age, because they experiment with it, and that is why talking to them about how they act with others in the class, but also in general in society is a good idea here. Maybe they have already heard it, but now they are able to really understand it.

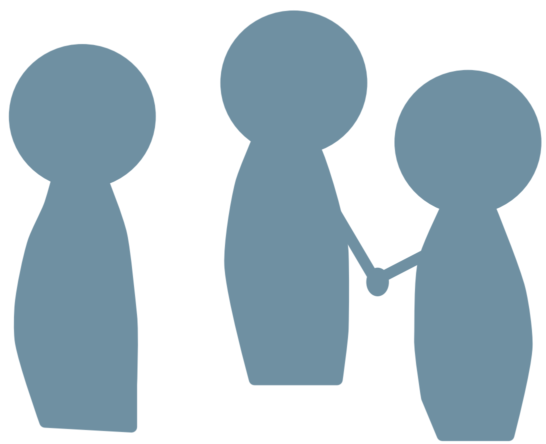
Using acting as a teaching method is beneficial for both stopping bullying, but also for the children to learn new languages, because speaking another language is easier, when acting it out. (Knudsen, 2008)

Finding the child's outer motivation is also becoming more important for many children, giving them a reason to learn something will motivate them, others will learn a new language, because they think it is fun and interesting (Knudsen, 2008).

No matter the age of the child, school must provide challenges and obstacles for the child to overcome and thereby improving the child's well-being both physically and socially, and improving its ability to solve problems by themselves.



Ill. 36 Children 6 - 9 years old



Ill. 37 Children 10 - 13 years old

LEARNING ENVIRONMENTS

By teaching according to Dunn and Dunn's learning style, requires facilities that is flexible and provide a range of different spaces and niches. Most of the learning styles as explained on page 17, are physical, which means they can be transferred to the architecture, and the learning spaces.

The learning environments should accommodate both situations where bright or dim light is wanted, and there should be spaces for working alone and spaces for working in pairs and bigger groups. There should also be different areas with more formal or informal furnishment, so the children can either sit at a table, on the floor or in more soft and relaxing furniture like a sofa.

The learning environments should be designed, so some places are more for quiet work, whereas others should be designed for a more playful and more noisy atmosphere.

When teaching a class of young students, every single student will not have completely different learning style, the students will divide into bigger groups, not always the same groups, but they will have things in common, therefore every learning area do not have to provide spaces for all the different learning styles (Kazu, 2009, pp. 85-94).

The most important factors to accommodate are the geneticly determined variables suchs as sound, light, temperature and number of students working together.

SPATIAL RELATIONS

On the following pages the different rooms and their relation to each other will be presented. The rooms chosen are based on the subject the students will have during their time at the school, together with the results from the user analysis, that have lead to different needs for rooms, and especially niches, which are placed throughout the school, to always provide a variety of settings for the children to be in, and learn in.

Furthermore the diagrams are divided into the children universe (0^{th} - 3^{th} grade) and the junior universe (4^{th} grade - 6^{th} grade) and in each of the universes there are the year clusters, that in a matter of rooms are the same, but the design of the rooms are adjusted to fit the grade and the age of the children using it, based on the user analysis.

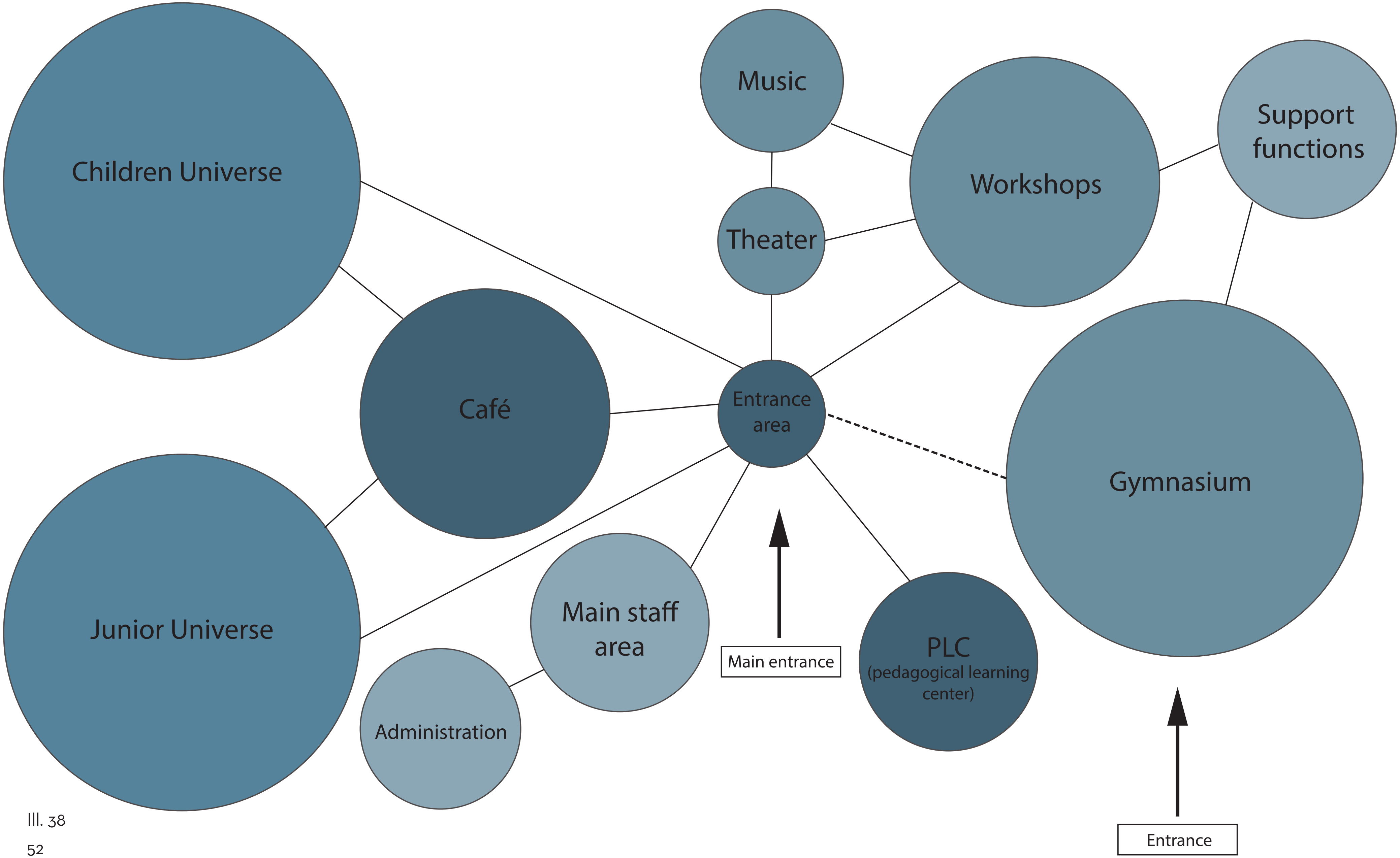
The different niches and open areas will be used to address the children and their different learning styles and needs. The classrooms will also be designed to accommodate the different needs of the children in a learning situation.

The main function diagram shows how all the different sections of the school are all connected to each other. The rooms are drawn so the circles sizes match the size of the rooms in relation to each other.

The wish is to create a closer relation between the teachers and the children out i n the universes. There will be localised teacher areas in the universes, to make the teachers more visible in the daily life and not only when they are teaching, there of course needs to be a space where the teachers can sit in quite and prepare for the classes, but the general idea is to keep the teachers close to the children.

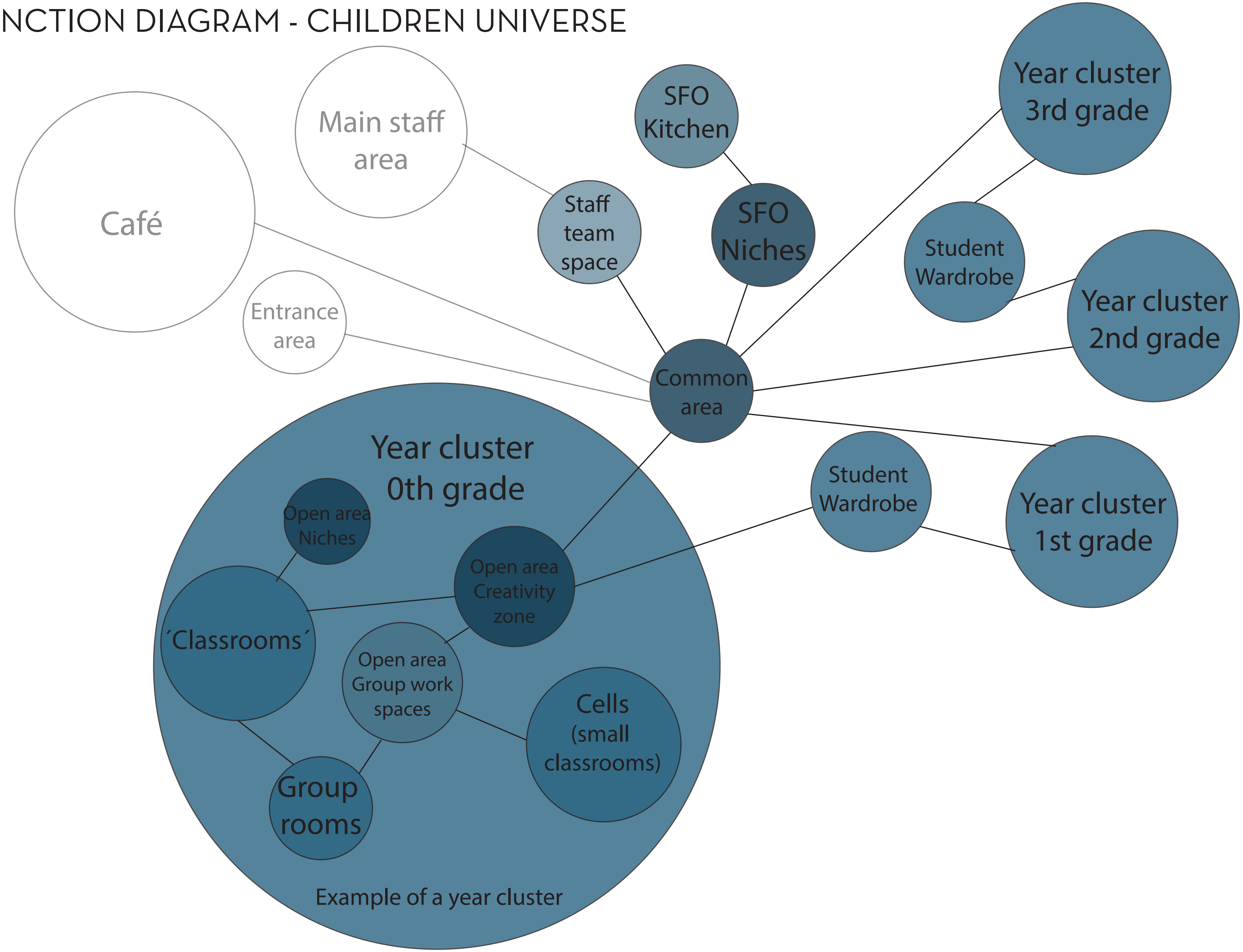
Following the function diagrams are the room program, that in a more general way explains the size, number, demands and architectural wishes for the different rooms.

FUNCTION DIAGRAM - MAIN



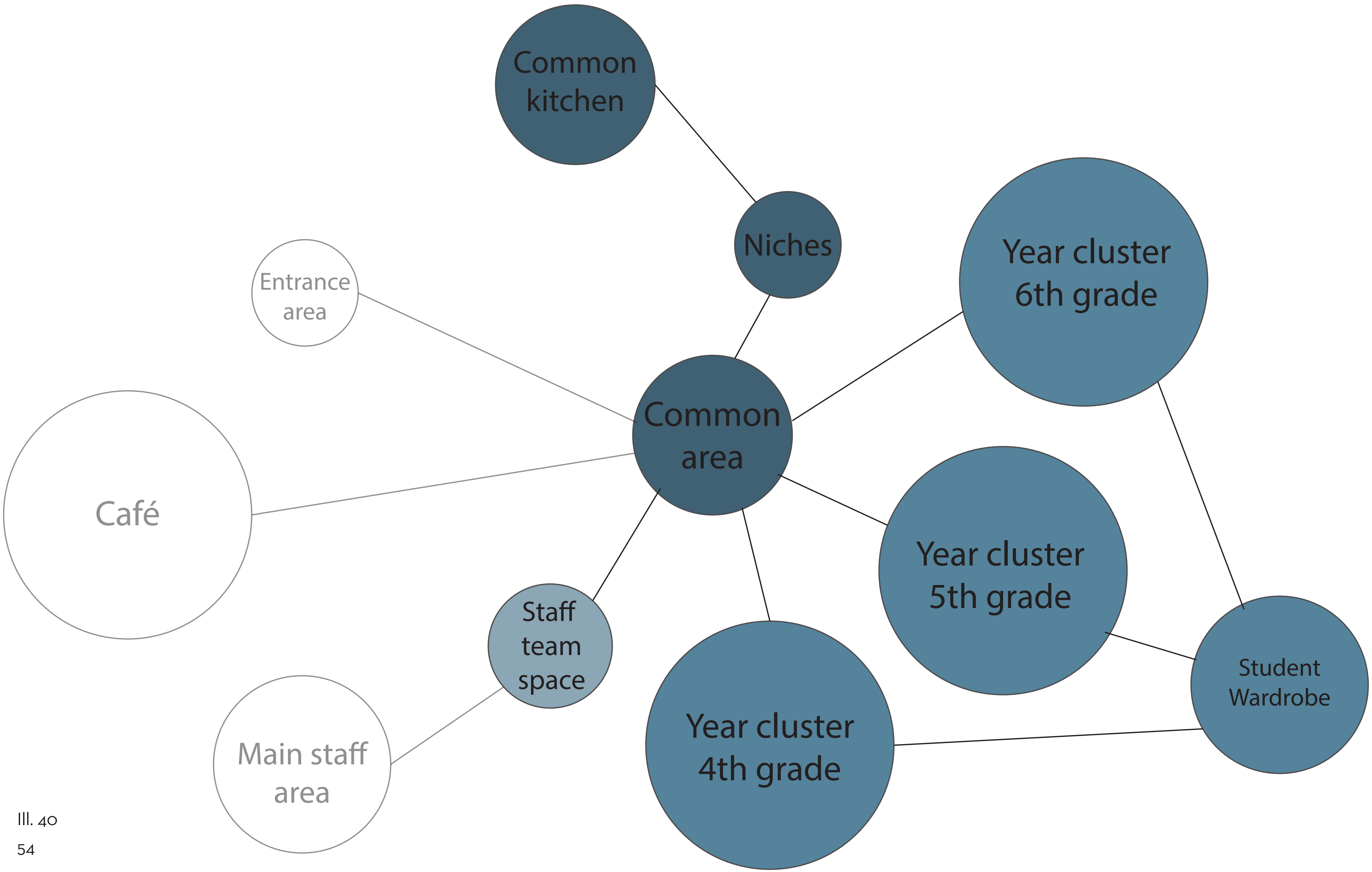
Ill. 38

FUNCTION DIAGRAM - CHILDREN UNIVERSE



Ill. 39

FUNCTION DIAGRAM - JUNIOR UNIVERSE



Ill. 40

ROOM PROGRAM

This next section is a table of the different rooms, their size and how many of them there are in the building and needs in different areas. The areas in focus is ventilation, daylight, acoustics, private/public, materials, atmosphere and special requirements.
Below is a ledger for the annotation used in the room program.

●	Normal air quality (900 ppm CO_2)	●	T<0,4sek. reveberationtime	●	Optional daylight
●●	Other demands	●●	T<0,6sek. reveberationtime	●●	Daylight
●●●	Air extraction	●●●	T>0,8sek. reveberationtime	●●●	Diffuse daylight
●	Easy to clean	●	Private	●	Inviting
●●	Durable	●●	Semi private	●●	Playful
●●●	Colorfull	●●●	Public	●●●	Professional
●	Hygenic				
●●	Flexiable				

		Children universe	SFO Kitchen	SFO Storage	SFO niches	Student wardrobe for 2 years	Student toilet (12 + 1 accessable of 5m2)	Staff teamspace	Staff printer/storage	Staff toilet	Staff toilet	**Junior Universe**	Niches	Student wardrobe	Student toilet (10+1 accessible of 5 m2)	Staff teamroom	Staff - Printer/storage
Functional	Amount	1	1	1	3	2	14	2	1	1	1	1	1	2	11	1	1
	Area		18	14	10	122	3,5	16	19	5	5		10	67,5	3,4	20	15
	Total area	2167	18	14	30	244	49	32	19	5	5	1539,4	10	135	37,4	20	15
Technical	Ventilation rate		●	●●	●	●	●	●●		●●	●●		●	●	●●	●	
	Daylight		●●	●●	●●	●●	●	●		●	●		●●	●	●	●●●	
	Acoustic		●	●●	●	●	●	●●		●●	●●		●	●	●●	●●	
Architectural	Private/public		●●●	●	●●	●●	●	●●		●	●		●●●	●●	●●	●	
	Material		●●	●	●●●	●●●	●	●		●	●		●●●	●	●	●●	
	Atmosphere		●	●●●	●●	●●	●●●	●●●		●●●	●●●		●	●●●	●●●	●●●	
	Special requirements		●	●	●●	●●	●	●		●	●		●●		●	●●	

Staff toilet	**Workshop areas**	Sports halls, 3 pieces incl. a theater and storage	Sports hall, Changing rooms (Gender seperated, with toilets)	Gym, hc toilet with shower in changing room		**Music**	Music practice room	Music and theater storage		Multiworkshop, open area	Multiworkshop, rough zone	Multiworkshop, wood incl. storage	Multiworkshop, wet zone	Multiworkshop, fine zone incl. storage	Multi workshop, nature storage	Multiworkshop, owen		
1		3	2	2		1	2	2		1	1	1	1	1	1	2		
5		151	71,5	4		70	12	20		100	80	65	70	50	10	7		
5		453	143	8		70	24	40		100	80	65	70	50	10	14		
●●		●●	●●	●●		●	●	●		●●●	●●●	●●●	●●●	●●●	●●●	●●●		
●		●	●	●		●●	●●	●		●●	●●	●●	●●	●●	●●	●●		
●●		●●●	●●	●●		●●●	●●●			●●	●●	●●	●●	●●	●●	●●		
●		●●●	●●	●		●●	●●	●		●●	●●	●●	●●	●●	●●	●●		
●		●●	●	●		●●●	●●●			●●	●●	●●	●●	●●	●●	●●		
●●●		●●	●●●	●●●		●●	●●			●●●	●●●	●●●	●●●	●●●	●●●	●●●		
●		●●	●	●		●●	●●			●●	●●	●●	●●	●●	●●	●●		

		Café, common area, incl. 2 lifts and weather porch	Cafe, teaching kitchen	Café storage	Café visitors toilet (3+1 disabled of 5 m2)	**Common area**	**Year clusters**	Forum and classroom	Cell as message zone	Grouproom	Open area - creativity zone	Open area - niches	Open area - scene, group workspaces,hallways	**Pedagogical learning center (PLC)**	PLC, open area, with shelves, exhibition, group/reading spaces	PLC, storage	PLC, offices
Functional	Amount	1	1	1	5		7	7	14	14	4	14	2		1	1	1
	Area	426	89	34	4,2		439	60	30	12	88	10	239		51	12	14
	Total area	426	89	34	21			420	420	168	352	140	478		51	12	14
Technical	Ventilation rate	●	●●		●●			●	●	●	●	●	●		●		●
	Daylight (DF)	●●	●●●		●			●●	●●	●●●	●●●	●●	●●		●●		●●●
	Acoustic	●	●●		●●			●●	●●	●	●	●	●		●		●●
Architectural	Private/public	●●●	●●		●●●			●●	●●	●●	●●●	●●	●●●		●●●		●
	Material	●	●		●			●	●●●	●●	●●●	●●	●●		●●●		●●
	Atmosphere	●	●●●		●			●	●●	●●●	●●	●	●●		●		●●●
	Special requirements	●	●		●			●●	●●	●●	●●	●●	●●		●●		

PLC, Counselors	**Administration (ADM)**	ADM, Mangement office, with meeting facilities	ADM, shared office, 2 people	ADM, Meeting space with work faciliies	ADM, printer/storage	Staffroom	Staff, preperation room	Staff, wardrobe	Staff, toilet (3+1 disabled of 5m2)	**Support functions**	Janitoroffice	Janitor workshop, depot, good delivery, lawnmower etc.	Laundryroom	Cleaning room	Toilet and changing area with toilet and shower	Technical room
1		4	1	2	1	1	1	1	2		1	1	1	2	3	
14		14	14	14	10	152	60	40	5,5		12	176	4	11,5	6,7	
14		56	14	28	10	152	60	40	11		12	176	4	23	20,1	529
●		●	●	●		●	●		●●		●	●●	●●	●●	●●	
●●●		●●●	●●●	●●●		●●	●●●		●		●●●	●●	●	●	●	●
●●		●●	●●	●●		●●	●●				●●	●●	●●	●●	●●	
●		●	●	●●		●	●		●		●	●	●	●	●	●
●●		●●	●●	●●		●●	●●		●●		●	●●	●	●	●	●
●●●		●●●	●●●	●●●		●●●	●●●				●●●	●●●	●●●	●●●	●●●	●●●
						●●			●		●●	●●	●	●	●	

OUTDOOR AREAS

Studies show, that children who play outdoor and in a nature rich environment, tend to have fewer sick days and they are better at concentrating in school and they have better movement and balance, than children who have been playing a lot inside and on traditional playgrounds. Nature also helps challenge and develop children's imagination and creativity.(Nevstrup Andersen, 2008)

There are no official demands for the size of the outdoor play area in schools in Denmark. The department of health recommends, that schools and kindergartens are placed and designed with the possibility of nature, or the opportunity to use the green areas in the surrounding area.

The play area should not be to planned,there need to be space for the children to create their own spaces and invent things, build caves and so on. If the playground is too planned, the children will get bored and not use their own creativity to come up with a game or a play.

The more unplanned areas are also good for teaching, because there are no restrictions on what can happen in that space.

The playground should be a safe space where the children can be on their own, or with others, if they wish, but they should be able to walk around on their own, which will help prepare them for the outside world.(Nevstrup Andersen, 2008)

A playground should reflect the children using it, so it should have challenges for both the smaller and the bigger children.

Unlike adults, children move to practise and learn, and therefore the playground should challenge children of all ages, so they can learn as much as possible. For an example, swings can help children to not get motion sickness when sailing and flying, because the swirling and swinging on the swing helps them enhance their balance. (Cooper, 2015)

Children at the age of 6-10 years old, would prefer to play outside when given the chance. The childrens reason for wanting to be outside is because there is more room for them to play, and the play can be more loud and moving, without being corrected by the teachers.

With the older children, it is important, that the teachers are good examples and also go outside, instead of just sending the children out to play. Children also learn more when an adult is giving them some of the themselves. This could be telling the children how he/she played as a child.

When the children are younger, they will meet each other in one spot on the playground, and then, when gathert, they will move to another place and spread out more, where as the older children will meet in one place and stay there to play, the seldom move far away from the meeting point.(Cooper, 2015)

Water on the playground is also something that gathers the children and can inspire to many games, especially when the playground changes due to rainwater. The smaller children do not mind the rain, because they are used to be outside every day from kindergarten.

Maintenance of the stationary playground equipment, is very important, because the children notice if something is worn down or needs paint, they will stop playing with the used item and turn to other things.(Cooper, 2015)

All in all nature is a important part of children's learning and it helps them develop skills and play more free. Having space, that are not planned, is just as important as the stationary playground, because the two gives the children different opportunities and skills. And the adults to be a part of the outdoor life and sometimes the play is also important because sometimes children needs help to start a good game. (Nevstrup Andersen, 2008)

SUMMARY OF USER ANALYSIS

As the analysis of the user shows, there are some very different user groups of a school, and the building should accommodate both the teachers and the students.

Dealing with smaller children there will be a need to understand how best to design environments, that improves their learning and their will to learn something new. There should be a strong connection between the students and the teachers, as well as the administration should be more visible and more a part of everyday life at the school. These connections will be made both physically but in some places a visible connection can be enough.

The students should have the access to different types of niches and learning areas, where light, temperature and different types of sitting-positions and materials are possible. Furthermore, the air-quality should uphold the demands for offices.

The staff should have access to quiet areas for preparation, and areas with more informal atmosphere, where the different employees can interfere.

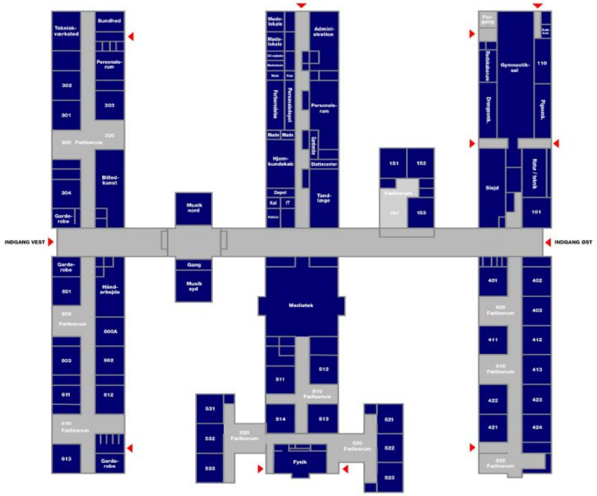
The difference between the users should also be reflected in the outdoor areas, which should comply the needs of the different users, both in relation to play, personal evolving, learning and education.

There are many facilities required at a school to give the children the best education, these facilities should also benefit the local area, and thereby involve the community.

CASE STUDY

RØNBÆKSKOLEN, HINNERUP

Rønbækskolen is a public school in Hinnerup, close to Aarhus. The school were built in 1970-73, as a one storey building with three wings, like a "kamskole", but expanded to seven wings during the renovation in 2001-08. The school has 685 students today, whom are normally divided into three tracks, sometimes two or four tracks. These tracks, from the different years, are often kept in the same sections, to increase the social relation between pre-teens and teenagers. (Roenbaekskolen.dk, 2009)



Ill. 41 - Floor plan

The plan shows the school plan from 2018, The school looks like the "kamskole", which were very current for the 1960-70s, were the school were original built. The "kamskoler", in english; comb schools, are characterized by dividing the different function into different wings of the school. This means, that the administration functions are in one wing and class rooms in another wing etc. This is also visible in the plan drawing from Rønbækskole, look at Ill. 41.

Ill. 42

Ill. 43

Ill. 42 from 1980 and Ill. 43 from 1989 shows the different learning areas at Rønbækskole. Both of the illustrations are numbered rooms on the plan drawing, which are the traditional classrooms. As the illustrations show, the traditional classrooms are arranged in different ways; the horseshoe shape and the front facing the blackboard, which were the educational approach in the 1980ties.

Ill. 42 and Ill. 43 also shows some of the materials inside the danish public school in 1980ties, the floors are linoleum or vinyl, often with acoustic effects, that lowers the sounds from steps and the floor is often incredibly durable. The floor is often in a gray-, green- or bluish color, with different gradients. The walls are painted in matte, bright colors, like yellow or red- as shown on the illustrations. The materials on the outside of the school, is shown on Ill. 44 and Ill. 45 from 1992. The outer walls are build in

Ill. 44 (Rubowarkitekter.dk, n.d.)

Ill. 45 (Rubowarkitekter.dk, n.d.)

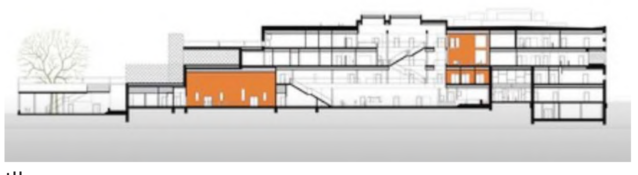
yellow, graded bricks and with gray or black roof tiles. The windows and doors are white or black plastic, which are also very durable. Besides that, the newer part of the school have solar shading in the form of wooden lamellas, this improves the indoor environments by decreasing the temperatures, but still lets in natural light.

According to a document from Rønbækskole about their pricipels for well-being and inclusion. The school writes, that they are all - both students and teachers - are equal in the "community" of the school. The teachers, pedagoges and parents have to find flexible communities, which supports the professionnalisme, social and personal development. To implement these things, the school has a pedagogisch learning center, PLC, combined with the library, where the students can seek professional and pedagogisch instructions from teachers. (Roenbaekskolen.dk, 2009)

FREDERIKSBJERG SKOLE, AARHUS

In 2016, a new school were finished in Aarhus. The school is called Frederiksbjerg Skole, drawn by Henning Larsen Architects and GPP Arkitekter(Henninglarsen.com, n.d.), this school is one of the first schools, which are based on the new school reform from 2013. It has a areal of 15.000 m² and the school has 956 students divided into 40 classes. (Frederiksbergskole.dk, n.d.)

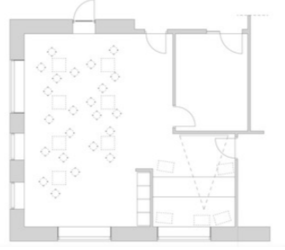
Ill. 46



Ill. 47

The plan and cross section of the school is shown on Ill. 46 - Ill. 47. The plans show this creative approach, where there is a combination of the traditional classrooms, but also classrooms, which are combined with the possibility of sitting in an alternative way on staircase-formed interior. It is not only the classrooms, which are different, but also the common areas, where staircases are mixed with climbing walls or flexible sitting areas and organic-formed areas, where the students creativity is the limited. There entire school changes during the day, because of the daylight, but also the differences between all the areas - none of the floors look alike.

The cross sections also shows this creative buildup of the school, the large atriums, which goes through all levels and combine the building vertically and makes it possible to see the activities at all levels. These large atriums also has another, more technical function, they can be used for natural ventilation and to let in more daylight. The section also shows the outer form of the building, it shows, that the building steps down, which makes it possible to make some outdoor terraces with room for outdoor play.



Ill. 48

Ill. 49

Ill. 48, is a plan of one of the classrooms, where the arrangement of the tables show the modern group-approach to teaching in the left part of the room. The smaller part of the classroom, is a niche with this sitting-staircase, which makes it possible to teach in a more flexible way.

The materials used inside is very colorful to make it easier to navigate in the building, but also to make it more playful. The floors are either concrete as the pillars or linoleum or vinyl, which are all strong, durable materials.

The walls are painted white or very colorful, the majority of white color, makes the school seem more light and inviting. Some of the fixtures are made in wood, which makes them warm and inviting to sit on during the lessons. The illustrations also show some of the creative common areas and classrooms.

The indoor materials collaborates with the outdoor materials, the concrete pillars from inside is also used outside combined with the red, reused bricks and the steel fence. The windows are in various sizes, which makes the facade more playful, with the black curtains, which are plain with the facade. The facade is also breached by having the different cut-ins, which makes some interestings outdoor spaces.

As the plans and cross sections show, this school provides every possibility of integrating play and professionalism, as well as more exercise during the school day, which fits the new school reform from 2013.

Ill. 50

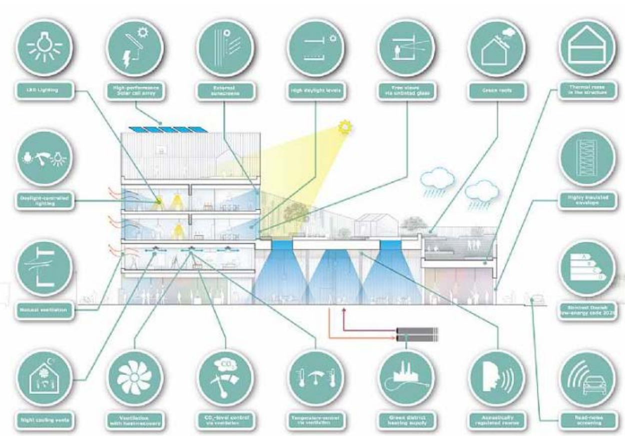
Ill. 51

NEW ISLANDS BRYGGE SKOLE, COPENHAGEN

The school called "Ny Islands Brygge Skole", is a extension of the existing school at Islands Brygge in Copenhagen. The extensing is going to accommodate 6th, 7th, 8th and 9th grade with 784 students, on an area of 10.000m² and 4.000m² of outdoor area. It is designed by C. F. Møller and THIRD NATURE and was finished in 2017 and will be taken into use in 2020 (C.F. Møller and MT Højgaard, n.d.). (TREDJE NATUR, n.d.)

The design focus' on a sustainable approach to school buildings, with urban gardens, which the students can use to grow their own food or roof terraces for play and exercise during the school day. The building af DGNB-screened to evaluate the economic, social, process-related, technical and environmental qualities. (C.F. Møller and MT Højgaard, n.d.)

Ill. 52 shows a cross section of the school and their use of sustainable solutions as solar cells, green roofs, highly insulated envelope, low energy demands for 2020, natural



Ill. 52 (C.F. Møller, n.d.)

Ill. 53

Ill. 54

Ill. 55

Ill. 56

ventilation and ventilation with heat recovery. These are some of the demands for the new school.
Ill. 53 and Ill. 54 shows some of the indoor learning environments. The first illustration, Ill. 53, shows these creative, sitting-staircases with different levels, which makes it possible for the students to sit in the position that fits them best. The second illustration, Ill. 54, shows the large common, dining areas, which also include smaller, cirkular niches for the students to sit in smaller groups and work more intensified and undisturbed.

These illustrations also shows the indoor materials, which are mainly a combination of light, wooden walls and interior fixtures and concrete floors and ceilings, as well as some matte red floors and wooden, framed glass-walls. In some of the areas, the ceiling is plastered with white, acoustical ceiling panels, to lower the reverberation time in the large common areas.

Some of the indoor materials are also reflected in the outdoor materials, like the light, wooden lamellas, the light concrete and the red color. The wooden lamellas are used on the facade and as shield from the roads on the roof terraces. The concrete is used both for the pillars and the floor of the roof terraces and ground floor and the red color is only used on the floor to make it more eye catching. The window- and door-frame seems to be a combination of light wood and black steel.

Ill. 58

The building is very characterized by the big, red staircase, which leads up to the outdoor terrace behind the front of the building and the large roof terraces in different levels with green houses, lots of plants and sports fields.

This school is designed with focus on optimizing the indoor environment and make some creative and sustainable rooms for the students. It also creates the possibility of making a healthier approach to the Danish school and students, with the possibility of exercising on the rooftops or growing their own food in the green houses. (TV 2 Lorry, n.d.)

Ill. 57

Ill. 59

ARCHITECTUAL QUALITIES

The architectural qualities are used to sum up the qualities from the different school designs, from the strong materials in the traditional school, the sustainable strategies from the design suggestion in Copenhagen, to the new school in Aarhus, which are based on activating the students more according to the new school reform from 2013.

These different qualities, which works well in the existing schools, will be used and improved in the upcoming design process.

Rønbækskolen, Hinnerup:
- strong, durable materials
- different, playful colors
- seperation of the different function
- warm, wooden materials on the interior fixtures
- bricks as heavy, thermal mass
- large window areas
- common areas with a PLC area
- solar shading with lamellas

Frederiksbjerg Skole, Aarhus:
- (combined traditional and creative classrooms)
- sitting-staircases to alternative teaching
- staircases combined with exercise - as climbing
- warm, wooden materials on the interior fixtures
- different, playful colors - also used for orientation
- large window areas
- large, open spaces - also used for natural ventilation and vertical connection
- strong, durable materials
- large, outdoor roof terraces
- (modern group-approach through table settings)
- reused materials
- bricks as heavy, thermal mass
- solar shading with outer curtain

Ny Islands Brygge Skole, Copenhagen:
- urban gardens/ green houses
- large, outdoor roof terraces
- large, open spaces - also used for natural ventilation and vertical connection
- strong, durable materials
- large window areas
- warm, wooden materials on the interior fixtures
- solar cells
- low energy demands from 2020
- large, common areas, with smaller, private niches

DESIGN CRITERIA

Technical
- Mainly natural ventilation during the summer
- Daylight in all working areas
- Make use of the qualities of the materials
- The building must be a Nearly Zero Energy Building
- Uphold category two of the chosen DGNB demands
- Use materials with a good LCA score.
- Integration of passive strategies, geothermal power and solar cells
- Hallways must be 1,3m wide
- Diffuse light in offices and direct light in common areas
- Students working areas should uphold the demands for office air-quality

Aesthetic
- Reuse of rainwater in the urban setting
- Durable materials
- Wood construction and cladding
- Green or asphalt roofing
- Create outdoor spaces for play, learning and sports
- Connect new paths to the existing system of paths
- Access from Gammel Hørregårdsvej
- Low maintenance vegetation, native to the area
- Different light settings accommodate the user
- All niches must have warm materials
- Learning areas and niches with informal furnishment
- Colorful areas
- View to greenery from every class room

Functional
- Close relation between teacher and student areas
- Facilities open for the local community
- Outdoor areas with greenhouses
- Parking lot with one space per 100m2 in relation to Gammel Hørregårdsvej
- Bike parking one space pr. 10th students
- Shield the outdoor play and learning areas from strong, western wind
- Flexible learning areas, with different light, materials and sitting-positions
- Niches that accommodates both working alone and in groups
- Quiet workspaces and playful/noisy workspaces
- Accessible for all
- Alternate teaching environments
- Include physical activities in the common areas both in- and outdoor
- Professionalism in classrooms
- Building placed in the north, part area one
- Covered outdoor areas
- Quiet preparation rooms for staff
- Common area for staff
- Vegetation and green area to the west and south
- Collection rainwater from the roof
- Outdoor area for each cluster
- Distribution from common, entrance area
- Lower hill to the southeast to let the path go through
- Shield cemetery from noise

VISION

The vision with the design of the school in Haderslev municipality, is to make a sustainable building, which is good for both the environment and the users.

The school will be designed with focus on optimizing the indoor environment, through the air quality, materials, temperatures etc. and also to design learning environments based on the different learnings styles of children. These things will form the frame of the best possible approach to designing an optimized school for the students.

The idea is to make a school, which will include all the good qualities from the traditional school, but also use new knowledge to focus on the children's learning, based on their needs. The school will be a place where professionnalisme and play are combined to approach learning in a better way for the children.

The building will fulfill the requirements of a ZEB, through both passive and active strategies, it will also fulfill some of the DGNB demands to reach a higher level of sustainability, through an, improved air quality, temperatures, materials, acoustics, daylight etc.

DESIGN PROCESS

DESIGN PROCESS INTRO

The following section of the report describes the process behind the final design. The iterative process are divided into seven phases, which were moved between.

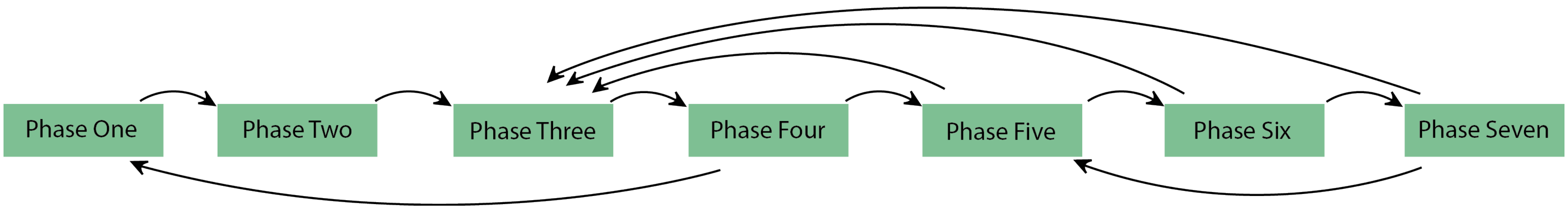
Phase one explains the start-up of the design process, all the initial sketches and models and how to choose between them. Phase two shows the development of four concepts into two concepts.

Phase three approaches the project from the inside and out, there the involvement of the mainly used rooms, such as the office, classroom and common area in the cluster are the focus points. The rooms were tested and adjusted according to the DGNB demands for indoor climate, daylight, acoustics and materials.

Phase four then goes back to phase one, with sketching a new concept, which meets the new knowledge from phase three. Phase five then focuses on the indoor of the new concept, combining the concept from phase four with the rooms from phase three. Phase five also include the development of the office, classroom and common space in the cluster in the plan for the new concept, to comply with the design criteria from the program.

Phase six developed the concept and plan from phase five, with going more into details with the construction and choosing more specific materials.

Phase seven sums up all the previously phases and making the construction details and the common space so it complies to the DGNB demands and finally designing the surrounding, urban area. Phase seven ties all the loose ends.

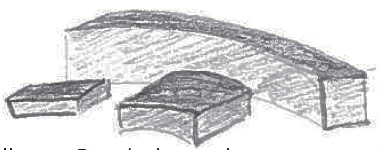


PHASE ONE

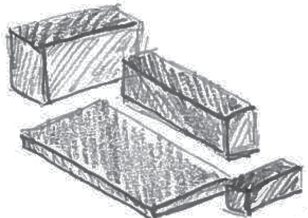
The design process started with getting an idea of the size of the site, this happened by making the “blue suitcase” which is a method where a familiar building is put onto the site, to get an idea of the size of the site, in this case Create and Rytterskolen was used. These examinations are shown in Appendix 2.

After concluding, that the area of 6,3 Ha is extreme large and space enough for the known, familiar buildings. it was also examined how much a school of 6.000m² would fill on the site, this was tested through the ”volumen studies”, first it was test how much a school of one level would fill, than two levels and at final three levels, these investigations are shown in Appendix 3.

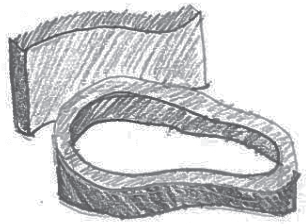
The “blue suitcase” and “volumen studies” led to nine different approaches. These different approaches were a way of getting the shape started, and give an general idea of different ways to create multiple concepts ideas in the upcoming design process. The approaches are shown on Ill. 61 - Ill. 68.



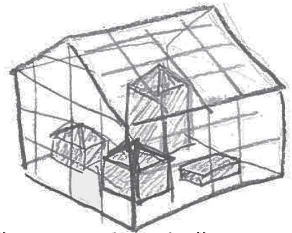
Ill. 60 - Divided into three



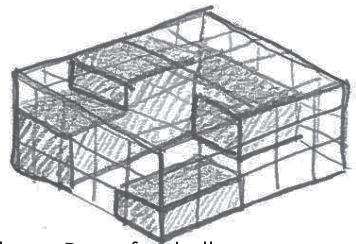
Ill. 61 - Divided into four



Ill. 62 - Divided in two



Ill. 63 - Inside a shell



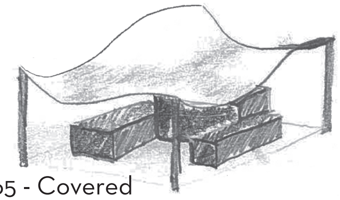
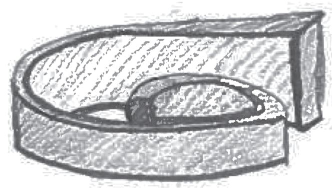
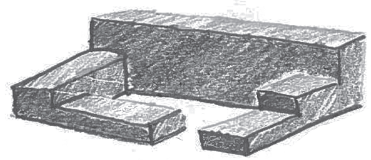
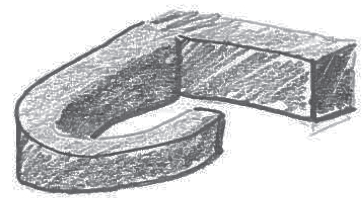
Ill. 64 - Part of a shell

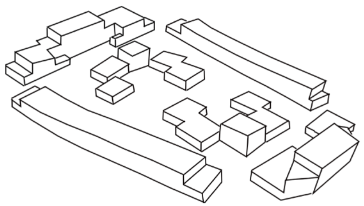
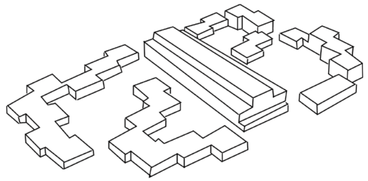
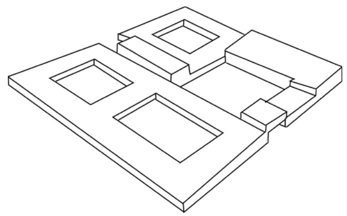
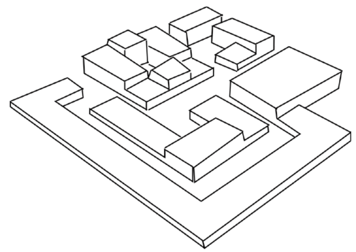
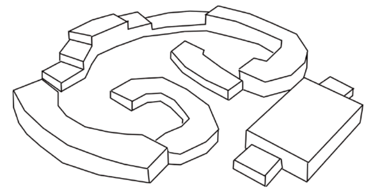
Ill. 60 - Divided into three	Ill. 61 - Divided into four	Ill. 62 - Divided in two	Ill. 63 - Inside a shell	Ill. 64 - Part of a shell
- Outdoor area for each cluster 0 - Open areas - Include outdoor activity 1 - Protect outdoor areas from wind - Open outdoor areas 0 - Main entrance as landmark 1 - Daylight in all working areas 1 - max 10m wide - no self shading - View to greenery 1 - Connect new paths to existing system 1 - Accessible for all 0 - multible floors - No cooling demand in summer 1 - natural ventilation	- Outdoor area for each cluster 1 - buildings creating spaces - Include outdoor activity 1 - Protect outdoor areas from wind - buildings shield from the wind 1 - Main entrance as landmark 1 - Daylight in all working areas 1 - no self shading - View to greenery 1 - Connect new paths to existing system 1 - Accessible for all 0 - multible floors - No cooling demand in summer 1 - natural ventilation	- Outdoor area for each cluster 1 - Shape creates closed outdoor area - Include outdoor activity 1 - Protect outdoor areas from wind - Outdoor area protected by the building 1 - Main entrance as landmark 1 - Daylight in all working areas 1 - no self shading - View to greenery 1 - Connect new paths to existing system 1 - Accessible for all 0 - No cooling demand in summer 1	- Outdoor area for each cluster 1 - The shell creates outdoor spaces - Include outdoor activity 1 - Protect outdoor areas from wind - the shell protects 1 - Main entrance as landmark 0 - Daylight in all working areas 0 - The shell shades - View to greenery 1 - Connect new paths to existing system 0 - The shell creates a boundery - Accessible for all 0 - No cooling demand in summer 0 - No natural ventilation	- Outdoor area for each cluster 1 - The shell creates outdoor spaces - Include outdoor activity 1 - Protect outdoor areas from wind - The shell shields from the wind 1 - Main entrance as landmark 0 - Daylight in all working areas 0 - The shell shades - View to greenery 1 - Connect new paths to existing system 0 - The shell creates a boundery - Accessible for all 0 - No cooling demand in summer 0 - No natural ventilation
Total: 6	**Total: 8**	**Total: 8**	**Total: 4**	**Total: 4**

The different approaches were evaluated in a scheme, to get some guidelines for the upcoming concept ideas, which would fit with the design criteria from the Program, only the design criteria relevant for this stage in the process, which was the criteria concerning the outdoor areas and the general shape of the building
.
The scheme is shown on page 73 and page 74, and it shows that the following concepts should be either one building or divided into three or four buildings, and that the building form could be organic, geometri or a combination. Based on these results, the sketching phase began, some are shown on Ill. 69 - Ill. 77, more are put in Appendix 4.

Many of the sketches were also tested in models, theses drawings and models of nine different concepts, were then evaluated through the relevant design criteria in a scheme, during this phase more design criteria was added to the list, which is why the nine concepts are evaluated based on more criteria than the overall idea before, the evaluation is shown on page 75 and page 76.

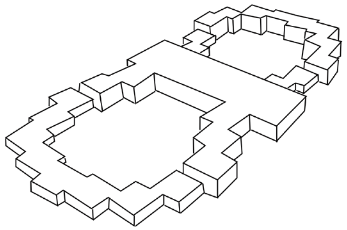
As the scheme shows, four of the concepts had more points than the others. this were concept 2 , 5 , 6 and 7, which are worked further on in Phase Two.

 Ill. 65 - Covered	 Ill. 66 - Organic	 Ill. 67 - Geometric	 Ill. 68 - Combined
- Outdoor area for each cluster 1 - The cover creates spaces	- Outdoor area for each cluster 1 - The shape creates spaces	- Outdoor area for each cluster 1 - Shape creates spaces	- Outdoor area for each cluster 1 - Shape creates spaces
- Include outdoor activity 1	- Include outdoor activity 0	- Include outdoor activity 0	- Include outdoor activity 0
- Protect outdoor areas from wind 1	- Protect outdoor areas from wind 1	- Protect outdoor areas from wind 1	- Protect outdoor areas from wind 1
- Main entrance as landmark 0 - The cover hides the main entrance	- Main entrance as landmark 0 - The main entrance does not stand out	- Main entrance as landmark 0 - Main entrance does not stand out	- Main entrance as landmark 0 - Main entrance does not stand out
- Daylight in all working areas 0 - The cover shades	- Daylight in all working areas 1	- Daylight in all working areas 1 - No wider than 10m	- Daylight in all working areas 1 - No wider than 10m
- View to greenery 1	- View to greenery 1	- View to greenery 1	- View to greenery 1
- Connect new paths to existing system 0	- Connect new paths to existing system 1	- Connect new paths to existing system 1	- Connect new paths to existing system 1
- Accessible for all 1	- Accessible for all 1	- Accessible for all 1 - No going between buildings	- Accessible for all 1 - No going between buildings
- No cooling demand in summer 0	- No cooling demand in summer 1	- No cooling demand in summer 1	- No cooling demand in summer 1
Total: 5	**Total: 7**	**Total: 7**	**Total: 7**

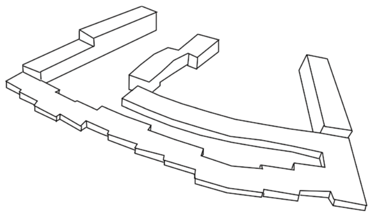






	Ill. 69 - Concept 1	Ill. 70 - Concept 2	Ill. 71 - Concept 3	Ill. 72 - Concept 4	Ill. 73 - Concept 5
- Outdoor area for each cluster	1	1	1	0	1
- Include outdoor activity	1	1	0	1	1
- Protect outdoor areas from wind	1	1	1	1	1
- Main entrance as landmark	0	1	0	0	0
- Daylight in all working areas	1	0	1	0	1
- View to greenery	1	1	0	0	1
- Connect new paths to existing system	0	0	0	0	0
- Accessible for all	0	0	1	0	0
- Potential for natural ventilation	0	1	0	0	0
- Access from Gammel Hørregårdsvej	1	1	1	1	1
- Minimal amont of cold bridges	0	0	1	0	0
- Potential for solar cells	1	1	0	0	1
Total:	**7**	**8**	**6**	**3**	**7**

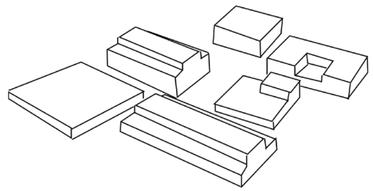
Table 3



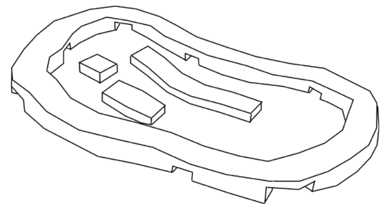
Ill. 74 - Concept 6



Ill. 75 - Concept 7



Ill. 76 - Concept 8

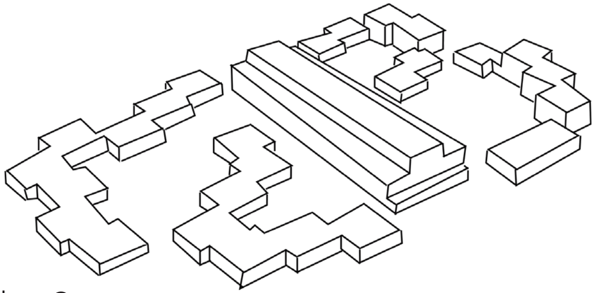


Ill. 77 - Concept 9

	Ill. 74 - Concept 6	Ill. 75 - Concept 7	Ill. 76 - Concept 8	Ill. 77 - Concept 9
- Outdoor area for each cluster	1	0	0	0
- Include outdoor activity	0	1	1	1
- Protect outdoor areas from wind	1	1	0	1
- Main entrance as landmark	0	0	0	0
- Daylight in all working areas	1	1	0	1
- View to greenery	1	1	1	1
- Connect new paths to existing system	0	0	0	1
- Accessible for all	1	1	0	0
- Potential for natural ventilation	1	1	1	0
- Access from Gammel Hørregårdsvej	1	1	1	1
- Minimal amont of cold bridges	1	0	0	0
- Potential for solar cells	1	1	1	0
Total:	**9**	**8**	**5**	**6**

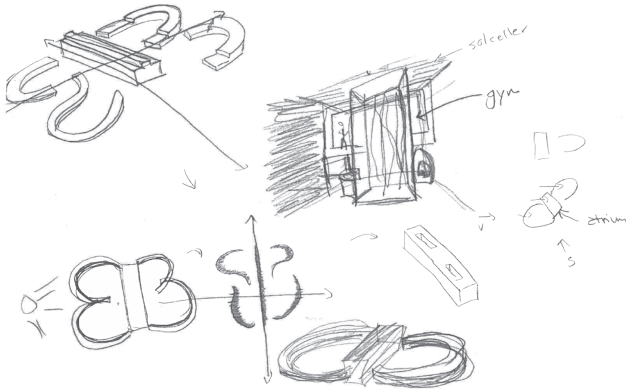
PHASE TWO

The further evolvement of concept 2, 5, 6 and 7 were based on the grading from the scheme. The points, where each concept had done purely, were the areas where the concept was improved, this was done by combining the qualities of some of the other chosen concepts. An example is concept 2, as the scheme shows, the concept has a risk of having a lot of cold bridges, because there are multiple buildings, this was improved by making it into two buildings like concept 5 or one building like concept 6.



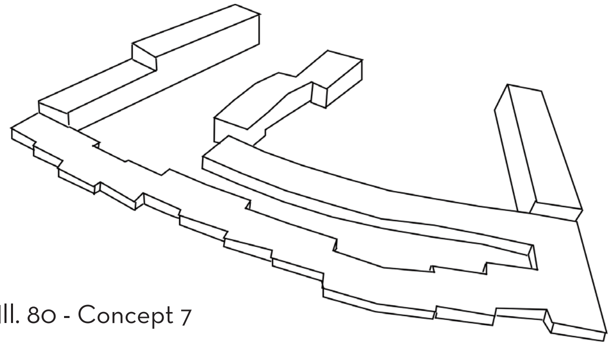
Ill. 78 Concept 2

Concept 2 also lacked at daylight and accessibility, which were better at concept 5 and 6. This led to a combination of the three concepts, concept 2, 5 and 6, into “concept 2, the butterfly”, which are shown on Ill. 78.

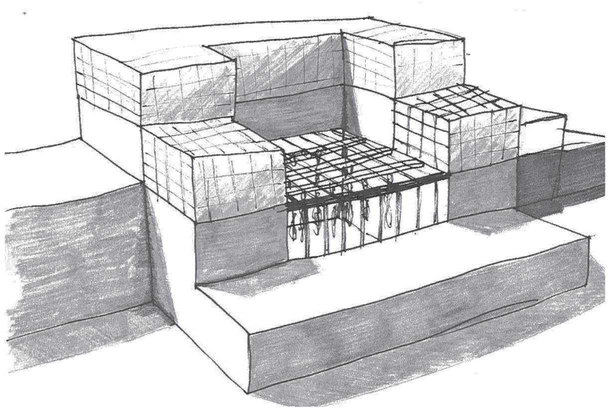


Ill. 79

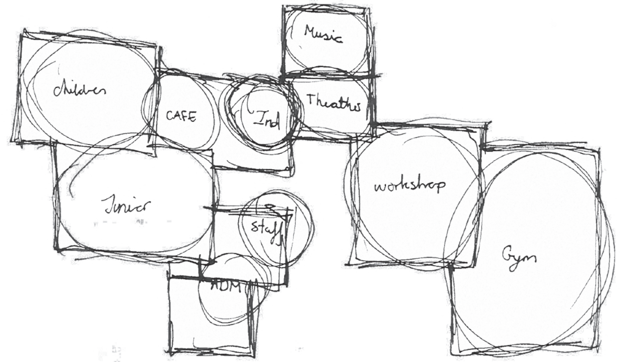
Concept 7 (Ill. 80) evolved in another direction, to improve its qualities. To improve the relation to the existing paths and make a natural main entrance, which also functioned as a landmarc, the building were segmented into small buildings, which were build together. This turned into “concept 10, the geometri”, which are shown on Ill. 81 and Ill. 82.



Ill. 80 - Concept 7



Ill. 81 - Concept 10, main entrance



Ill. 82 - Concept 10, plan

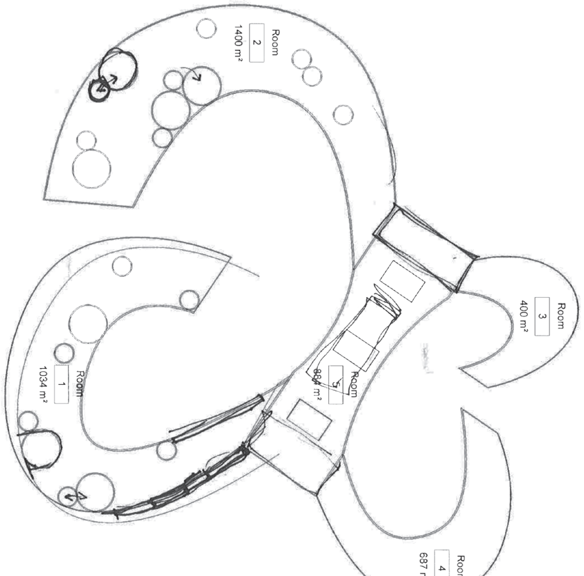
The next step of the evolvement, were to make a plan-drawing for the two concepts, based on the function diagram from the Program. The first draft for the plan for respectively concept 2 and 10 are on Ill. 83 and Ill. 84/ Appendix 5. Both of the plans were further evolved to meet the demands of room program, the final draft are shown on Ill. 85 and Ill. 86.

The concepts and plans were evaluated based on the design criteria some which are the same as in phase one, and others that were added during this phase, and some again, that became relevant when a more clear shape was made, the evaluation is shown in the Table 4.

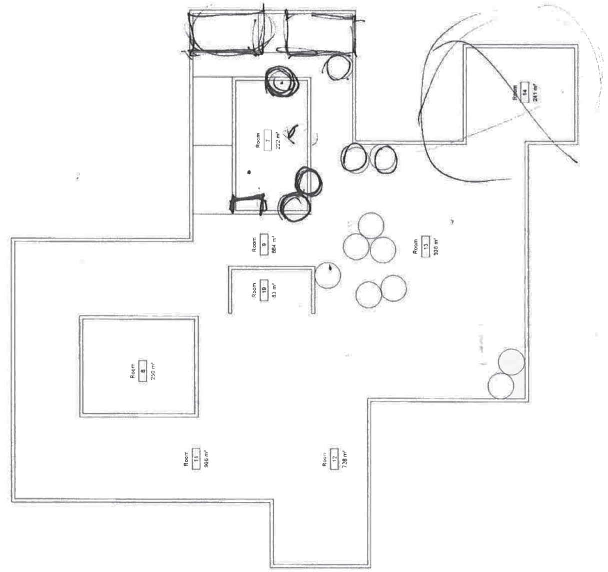
	Concept 2	Concept 10
Main entrance as a landmarc	1	0
Connecting to existing paths	1	0
Static form	0	1
Closely related outdoor areas	1	1
Relation to context	0	1
Dynamic form	1	0
Functional rooms	0	1
Sum	4	4

Table 4

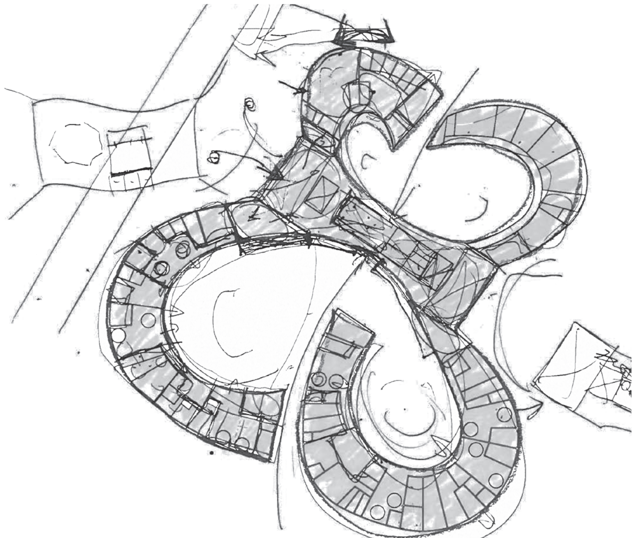
Both of the concepts worked in different ways, each of them could work in the further design process. To rule one out, the two concepts were put in Be18, which showed that there were only a difference 6,2 kWh/year, which could easily be improved. Besides that analysis, concept 2 were put in flow, to see the wind-proportions and in Revit, to see the shadows from the building, these studies can be seen in Appendix 6 . Both of the concepts were brought to Midterm, to get other peoples professional feedback.



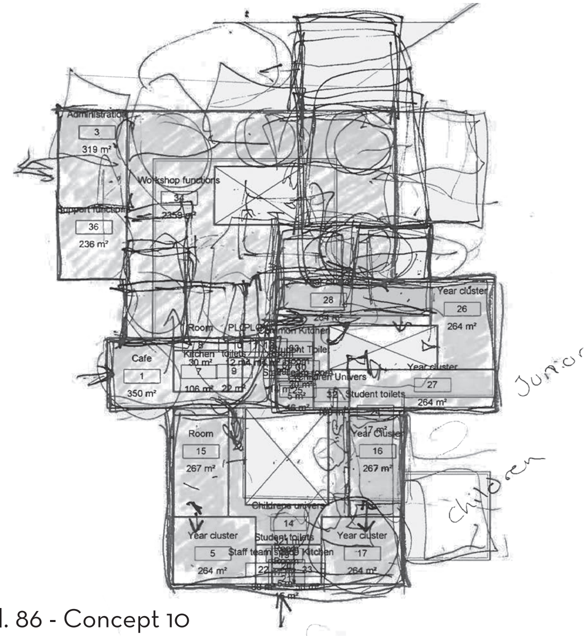
Ill. 83 - Concept 2, initial plan



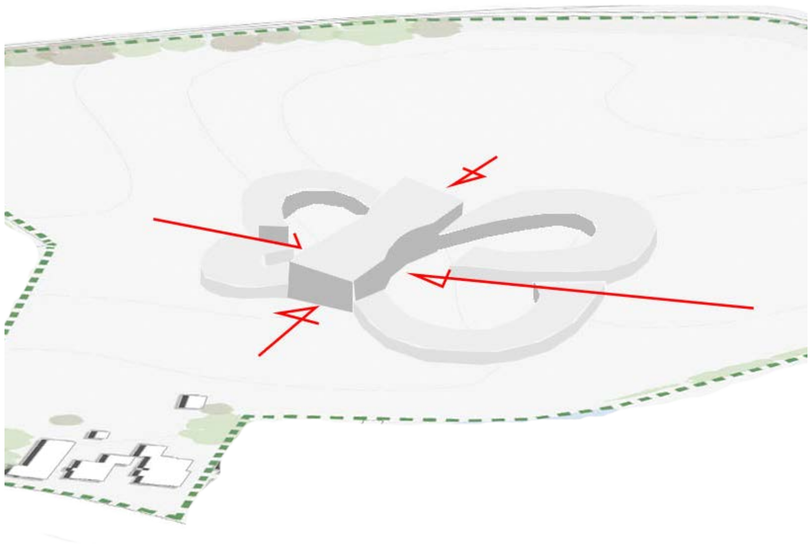
Ill. 84 - Concept 10, initial plan



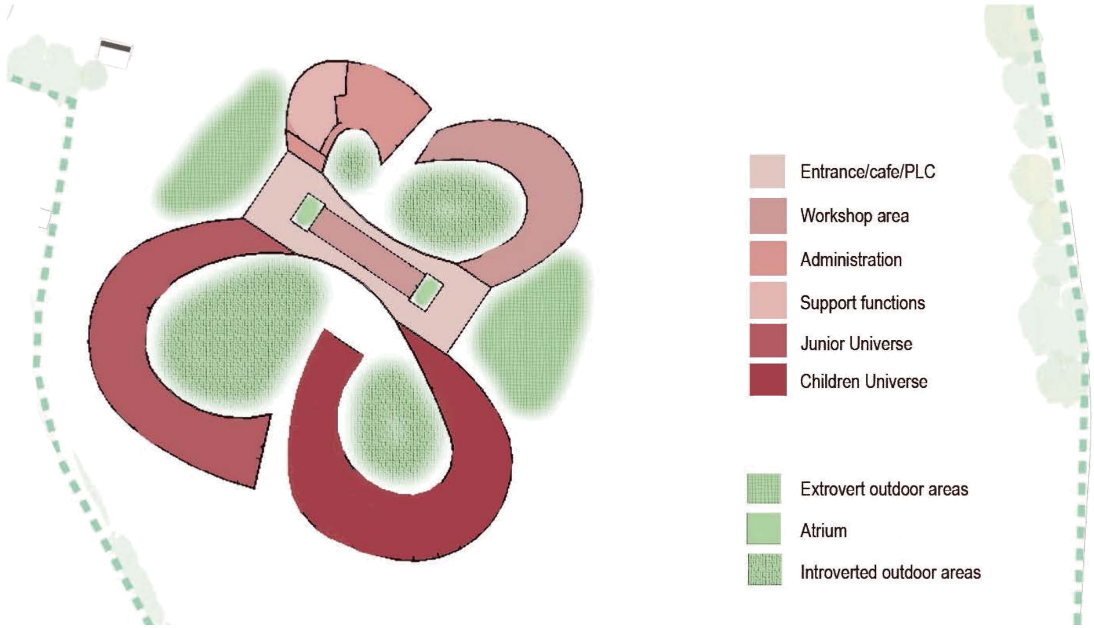
Ill. 85 - Concept 2



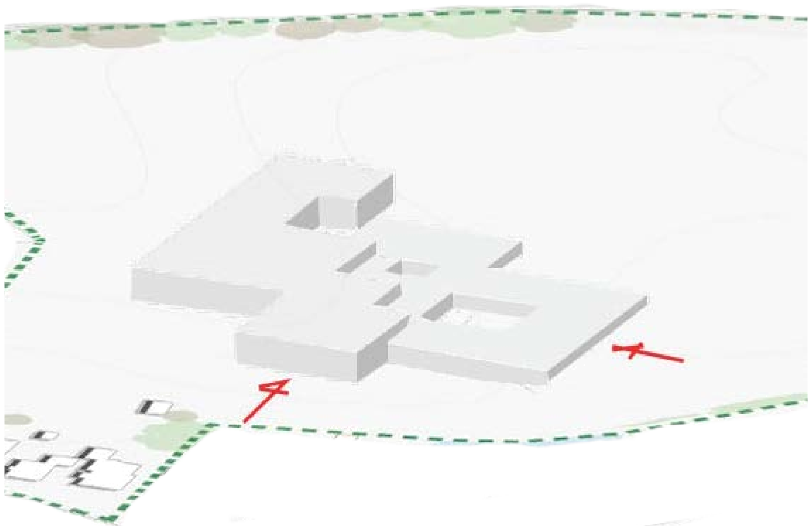
Ill. 86 - Concept 10



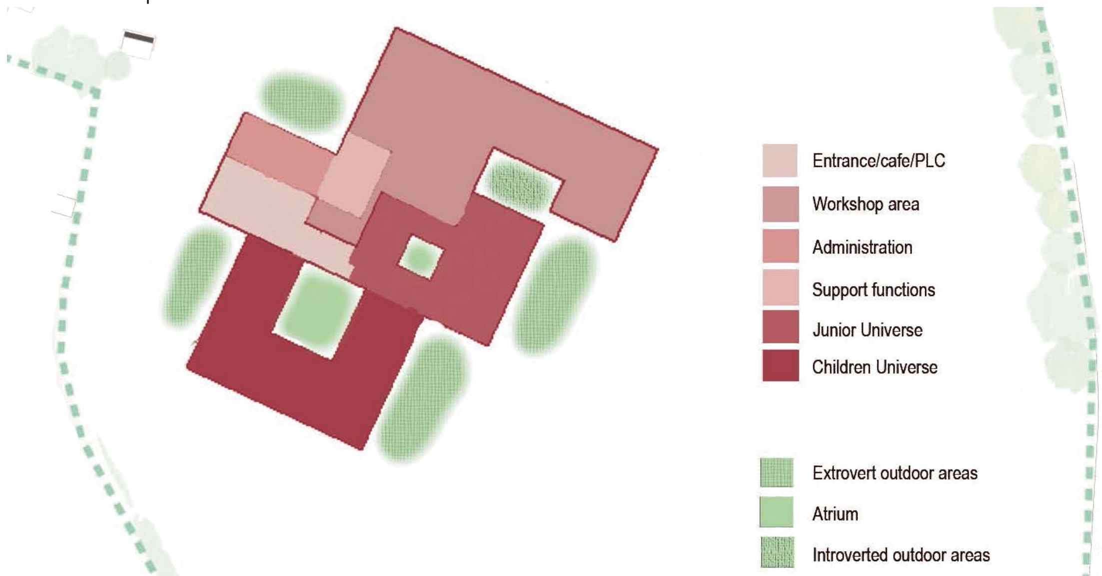
Ill. 87 Concept 2 - Access



Ill. 88 Concept 2 - Functions



Ill. 89 Concept 10 - Access



Ill. 90 Concept 10 - Functions

PHASE THREE

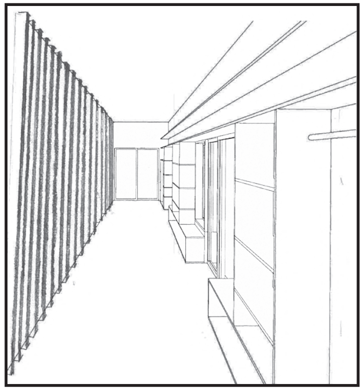
After the midterm, the best way to evolve and improve the concepts, were to combine the two concepts, because both of them had qualities, that the other one needed. Concept two's main qualities were, that part of the building were a clear connecting between the access road the path below the roundabout in the south-east, that part of the building is a naturel landmarc and the form is dynamic.

The previously mentioned qualities, are the qualities that concept ten lacks, instead concept ten's has main qualities as a static form, but dynamic plan, relation to the buildings in the area - based on the forms and the plan gives some functional rooms, which concept two lacks. Before the evolvement of the form of the concept, it would be better to get a spacetial idea of the rooms and how they work.

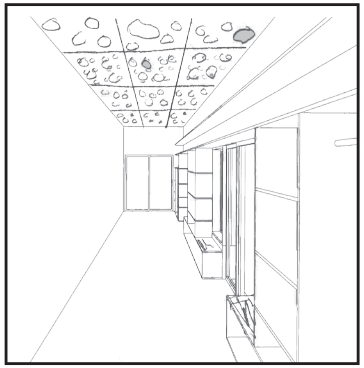
This approach would also give a new idea of to form the concept, which would create a design, that works both in plan, form and function.

To get more down to detail and spacetial approach, it was better to focus one a few of the most important rooms. Therefore three of the most important and mainly used rooms were chosen, these rooms are the offices, classrooms and common areas.

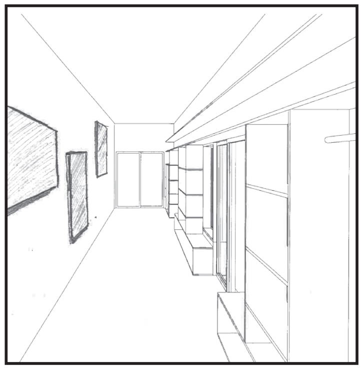
One of the first focus points was the acoustic solution in the hallway and classroom, Ill. 91 - Ill. 93 shows the three different solutions: the panels, the lamella-wall and lowered perforated plasterboard, these different solutions were evaluated with pros and cons.


Ill. 91 Lamellas

Pros	Cons
- Relates to the debth of the niches - Simpel	- Noisy combination of materials - Dead sound - Clash between horizontal and vertical - Aggressive


Ill. 92 Perforated plasterboard

Pros	Cons
- Simpel - Few different materials - Do not affect the space	- Less creative - Less relation to children


Ill. 93 Sound panels

Pros	Cons
- Creativity/ used for hanging drawings - Color difference - Wayfinding	

The panels were chosen and will be used all over the school, but in the hallways, where there are a larger risk of noise, there will also be used perforated plasterboard on the lower ceiling. This lowered ceiling also covers all the technical pipes and wires and it protects them from the childrens play in the hallways.

The panels also get another function, by using them as wayfinding. The school is such a large building, that it is necessary to make some kind of way-finding, two solutions were discuss, the panels or lines in the floor. The panels could be used for two things, way-finding and acoustics, opposite the lines in the floor, which only could be playful, but they also relates to hospital hallways.

The chosen solution for the acoustics were also affected by the choosing of materials, the list shows the different materials for respectively the wall, floor and ceiling. The list also shows the pros and cons for the different materials, the renderings of the materials are in Appendix 7.

Floor	
Bamboo (common area)	(+) durable (+) soft tread layer (+) sustainable
Concrete	(-) cold
Laminate (hallways)	(+) used in existing schools (+) low step-sounds (+) durable
Carpet	(-) not durable (-) to much maintenance
Vinyl	(-) institution look (-) soft tread layer (+) durable

Table 5

Wall	
Concrete	(-) cold (-) doesn't fit with wood-construction (+) contrast between soft and raw
Plasterboard	(+) warm (+) colors/colerful/creative (+) durable
Lamellas	(-) aggressive (-) dead sound
Bamboo	(-) too much wood

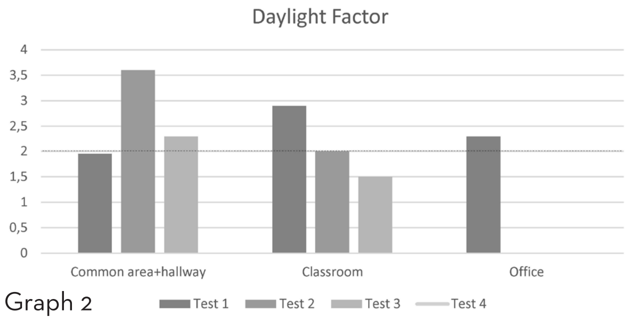
Table 6

Ceiling	
Perforated plasterboard	(+)lowered ceiling (+) simpel (+) sound-absorption
Troldtekt	(-) industri look (+) sound-absorption
Wood-panels	(-) cottage look (-) many different materials
Plasterboard	(+) simpel
Lamellas	(-) no easy access to technical pipes (-) messy

Table 7

Perforated plasterboard were chosen for the ceiling on the entire school, all the walls should be plasterboard walls, colored white and the floor should be wooden bambus in the common areas and laminate bambus in the hallways. Ill. 94 - Ill. 96 shows the materials in the office, classroom and common area.

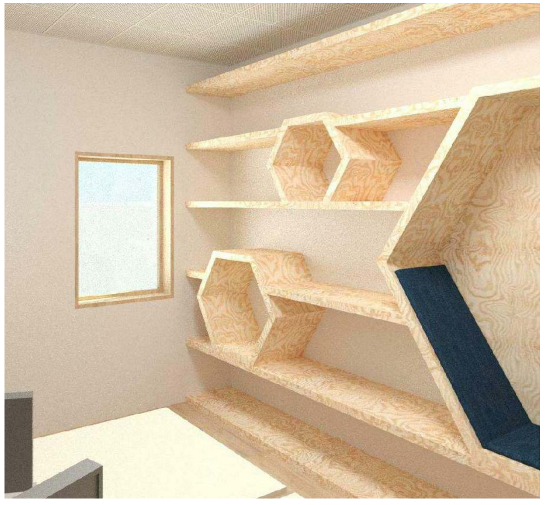
The next step was to test how the chosen materials would affect the daylight factor in these rooms, but the Velus simulation were also used to get the recommended daylight factor of 2 % in the rooms Graph 2, shows the results of different test, where the adjustable parameters are the amount of windows and doors with glass.



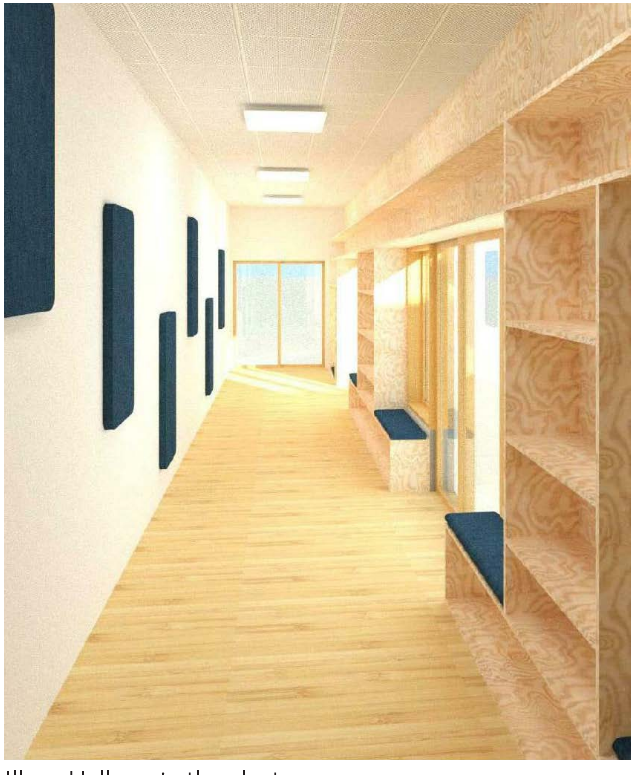
Graph 2

As the graph shows only few of the test meet the demand of 2% daylight factor. But it is not enough to have good daylight, the thermal and atmospheric indoor climate also had to meet the demands, which is why the velux simulation as done simultaneously with BSim, to see how the two affet each other, and to thereby create rooms that have a good indoor environment both visually, atmospheric and thermal.

Ill. 94 - Ill. 96 show how three of the rooms will look, with the current amount of windows and materials.



Ill. 94 The office



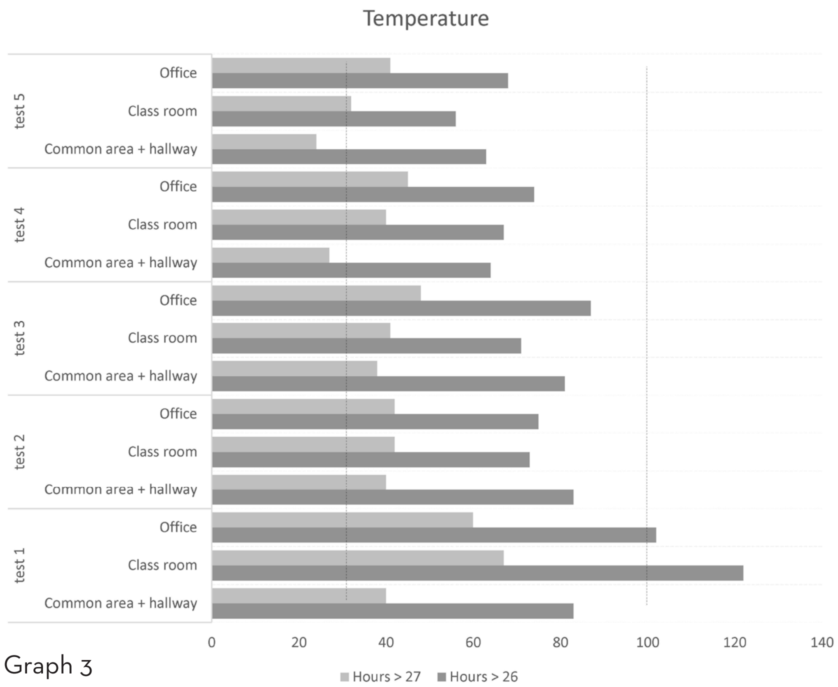
Ill. 95 Hallway in the clusters

Ill. 96 Common space in one of the custers

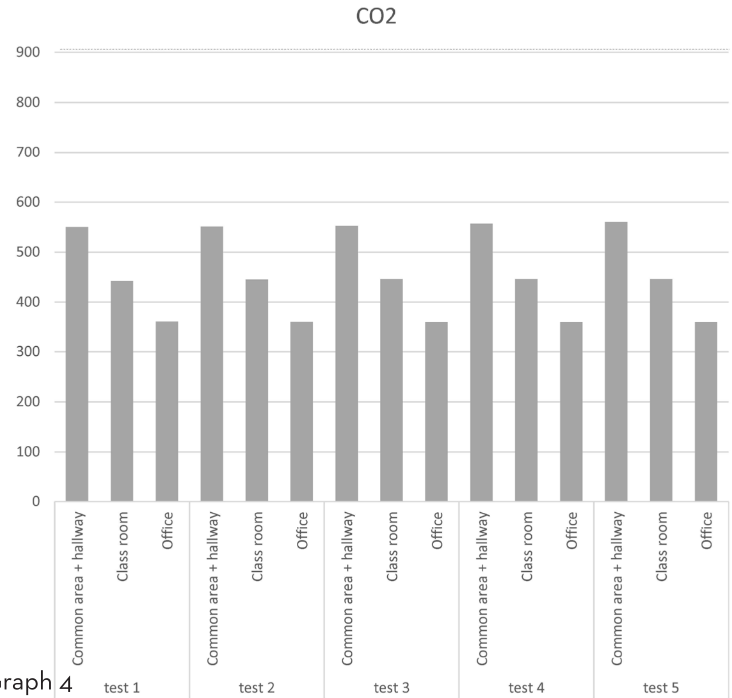
The results from BSim are shown in Graph 3. The first BSim test was based on the second Velux test, because the first Velux test showed, that the daylight factor was 3,5%, which are way higher than needed.

The result from the BSim and Velux simulations show, that the main room were close to uphold the DGNB demands for the daylight factor, the temperature and CO_2-level. The testing were temporarily paused, because the rooms were not yet settled in a plan, therefor the testing are more specific in the Phase Six were the main rooms are but in a plan for the concept.

The BSim results also showed that the classroom had to turned north, to avoid overheating, which was the start of a new sketching- and model-phase for a new concept. The new knowledge about turning the classroom north, should be combined with the combination of the geometric and organic shape from the previously sketching- and model-phase.



Graph 3



Graph 4

Test differences in classroom

Test	Orientation	Overhang	Windows	Size
1	South	0	5	1,25 x 0,915
2	North	0,5	5	1,2 x 0,915
3	North	1	5	1,2 x 0,915
4	North	1,5	5	1,2 x 0,915
5	North	1,5	5	1,2 x 0,915

Test differences in the office

Test	Orientation	Overhang	Windows	Size
1	North	0	1	1,2 x 0,915
2	North	0	1	1,5 x 0,915
3	North	0	1	0,9 x 2
4	North	0	1	0,5 x 2
5	North	0	1	0,4 x 2

Test differences in the common space

Test	Orientation	Overhang	Windows	Size
1	South	0	9	1,5 x 0,915
2	South	1	9	1,5 x 0,915
3	South	1,5	9	1,5 x 0,915
4	South	1,5	7	1,5 x 0,915
5	South	1,5	6	1,5 x 0,915

PHASE FOUR

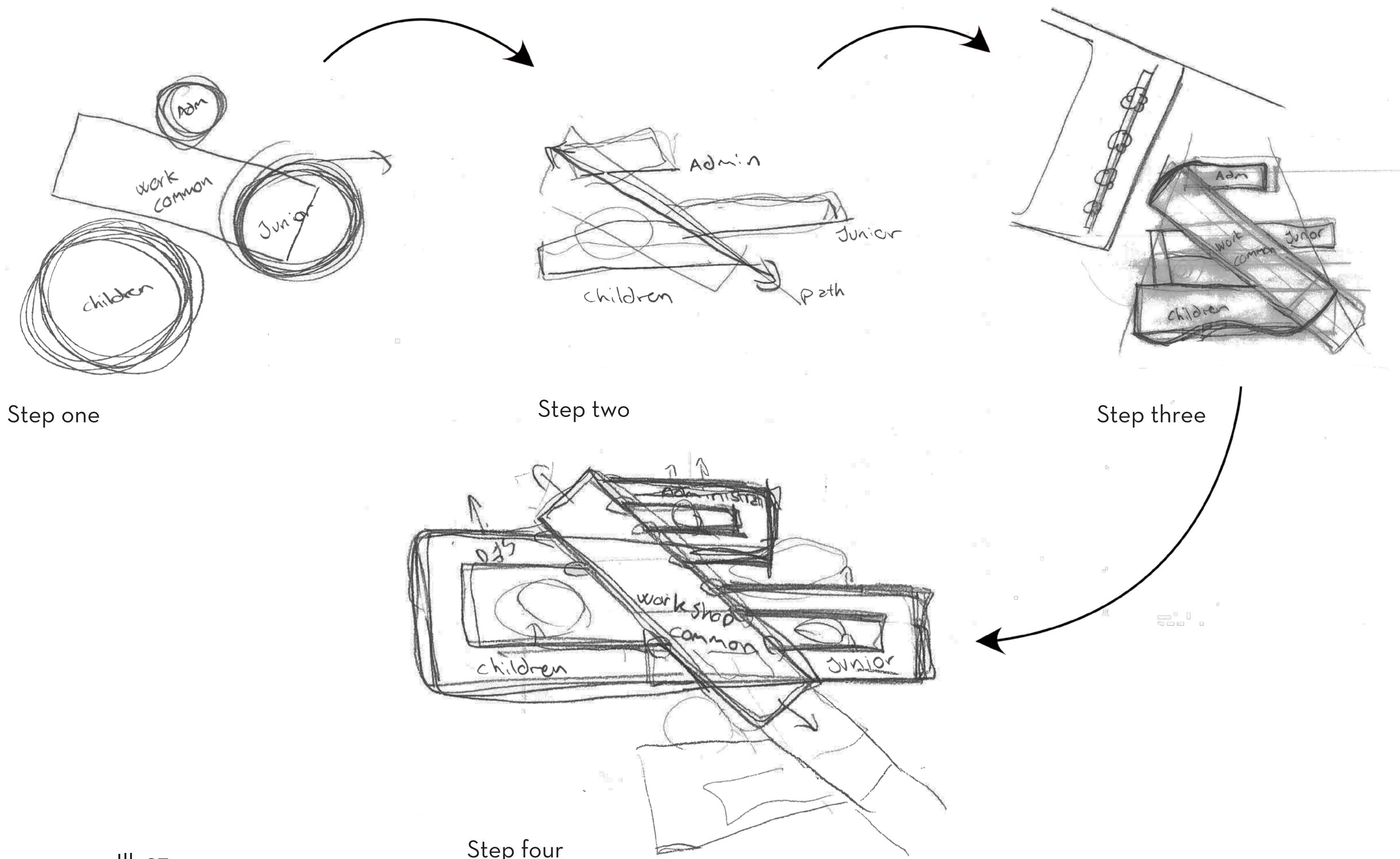
This phase started with sketching new concepts based on the new knowledge from phase three. The evolution and sketching phase of the combination of the two previously concepts are shown on Ill. 97.

These sketches ended in a new concept, concept 11, which was a combination of qualities from concept two and ten, but also the results from phase three.

In step one the middle common space from concept two is used as a starting point, with the other functions surrounding it, as a concept.

In step two the other functions are connected to the common space as buildings taking into consideration that all the classrooms in the clusters should face north. In step three the entrance together with the parking is considered, and this gives the placement and orientation of the common space, to make sure it connects to the cycling path to the south.

Finally in step four, a dynamic building shape is created, and ends up as concept 11. The next step was to develop the plan og concept 11, to see how the rooms fit in the new shape.

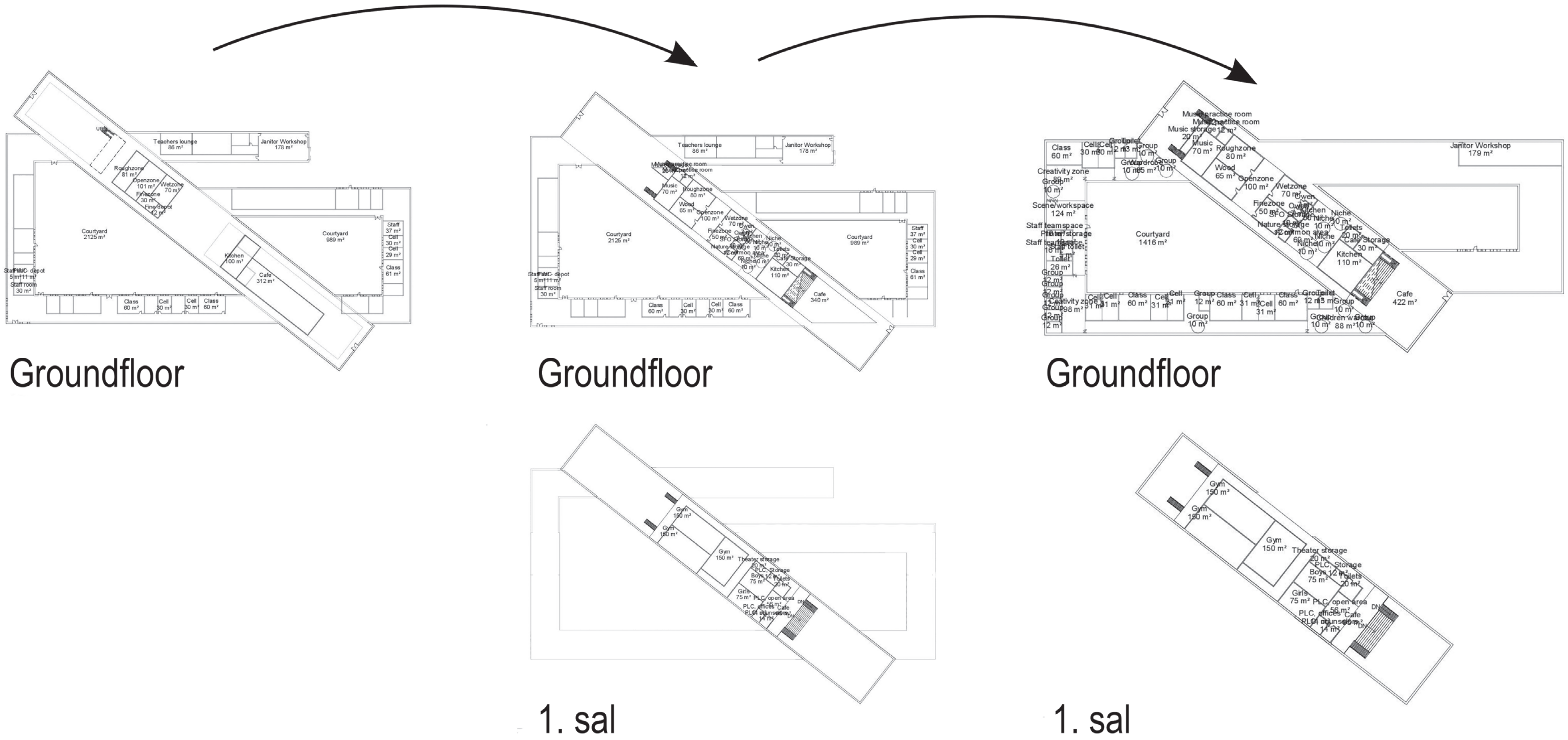


Ill. 97

PHASE FIVE

Phase five started with making a plan, which meet the demands of the function diagram and all the rooms from the room program.

The first plan-draft, concept 11.3, had the administration and janitor in the wing farest north, and the gyms had not been placed, so this lead to concept 11.4, where the gyms are put on the first floor, but the form of the building seemed discordant and the administration and teachers would not be close to the students, as the design criteria described. To change this, the idea was to put the SFO and administration into the common space, to gather all the common functions one place, concept 11.5.
This also made it possible to close of the clusters after school hours, when they are not in use, but still have the common space and functions open for the public to use. , see the plans in Ill. 98.

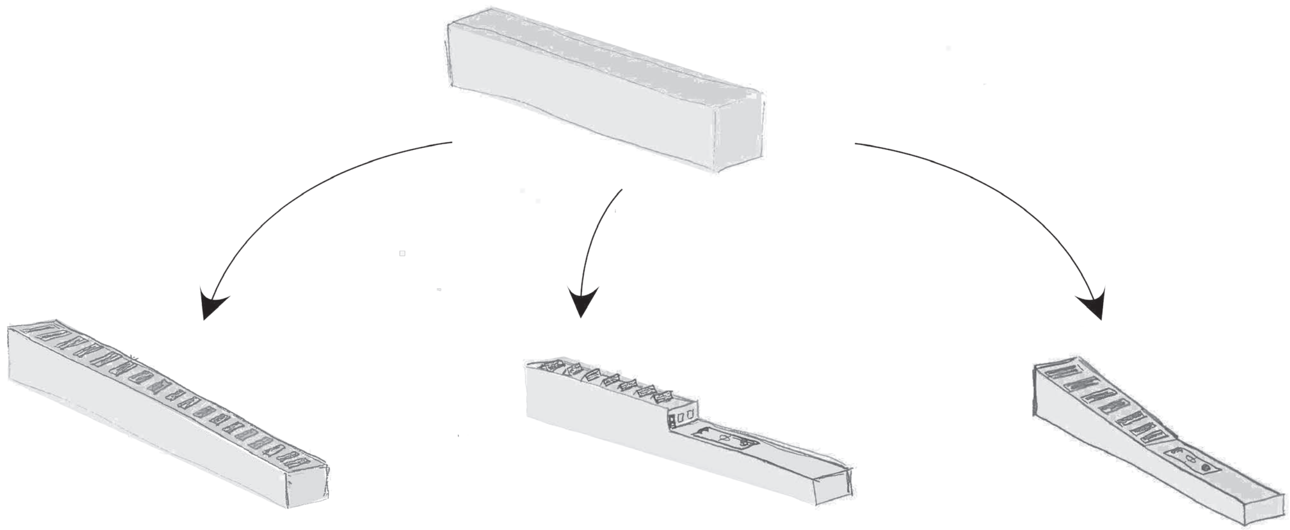


Ill. 98 Concept 11.3 Concept 11.4 Concept 11.5

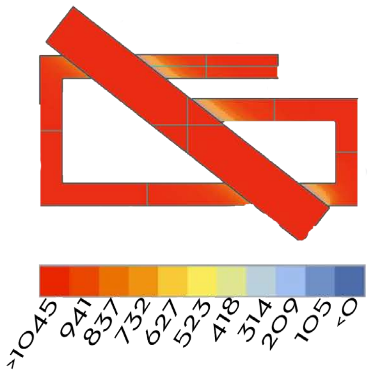
SUN RADIATION

To get a roof-shape which makes it possible to both collect rainwater to the inner courtyards and collect as much sunlight for solar cells as possible. Ill. 99 shows the initial sketches of the roof shape, which were then tested in Ladybug, which is a plugin for Grasshopper.

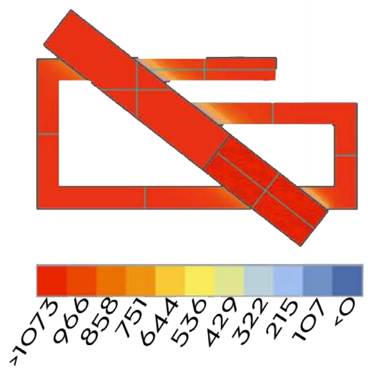
The program were used to simulate how much sun radiation, that would be on the roof surface, Ill. 100 - Ill. 104, as the illustration shows there are not a big difference in the amount of sun each roof shape gets, but there is a small difference, and the architectural appearance of the roof was also considered. That is why there was worked further on the roof that had the common space angled and an angle on the clusters which is Ill. 102.



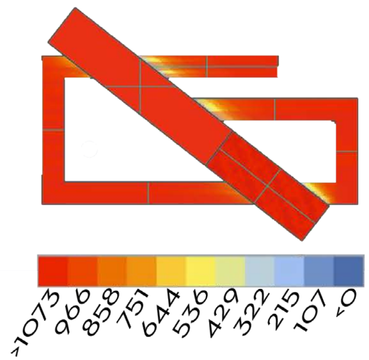
Ill. 99



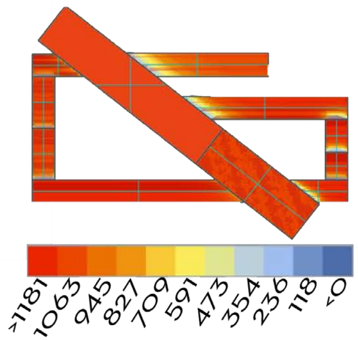
Ill. 100 - Flat roofs



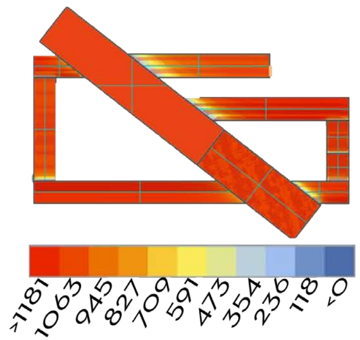
Ill. 101 - Angled roof on common space



Ill. 102 1,5 degree angle on clusters



Ill. 103 15 degree angel on clusters



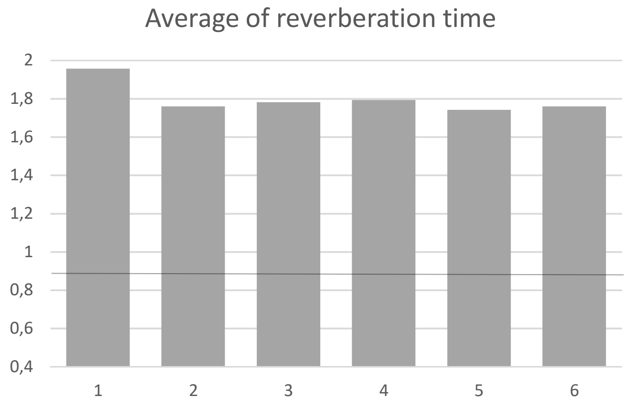
Ill. 104 Different angels on all the roofs

ACOUSTICS

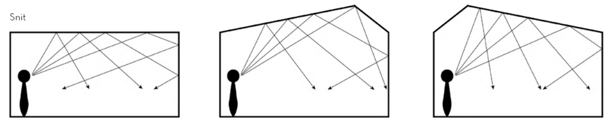
The shape of the roof would also be affected by the acoustics in the classroom. Ill. 105, shows how the soundwaves would spread theoretically in the room, as the illustration shows, number three in the cross section and number one or two in the plan would spread the soundwaves most equally and make them as short as possible. Number one of the plan are choosing because it fits better into the overall plan, without making unuseful corners.

These first acoustic analysis was made based on pure theory, and based on the result of these initial acoustic analysis, the acoustic in the classroom were tested in pachyderm, to find the measurements for the classroom, this happened along side with the radiation simulation in Ladybug. Graph 5, shows that a classroom with the dimensions 7 m * 8,6 m gives an average reverberation time of 1,76 seconds.

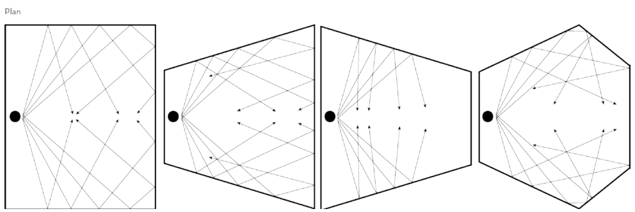
Ill. 107 and Ill. 108 shows the final roof shape, based on the acoustics of the classroom, the amount of sun radiation on the roof surface.



Graph 5

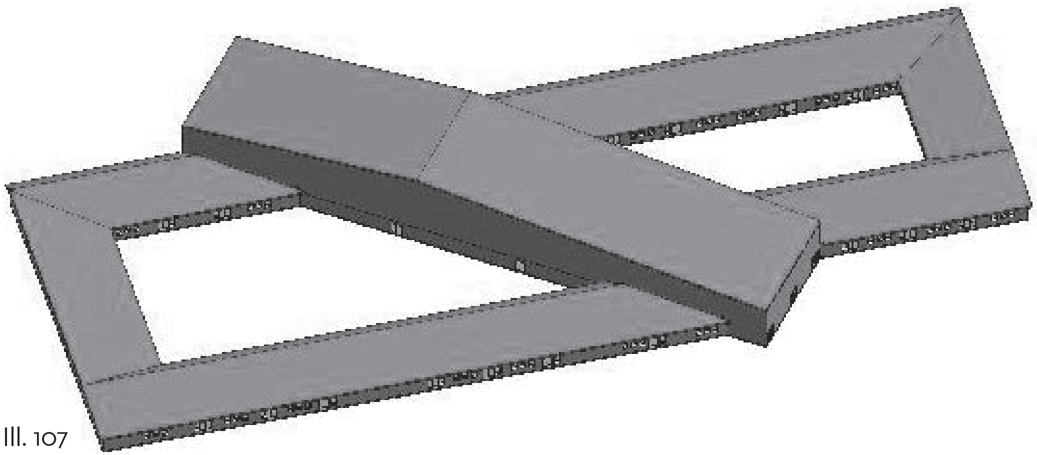


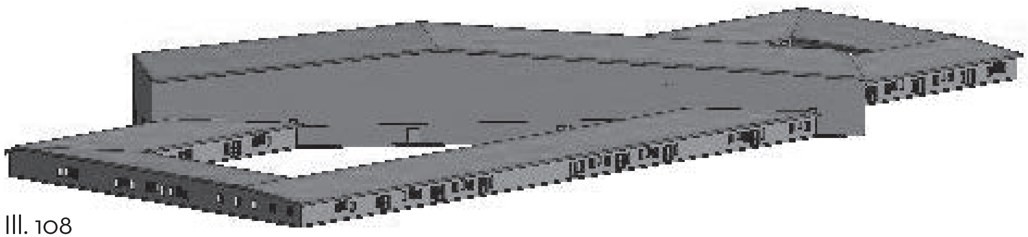
Ill. 105 Acoustic in section



Ill. 106 Acoustic in plan

	Lenght x width	Højde
test 1	6x10	2,5
test 2	7x8,6	2,5
test 3	8x7,5	2,5
test 4	9x6,7	2,5
test 2	7x8,6	3,5
test 3	7x8,6	4,5

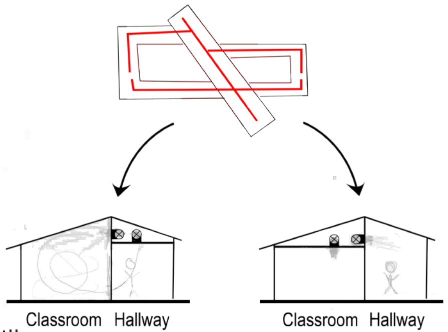

Ill. 107


Ill. 108

VENTILATION

The next step was to examine weather it was possible to only use natural ventilation on the school to minimize the energy demand for the school. The simulations showed, that it was possible to use natural ventilation, but the building regulations states, that there has to be mechanical ventilation, to secure a CO_2-level below 1000 ppm at all times (Bygningsreglementet.dk, 2019). Which is why hybrid ventilation will be used.

This meant, that ventilation pipes should be incorporated, Ill. 109 shows how to incorporate the pipes. By choosing solution one, where the pipes are in the hallways, it would create more spacecial and light classrooms, and at the same time creating intimate and cozy hallways, where it is easy to reach the pipes behind the lowered ceiling.
The lowered ceiling is incorporated to hide the pipes, but



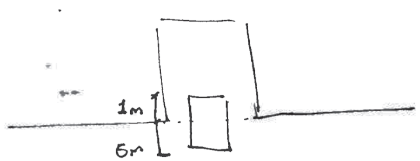
Ill. 109

also to make cleaning of the school easier because the suspended ceiling prevents the dust collecting on top of the pipes from falling down into the hall and create a worse indoor climate.

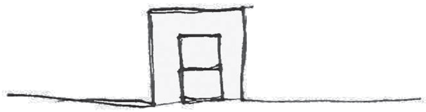
After getting the outer shape, Be18 were made for the new concept and the energy demands were 17,2 kWh/year and with the solar cells, the building becomes a zero energy building, which produces more energy than it needs.

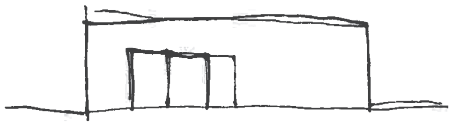
INTERIOR DESIGN

Afterwards the focus was on the interior design of the common area, mainly on the placement of the gym (Ill. 110-Ill. 114), number three (Ill. 112) were chosen, because it makes it possible to get visuel contact to the physical activity in the gyms and connect them, to make them into a theater. By lifting them up on the first floor, made it possible to have a more open ground floor, which linked the two courtyards together.

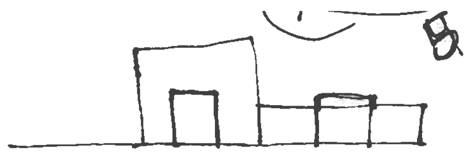


Ill. 110 Partly buried

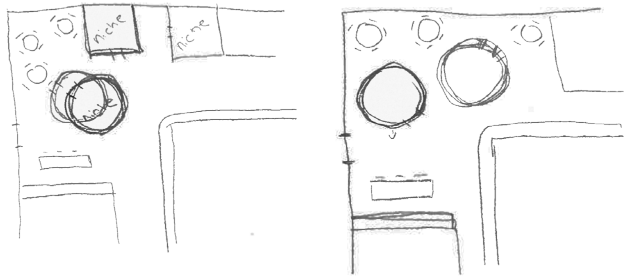

Ill. 111 Stacked

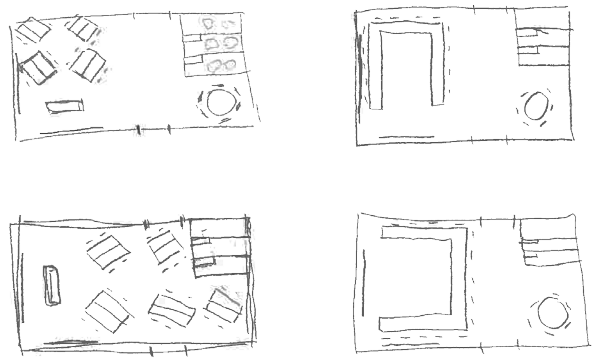

Ill. 112 Next to each other

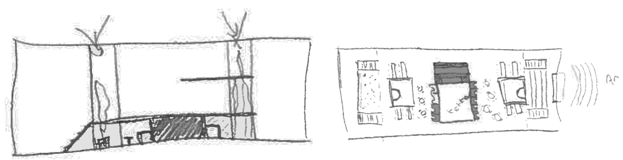

Ill. 113 In the clusters


Ill. 114 Divided into cluster and common

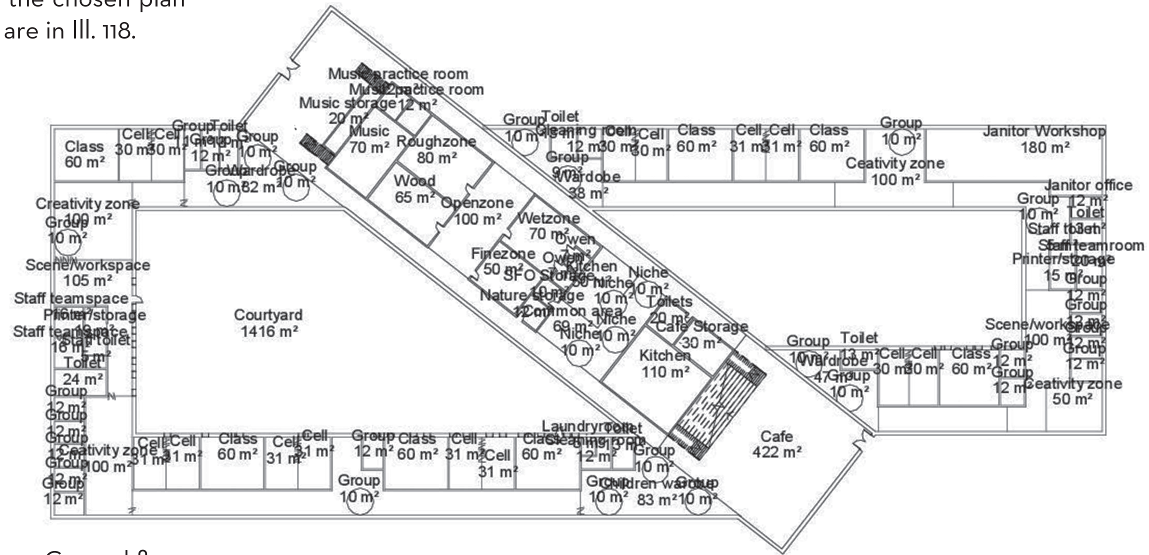
Another focus point of the interior design, was possible ways to design the classrooms, cells, common spaces in the clusters and the large common space. The different designs are shown on Ill. 115 - Ill. 117. The cells are always placed two and two, with a flexible wall between, this makes it possible to transform two cells into one classroom.


Ill. 115 Common area/hallway

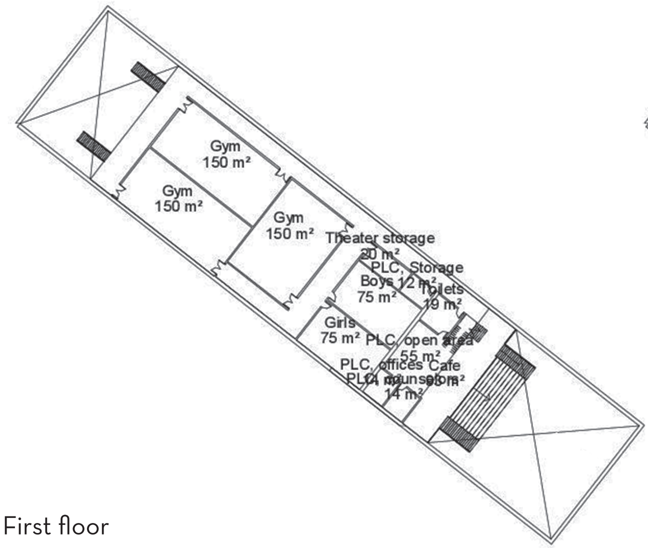

Ill. 116 Classrooms


Ill. 117 Common space/entrance

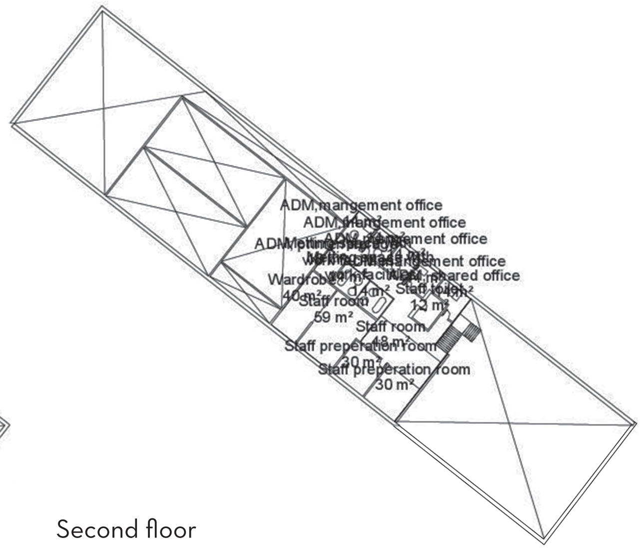
Combining the new interior design with the chosen plan from the beginning of Phase Five, which are in Ill. 118.



Ground floor



First floor



Second floor

Ill. 118

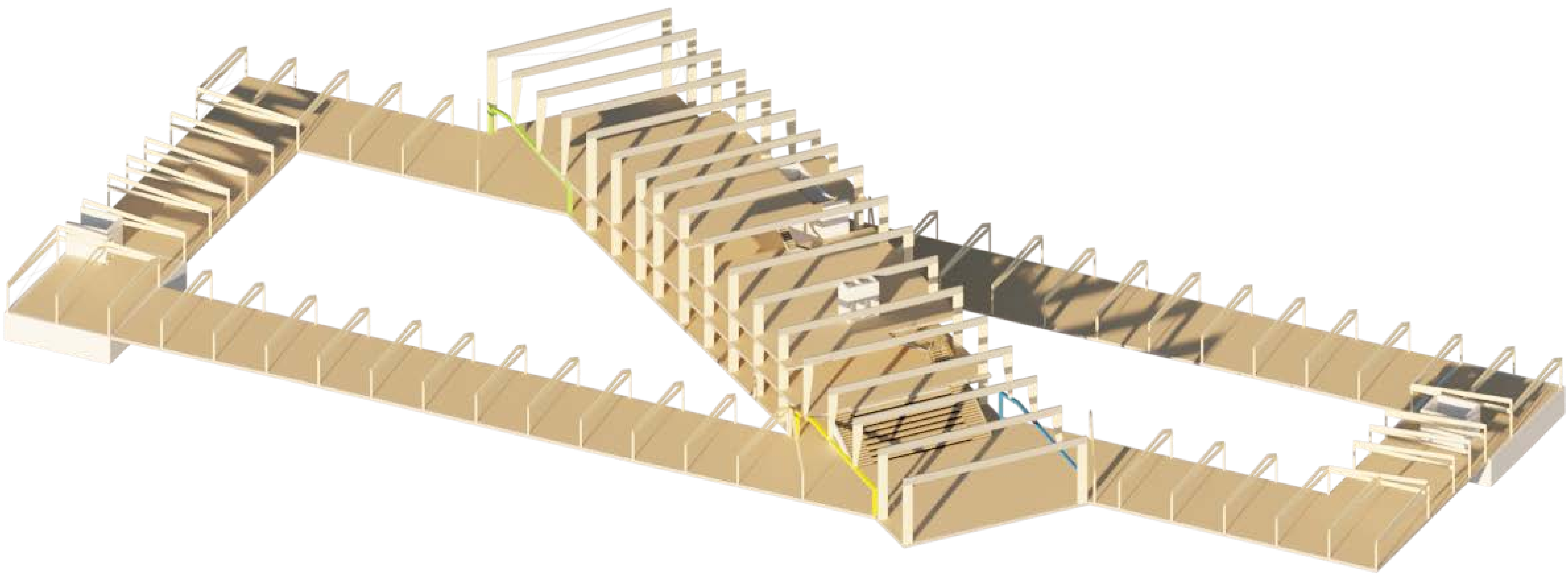
PHASE SIX

During Phase five the width of the building had extended to around 12 m, therefore it was necessary to examine if it was possible for a wood-construction.

The dimensions of the construction are based on a diagram, the wish was to get the largest span between the pillars, without getting a to large cross section in the clusters, because they had to be hidden in the walls, to avoid that they would take up space in the hallways and classrooms.

In the common space, the wish was to have no pillars between the entrance to the clusters and the common space, because it would separate the rooms and the wish was to connect them.

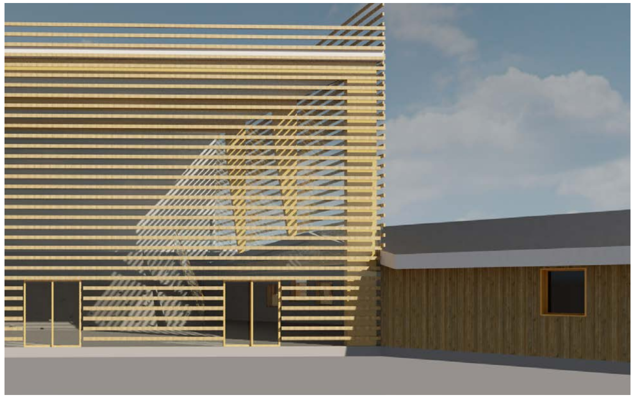
The pillars for the cluster had to have a cross section of 125*125 mm and are placed in the inner part of the wall to minimize the risk of cold bridgets. In the common room, the distance between the pillars had to be around 17 m, to avoid having pillars between the cluster entrance and common areas, which is not possible with a wood construction in such a large room. To solve this issue, a steel frame are constructed around the cluster entrance, this steel frame is dimensioned to carry the loads of the wood pillars and keep the entrance free of any pillars.



Ill. 119 - Construction

FACADE & LCA

The next step was to design the facades, the first idea was to have horizontal lamellas on the common building to make it seem smaller and vertical on the clusters to make them seem higher. Besides the rotation of the lamellas, the transparency of the underlying were also different, which made the design seem messy and it seperated the building to much, Ill. 120.



Ill. 120

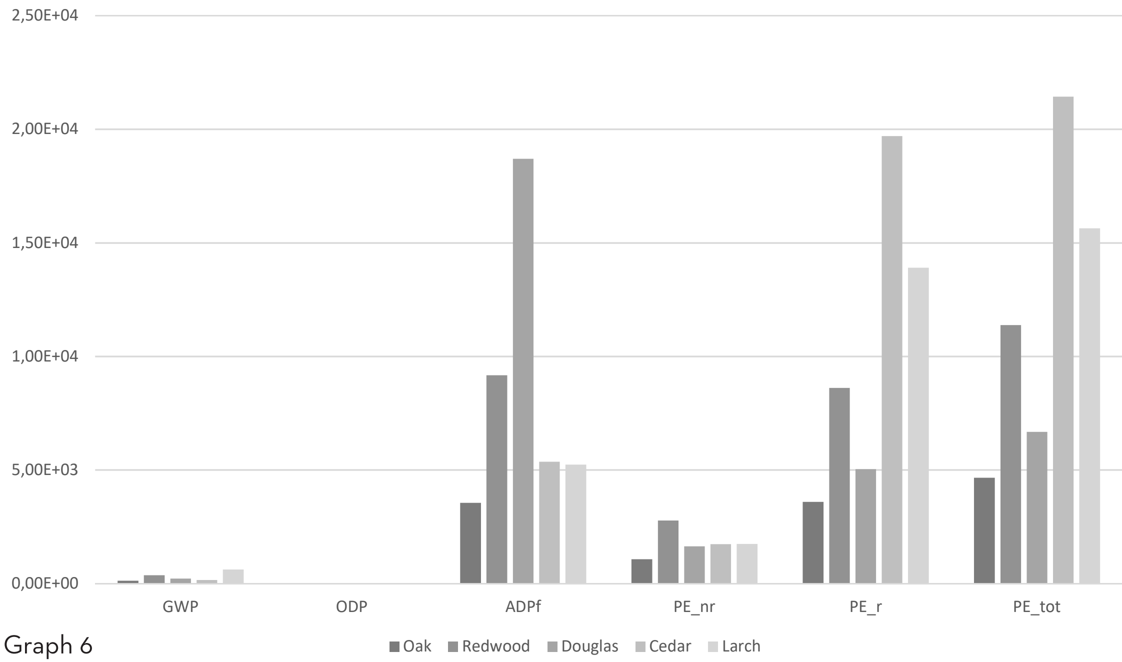
Ill. 121

The design was tried out with different sizes of lamellas and different spacing, see Appendix 9, but it never quit gave the expression that the design needed.

After looking for inspiration, a solution were found, Ill. 121 shows the solution. The variation of distance between the

Afterwards the wood material were choosing through different demands, which are shown in the table. The table shows, that oak met most of the demands and was therefore chosen and the graph shows, that oak are also doing good in LCA see Graph 6.

	Western Red Cedar	Douglas fir	Larch	Scots pine (redwood)	Norway spruce (Whitewood)	Oak
Uses	Facade, roof, outdoor furniture	Veneer, planks, lumber, facade cladding	Outdoor furniture, facades	Planks,furniture veneer, facade cladding.	Construction, lumber, planks, facade cladding	Floors, tools, furniture, faade cladding
Color	Redbrown	Light yellow	Light brown	light redbrown	Light yellowish	grey-yellow
Texture	Clear markings of year rings	Clear markings of year rings	clear markings of yearrings			Lifely and decotrative
Durability	Durable - 20 years	Moderate duration	Moderate durable	Moderate durable	Low durability - 5 years	Durable - 50-125 years
Hard/soft	Soft	Soft	Soft	Soft	Soft	Hard

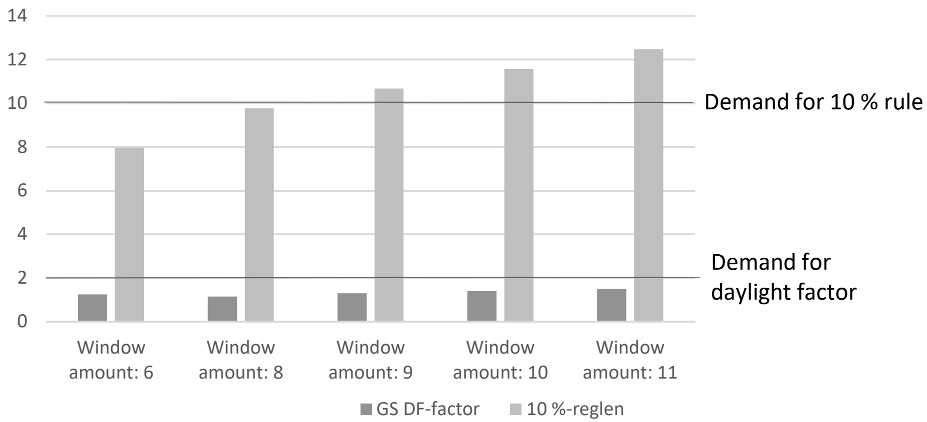


Graph 6

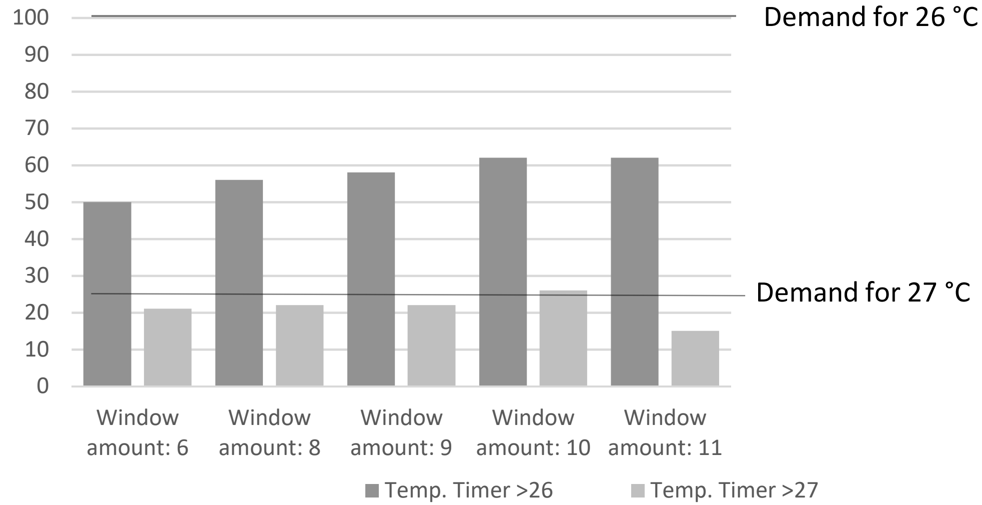
INDOOR CLIMATE

lamellars gives the possibility of closing of or opening up depending of the function behind the facade.
The plan of the school had changed in Phase five. The main rooms were put into a plan for the new concept, which made it possible to make an indoor simulation of the indoor climate and daylight factor, that is more specific for the concept. Graph 7 shows, the daylight factor for the worst case scenario, based on temperature for respectively the office, classroom and common area in the cluster, the graphs shows, that all of the room uphold the 10 %-rule, where the glass area equals 10% of the floor area and the rooms almost meet the demands of a daylight factor of 2%.

Graph 8 shows the temperatures in the rooms. These graphs shows, that the rooms almost ophold the DGNB demands of maximum 25 hours above 27 degrees and 100 hours above 26 degrees, the deviation is maximum three hours above the demand for hours above 27 degrees.



Graph 7 Daylight factor

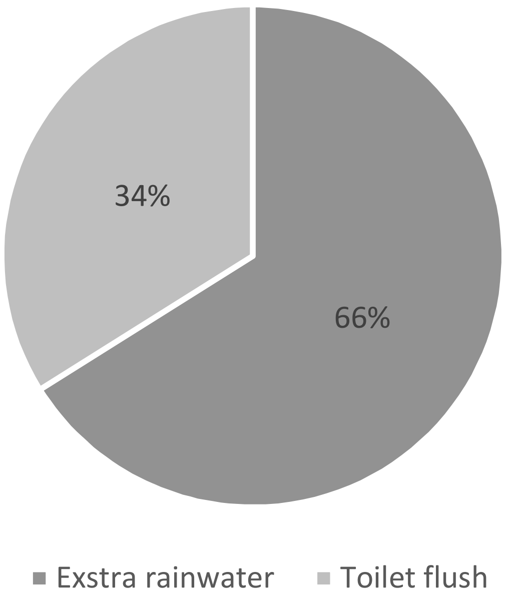


Graph 8 Hours above

OUTDOOR SPACE

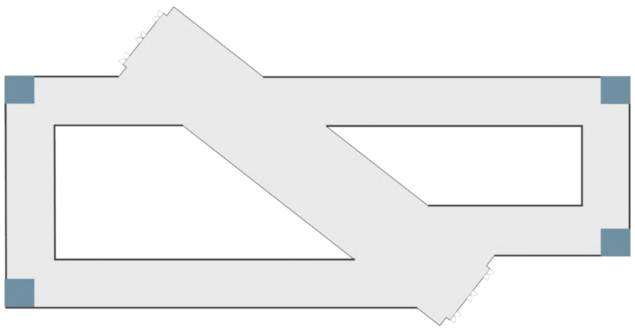
After settling the outer shape of the roof, made it possible to calculate the amount of water, which could be collected on the roof surface. It is possible to collect 4.598 m³ rainwater, which is around 383 m³/month. Graph 9 shows, that it is enough to use for toilet flush and to have some rainwater in the LAR bassins in the courtyards to play with.

Ill. 122 shows where the placement of the tanks for the rainwater to toilet flush are placed, where the rainwater will run in the courtyards is shown in Ill. 123.



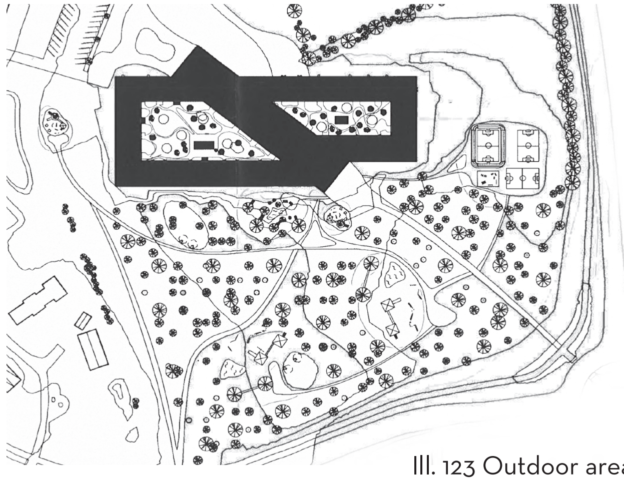
Graph 9 Use of collected rainwater

The collection of rainwater also affected the design of the courtyard, but also the other outdoor areas. There are five different types of outdoor areas, too fit with different needs, the courtyards, which makes it easy for the teachers to keep an eye on the children. The sports field, which are used during lessons or other sports events for the public.

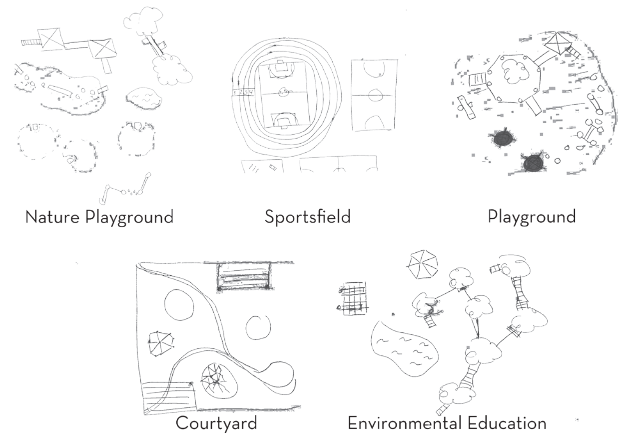


Ill. 122 Collection of rainwater

The environmental education area, which are also used during lessons for the students to give them a closer relation to nature. The environmental area also provides climping in the trees, as a part of another approach to sports. The two last areas are the playground, the nature playground which are found hidden in the woods, it should fit into the wood and the other is a traditional playground, which are more open and related to the paths. Ill. 123 shows the urban plan, with the different areas.



Ill. 123 Outdoor area



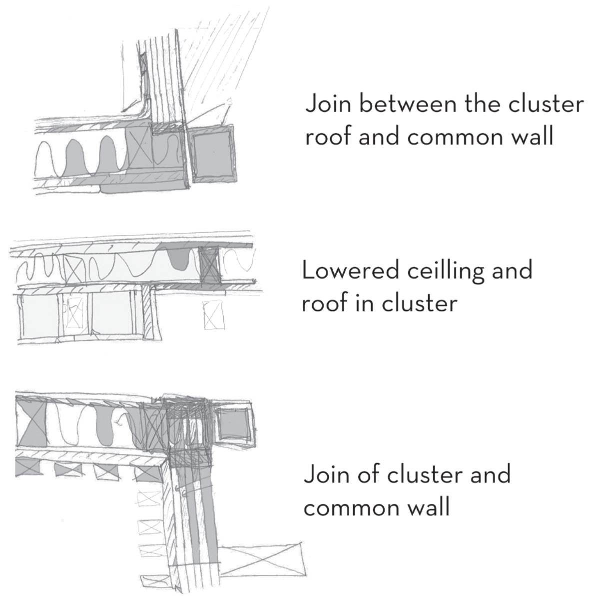
Ill. 124 Types of outdoor areas

PHASE SEVEN

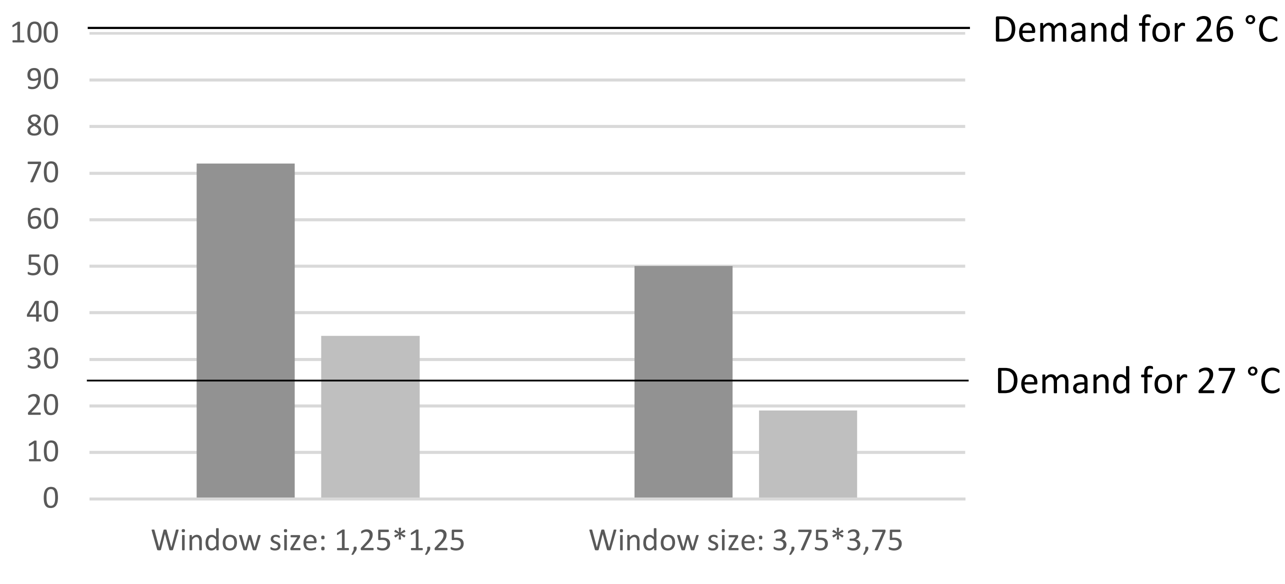
After finishing the outdoor area, Phase seven started with going more into the detail of the building, to tie up the last loose ends. The overall construction were decided and finished in phase six, and this phase started with designing the construction details and meeting of the building envelope. Ill. 125 shows the sketches of the first draft, afterwards small adjustments were made to reach the final construction details.

The next step was to finish the simulations for the school. In phase six the main rooms, herunder the office, classroom and common area in the cluster were tested, until they came as close to upholding the demands for indoor climate and daylight factor as possible. The last room, which also could be critical, was the large, common area.

This room were also tested in BSim to see how many square meters of window, that should be possible to open to avoid overheating, Graph 10 shows the different tests. The results show, that by having 3,75 m^2 of openable window on the western and eastern side, the room upholds the DGNB demands.



Ill. 125

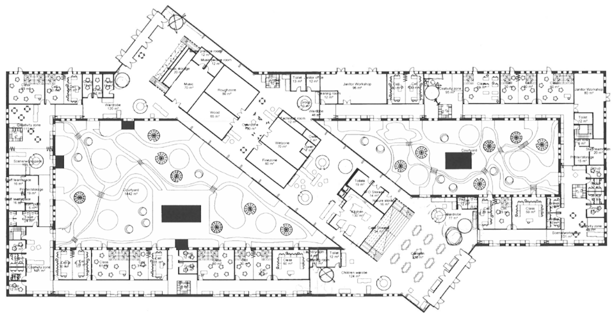


Graph 10

After simulation of the different rooms, the dimension of the pipes were calculated, the results showed, that to avoid too much pressure loss, the dimension had to be 560 mm from the aggregate and 270 mm into the blowin for the classrooms. This led to adjusting the first draft for the ventilation system from phase five.

The new system had three ventilation aggregates, instead of the initial one system. The three systems were placed in the two clusters and one in the common area. The two ventilation-systems in the clusters were placed in the basement instead of the ground floor, because then the large technical rooms would not create a long hallway area and the building had to be extended, which would cost more material.

The last system in the common area, is placed above one of the gyms and is accessed from the staff area, this room already had a technical shaft that led, down to the ground floor.



Ill. 126

After designing the ventilation system, the plan changed and extended, besides changing the ventilation system, an entrance area was also added to improve the indoor climate in the common area, Ill. 126 shows the final plan for the school and the closest of the outdoor area.

When the plan changed in phase five and in this phase, it changed the spacetiallity of the rooms a bit, some draft renderings were made, which are shown on Ill. 127 - Ill. 130. The illustrations also shows the effect of the facades, both on the indoor light, the outdoor spaces and the connection between the clusters and common area.

Ill. 127 Common space in the cluster

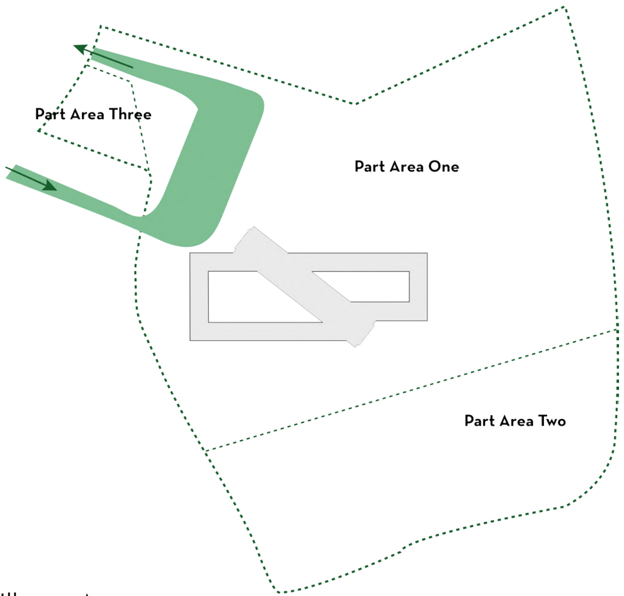
Ill. 128 Canteen area, the southern end of the common area

The diagrams on the next page sum up the main points of the final concept, which are decided during the process. All the other final decisions, as plans, cross sections, details, master plan, ventilation system and construction are placed in the presentation part of this report.

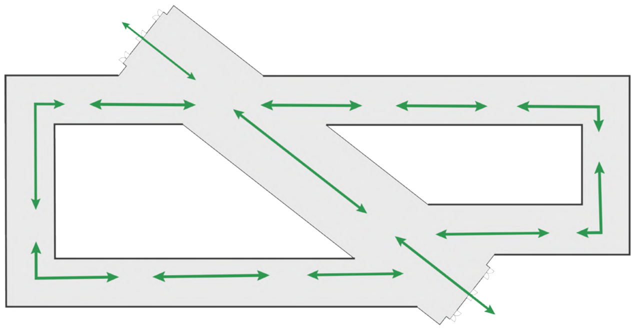
Ill. 129 Coutyard in the cluster

Ill. 130 Main entrance towards north

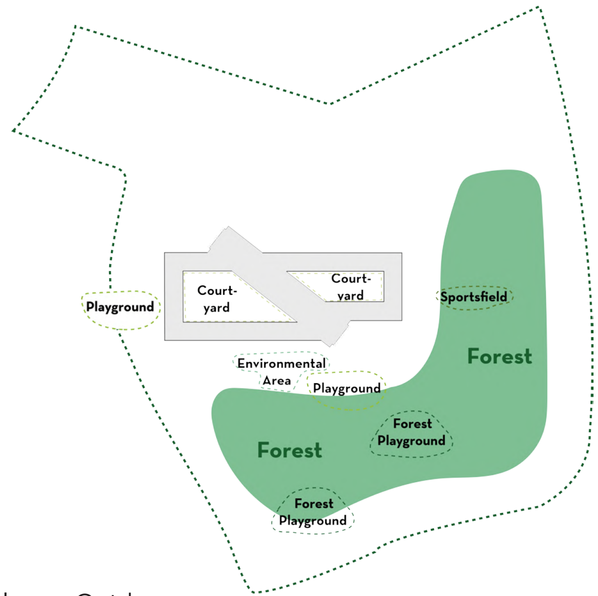
CONCEPT DIAGRAMS



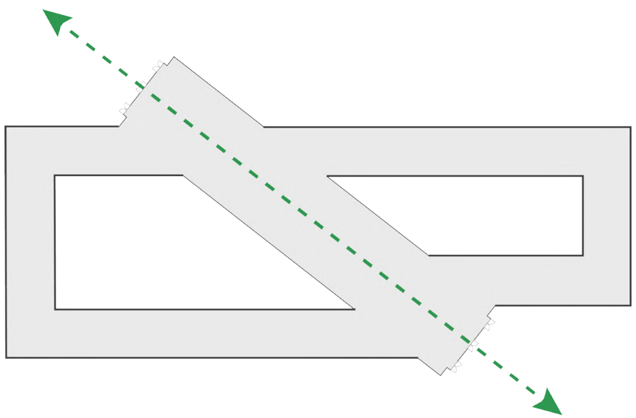
Ill. 131 - Access



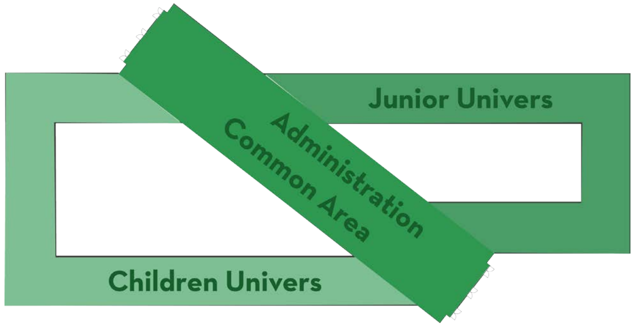
Ill. 133 - Distribution from main entrance



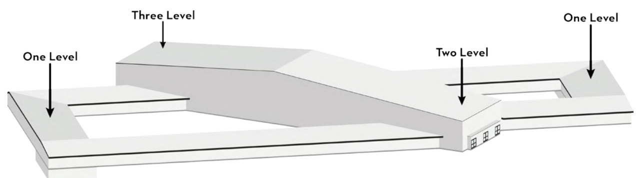
Ill. 135 - Outdoor area



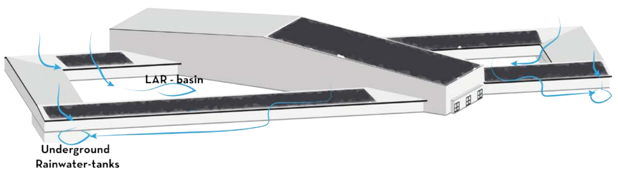
Ill. 132 - Connection to path



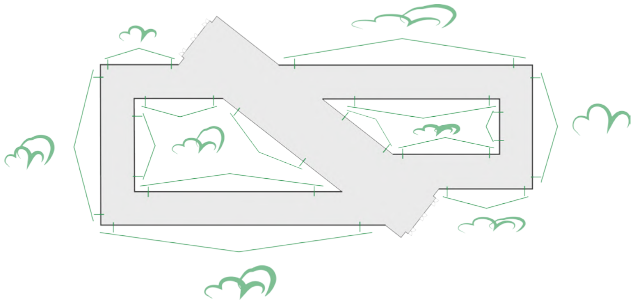
Ill. 134 - Function



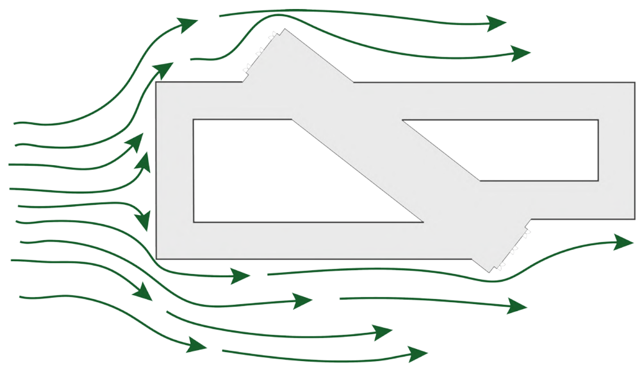
Ill. 136 - Heights



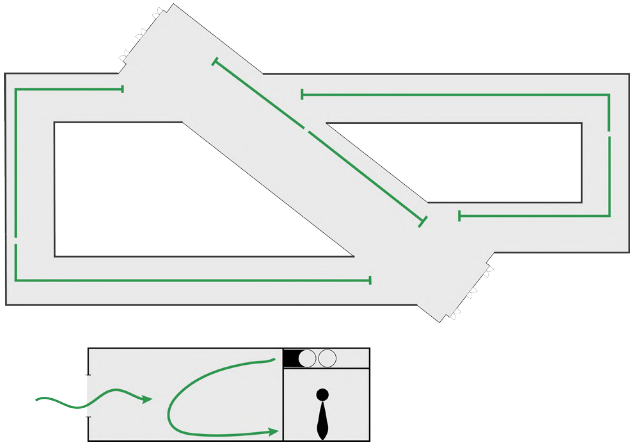
Ill. 137 - Rainwater and solar cells



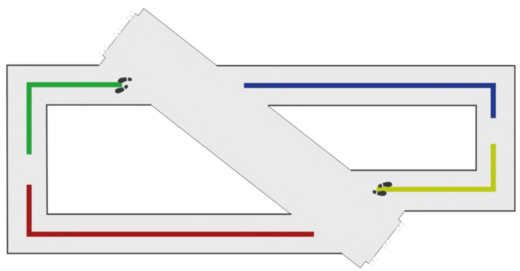
Ill. 139 - View to greenery



Ill. 141 - Wind



Ill. 138 - Ventilation



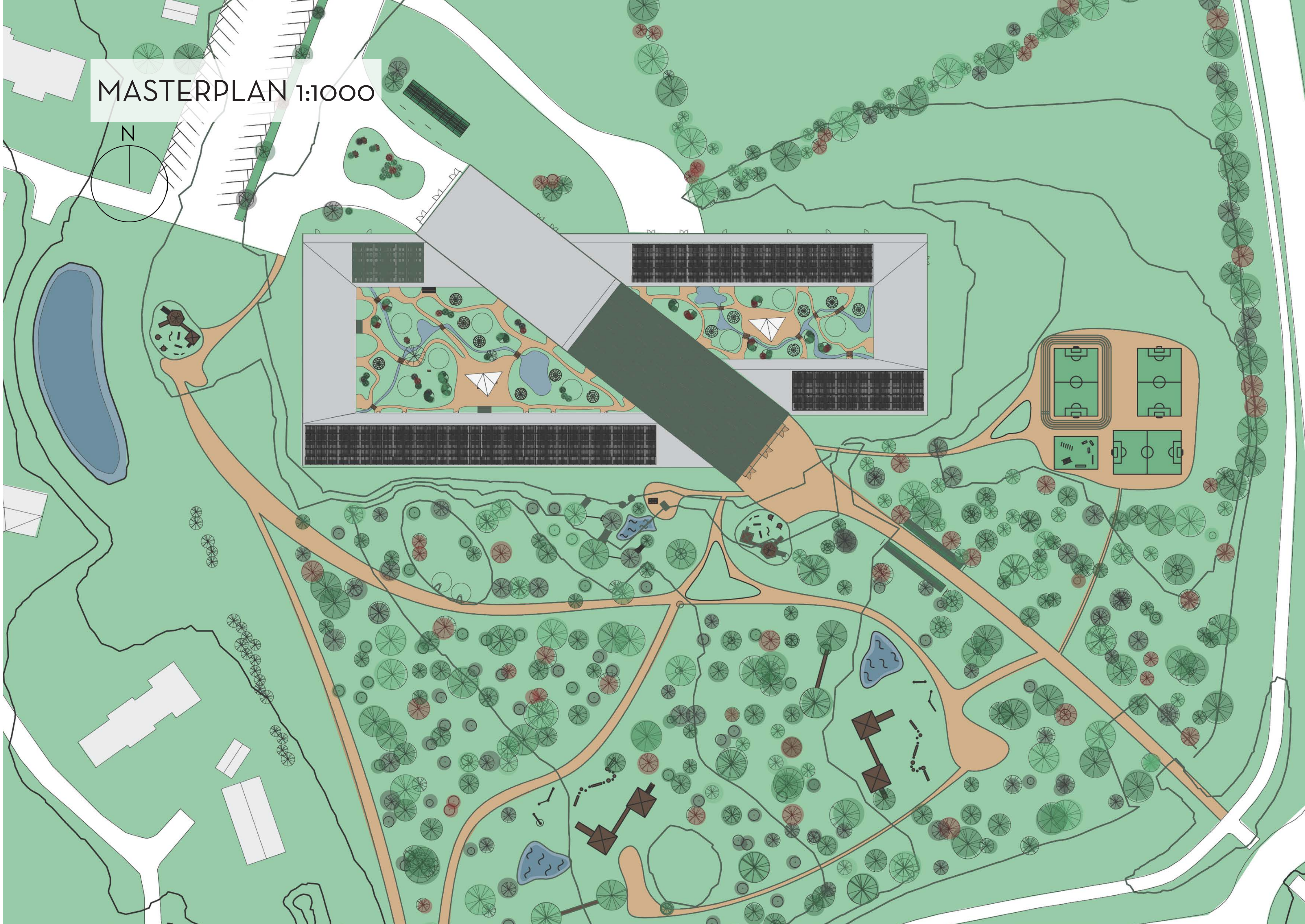
Ill. 140 - Wayfinding

PRESENTATION

This section presents the final design of the new primary school in Haderslev with masterplan and outdoor areas, floorplans, sections and elevations. This section also describes the different rooms and their functionality and flexibility and the idea behind the design of the classrooms, common spaces and the offices.

There is also a presentation of the construction of the building including the construction details and use of materials.

Furthermore there is a presentation of the ventilation principles and the indoor climate in general together with the energy demand.


MASTERPLAN 1:1000
N

OUTDOOR AREAS

The outdoor area around the school is divided into different zones as the plan shows. The area at the south end of the building is regular playground using nature materials, further to the west there are some hills and the environmental playground, that helps teach the children how to take care of the environment.

The rest of the area to the south is more nature playgrounds that are places inside the more forest like area of the site. Through this area there is a bike path that leads from the roundabout to the school.

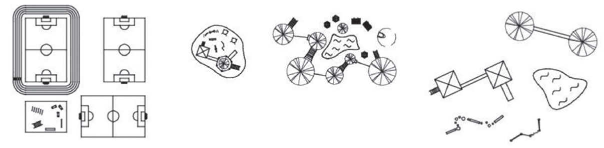
On the east side of the building the ballcourts are placed, because this is the most even part of the site.

Inside the courtyards the outdoor area is more quiet and there are space to sit down on various kinds of furniture, there are also some small green houses that can be used as a part of the environmental education, or for the children to stay in during recess, when it is cold outside.

The roofs on the clusters are used to collect rainwater to be used to flush the toilets in the school, but the remaining rain water will be collected to use to water the plants in the courtyards especially, and to deal with the rest of the rainwater the courtyards are designed with a stream system, that is designed to fill up with water when there has been a heavy rainfall, and thereby creating new possibilities for playing in the area.

The moodboards illustrates the feeling and idea of the different outdoor areas to give a general idea of the thoughts behind each area.

The playgrounds are marked on the site with the signature on Ill. 142.



Ill. 142 - Playground signature

Ill. 143 - Inside til clusters

Ill. 144 - Environmental playground

Ill. 145 - Forest playground

Ill. 146 - Regular playground

Ill. 147 - Sports fields

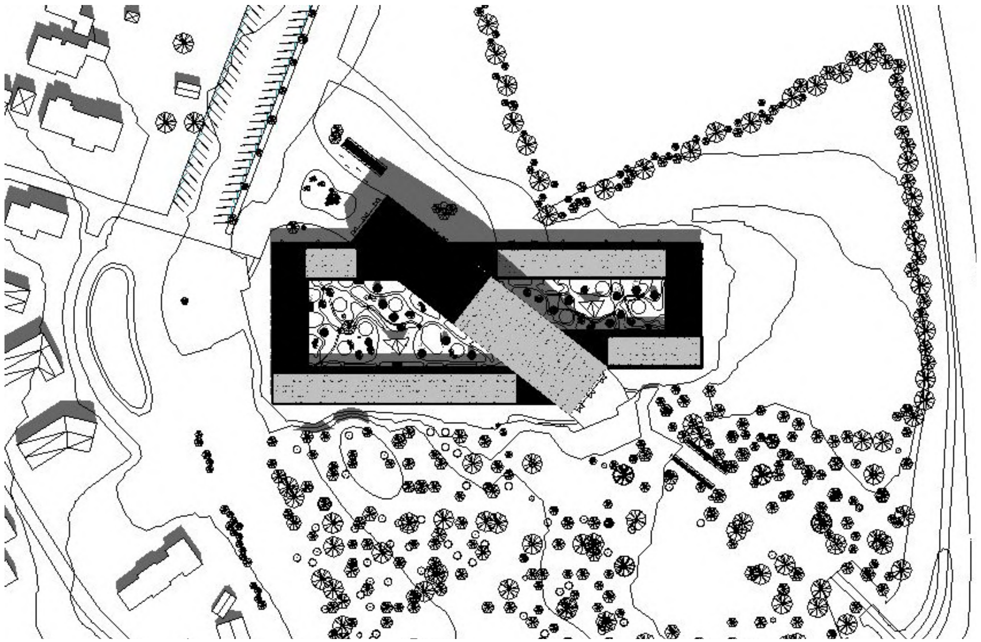
SHADOW AND WIND

The final design secures comfortable and attractive outdoor spaces, both with different types of areas, but also with the sunlight and wind.
The shadows mainly falls on the northern side of the building, where no playgrounds are placed, they are placed to the south, where the building never casts shadows.

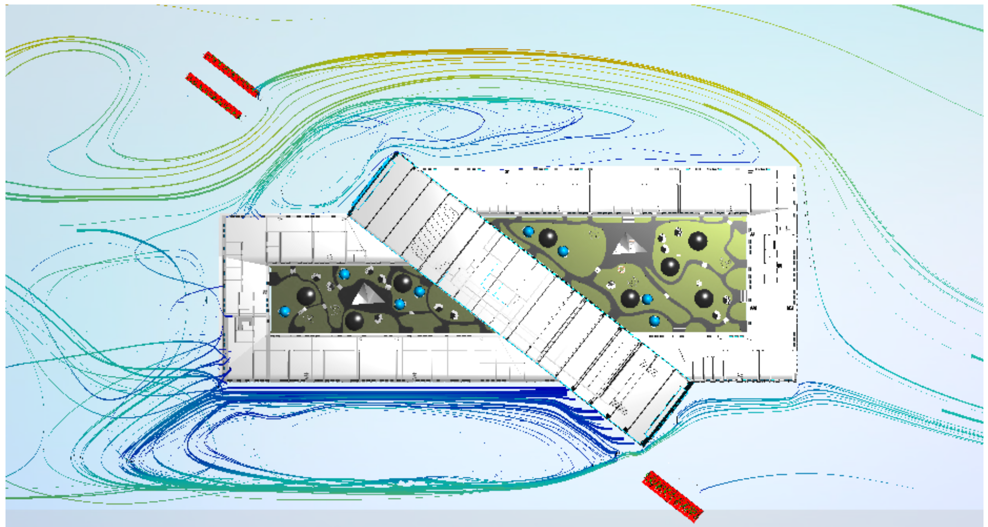
The playground are shaded by trees, but these trees also protects them from the wind, which flows on the southern side of the building, as Ill. 149 shows. Ill. 148 shows the shadows, which the final design casts at midt day on spring equinox, that is one of the days were the sun is lowest. It is taken midt day, because that is when the outdoor areas are mainly used.

The illustration shows, that the shadows do not fill up the entire courtyard, which makes the courtyards useable even in winter.

The wind simulation, on illustration xx, also shows that there is no wind in the courtyard at a wind strength of 5 m/s, which is a even wind. This means, that the courtyards have sunlight all year and no wind problems, which makes them comfortable to play in all year.



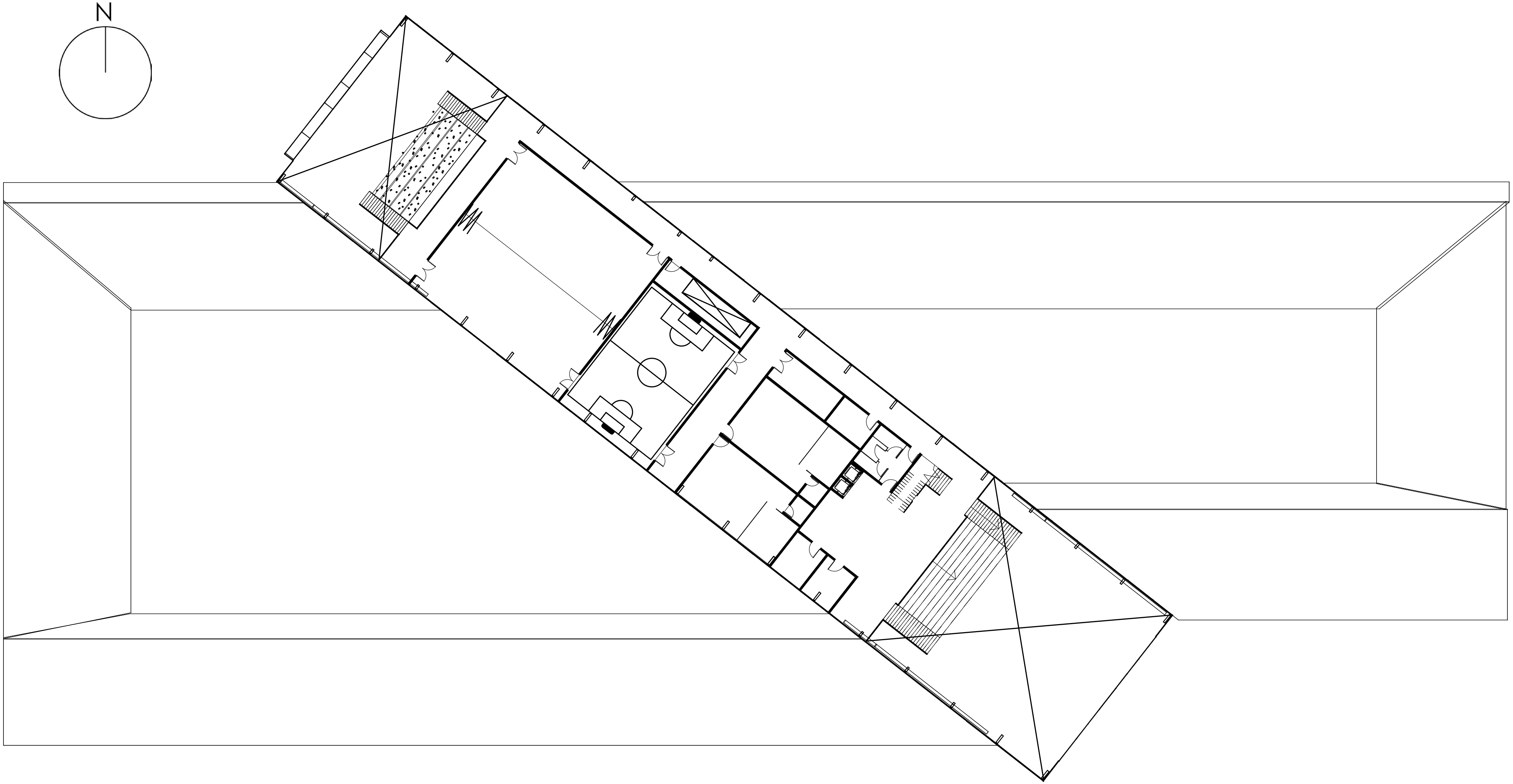
Ill. 148 - Shadows on the site at spring equinox at 12 o'clock



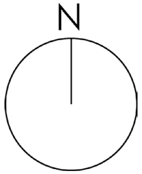
Ill. 149 - Wind at 5m/s from west

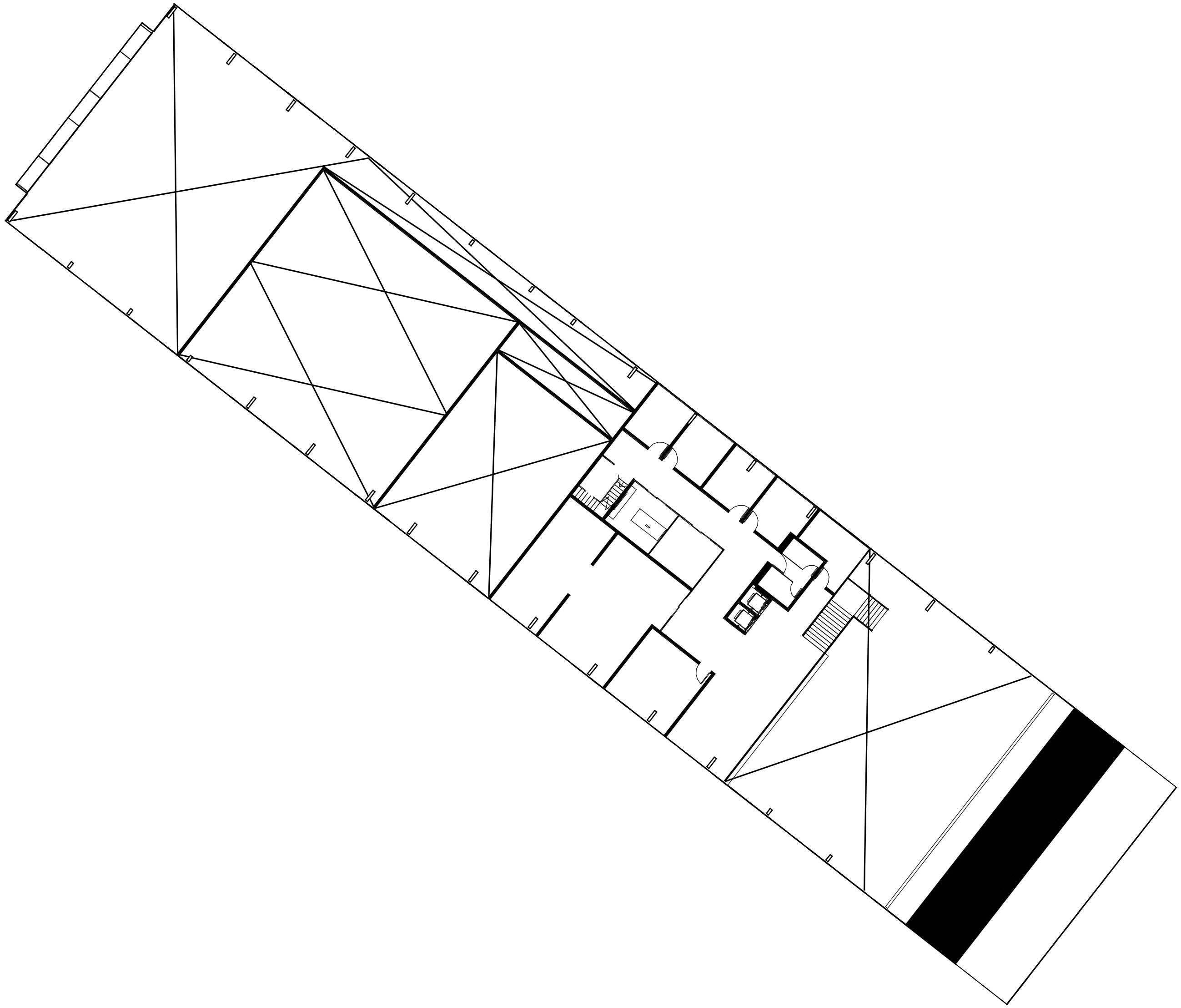
GROUNDFLOOR 1:500

FIRST FLOOR 1:500



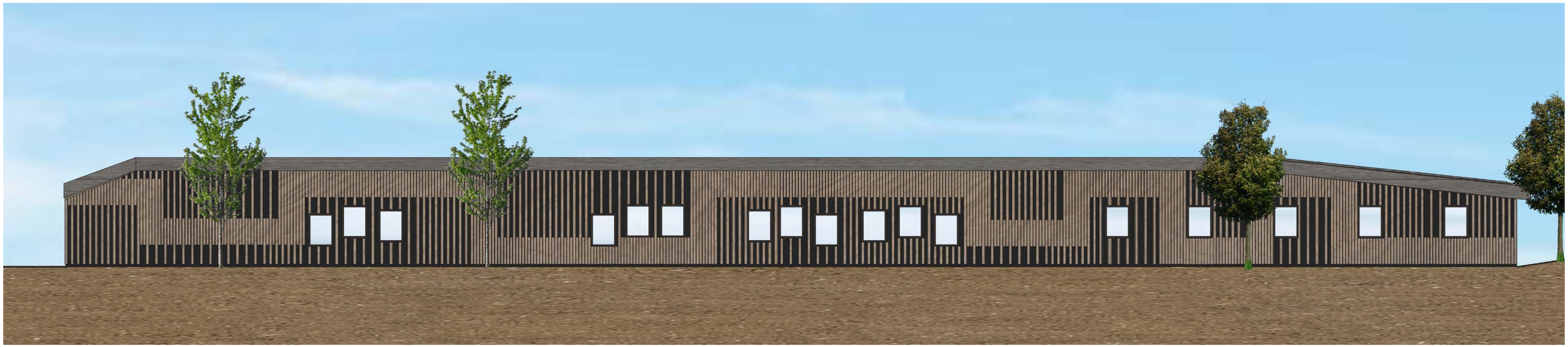
SECOND FLOOR 1:500





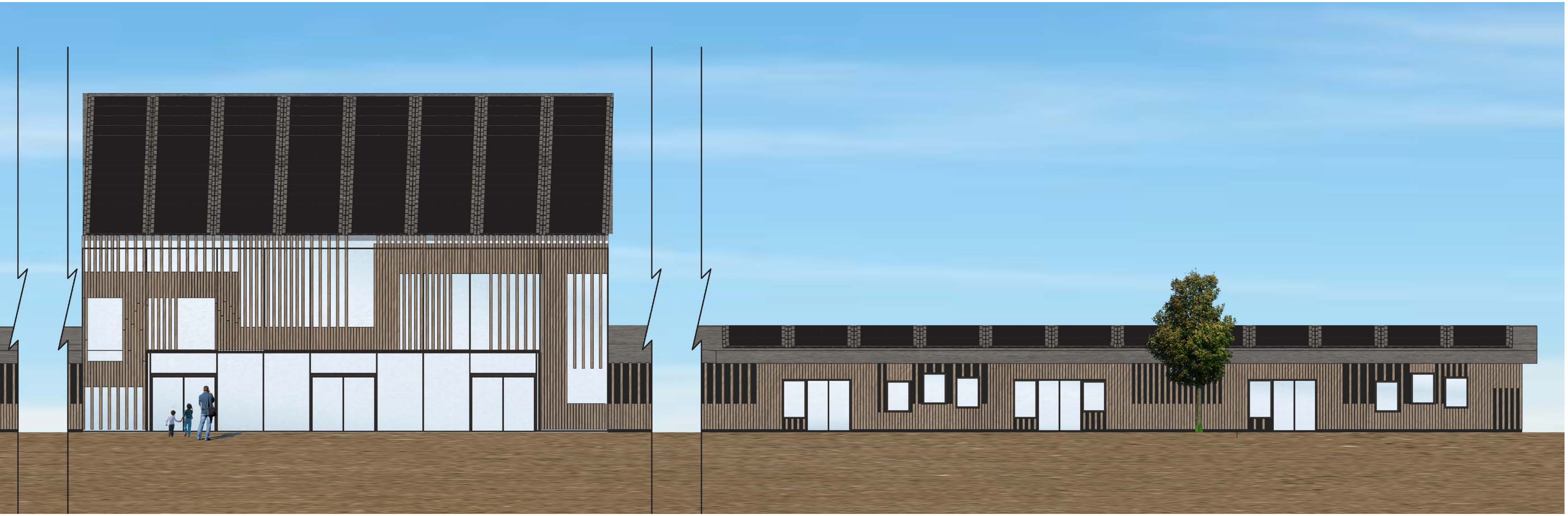
EAST FACADE 1:200

WEST FACADE 1:200




NORTH FACADE 1:200


SOUTH FACADE 1:200



SECTION AA 1:200

SECTION BB 1:200

VENTILATION & INDOOR CLIMATE

The main ventilation in the building is natural ventilation, that will ventilate the building in the summer, but due to the regulations and heat loss there will be mechanical ventilation in all the rooms, to ventilate during the winter.

To calculate the amount of ventilation in the rooms, an olfaction calculation was made for each of types of rooms to see how much ventilation each room needs. The calculation can be seen in Appendix 11.

The mechanical ventilation will be using mixing, and the supply will be in all the rooms suchs as class rooms, group rooms, staff rooms and so on, and the extraction will happen in the hallway, as the floorplan shows, the rest of the floors can be seen in Appendix 12. Section AA 1:200 shows how the pipes run above the suspended ceiling and the supply in the rooms are placed above the door into the room.

Because the mechanical ventilation principle are based on mixing ventilation, the rooms have been checked to make sure that all of the air is mixed without causing draft, the calculation can be seen in Appendix 14.

The indoor climate in the rooms regarding over temperatures and CO_2 levels can be seen in Graph 11 and Graph 12.

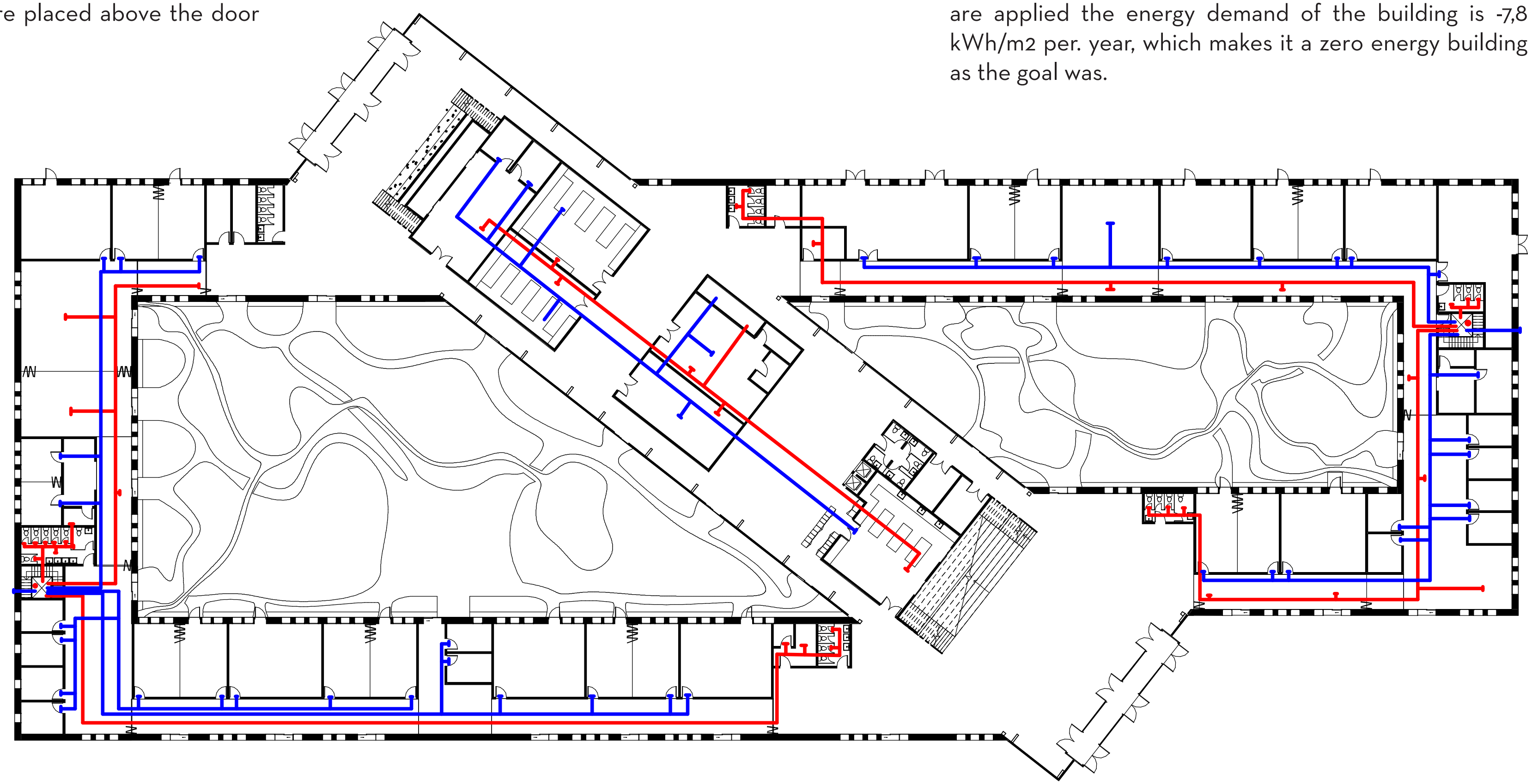
Besides from the atmospheric indoor climate the visual indoor climate has also been in focus, all of the rooms are upholding the 10% rule from the building regulation, and most of the them also have a daylight factor over 2% in average.

It is only the common space in the clusters where the hallway is a little lower than 2%, but due to the use of the room, it has been assessed that this part of the room do not need a higher daylight factor, since it is more a transit zone, than a working zone.

Illustration xx and xx shows the daylight factor of the classroom and the commonspace in the cluster.

The goal for the schools energy demand was to create a Zero energy building, and this is obtained when there are solar cells on some of the roofs.

The final energy demand without the solar cells are 17,2 kWh/m2 per. year, the school thereby upholds the 2020 demands for energy use, and then when the solar cells are applied the energy demand of the building is -7,8 kWh/m2 per. year, which makes it a zero energy building as the goal was.



DGNB

For this project, the focus has been on social criteria, which contains the demands for the user's comfort in different aspects, such as the air quality, safety, accessibility and the quality of the termal, visual and outdoor areas. The main focuses were especially on SOC 1.1: thermal comfort, SOC 1.2: indoor air quality, SOC 1.4: Visual comfort, SOC 1.6: quality of the outdoor areas and SOC 1.7: safety and security. (Dk-gbc.dk, 2019)

SOC 1.1 contains the demands for thermal comfort, to promote health and well-being at work and institutions. To get a room with an optimal thermal comfort, the room cannot be too cold or too hot, the air cannot be too dry or too damp and there cannot be any drag discomfort. To uphold SOC 1.1, the building has a combination of natural and mechanical ventilation, where the user can adjust the temperature by opening the window or door to satisfy their demands.

Beside the possibility of opening the windows, the outdoor blinds are also personal regulated. Through the simulations in BSim of the worst scenarios of three of the main rooms, an office, a classroom and a common room. It was possible almost to uphold the demands of 100 hours above 26 C and 25 hours above 27 C, in these rooms, the results had a deviation of three hour. To avoid drag discomfort during the winter, mechanical ventilation with recycling will be used, this would minimize the temperature difference and the drag.(Dk-gbc.dk, 2019)

SOC 1.2 is a demand, which secures an optimal air quality, by avoiding high concentrations of CO_2 and odor. This can be solved by dimensioning the ventilation-system or having windows which can open. In the final building the CO_2-concentration in the air, measured in ppm, does not exceed 900 ppm. It places the building in the low end of an Indoor Air Quality, category 2, which is a medium indoor air quality.(Dk-gbc.dk, 2019)

SOC 1.4 contains the demands for visual comfort, including daylight. Natural light has a positive effect on peoples mental and physical health, and it improves the learning environment. The average for the primary room, such as offices, classrooms and common spaces all nearly have a daylight factor of 2 %, they also meet the 10 %-rule, there the glass-area of the windows and doors corresponds to 10 % of the room area. To void glare, every window has a blind, which are personal regulated.(Dk-gbc.dk, 2019)

SOC 1.6 focuses on the quality of the outdoor areas close to the building, which are accessible for the user and public. The outdoor areas can promote the interaction between the users and improve the microclimate, like the LAR basins in this project. A varicosity of different outdoor areas, which accommodate the users' needs improves the quality of the stay, like the different types of outdoor areas in this project, such as the sport fields, the nature playground, the playground and the environmental, educational area.

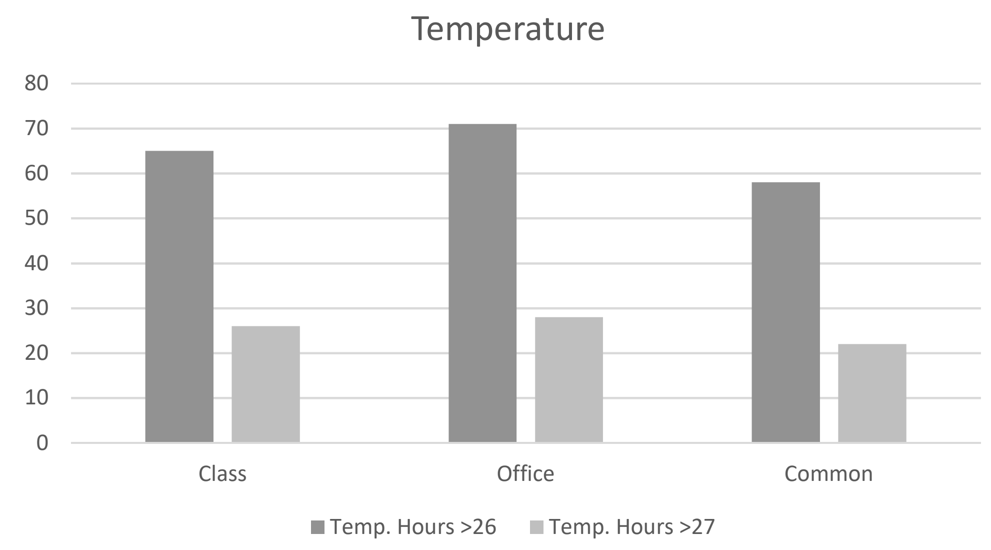
The related outdoor area also creates a relation between the indoor and outdoor. The outdoor areas are used in a social manor, especially with sitting opportunities. The building and outdoor area should be related through direct access and/or view from every room, which is also a possibility in the project. The roof is also actively used, both with solar cells and collecting rainwater, which are also one of the demands. The areas also include different types of shielding from both the sun, rain and wind, through planting, shields and lamellas.(Dk-gbc.dk, 2019)

SOC 1.7 is demands, which secure the safety and security feeling, that are foundational for people's well-being. To uphold this demand, it is a good idea to place light along the paths and outdoor areas, make manageable access-roads and parking areas for both bikes and cars, this can happen through way-finding. In this project, way-finding is integrated in the building through the sound panels, which are colored after the color of the concerned wing of the building. All the paths and parking areas on the site is lit by outdoor lamps. (Dk-gbc.dk, 2019)

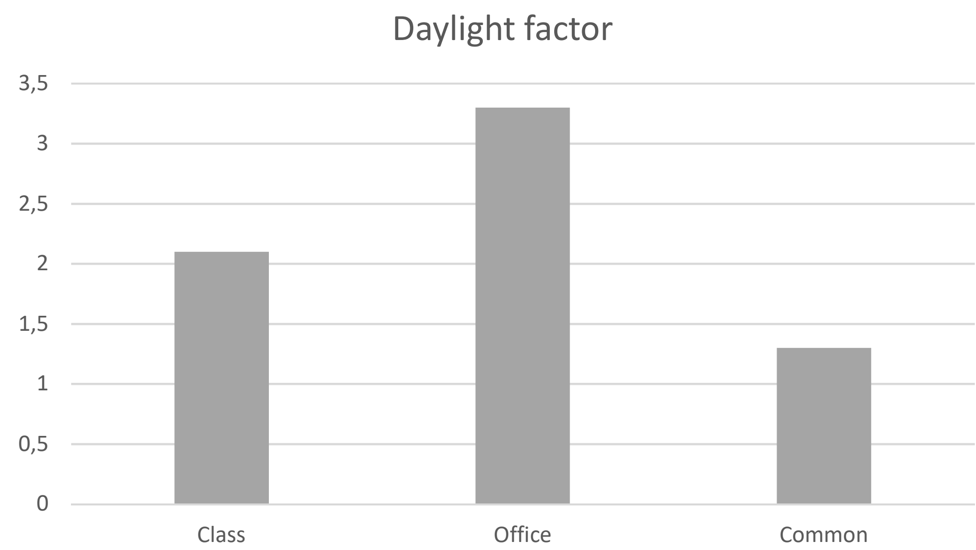
THERMAL AND VISUAL INDOOR CLIMATE

The graphs below show the final conditions in the classroom, office and in the common space in the clusters. As shown on the graph for daylight factor, only two of the room meet the demand of 2% daylight factor, but they all meet the demand of the 10% window area rule, that is described earlier in this report.

Regarding the temperatures, some of the rooms have a few hours more above 27 than wanted, but it has been an evaluation between having good daylight and having good tempratures in the rooms, there for this is the compromise that was made to meet both demands.



Graph 11



Graph 12

CONSTRUCTION

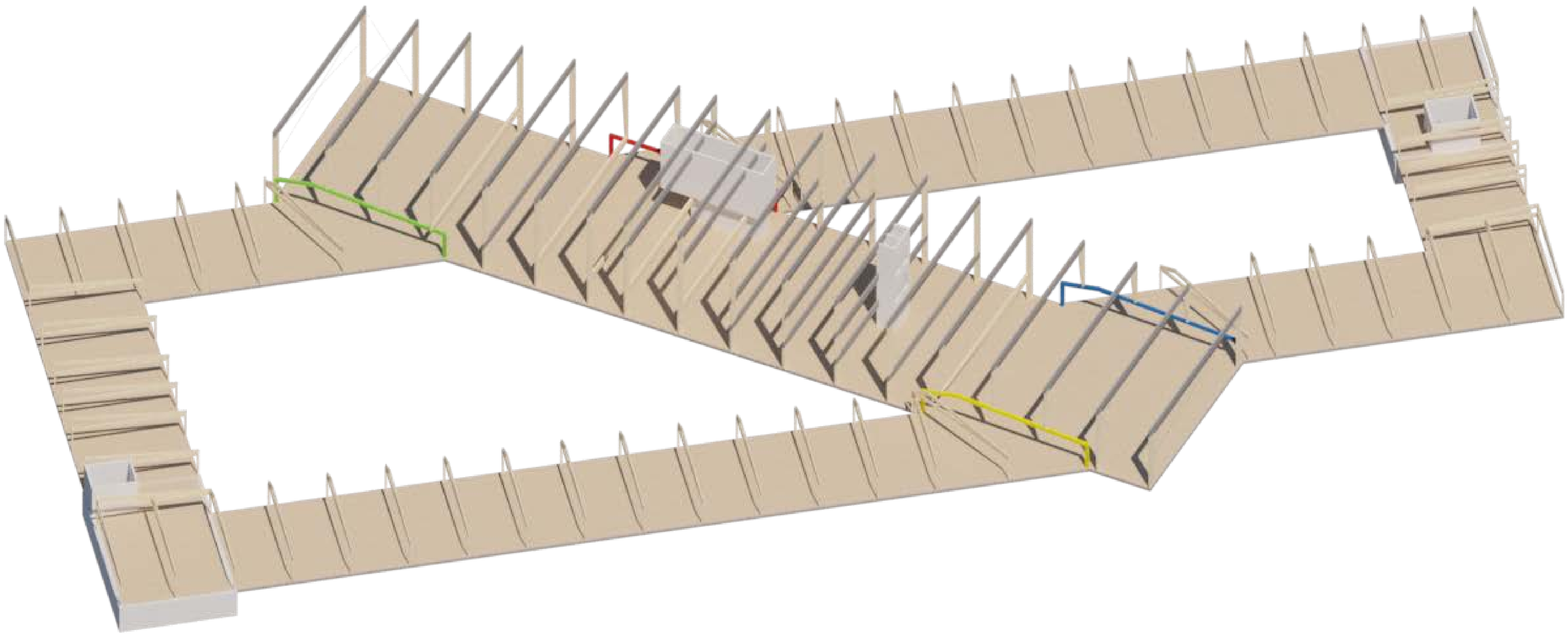
The final construction consist of columns and beams made from glulam. The dimensions for the glulam system in the clusters are 90 x 400 mm beam for the span of 11 m, which is the span for the cluster, and 90 x 200 mm for the columns to reach a distance of 5,8 m between each column.

The dimensions in the common area is 185 x 800 mm for the beam to reach a span of 19,7 m, which are the span in the common area, and 185 x 900 mm for the columns to reach the height of 8,6 m, which is the height for the of the highest column in the open common area.

The columns in the highest part of the common area are divided at each level. Between each column there is a distance of 5,5 m.

As mentioned before, the distance between the columns in the common area is 5,5 m, which creates an issue, with the wish of having open opening into the clusters. The distance between the columns should be 17 m to comply to this wish. The solution was to make a frame in steel, with a 300 x 300 mm square cross section, which can hold the loads from the columns, from the roof, and leed the loads to the ground.

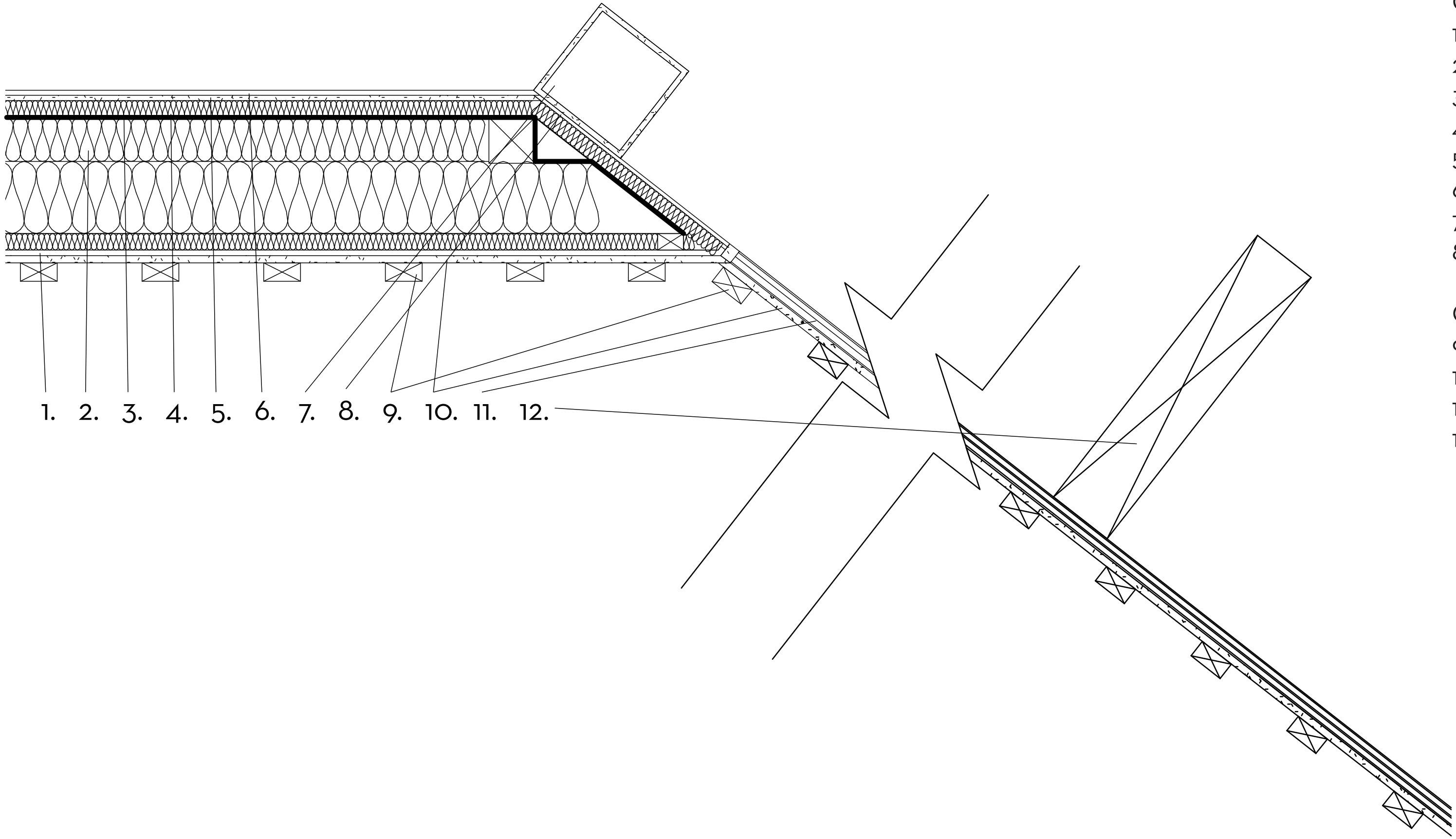
To secure stability in the construction, cross-bracing are placed in the ends of the clusters and the common area. The cross-bracing are placed in each of the outer walls and the roof, as seen on Ill. 150.



Ill. 150 - Load-bearing constuction

CONSTRUCTION DETAILS

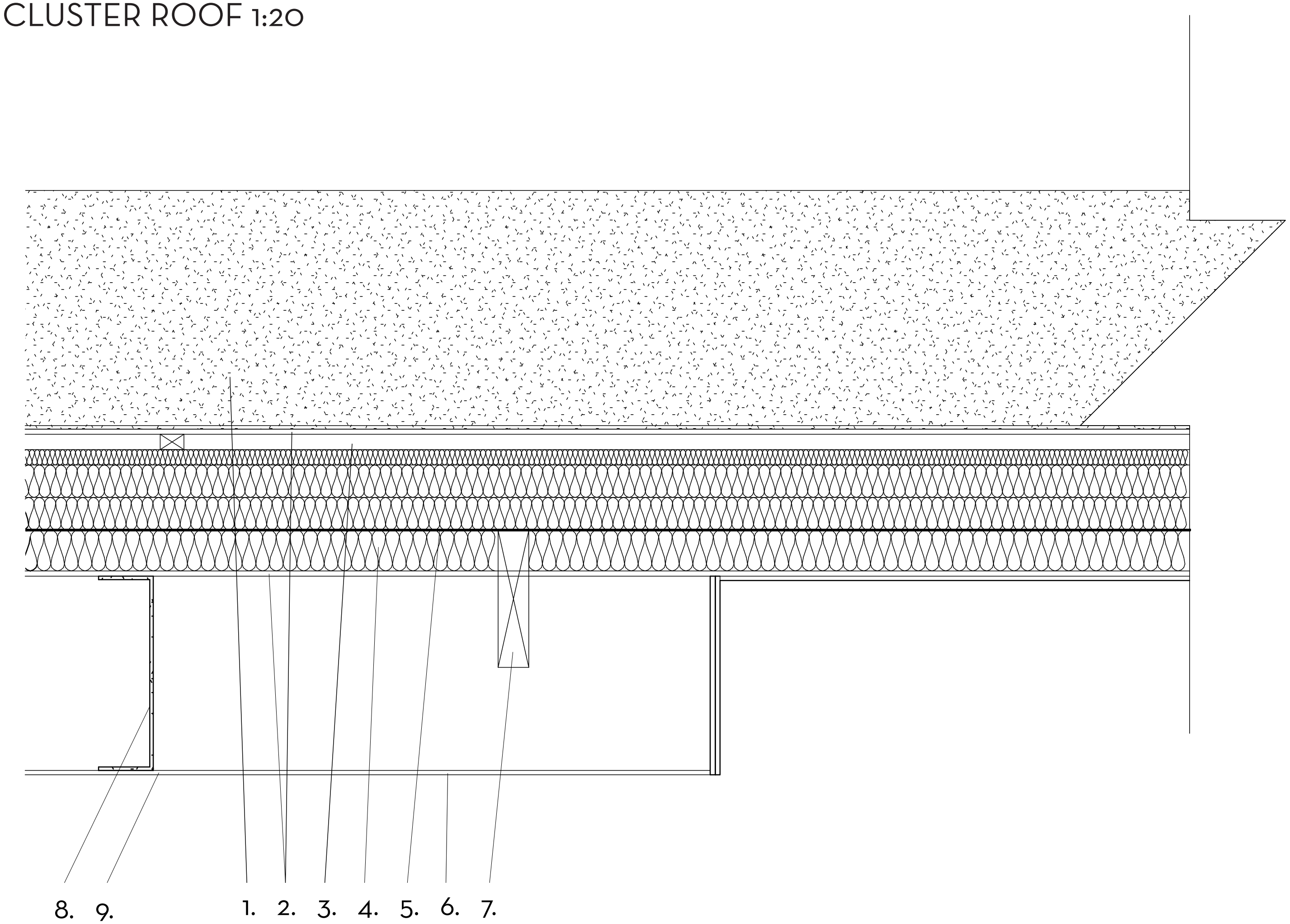
CLUSTER WALL AND GLASS WALL 1:20



Materials:
Cluster wall
1. Wind barrier
2. Insulation 45mm+95mm+95mm+120mm
3. Vapour barrier
4. Insulation 45mm
5. Plywood 15mm
6. Gypsumboard 13mm
7. Steel column 300x300mm
8. Plaster 10mm

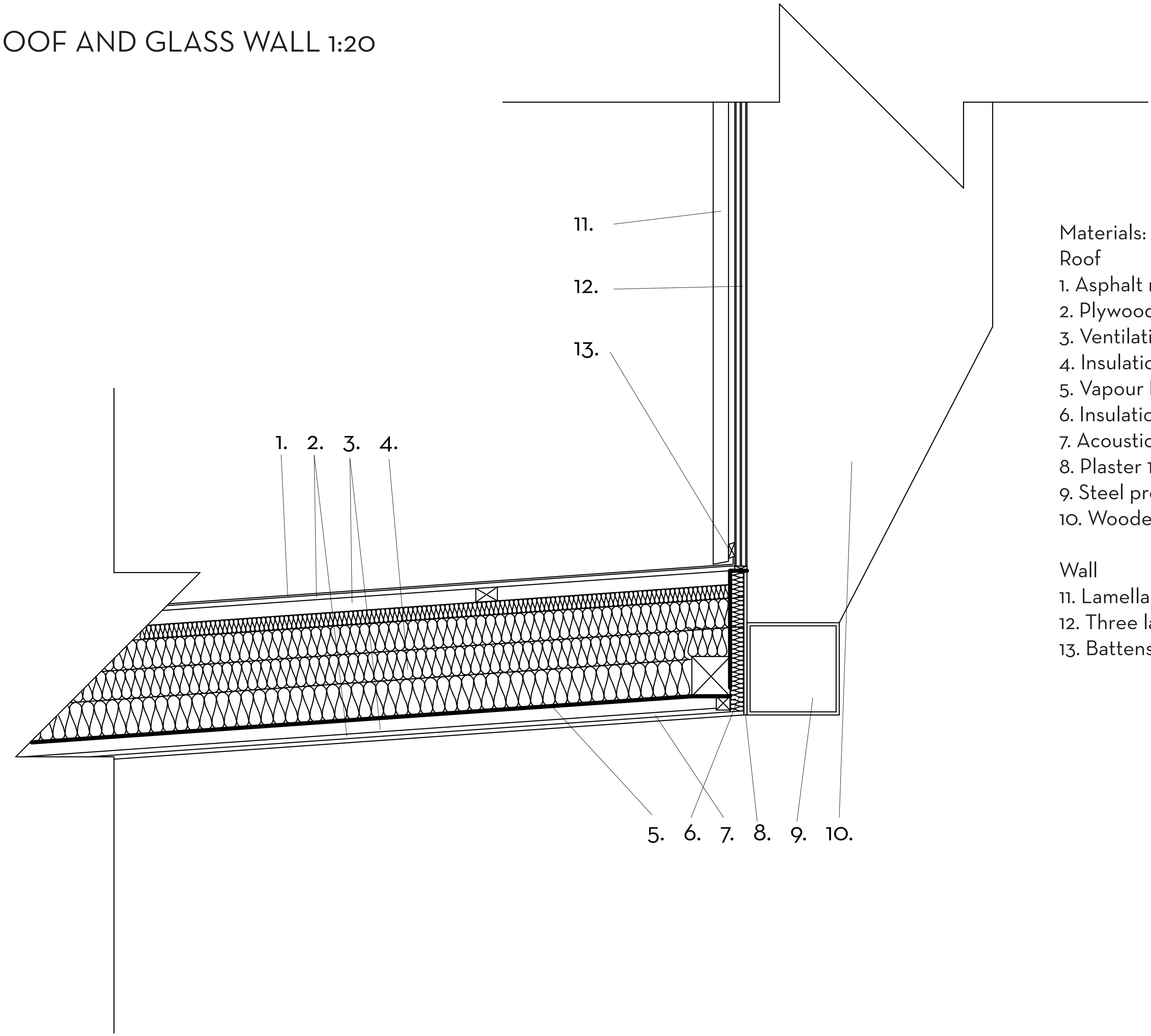
Glass wall
9. Lamella
10. Spaceing 25x50 mm
11. Three layer energy glass 40mm
12. Wooden column L40 800x185mm

CLUSTER ROOF 1:20



Materials:
1. Asphalt roofing
2. Plywood 15mm
3. Ventilation gap 45x70mm
4. Insulation 45mm+95mm+95mm+120mm
5. Vapour barrier
6. Acoustic gypsumboards 13mm
7. Wooden beam 90x400mm
8. Steel
9. Acoustic gypsum board

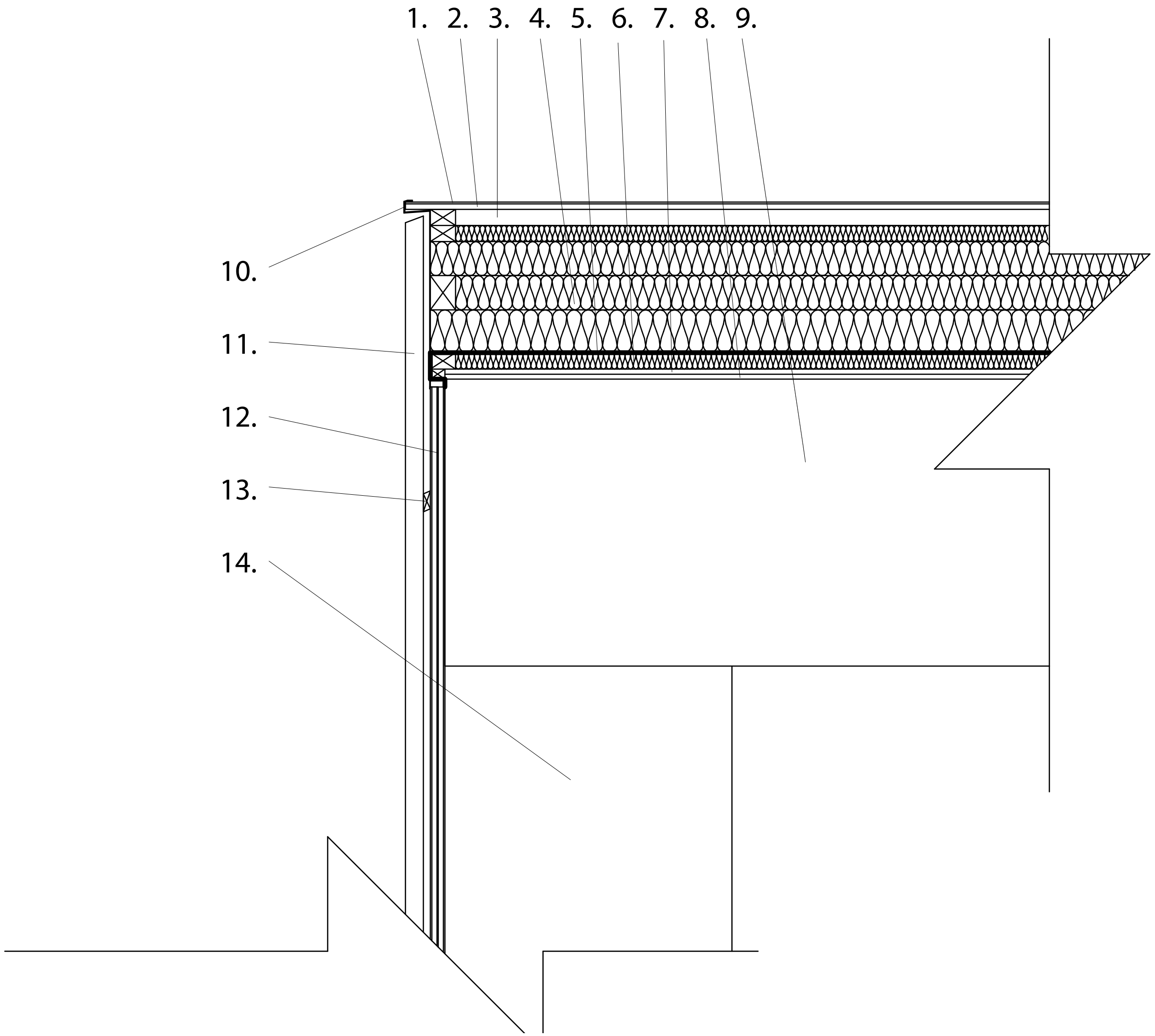
CLUSTER ROOF AND GLASS WALL 1:20



Materials:
Roof
1. Asphalt roofing
2. Plywood 15mm
3. Ventilation gap 45x70mm
4. Insulation 45mm+95mm+95mm+120mm
5. Vapour barrier
6. Insulation 45mm
7. Acoustic gypsumboards 13mm
8. Plaster 10mm
9. Steel profile 300x300mm
10. Wooden column 185x800mm

Wall
11. Lamella
12. Three layer energy window
13. Battens 20x45mm

ROOF AND GLASS WALL 1:20



Materials:
Roof
1. Asphalt roofing
2. Plywood 15mm
3. Ventilation gap 45x70mm
4. Insulation 45mm+95mm+95mm+120mm
5. Vapour barrier
6. Insulation 45mm
7. Plywood 15mm
8. Acoustic gypsumboards 13mm
9. Wooden beam 185x800mm
10. Zink edge

Wall
11. Lamella
12. Three layer energy window
13. Battens 20x45mm
14. Wooden column 185x800mm

MATERIALS

The materials used in the school are all warm, durable, easy to clean and the ones that are coloured are done so in a calm colour to give a calm, warm and welcoming look inside the school.

The materials used in the clusters are perforated gypsum ceiling plates for the ceiling to ensure a good acoustic environment in the hallway, the floor in the hall is bamboo, which is also the floor material used in the classroom.

In the common space in the clusters the floor material is bamboo laminate, in order to keep the noise down. All the walls in the clusters are white gypsum, but the niches that are placed along the wall are made of plywood.

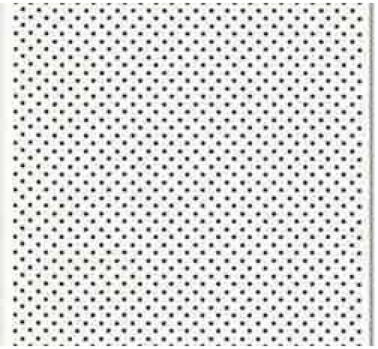
On the walls there are acoustic panels, that are fabric panels in toned down colours.

In the big common space the floor is also bamboo, and in here the walls are white gypsum as well. In the common area the construction is visible, and the construction is made of glulam L40 bamboo. One room that stands out from the others are the gyms, which walls are made of translucent polycarbonate, in order to show the shadows of the children using the gym.

On the outside, the building is covered in oak lamellas a long the facades. On the clusters the background of the lamellas are a black air barrier, and on the common space it is a glass wall. The frames of the window in both the clusters and the common space are black aluminum, because it makes the windows stand out, and is the most durable when choosing outdoor materials for a window.

On the roof of the building there are two materials, in some places there are solar cells, that keep the building a zero energy building, but in the places where there are not solar cells there are black asphalt roofing.

The materials can be seen on the pictures on the next pages.

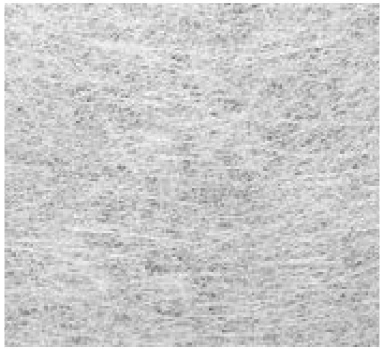

Perforated gypsum ceiling

Gypsum walls


Bamboo floor


Bamboo laminate floor


Glulam bamboo columns and beams


Fiberglass niches


Plywood wall niches

Polycarbonate wall


Fabric panels


Oak lamellas

FIRE ESCAPES

The fire escapes in the building in the ground floor from the doors along the hallways in the cluster and the main entrance area. The fire escapes is shown in Ill. 151. There are less than 25 meters from the center of each room to a fire escape that leads to the outside. The door to the courtyards inside the clusters are not considered fire escapes since there are no way to get away from the burning building inside the courtyard. All fire doors are opening in the direction of the escape, which means outwards.

Ill. 151

MAIN ENTRANCE

The main entrance of the school is placed towards the north, where the road is, and the parking lot. When entering the school people are met by a big climbing wall, that is made in combination to the staircase that leads up to the gyms. On top of the stairs the gym walls are made of polycarbonate to show the activity happening in the gyms.

At the entrance there is a view of the first two hallways, that lead to the different clusters, as mentioned earlier each cluster opening has its own color to make wayfinding easier.

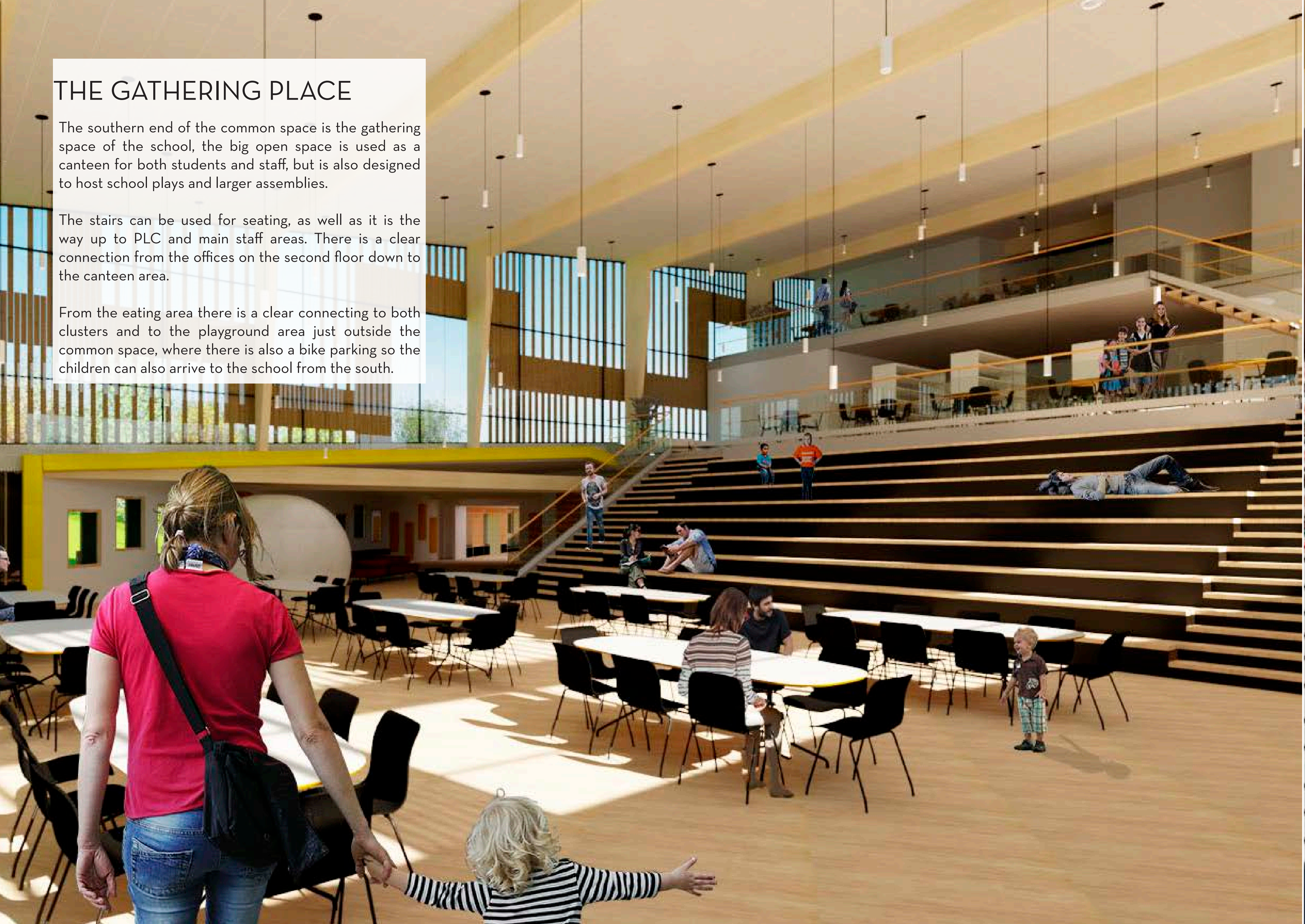
The double height in the room helps create a “wow” effect when entering the building, and the staircase/ climbing wall creates a good connection to the gyms on the first floor.

THE GATHERING PLACE

The southern end of the common space is the gathering space of the school, the big open space is used as a canteen for both students and staff, but is also designed to host school plays and larger assemblies.

The stairs can be used for seating, as well as it is the way up to PLC and main staff areas. There is a clear connection from the offices on the second floor down to the canteen area.

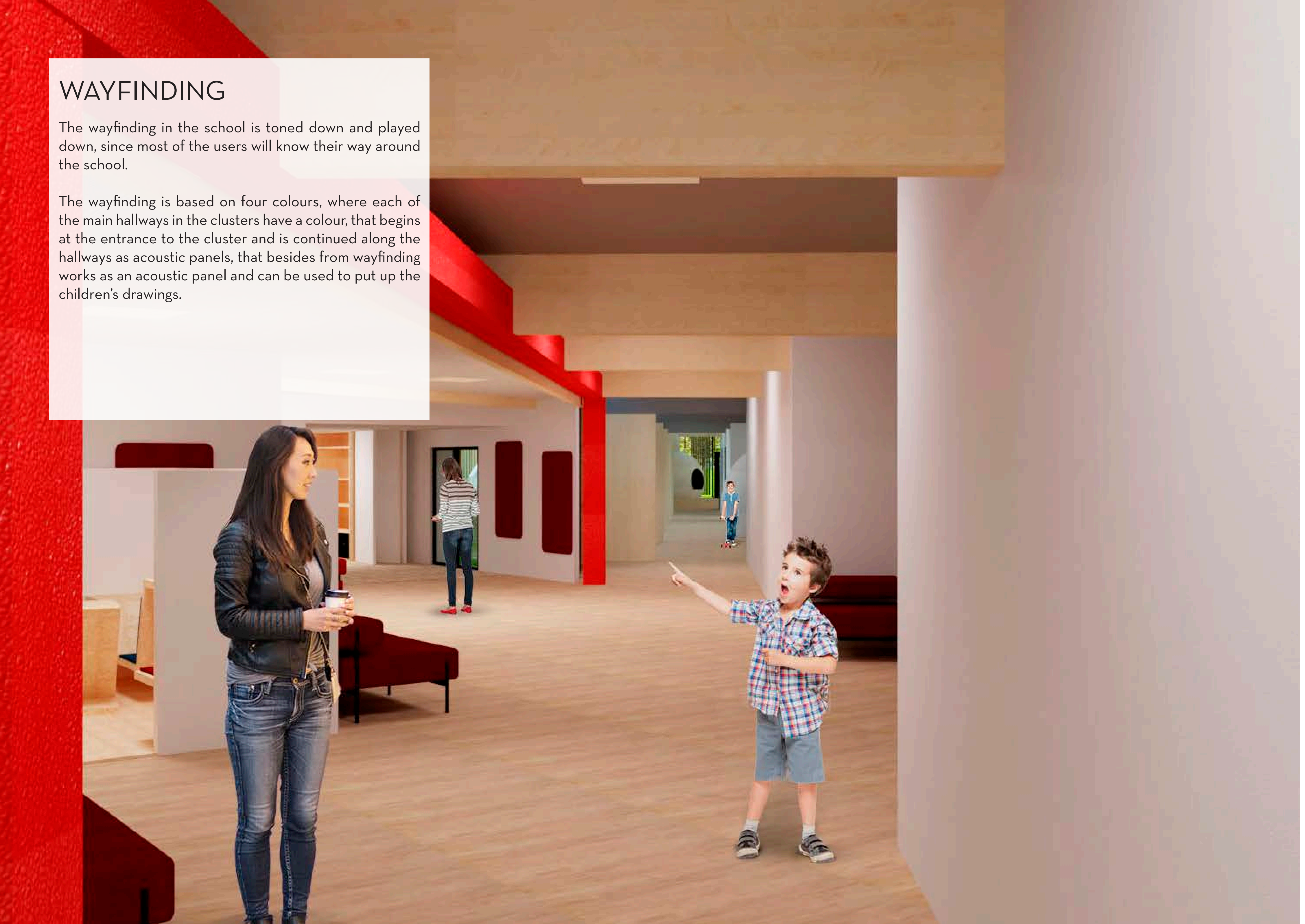
From the eating area there is a clear connecting to both clusters and to the playground area just outside the common space, where there is also a bike parking so the children can also arrive to the school from the south.



WAYFINDING

The wayfinding in the school is toned down and played down, since most of the users will know their way around the school.

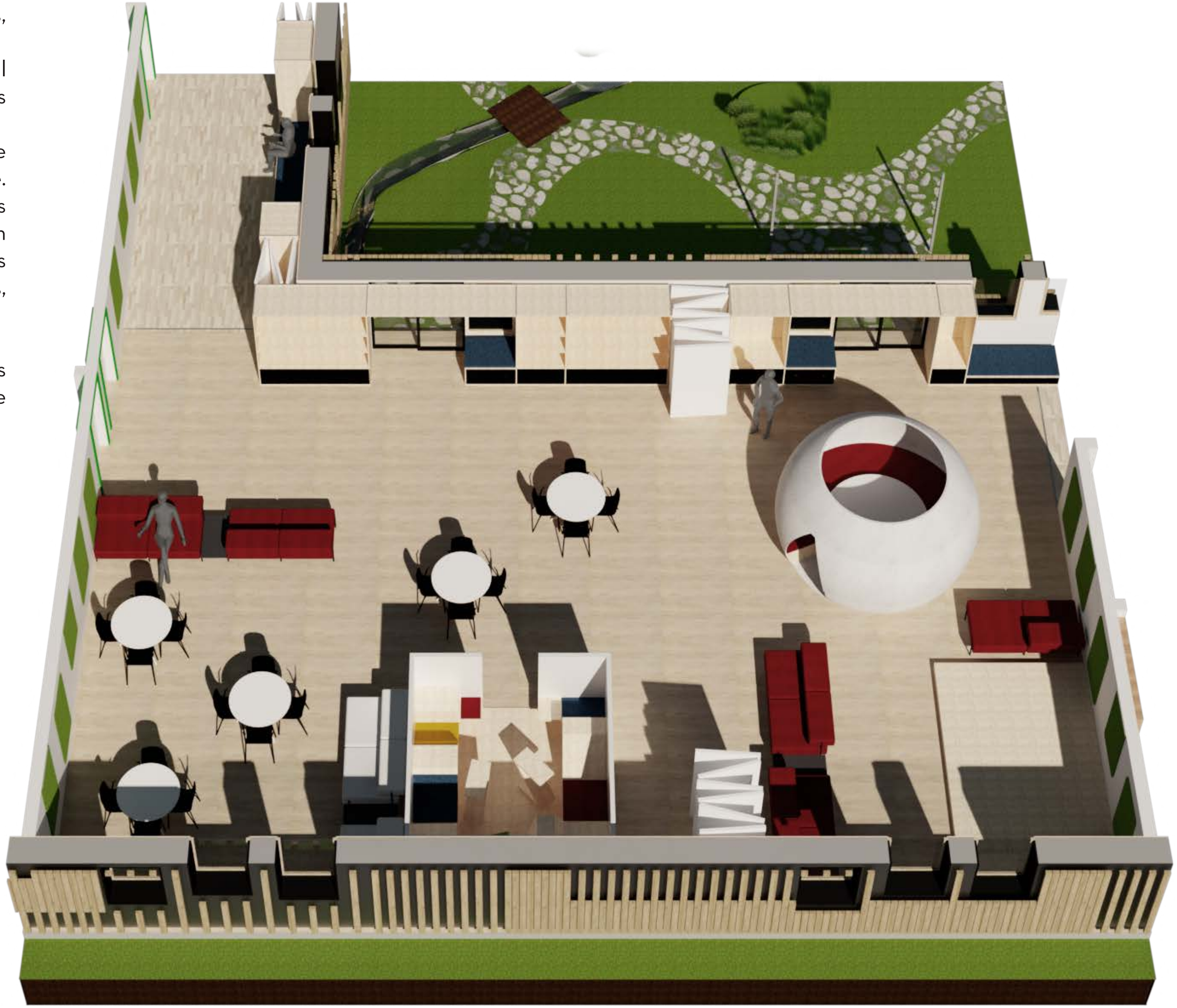
The wayfinding is based on four colours, where each of the main hallways in the clusters have a colour, that begins at the entrance to the cluster and is continued along the hallways as acoustic panels, that besides from wayfinding works as an acoustic panel and can be used to put up the children's drawings.



COMMON SPACES IN THE CLUSTERS

The common spaces in the clusters are designed to accommodate different types of learning. The common spaces are spaces for the children to use during recess, but also as group space during classes.
Some of the common spaces are organized with a small elevation in a section of the floor, the children can use as a stage.
In the common spaces some of the smaller niches are placed, to create smaller spaces inside the bigger space. This is also done along the halls, where there are niches all the way down the hall, these niches are designed with both wardrobe space as shelves and rags for the childrens jackets, there are also seating space in different heights, that the children can use.

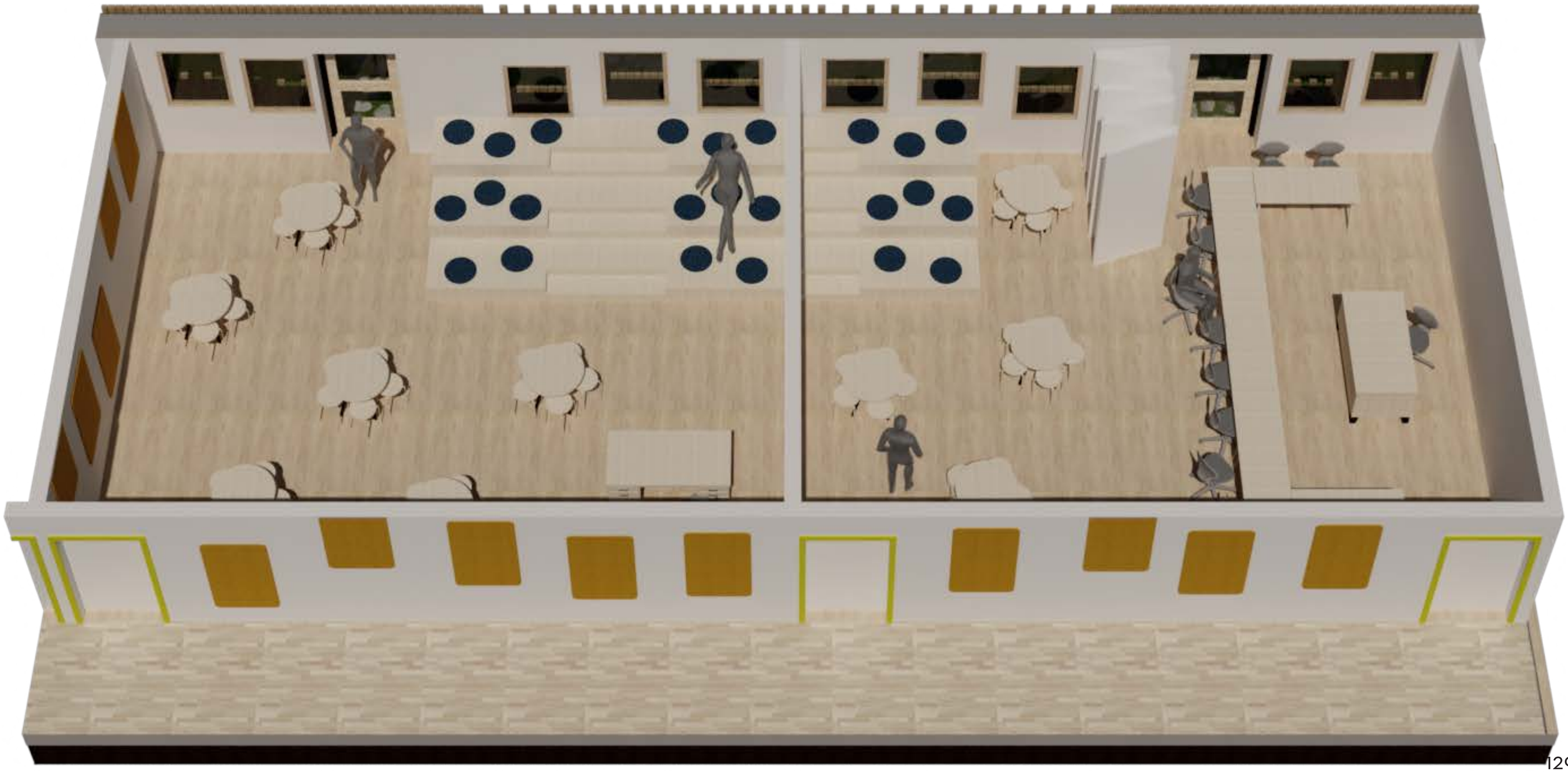
The halls are used for wayfinding, as the different halls have their own color, and this color is repeated in the acoustic panels down the hallway.



THE CLASSROOM

The classrooms at the school are designed to fit all kinds of different learning styles and types of teaching. All the classrooms are facing north, to get the good diffuse light for the children to work at.

The classrooms are designed with space for both regular blackboard teaching, but also with a small staircase, where the children get the opportunity to sit or lay down during class, this gives the children the opportunity to place themselves as they would like during class.
The different layouts for the classrooms can be seen in the floorplan.



CUBE NICHE

The cubed niche is open at the top to let in some daylight, but still allow the children to work in peace inside.

The inside design is a seating arrangement, that has many different heights in a curved shape, that runs along the wall of the niche, in the middle there are tables that can be moved to allow the students to place them as they need.

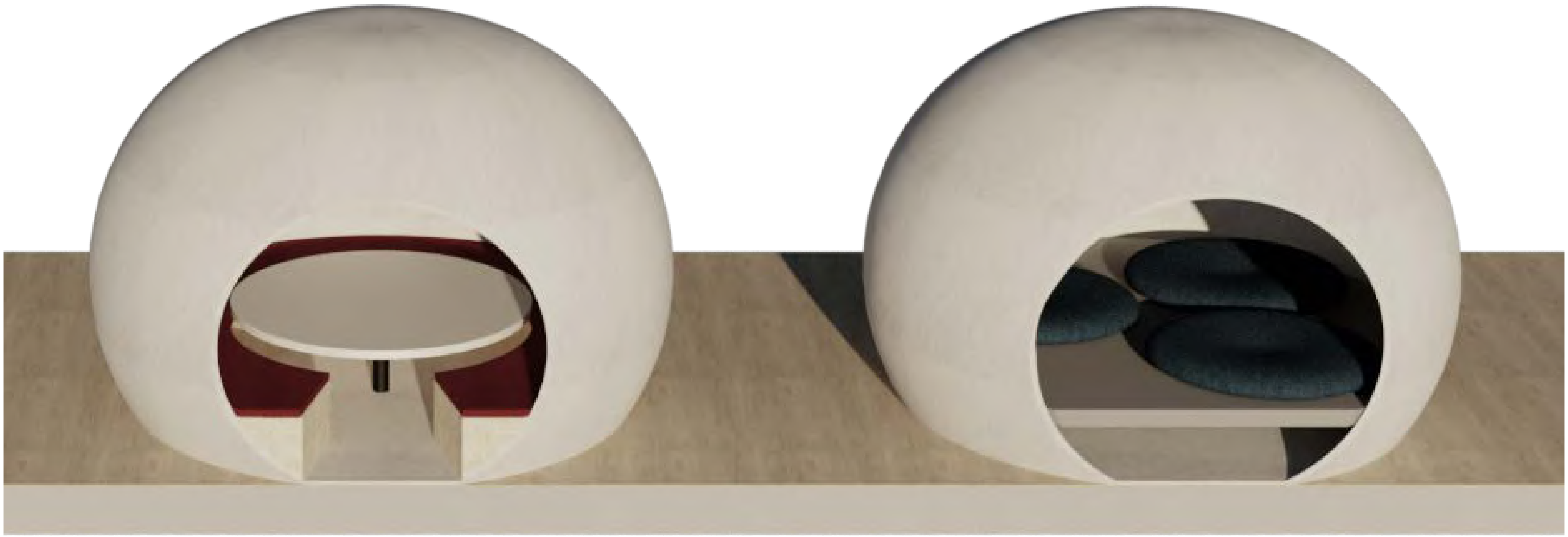
The shape of the seating makes it possible for the children to sit in the exact position they prefer. There are pillows on the seats, but otherwise it is made out of fiberglass, and the walls are made of plywood.

ROUND NICHE

There are two different round niches, one that is one big pillow the children can lay on, and one that has a bench along the side and a table in the middle.

The round niche is closed in the top, so no daylight can get into the niche except from the entrance. The light inside the niche can be regulated by the children, so they get the choice to work in dim or bright artificial light, in this way the niche accommodate many different learning styles.

The niches is made of fiberglass to obtain the round shape, and this also allows the school to have the niches in different colours if wanted.



OFFICE

The offices are placed on the 2. floor with a good visual connection to the lower floors and an overview of the canteen area.

The office is designed for two people, and has a build in bookshelf, that also has a seating in it, with a soft pillow, so the staff also have the possibility to sit and work more comfortably, in the possisition they prefer.

Besides from the offices, the staff area on the 2. floor also has meeting and preparation rooms. The meeting rooms can also be used as offices when not in use for bigger meetings, the preparation room is a more quiet room for the teachers to sit in quiet and prepare for their classes.

CONCLUSION

The final design is a sustainable primary school, that motivates the children from 0th to 6th grade to learn new things and do so on their own terms according to the individual child's learning style. This is done with classrooms, that are flexible and design to create different learning environments, also the common spaces in the cluster are designed to be flexible and of many uses, besides form the classrooms and common spaces there are niches all over the school, that either gives the children the privacy or community they need to learn something new.

The main entrance of the school is a large open space, that opens up and gives the user a view of many levels as soon as they enter the building. In the entrance area there is a big staircase that leads up to the 1. floor where the gyms are located.

The middle of the staircase is a climbing wall, so the children and teacher can chose to climb up to the gym or take the stairs, there are also an elevator in the school, but this is only for disabled people and for transporting goods and equipment from one floor to another. The gyms are designed with a polycarbonate wall that is translucent which gives an idea of the movement happening behind it, but still keeps the privacy of the users of the gyms.

There are also the possibility to work in different light settings, which is also provided by the niches, since there are niches, that are open to daylight, some that are closed and many that is placed along the halls to also give the school some life during classes.

In the hallways there, are also acoustic panels along the walls, that has three different functions, number one is creating a better acoustic environment in the hall, number two wayfinding due to the colour coding of the hallways and the clusters, and lastly as a creative way to show all the different things the children make during the day, suchs as drawings. The school is designed centered around a large common space, that hosts the gyms, workshops, staffarea, PLC and the canteen.

The canteen is for everybody at the school, and teachers are encouraged to eat their lunch in the canteen with the children, both to get better relations to the children, and to keep an eye on the children to make sure there is no trouble during the break.

The open canteen area is also a transit area from the inside of the school to the outside playgrounds, which are divided into different zones, which all use natural materials. The zones are a regular playground, forest playground, sports area and an environmental education playground, that the teacher can use during class to teach the children how to take care of the environment and how they can grow their own vegetables, compost and recycling.

The school itself is made sustainable with passive cooling and heating to save energy. Also the school collects rainwater to flush toilets, and to use for watering the plants in the greenhouses and the other plants in the outdoor areas.

Last but not least there are used two different renewable energy sources, which are solar cells and geothermal heating. All these strategies help make the school a zero energy building.

The passive cooling and heating is also important to obtain a good, low energy, indoor climate. The indoor climate has been a big focus of this project, there has especially been a big focus on the atmospheric, visual, acoustic and thermal indoor climate.

The chosen DGNB demands is obtained in the project, and they were chosen to ensure a good indoor climate in the classrooms, offices and common spaces. In all the working spaces there are a daylight factor around 2%, a CO_2 level well under 900 and the temperatures in the rooms do not exceed 26 degrees more than 100 hours a year, and there are less than 25 hours above 27 degrees.

The materials for the school is chosen based on a sustainable and durable focus, but also with a focus on the texture and the feeling the different material would give the building. The building is build in wood, because wood is sustainable and it has a warm and natural sensation to it. The type of wood for the facades and the interior were chosen based on a LCA calculation, to see which of the wanted wood types that was most sustainable

REFLECTION

The focus of the school was to create a learning environment with a good indoor climate, the indoor climate was investigated in different ways, but the common point in all of the investigations were, that they were all a simplified calculation. Most of the indoor climate was calculated in BSim, but due to the limitations of the program, the simulation of the big common space had to be made simple in order not to take up too much time.

The common space is calculated with a smaller percent of glass, that should make up for the missing lamellas, but of course this does not give a completely realistic result. The result can still be used, if it is taken into consideration that the simulation does not fit real life. The way we did this was to make sure, that the common space more than fulfilled the DGNB demands for the indoor climate, so that if the conditions were worse than calculated, there would be a buffer to handle the oven temperatures.

In relation to the indoor climate, the technical rooms were thought into the project very late, which means that they are not as well placed as they could have been, but by combining the technical rooms with the rainwater collection tanks a basement was made to contain both the rainwater tank and the ventilation unit.

The technical rooms should have been considered earlier in the process to integrate them into the project. One reason that they did not was, that at first the school was supposed to be ventilated only by natural ventilation, except from the toilets and the offices, but due to building regulations this was not legal, therefore the mechanical ventilation had to be worked into the plan.

This is also why there are two pipes running down the hallway, because the suspended ceiling was not suspended enough to fit a bigger pipe. The other reason was, that the pipes were divided into two was because of the pressure loss in the ventilation system, that was becoming too big.

Another thing, that could also have been thought into the project earlier are the fire escapes on the first and second floor. There are some problems with the distance to the outside, that does not uphold the demand in the building regulations. It could be solved by moving the floors closer towards the doors to the outside, but this would ruin the connection from the canteen area to the PLC and the staff area, and this connection is very important to keep the school tied together as one. The regulations also demands, that there are more than one escape staircase to each floor, which there is not on the second floor.

The rainwater collection in general is only designed and planned on a superficial level, it is well integrated into the outdoor areas, and handled as best as possible, and the outdoor area is designed to deal with big amounts of rainwater, but the rainwater collection for flushing the toilets in the school, is not planned down into the detail. The amount of collectable rainwater is calculated due to the amount of rainwater and the surface of the roof that we are collecting from.

Due to the placement of the school there are a large outdoor area surrounding the school, the focus regarding the outdoor area has been on the area inside the clusters and the area just around the building. The rest of the area is only defined by a principle, and a general idea of the use of the area. There could have been more focus on the rest of the outdoor area, and maybe it could have been used more in design, to make sure, that the area around the school is just as attractive as the environments inside the school.

The large outdoor area is also part of securing the school for the future. During the design phases the future of the school is also considered in the final design. Because of the final shape, it will be easy to expand the school, if needed, without ruining the architectural expression of the school, also the facade is easy to carry on if the building is expanded.

As it is with the simplified simulations for the thermal indoor environment, so it is for the acoustic simulations as well. In the calculations the rooms do not quite reach the DGNB goal, but the simulation is done without furniture and people which will lower the reverberation time even more than it is now, also the acoustic panels, that are placed all over the school, to be used as a pin-up board, but most importantly for acoustic reasons,. More of those can be hung or taken down according to the actual needs of the school.

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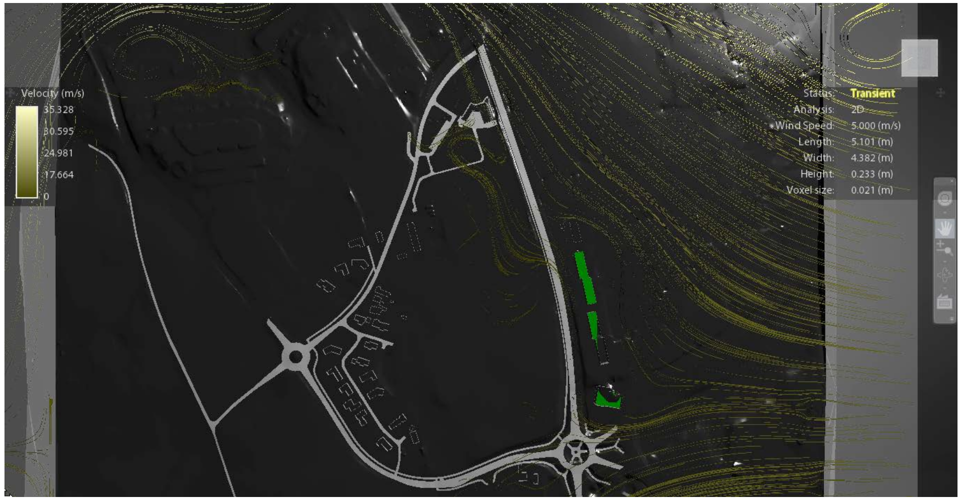
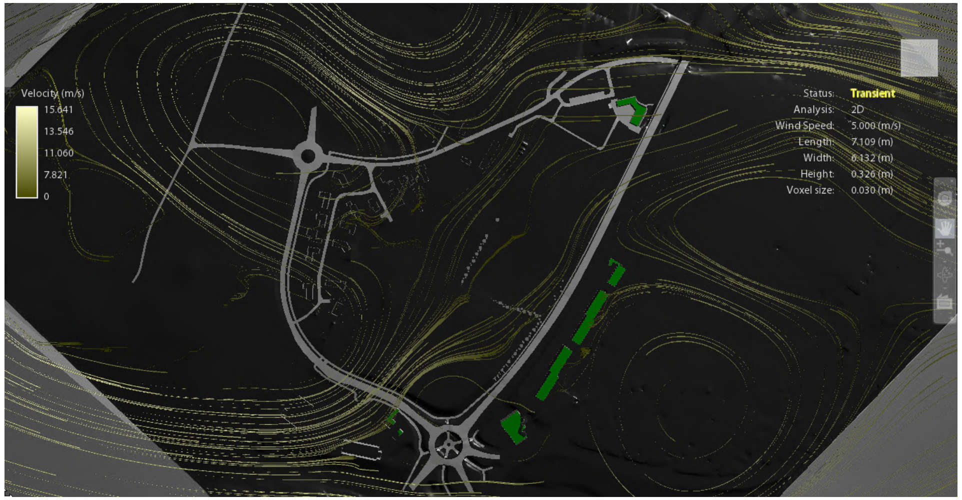
Ill. 60 - Ill. 151 - Own illustrations

APPENDIX

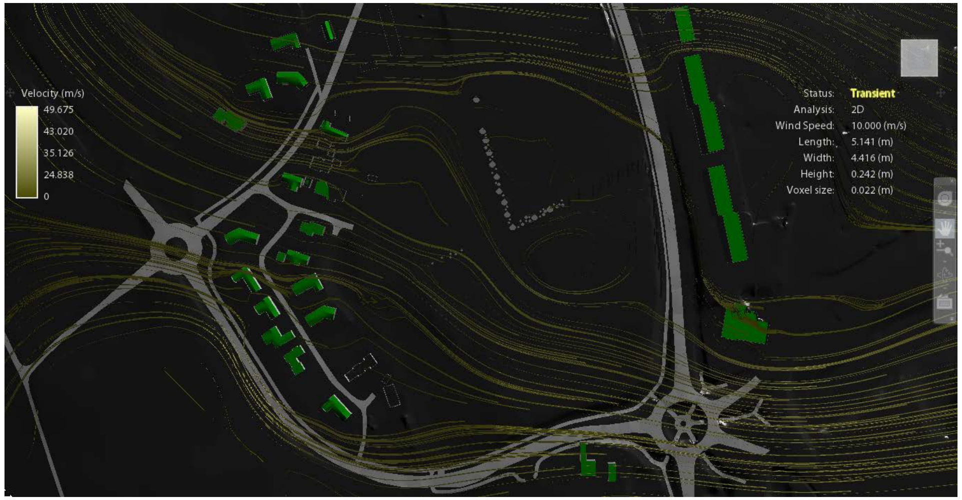
APPENDIX 1. - WINDFLOW ON THE SITE



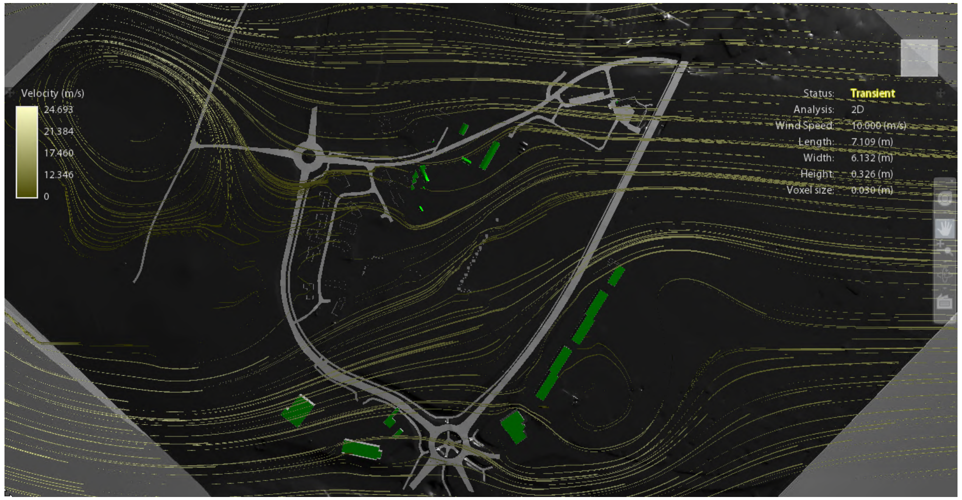
5m/s - West



5m/s - Southwest



10m/s - West



10m/s - Southwest

APPENDIX 2. - BLUE SUITCASE

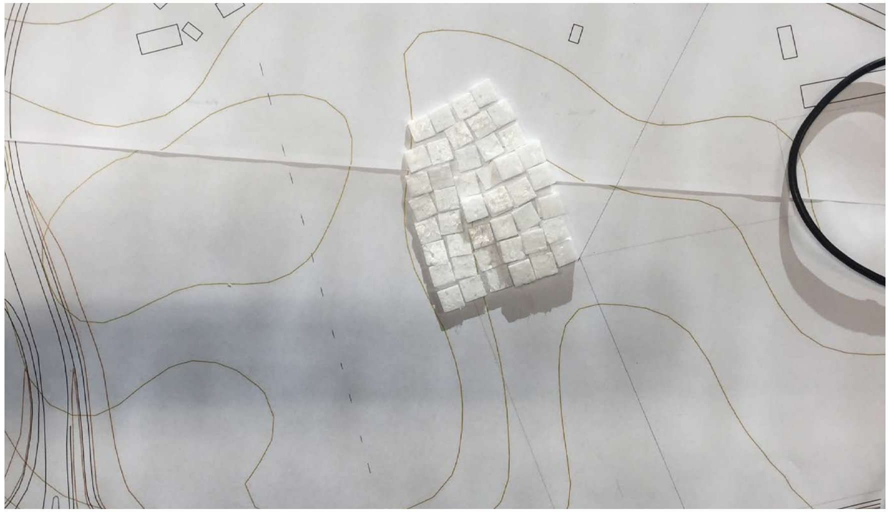
Blue suitcase with Create

Blue suitcase with Rytterskolen in Randers

APPENDIX 3. - VOLUME STUDIES

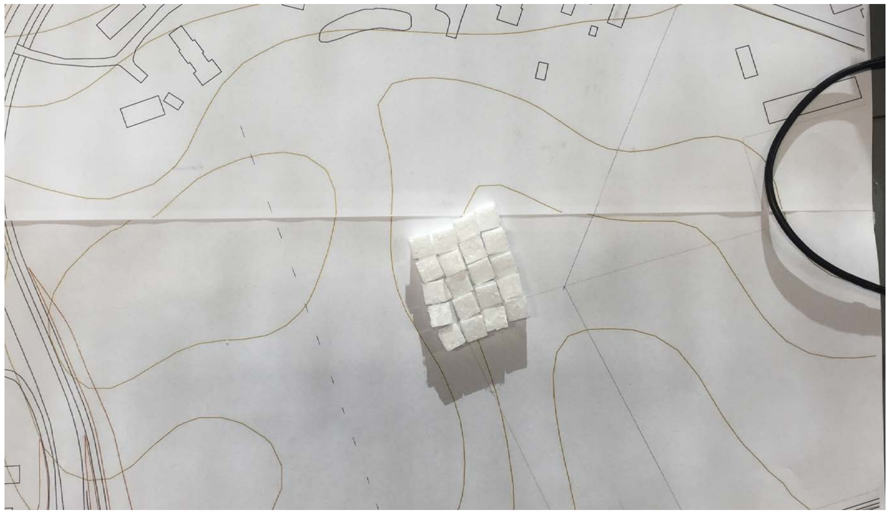
6500 m² as one floor

6500 m² as one floor and 1/2 floor

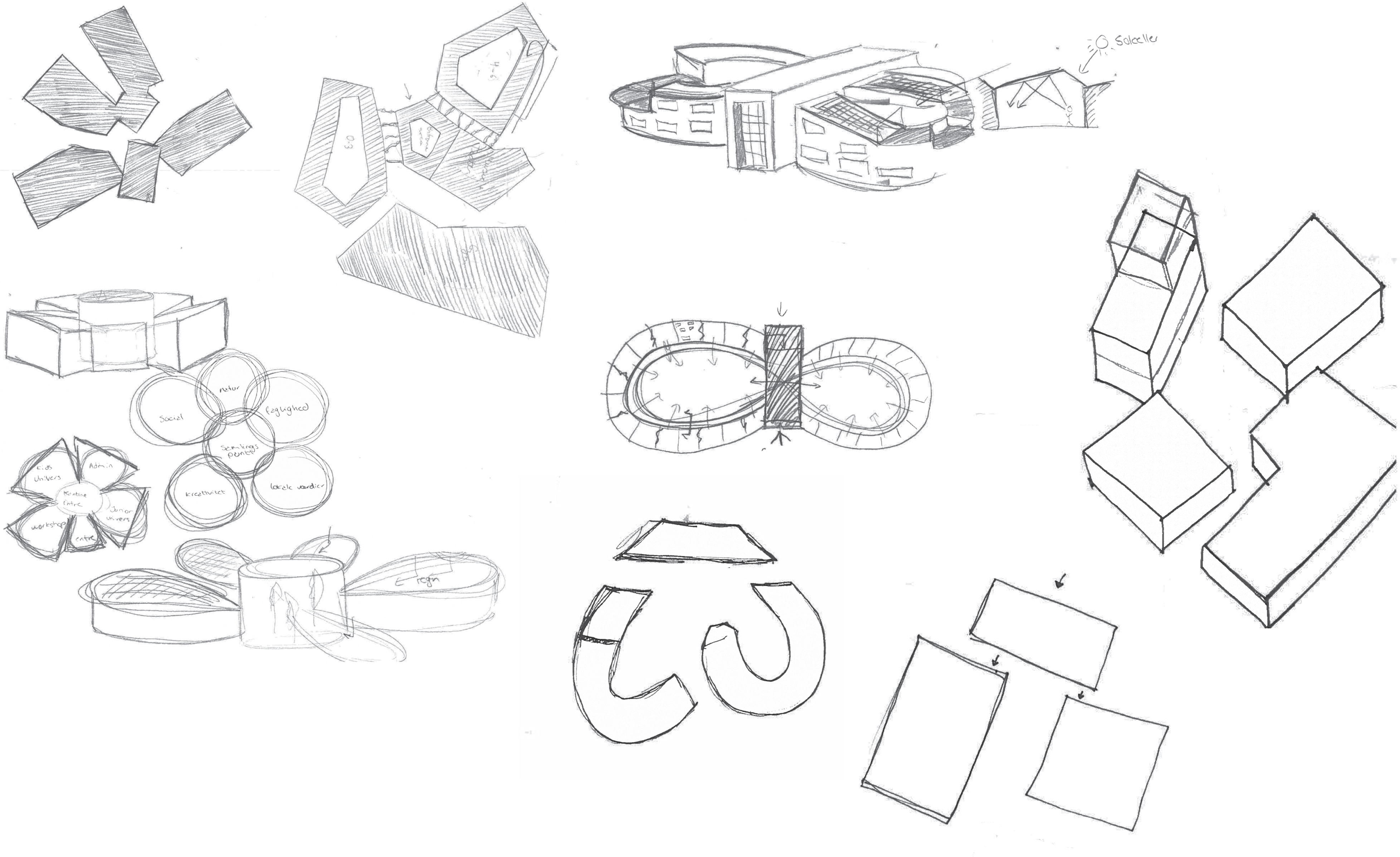


6500 m² as two floors

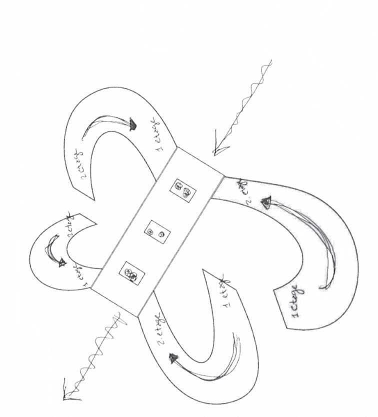
6500 m² as three floors

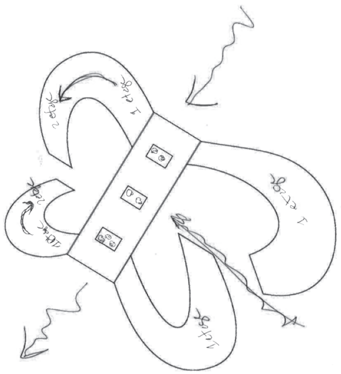


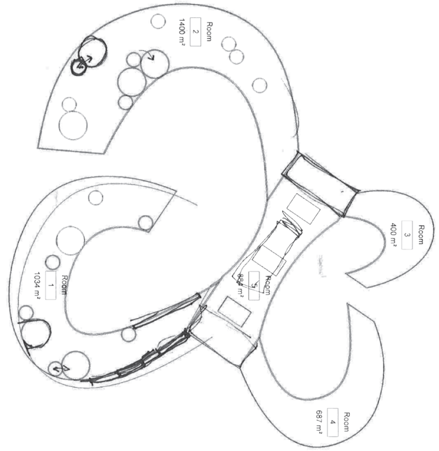
APPENDIX 4. - IDEA SKETCHES

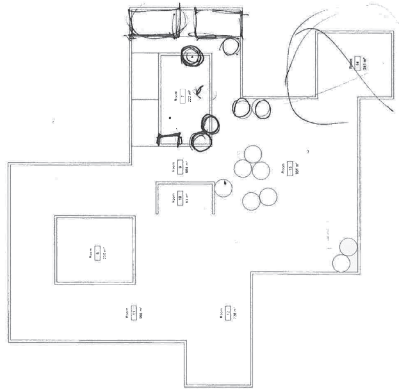


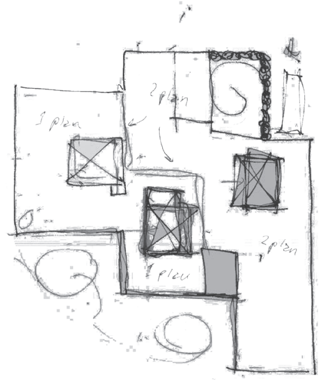
APPENDIX 5. - DRAFT FOR PLANS

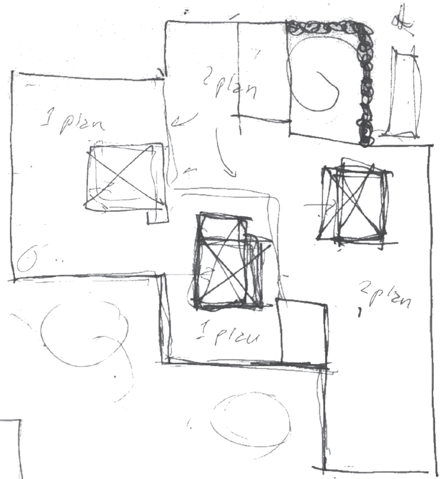


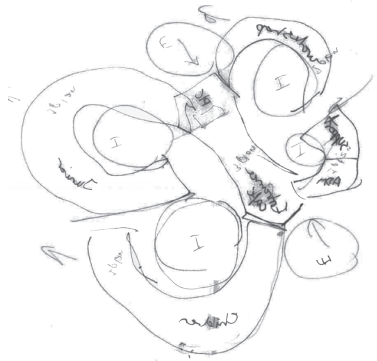


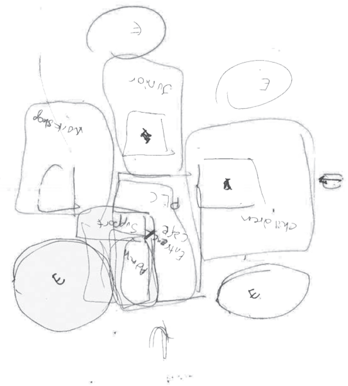




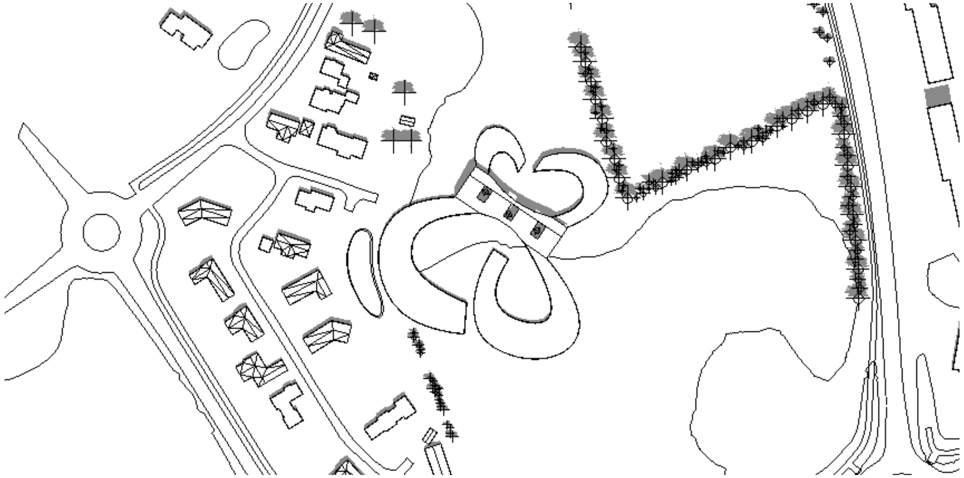






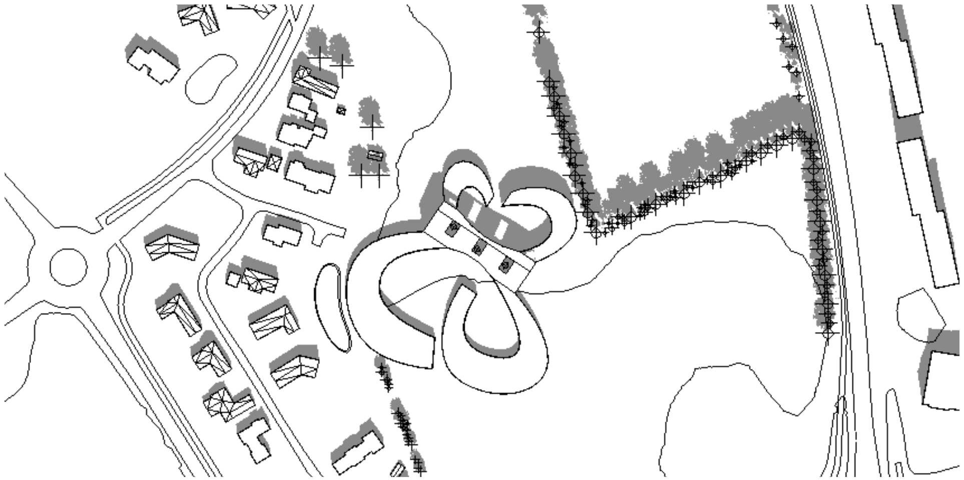


APPENDIX 6. - SUN ON CONCEPT 2

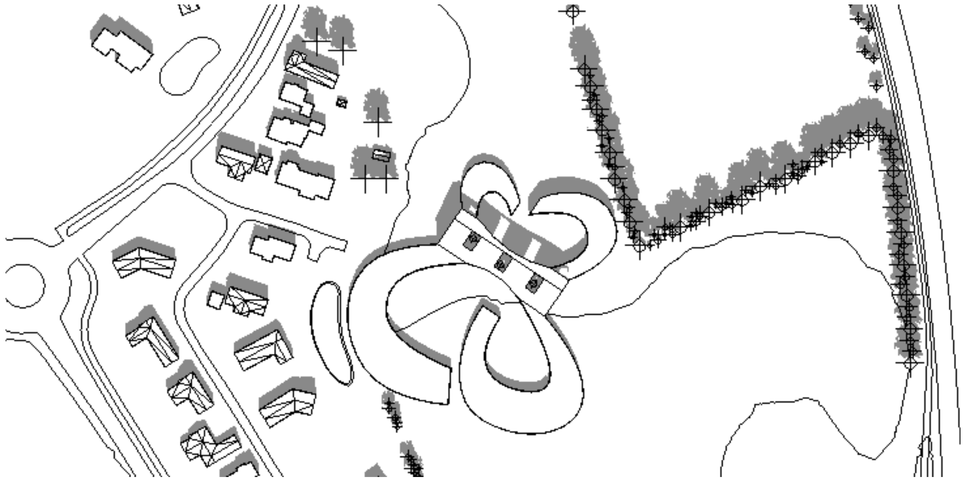


Summer at 12

Winter at 12

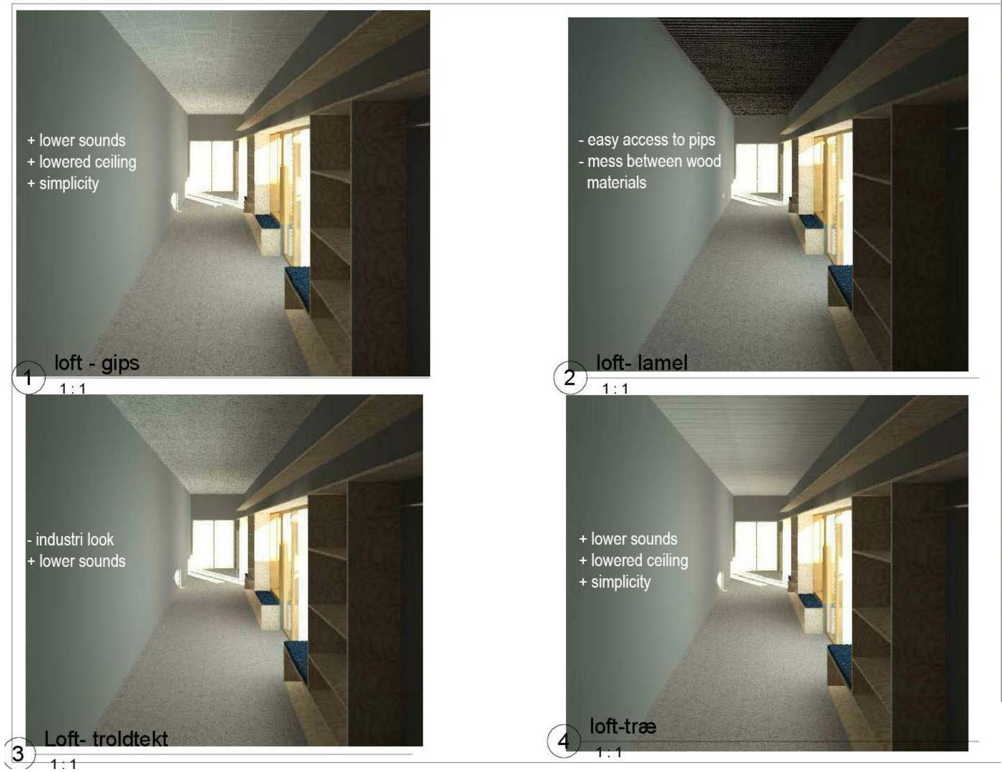


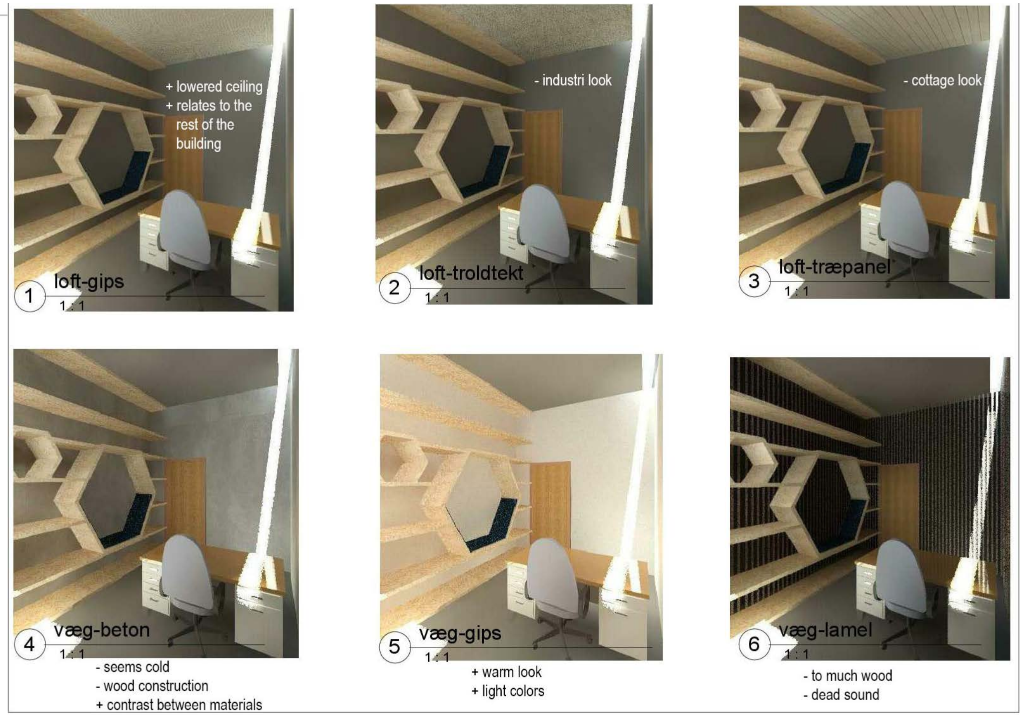
Spring at 12

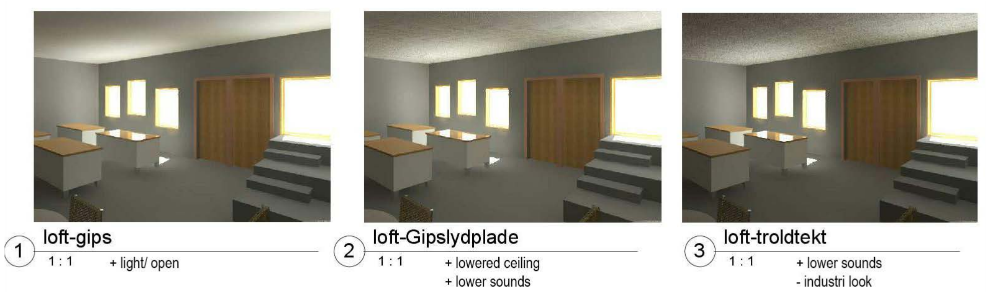


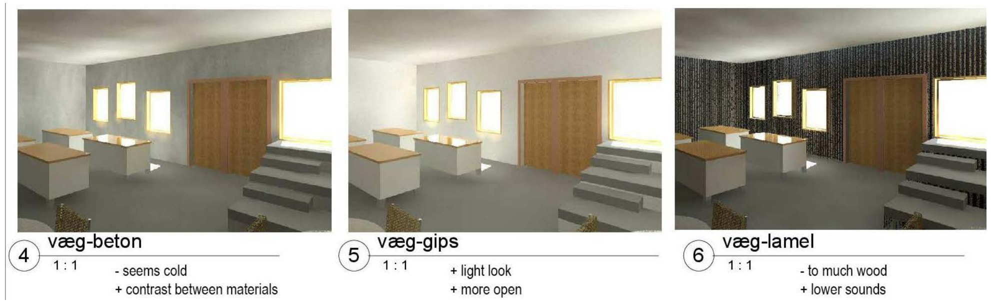
Autumn at 12

APPENDIX 7. - RENDERS OF MATERIAL

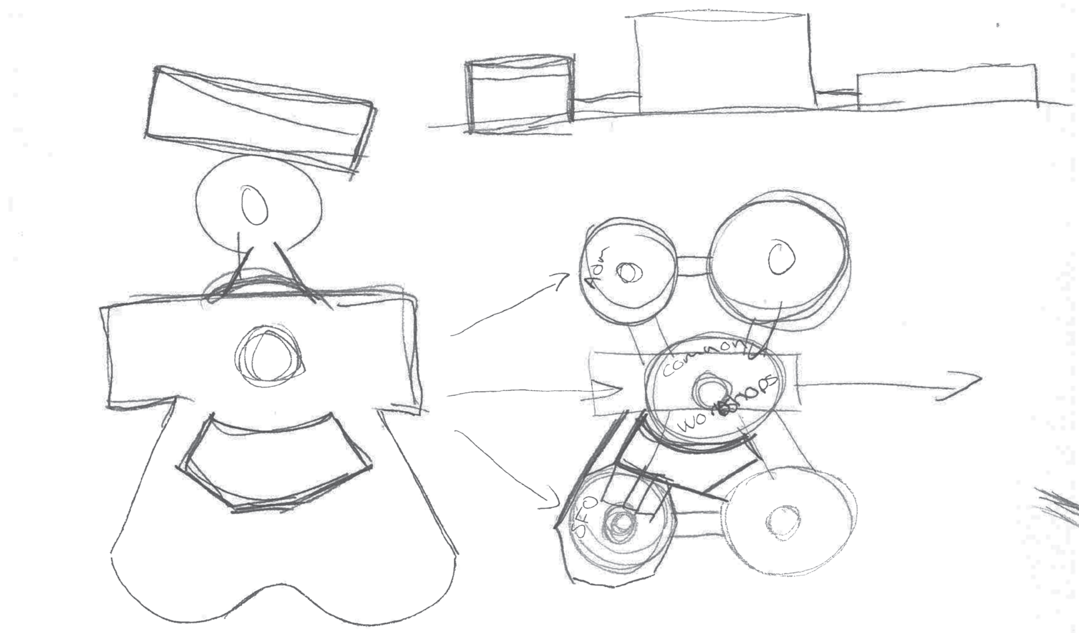


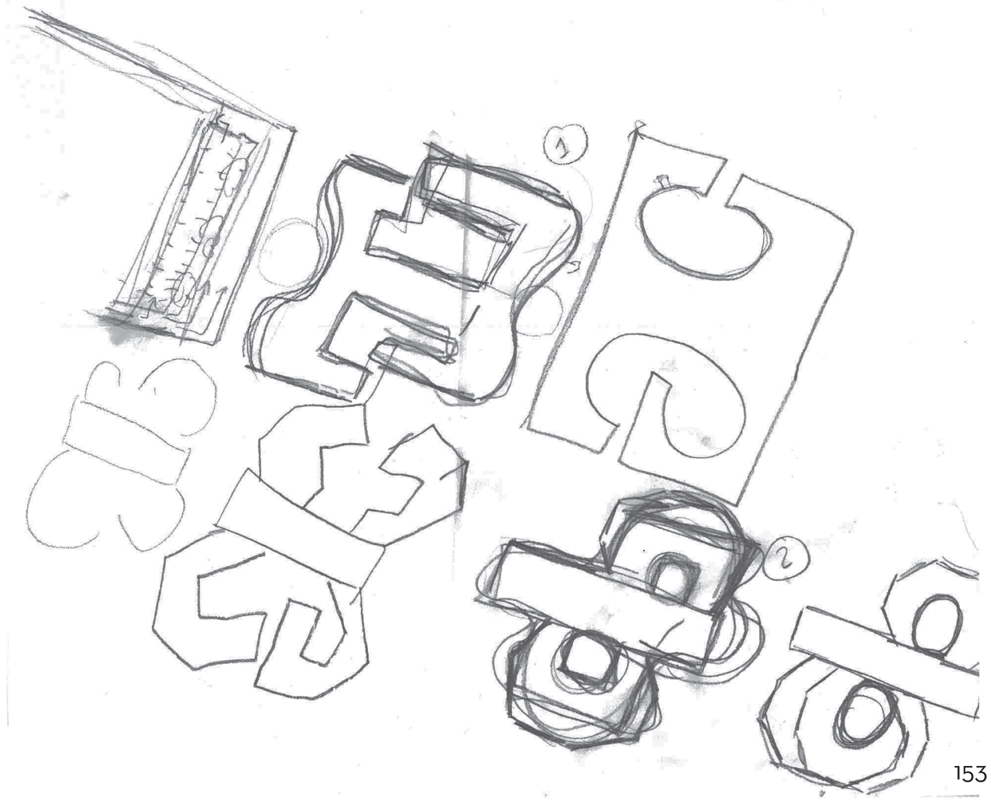




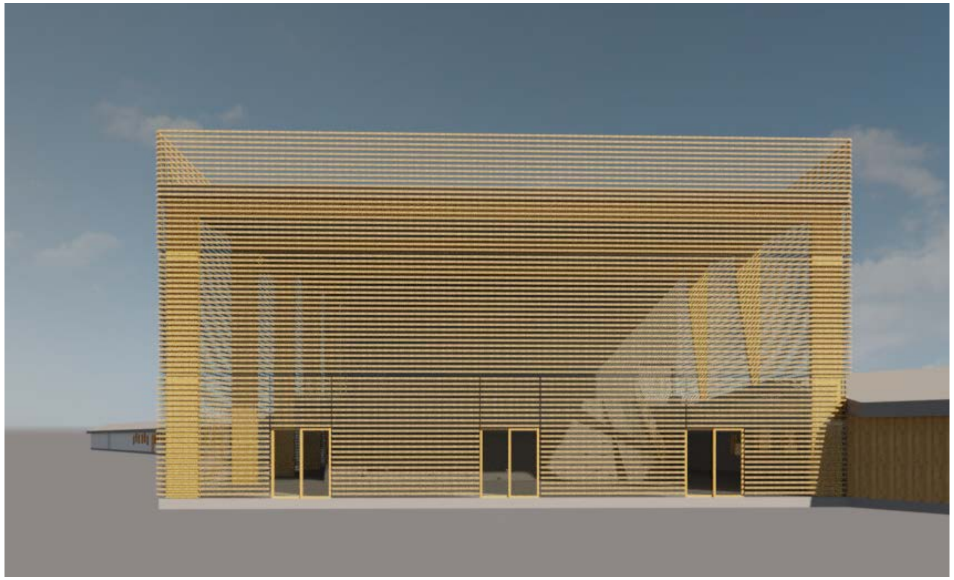


APPENDIX 8. - SKETCHES





APPENDIX 9. - FACADE ITERATIONS



Lamella: Width 50mm, Space 100mm

Lamella: Width 200mm, Space 100mm

Lamella: Width 100mm, Space 100mm

Lamella: Width 200mm, Space 200mm

APPENDIX 10. - RAINWATER COLLECTION

Collected amount pr. month on the roof for 2014-2018			
	m avr. Pr month for 5 years	m^3 collected	m^3 excess water after toilet flush use
january	0,0782	429,0172	299,0797
february	0,0446	244,5727	114,6352
march	0,0500	274,4174	144,4799
april	0,0544	298,2273	168,2898
may	0,0568	311,7232	181,7857
june	0,0620	340,2512	210,3137
july	0,0731	401,0378	271,1003
august	0,0886	486,1829	356,2454
september	0,0891	488,7065	358,7690
october	0,0751	411,9004	281,9629
november	0,0746	409,4865	279,5490
december	0,0915	502,0927	372,1552

Collection tanks for flushing the toilets must be around 50 m3
There needs to be 4 collection tanks in total, one on each outer corner of the clusters

Total use of water at a school		
55	l/person/day	
200	schooldays a year	
567	amount of people at the school	
	500	Students
	55	Teachers
	6	administration
	6	operating staff
6.237.000	Total water use (l)	
6.237	Total use (m3)	
25% for flushing toilets		
1.559	m^3 for toilet flush a year	
130	m3 for toilet flush a month	

APPENDIX 11. - VENTILATION - OLFACTION

		c
Demand	% unsatisfied	decipol
Cat. I	15	1
Cat. II	20	1,4
Cat. III	30	2,5

The calculation:
V=10*(q/c)

Classroom:

Load				q
	Olf pr. pers.	nr. people	olf pr. m²	Total olf
	1	30	0,1	35,98

Cat I	359,77	l/s	1295,172	m³/h	6,8	h⁻¹
Cat II	256,98	l/s	925	m³/h	4,8	h⁻¹
Cat III	143,908	l/s	518	m3/h	2,7	h⁻¹

Office:

Load				q
	Olf pr. pers.	nr. people	olf pr. m²	Total olf
	1	2	0,1	3,40

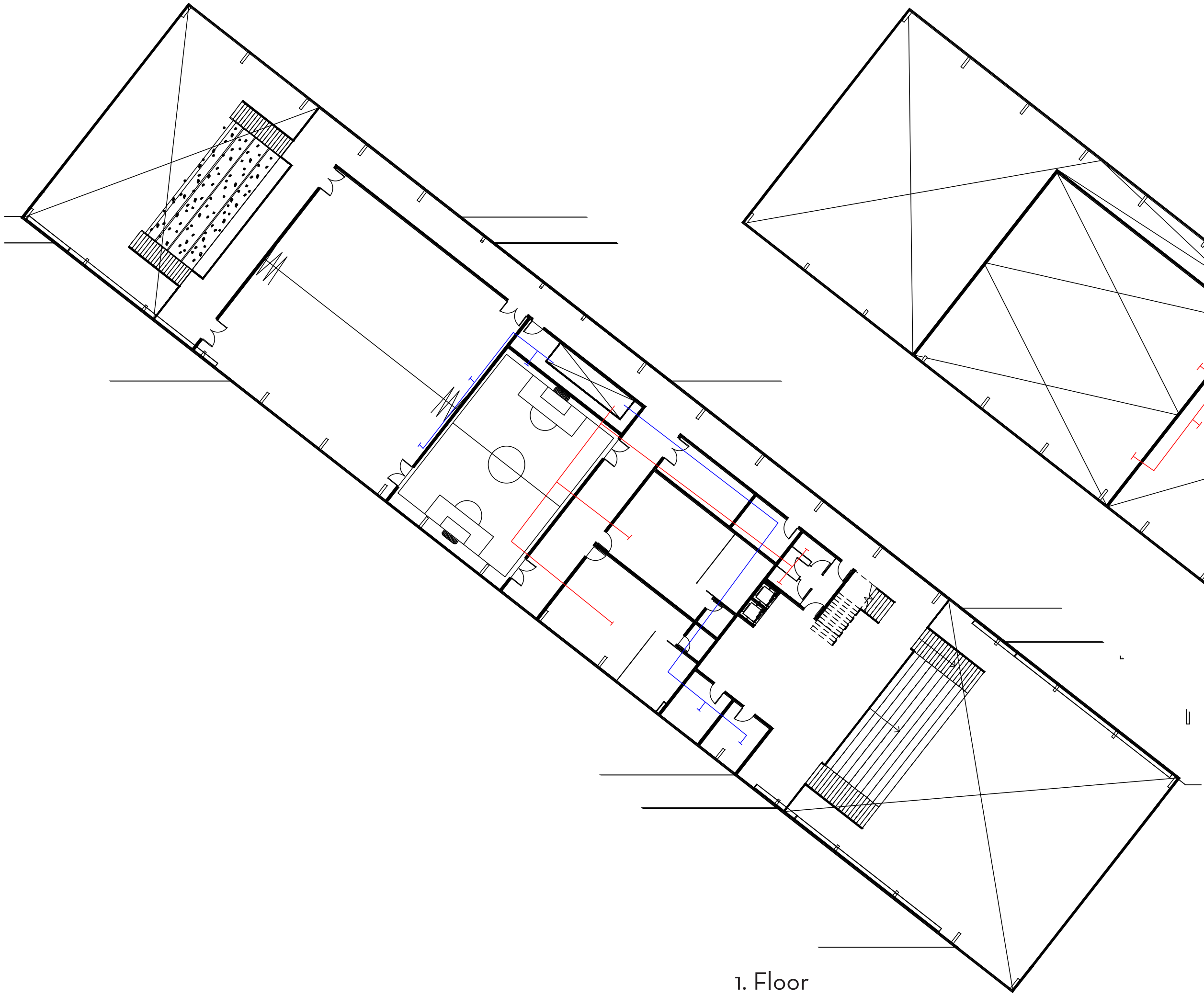
Cat I	34,0	l/s	122,4	m³/h	3,8	h⁻¹
Cat II	24,3	l/s	87	m³/h	2,7	h⁻¹
Cat III	13,6	l/s	49	m3/h	1,5	h⁻¹

Gym:

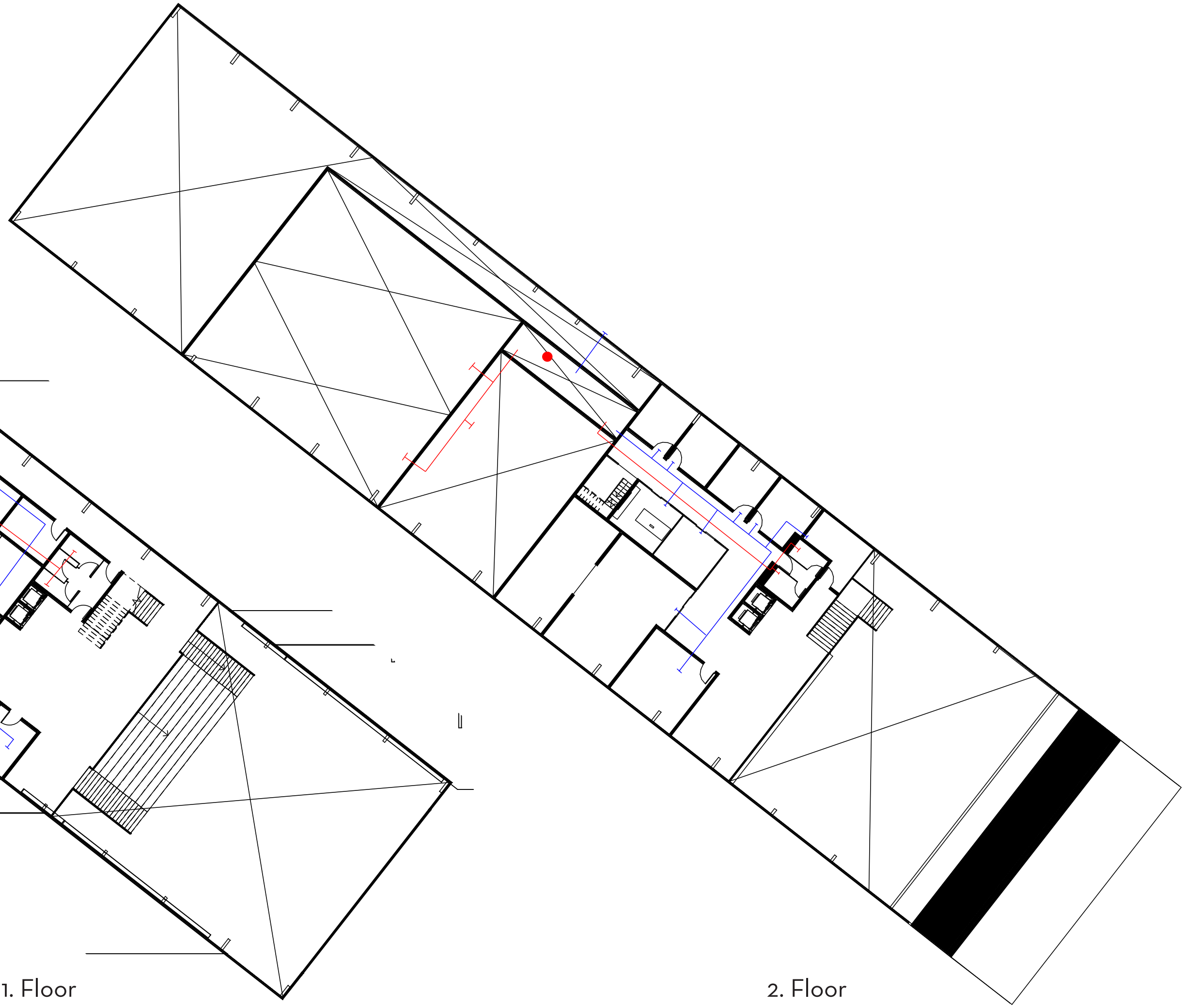
Load				q
	Olf pr. pers.	nr. people	olf pr. m²	Total olf
	1,2	30	0,1	51,00

Cat I	510	l/s	1836	m³/h	1,6	h⁻¹
Cat II	364,29	l/s	1311	m³/h	1,2	h⁻¹
Cat III	204	l/s	734	m3/h	0,7	h⁻¹

APPENDIX 12. - FINAL PIPING



1. Floor



2. Floor

APPENDIX 13. - VENTILATION - PRESSURE LOSS

Strech of pipe	Amount of air	Pipe dimension	Length		Pressure loss pr. m	dynamic pressure	Pressure loss	Total
	m3/h	diameter (mm)	·l	Single resistans	R	Pa	R*·l	Pa
a-b	2900	400					0	0,00
							0	
b	2900				0,98		0	0,00
							0	
b-c	2900				0,98		0	0,00
							0	
c	2900				0,98		0	100,00
							100	
c-d	2900	400	3		0,98		2,94	2,94
							0	
d	2900	400			0,98		0	0,00
				0,33			0	
d-e	2900	400	4		0,98		3,924	3,92
							0	
e	2900	400			0,98		0	0,00
				0,33			0	
f	2900	400			0,98		0	0,00
				1,8			0	
e-f	400	200	2		0,8829		1,7658	1,77
							0	
f-g	400	200	1		0,8829		0,8829	0,88
							0	
g	400	200			0,8829		0	0,00
				1,8			0	
g-h	100	200	1		0,07848		0,07848	0,08
							0	
h	100	200			0,07848		0	0,00
				1,8			0	
g-i	300	200	1		0,10791		0,10791	0,11

Strech of pipe	Amount of air	Pipe dimension	Length		Pressure loss pr. m	dynamic pressure	Pressure loss	Total
	m3/h	diameter (mm)	·l	Single resistans	R	Pa	R*·l	Pa
i	300	200			0,48069		0	0,00
				1,8			0	
i-j	100	200	1		0,07848		0,07848	0,08
							0	
j	100	200			0,07848		0	0,88
				1,8		0,4905	0,8829	
i-k	200	200	4		0,10791		0,43164	0,43
							0	
k	200	200			0,24525		0	0,88
				1,8		0,4905	0,8829	
k-l	100	200	1		0,07848		0,07848	0,96
							0	
l	100	200			0,07848		0	0,00
				1,8		0,4905	0,8829	
k-m	100	200	1		0,07848		0,07848	0,08
							0	
m	100	200			0,07848		0	0,88
				1,8		0,4905	0,8829	
m-n	100	200	1		0,07848		0,07848	0,08
							0	
n	100	200			0,07848		0	0,88
				1,8		0,4905	0,8829	
e-o	2500	350	8		0,21582		1,72656	1,73
							0	
o	2500	350			2,943		0	9,06
				0,33		27,468	9,06444	
o-p	2500	350	2		2,943		5,886	5,89
							0	
p	2500	350			2,943		0	49,44
				1,8		27,468	49,4424	
p-q	400	200	1		0,8829		0,8829	0,88
							0	

Strech of pipe	Amount of air	Pipe dimension	Length		Pressure loss pr. m	dynamic pressure	Pressure loss	Total
	m3/h	diameter (mm)	·l	Single resistans	R	Pa	R*·l	Pa
q	400	200			0,8829		0	13,24
				1,8		7,3575	13,2435	
p-r	2100	350	4,5		1,2753		5,73885	5,74
							0	
r	2100	350			1,2753		0	49,44
				1,8		27,468	49,4424	
r-s	400	200	1		0,8829		0,8829	0,88
							0	
r-t	1700	350	1		0,981		0,981	0,98
							0	
t	1700	350			0,981		0	28,25
				1,8		15,696	28,2528	
t-u	400	200	1		0,8829		0,8829	0,88
							0	
u	900	300			0,5886		0	10,59
				1,8		5,886	10,5948	
t-v	800	300	7		0,5886		4,1202	4,12
							0	
v	800	300			0,5886		0	10,59
				1,8		5,886	10,5948	
v-x	400	200	1		0,21582		0,21582	0,22
							0	
x	400	200			0,8829		0	13,24
				1,8		7,3575	13,2435	
v-y	400	200	6		0,8829		5,2974	5,30
							0	
y	400	200			0,8829		0	2,43
				0,33		7,3575	2,427975	
y-z	400	200	1		0,41202		0,41202	0,41
							0	
z	400	200			0,8829		0	13,24
				1,8		7,3575	13,2435	
							Total :	**341,44 Pa**

APPENDIX 14. - MIXING & DRAFT

	B	C	U_o	a_o	Ka
Classroom	6,9	3,3	2	0,05	4
Office	4	3,5	2	0,02	4
Gym	17,9	6,5	2	0,25	4

Range of air			
Classroom	7,65	$<l_{0,2}<$	10,2
Office	5,62	$<l_{0,2}<$	7,5
Gym	18,3	$<l_{0,2}<$	24,4

	$l_{0,2}$
Classroom	9
Office	5,7
Gym	20

APPENDIX 15. - BE18 RESULTS

Be18 results without solar cells

Nøgletal, kWh/m² år

Renoveringsklasse 2

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
135,5	0,0	135,5
Samlet energibehov		28,2

Renoveringsklasse 1

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
71,6	0,0	71,6
Samlet energibehov		28,2

Energiramme BR 2015 / 2018

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
41,2	0,0	41,2
Samlet energibehov		23,0

Energiramme Byggeri 2020

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
25,0	0,0	25,0
Samlet energibehov		17,2

Bidrag til energibehovet

Varme	26,0
El til bygningsdrift	0,8
Overtemp. i rum	0,2

Netto behov

Rumopvarmning	26,0
Varmt brugsvand	0,3
Køling	0,0

Udvalgte elbehov

Belysning	0,0
Opvarmning af rum	0,0
Opvarmning af vbv	0,5
Varmepumpe	0,0
Ventilatorer	0,3
Pumper	0,2
Køling	0,0
Totalt elforbrug	19,8

Varmetab fra installationer

Rumopvarmning	0,0
Varmt brugsvand	0,3

Ydelse fra særlige kilder

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

Be18 results with solar cells

Nøgletal, kWh/m² år

Renoveringsklasse 2

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
135,5	0,0	135,5
Samlet energibehov		3,2

Renoveringsklasse 1

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
71,6	0,0	71,6
Samlet energibehov		3,2

Energiramme BR 2015 / 2018

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
41,2	0,0	41,2
Samlet energibehov		-2,0

Energiramme Byggeri 2020

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
25,0	0,0	25,0
Samlet energibehov		-7,8

Bidrag til energibehovet

Varme	26,0
El til bygningsdrift	-9,2
Overtemp. i rum	0,2

Netto behov

Rumopvarmning	26,0
Varmt brugsvand	0,3
Køling	0,0

Udvalgte elbehov

Belysning	0,0
Opvarmning af rum	0,0
Opvarmning af vbv	0,5
Varmepumpe	0,0
Ventilatorer	0,3
Pumper	0,2
Køling	0,0
Totalt elforbrug	19,8

Varmetab fra installationer

Rumopvarmning	0,0
Varmt brugsvand	0,3

Ydelse fra særlige kilder

Solvarme	0,0
Varmepumpe	0,0
Solceller	24,4
Vindmøller	0,0