Gl. Hasseris skole

A new way of teaching

MSc04-ARC16, May 2017

Elisabeth G. Jensen, Rikke H. Frederiksen & Cecilia D. Johansen

Aalborg University
Deparment of Architecture & Design
MSc04 ARC 2017

Theme: Gl. Hasseris skole, The new way of teaching.
Group: 16
Project period: 01.02.2017 - 18.05.2017

Supervisor: Mary-Ann Knudstrup
Technical supervisor: Rasmus Lund Jensen

Pages: 175
Appendix pages: 199

Rikke Holm Frederiksen

Elisabeth Greve Jensen

Cecilia Dianna Johansen

Thank you:

This project could not have been possible without the help and support from a great many people. First, we would like to thank our main supervisor Mary-Ann Knudstrup and technical supervisor Rasmus Lund Jensen for their advice and supervision throughout the process. We would also like to thank the teachers: Hanne R Bækgaard, Karina Normann and Louise Hald, the principle of Gl. Hasseris Skole Michael Sørensen and Lene Thorhauge from the municipality of Aalborg for their participation in our interviews. Lastly we would like to thank Kaj Røjkjær guide at Stjernen and Kurt Johannesen principle of Stjernen for their input to the project.

Reading guide

This project illustrates the process and presentation of a school design based on Aalborg municipality's take on the school reform of 2014. Throughout this report the Harvard method will be used as referencing method and the extended reference- and illustration list can be found at the end of the Presentation.

The report commences with an abstract and a motivation presenting the project, followed by the analysis wherein the design criteria of the project are defined. Subsequently, the design process is described using diagrams, illustrations and technical analyses. The report concludes with a presentation of the design, portrayed through visualizations, illustrations, technical drawings and energy calculations.

Abstract

This masters' thesis represents a new public-school building to be placed at the site of Gl. Hasseris Skole in the western part of Aalborg. The aim is to design a school that supports a variety of teaching methods in a fast-changing school environment, focusing on flexibility in interior and diverse learning environments. Basic analysis of child development provides an understanding of the pupils' needs, along with a review of the new school reform and how it has affected the teachers and students, which is based on interviews with teachers, principals and the municipality. The surroundings are analyzed and the importance of the recreational area, Rotunden, is established, as well as the indoor environment as a key element to creating a good learning environment. An integrated design process is made where the focus is on diverse learning environments and the thermal, atmospheric and visual qualities. This results in the creation of a school where the shape is developed based on the surroundings and the interior is designed from the needs of each user group. The demands to the quality of the indoor environment is fulfilled and is a part of creating a stimulating learning environment. The outdoor areas are divided into zones, providing activity for a wide age-range. As a result, a school is created that can handle the new and ever-changing public-school.

Table of contents

Motivation

In Denmark, the public-school-system is called the municipal primary and lower secondary school, and will be referred to as public-school in this report. The public school teaches children ages 6 to 15 years of age. Because of this age range, the public school is often divided into three areas, to better accommodate the mental and physical changes the children undergo.

In 2013, the public-school system received a new reform, which entailed significant changes for the teachers, children and parents. The reform is based on new results from Europe, [Rasmussen, 2015] where e.g. longer school-days have proven effective minimizing the negative effect of the student's social background. Another aspect of the new reform is a change of focus. Previously the focus had been on the content of the teachers' lessons, but with the new reform, the children's skill-level was to be the new focus.
These actions have led to a change in the teachers' schedule, where further administrative duties, in addition to more teaching hours, have meant less time for the teachers to plan their lessons and more time behind their desks. [Rasmussen, 2015] This significantly influences the demands on the school architecture; Children and teachers need to use the facilities for longer periods of time, and the reform also created a need for new functions, such as the teachers work space.

When developing a school with a nurturing and stimulating environment for all age groups, while incorporating the new ideas and teaching methods of the reform, the indoor environments must be a priority. The students need different teaching environments that can help them improve their skills, inspire them and encourage their desire to learn.
The interior must support the teachers' needs, to help them develop new and improved teaching methods. Studies have shown that an optimal indoor environment can decrease the number of sick days and improve productivity, and it is paramount that student and teachers thrive, to develop a well-functioning teaching environment. [Pejtersen, 2002]

The focus of this master's thesis is to create a school adapted to the new reform, focusing on sustainable solutions and the indoor environment. The project will be developed based on the interpretations of the reform in Aalborg Municipality, and many of the principles of this project will be transferrable to school-architecture in general. The site of the project is the current location of Gl. Hasseris Skole in south-west Aalborg. The school has been chosen based on a study of all Danish public schools, which shows that Gl. Hasseris Skolel does not fulfill the requirements for the indoor environment of public schools. [Secher, 2016] The school is therefore currently in need of a renovation or a complete rehousing.
Because of the poor classroom conditions, and the spatial difficulties on the site, the project will focus on building the school anew.

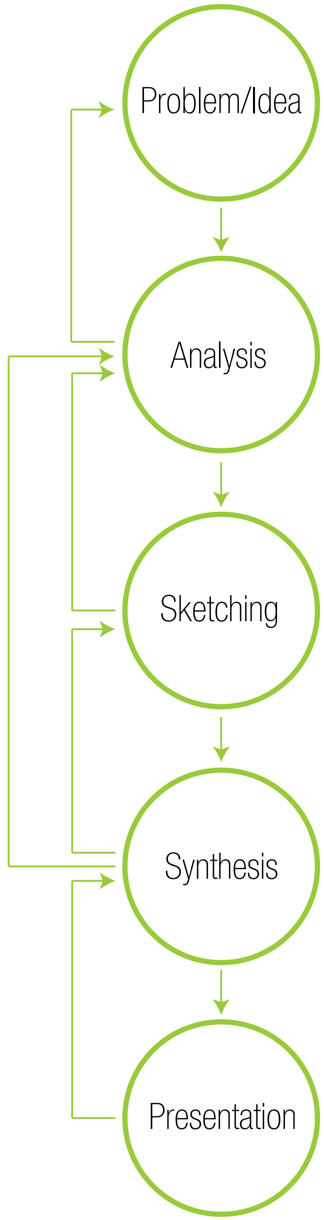
ill.1 - Mood picture

Methodology

In this project the Integrated Design Process has been used. This process is based on principles of the PBL (problem-based-learning) model. It consists of five different phases: the problem phase, the analysis phase, the sketching phase, the synthesis phase and the presentation phase. The Integrated Design method is an iterative process, which means that the project moves back and forth between the different phases, gradually resulting in a final proposal. The main idea is to integrate both architectural and technical elements into the final solution. [Knudstrup, 2004]

Each of the phases in the Integrated Design Process consists of several methods, giving the project a diverse knowledge base. In the analysis phase both deductive and inductive methods are used, as well as qualitative empirical knowledge in the form of interviews. The sketching phase can be described as a process in which all steps are evaluated, redeveloped and then evaluated again, which is the basic principle of the hermeneutic spiral. [Kafla, 2011]

Another method used is Evidence Based Design, which bases the design upon documented knowledge, increasing the quality of the design. This methodology is often applied in the design of healing architecture or educational environments, where the effects on the health and well-being of the user, by improving the indoor climate, can be measured. It is necessary to base the goals of the indoor climate on comparable data, due to the requirements of the government, to measure and follow the well-being of the students. [Frandsen et al., 2009]



ill. 2 - A diagram showing the integrated design process.

ill. 3 - Mood picture from Frederiksbjerg school

01

Program

The program illustrates and describes the important analyses and studies used in this project. The main topics of the program are Mapping, Sustainability, Indoor climate, School reform and Learning environment. The results of the analyses are used in the development of the design criteria, room-, and function program. The program is necessary in order to begin the design process.

Municipality

The location of the site is the city Aalborg in Denmark, in the area called Hasseris, and it is therefore a part of Aalborg Municipality. There is no local-plan for the site but in the municipality-plan the preservation and strengthening of the green connection between Rotunden and KFUM is a priority(see ill. 4). [Aalborg kommune 1, 2017] Rotunden is a significant urban architectural element and the identity of the area. [Aalborg kommune 1, 2017]

In 2013 when the new public-school reform was introduced, the municipality agreed on a vision for the public schools in Aalborg municipality. The vision can be loosely translated to: "Something to it" which means that the students should have a thorough knowledge, experience and understanding of a subject, enabling their ability to act, and to further develop their knowledge and identity within the subject. To further the understanding, and to strengthen the message; the municipality created guidelines. Some of these were to strive for pupils getting better schooldays, and the needed courage to contribute in the world. The teaching methods used, should strive to include experimentation and problem-solving. Delivering a high quality in every teaching situation is a focus, as well as involving the community in the school day. [Aalborg Kommune 2,2017]

Every year the municipality compiles a quality report to evaluate the schools' and the students' education. The goal of the report is to discover inadequate areas to improve. The most recent quality report showed that the boys have a harder time reading than girls, which have lead the municipality to make a special effort to improve the reading skills of boys [Aalborg Kommune 1, 2017]. At each school, they have a person who focus on the well-being of the pupils. This person works to reduce the level of absence; sometimes this is done by helping the students get to school by picking them up at their home. [Thorhauge, 2017] The municipality also focus on the work-environment, which can influence the level of absence of both pupils and teachers. [Aalborg Kommune1,2017]

It is also important that the pupils get to the school safely, whether they travel on foot or by bike, and the municipality is therefore attentive of making roads and areas leading to the school safe. [Nørgaard, 2013]

Sub-conclusions:

- Safe roads to school
- Rooms inviting to experimentation
- Different learning envirroments
- Good work-environment

ill. 4 - Mapping diagram.
The diagram show the green connection between Rotunden and KFUM.

Site mapping

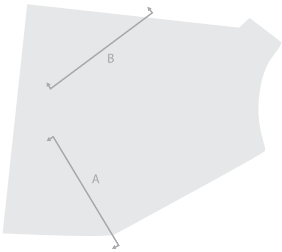
The surrounding typologies, green areas and functions can be analysed to evaluate the relation between the school and the neighborhood. The Infrastructure surrounding the school is, as mentioned, a focus for the municipality [Nørgaard, 2013], because children need to feel safe and secure when going to and from school.

To analyse the area, an adaptation of a Kevin Lynch's analysis has been made, along with field studies of the surrounding area.
The site is in the old part of Hasseris where the green area, called "Rotunden", is a recreational area and the determining factor for the orientation of the nearby buildings, see ill. 7. [Aalborg Kommune,2006] Rotunden is a circular area with tall, slim trees. It works as an architectural recreational element for the local area. Rotunden creates, along with the green area connected to the KFUM-Hall, a green zone in the area, which should be maintained and reinforced if possible. [Aalborg Kommune,2006]

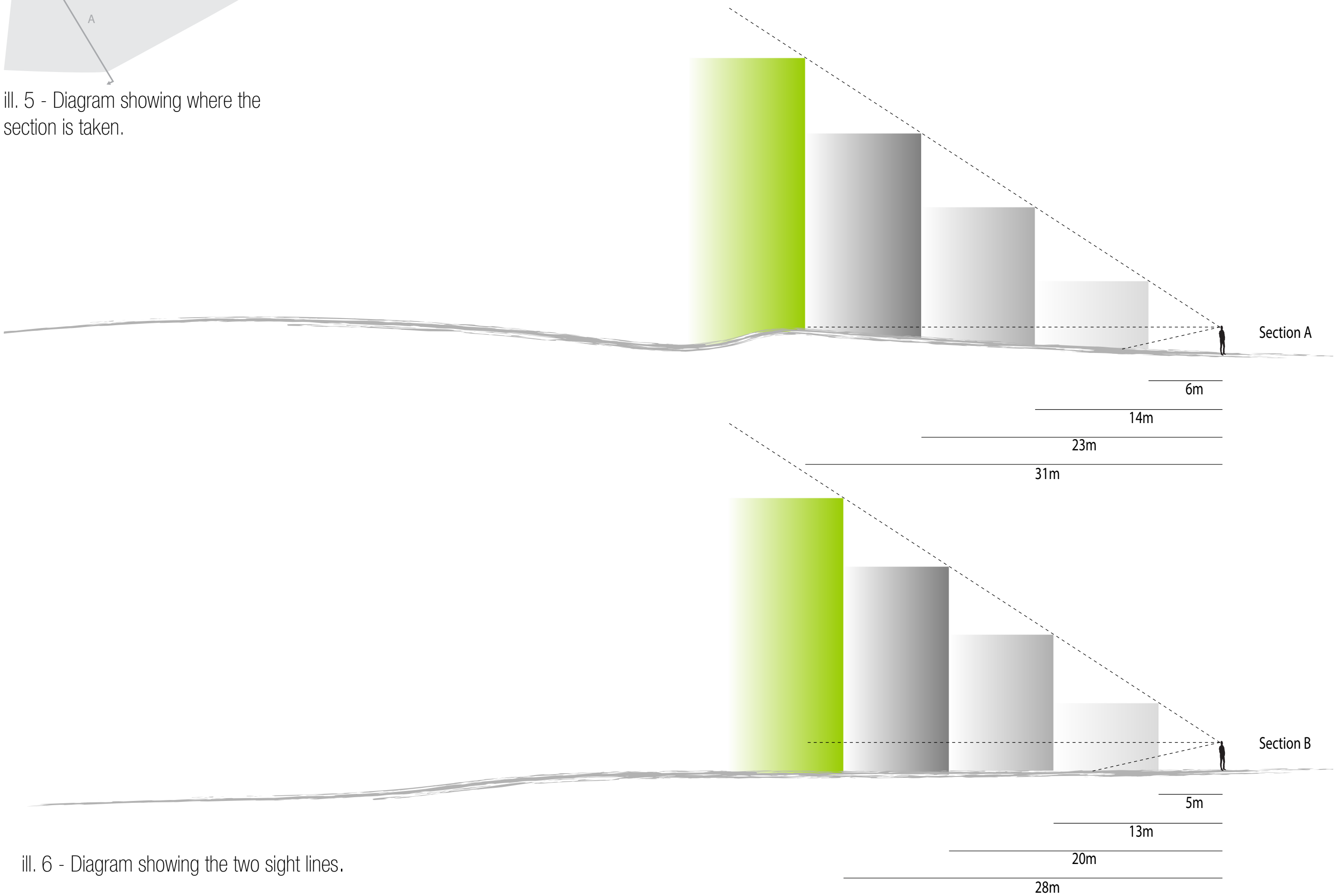
The Typology surrounding the site, is dominated by detached single-family houses, with few other functions, such as the KFUM-Halls and institutions like Nordjysk Handelskollegium. Since the area surrounding the site is mainly residential, it will be quiet and calm during the school hours. The typology of the area is characterized by mainly open/low buildings in one story, making the area very flat.
The existing school architecture is mainly build in two floors, with one three-storey building next to the road, Mester Eriks vej. The architecture takes advantage of the slowly inclining topography of the site, towards Rotunden. During one of the field trips to the site, two places where marked, where the topography greatly influenced how the building was experienced. In one case, the topography made the two-story building seem very tall, and in the case of the other sight line the building seemed relatively low, from the same distance.

Based on the perception studies of the book: "Architects Data" by Peter and Ernst Neufert, the sight lines of these two spots where analysed to find out; at what distance from the paths, a building would seem too high. Neufert describes the perception to be dependent on the amount of a building a person perceives at first glance. This means that if the whole of a building can be seen without moving the head, then it will be perceived as low, and otherwise it will be perceived as being tall. The comfortable centre of the sight line is at a 53 degree angle. From this angle, the eyes can comfortably move to perceive 10 degree angle below this point, and 27 degrees above, without moving the head.

The section of the site, based on the two sightlines, can be seen on ill. 5-6, where the angles of perception have been marked. This shows that an inclining topography influences the building, so that it feels higher faster. The study also shows that the buildings can be quite high on the site, without seeming too high, if they are placed further away from the surrounding pathways. This needs to be considered when designing the building.



ill. 5 - Diagram showing where the section is taken.



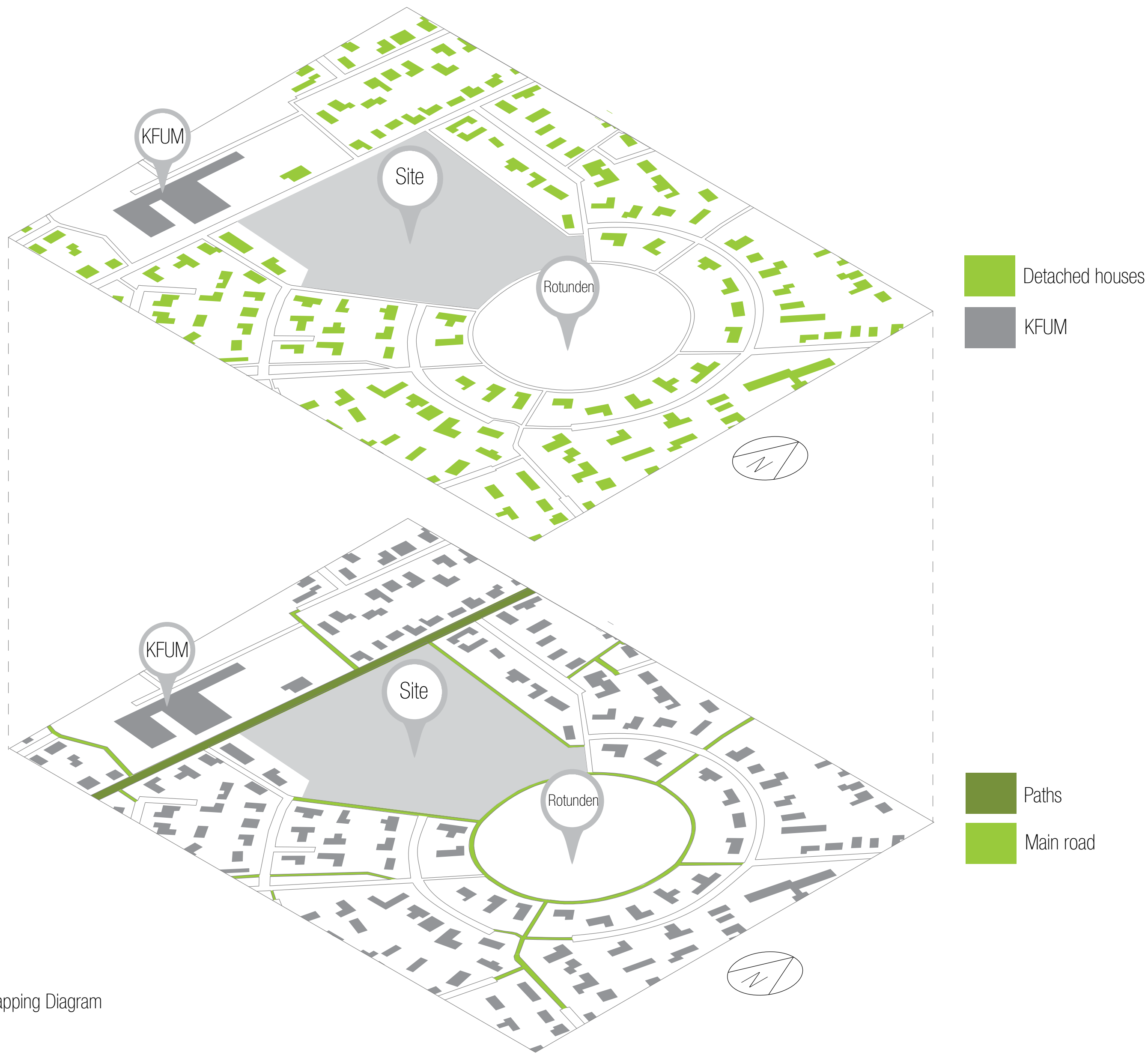
ill. 6 - Diagram showing the two sight lines.

The infrastructure around the site is mostly small roads with light traffic, which means that there are many safe paths for the pupils to take on their way to school. For the students arriving by foot or bicycle there are several paths passing through Rotunden. Ill. 7 shows that the recreational area and Mester Eriks vej create many entrances to the site from various directions, for pupils on foot or bicycle. The options for the use of public transportation is limited to one bus, arriving close to the school, west of the site at Under Lien and transport by car will happen through Mester Eriks vej.

The low typology of the area means that there is either the possibility of making the building fit the area, or allowing the school to rise above the horizon and stand out as a landmark. In the same way, the connection to the green areas surrounding the site gives the opportunity to strengthen the green zone creating a more synergetic local area. With the many ways to reach the school several entrance points should be considered to accommodate the different arriving possibilities.

Sub-conclusions:

- Strengthen the green zone
- Integration of entrance points
- Consider the surrounding typology



ill. 7 - Mapping Diagram

Climate

Sun

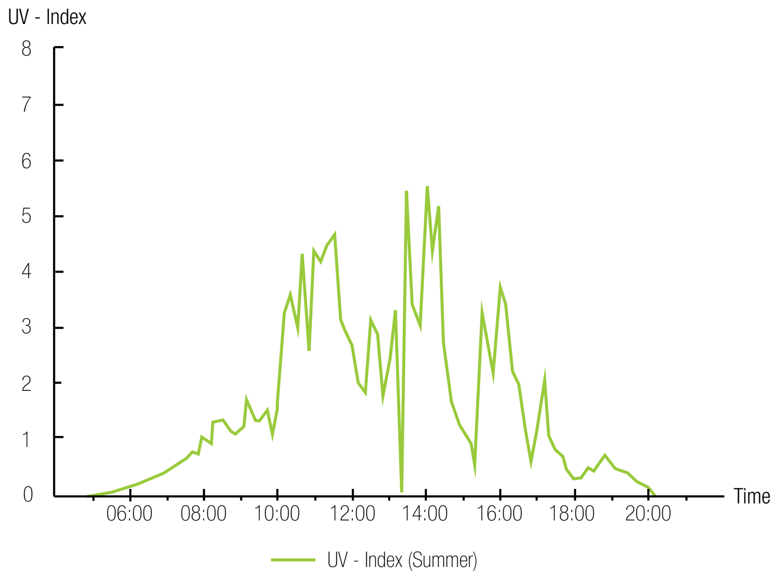
Denmark is located on the northern hemisphere, which means that the path of the sun varies a lot over the course of a year, giving a noticeable difference between the winter and summer season when it comes to the length of the day.[Gaisma.com, 2017] Because of this variation, the inclination and angle of the sun needs to be analysed, to ensure satisfactory daylight qualities and heat gains.
At gl. Hasseris Skole the pupils attend classes in the timespan 8:15 a.m. to 4 p.m.. In this timespan, the suns angle is the same throughout the year, only the inclination of the sun change. This means that when placing the school functions with overheating and glare in mind, it is not necessary to differentiate between summer and winter, yet, when it comes to designing how the light enters the building, it will still be relevant to look at the different inclinations of the sun.
In a school, many rooms, such as classrooms, have a high people load; these rooms should be placed in a way that to avoids direct sunlight. To do this, passive strategies can be employed; such as external and internal overhangs. In other rooms, such as hallways, atriums, etc., there may be a lower people load. Thus, the direct sunlight might contribute positively to the heat gain and design in these rooms.
For the outdoor spaces the path of the sun is a big factor. [Aalborg Kommune1,2017] Due to the high UV-radiation-levels in the middle of the day [Bason og Schønau, 2009], around the time when the students have their main break, the playground must have shaded areas, to minimize their exposure. This will also provide the pupils with areas where they can play during the hottest hours of summertime. (ill.8)

Wind

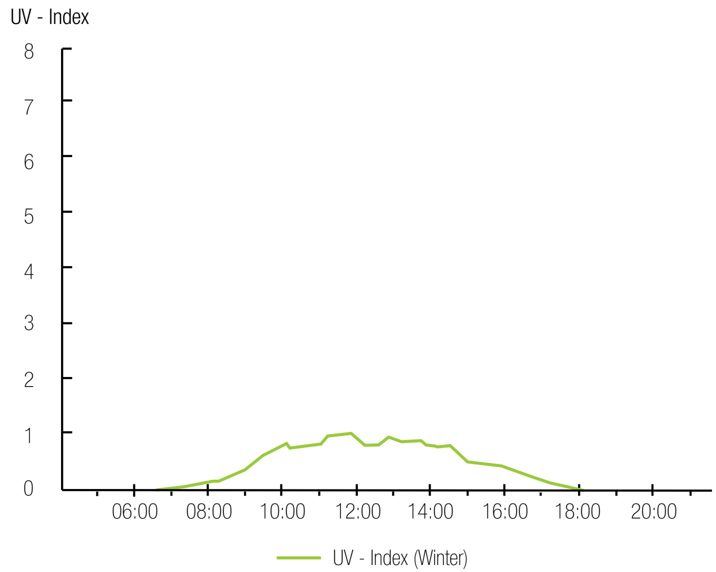
The wind conditions can influence the implementation of natural ventilation [Heiselberg,2006] and by using the wind-force in a positive and constructive way in the design of the school a better indoor climate can be created. The influence of wind on the outdoor areas is also relevant, and even more so, because of the decree of Aalborg municipality, that every playground should enable possibility of playing sheltered from the wind. [Aalborg Kommune1, 2017] The direction of the wind must therefore be kept in mind, when designing the playgrounds, schoolyards and sport facilities.
The wind blows mainly from southwest in Aalborg, [Cappelen and Jørgensen, 1999] and is generally moderate all year. In the winter season, there can be days with winds of storm strength, while in the summer season, the strength of the wind generally does not exceed a rigid gale. (ill. 10-11)
Based on the wind data, flexible shelter-solutions must be considered, to be able to create shelter from the wind all year round.

Sub-conclusions:

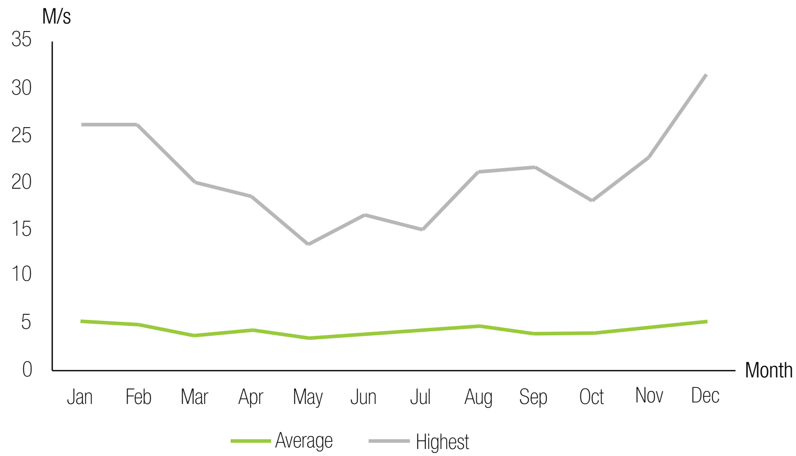
- Playgrounds must create shelter from sun and wind
- Classrooms must avoid direct sunlight
- Natural ventilation adjusted to the wind direction



ill. 8 - Graph showing the UV - index for a summer day.



ill. 9 - Graph showing the UV - index for a winter day.



ill. 10 - Graph showing the wind. Both the average and highest wind velocity.

Wind force	m/s	Name	Description
11	28,5-32,6	Powerful storm	Countless damages
10	24,5-28,4	Storm	Significant damage on houses. Trees are falling.
9	20,8-24,4	Storming gale	Roof tiles blowing down. Huge branches breaks.
8	17,7-20,7	Moderate gale	Difficult to walk against the wind.
7	13,9-17,1	Rigid gale	Large trees are in motion.
6	10,8-13,8	Strong wind	Large branches move
5	8,0-10,7	Fresh wind	Small trees are in a little motion
4	5,5-7,9	Moderate breeze	Dust and paper raised
3	3,4-5,4	Light breeze	Leaves moved

ill. 11 - Table showing the description of the different wind velocities.

School development

Through the years, the way schools are build have changed. From the 1850ies to year the 2000, the schools can be categorized by common values, into three different groupings; the storey school, function-based school and flexible school. (ill. 12-13)[Grontmij A/S et al., 2010]

The storey school-type was mainly build in the middle of the 19'th century. These schools are multiple storey buildings with around 3-4 floors. The main access is often through a central staircase dividing the flow of the building, with a main hall on each floor leading to the classrooms. These schools are often compact with a smaller tarmacked playground in the areas in-between buildings. [Grontmij A/S et al., 2010]
The compact building mass leads to a small footprint, which is beneficial for optimizing the use of space. However, the compact shape also minimizes the interaction between the building and its outside spaces.

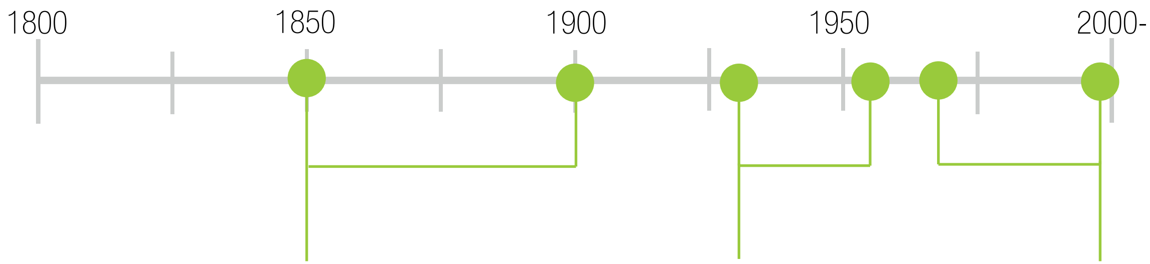
Function-based schools was mainly build around the 1960's. This type of school is built in only one level, with the key principle of gathering same-function rooms in sections. The sections are then often connected to a central part of the building where the common functions of the whole school are located. Outdoor areas around this school are often divided into smaller zones by the large shape and footprint of the building. [Grontmij A/S et al., 2010]
The scattered, but connected, building masses creates a partitioning of the playground, creating a natural division of activity. These schools take up a lot of ground-area and will often have different entrances, which can make the wayfinding more confusing.

The newest tendency in school buildings is the flexible school. This type works with the principle of everchanging work environments, with open plans where the location of functions can change freely, depending on the current needs of the school. These schools are often divided into smaller zones housing the different grades, focusing on minimizing the hallways and instead increasing the communal spaces. This type of school building is often organized around core-functions, such as the library, as the centre of the building. [Grontmij A/S et al., 2010]

The change in school architecture shows how the concepts and needs of the school have changed through time, leading to the current typology, the flexible school, where flexibility and future-proofing are the main foci.
The school of today must have the ability to adjust to new functions, technology and demands, and It needs to be possible to employ different teaching methods to adapt the teaching to future research. The school of today should not only focus on the future, but also learn from the past, by using the elements from the former school types that still work today, e.g. by considering the size of the building-footprint and the interaction between the school and its outdoor areas. These reflections are needed for the school of today to become the school of tomorrow.

Sub-conclusions:

- The school should be flexible for the future development



1850-1900
Several storey school

- Typically 3-4 levels
- Central entrance
- Main staircase to all floors
- The stories are structured with hallways where the classrooms are in succession.
- Typical paved areas

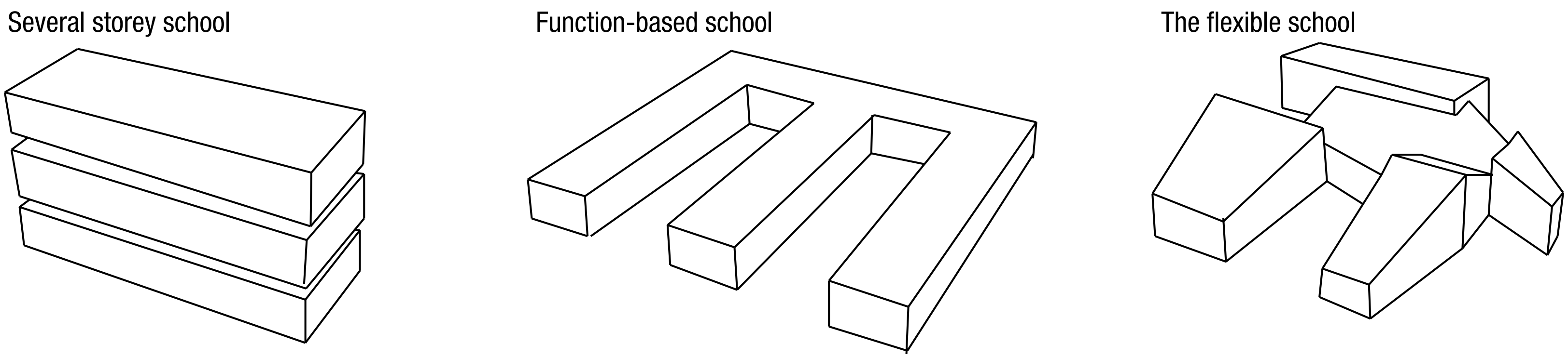
1930-1960
Function-based school

- Function differentiated buildings
- Often larger common areas
- One storey
- Placed in the edge of the town
- Rational architecture

1970-2000
The flexible school

- Home feeling areas
- Ability to establish different types of rooms
- Building can accommodate different teaching methods

ill. 12 - Timeline of the school development.



ill. 13 - Diagram of the different school types

School Reform - Theory

In 2013, the Danish Government enacted a new public school reform. The reform was created to raise the academic level, lessen the effect of the student's social background and to better prepare the students for future education. It includes changes in the teachers' assignment, an increased focus on the outcome of the lessons, and longer days for the pupils. The last modification was introduced to lessen the effect of the social background. The longer school day means less homework, and thereby less of the education depends on the parents. [Regeringen, 2013]

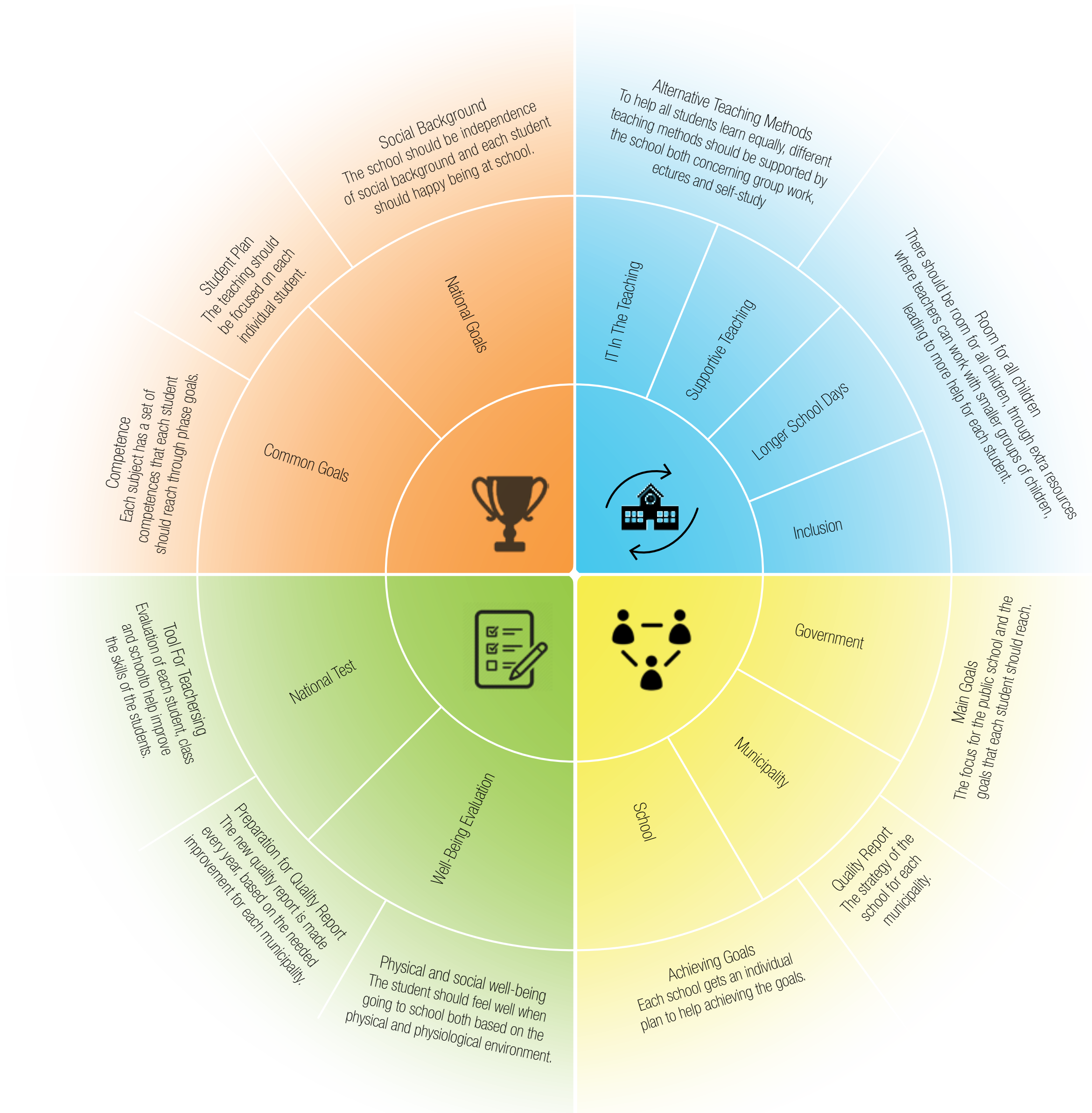
The school reform has three clarified goals, which directly translates to:

- The public school must challenge every student, so that all students have the opportunity to become as educated as possible.
- The public School must lessen the effect of the social background in relation to academic results.
- The trust and well-being of the public school must be strengthened through respect for the professional knowledge and practice. [Rasmussen, 2015 p. 14]

- To achieve these goals the reform concentrate on four main themes: The goals, which serve as guidelines for the school and the teaching.
- "Helhedsskolen", a term describing a school that considers both the stu dents' academic skills and their social skills. [Rasmussen, 2015 p. 14]
- Tests, which help evaluate the school and the students to see how the school is function,
- The delegation, which defines how the responsibility is delegated down though the system (ill.15)

From these 4 points, 7 principles will be extracted as architectural working principles. These can be seen on illustration14.

ill.14 - Diagram of the new goals in the school reform



ill.15 - Main principles of the new school reform

The school Reform - Applied

To analyse how the reform has been applied in practice, three interviews were carried out, with employees from different parts of the public education sector: The Headmaster of Gl. Hasseris Skole [Sørensen, 2017], three teachers [Bækgaard et al., 2017] and a Pedagogical consultant of the school administration of Aalborg municipality [Thorhauge, 2017]. (for full reference see Interviews and Excursions, under Reference list on p. 164) The information gathered from the interviewees has been organized in the table on the next page. (see ill. 18).

The implementation of the seven principles in the school system have given cause to rethink the learning environment, and have brought with it new requirements for the school facilities.
Some of the needs for the seven principles are similar. There is a general need for higher flexibility in the school environment and for using the outdoor spaces better. Additionally, there is a need for differentiated seating areas and innovative solutions concerning the use of IT in the education.

ill.16 - Mood pictures 1 from Nordstjernen in Frederikshavn

ill.16 - Mood pictures 2 from Nordstjernen in Frederikshavn

Sub-conclusions:

- Develop suitable workspace solutions for the teachers.
- Flexible environments and IT solutions.
- Easy access to outdoor areas.

Municipality	Teachers	Principal
• The new school reform states that 10 % of the supportive teaching must be carried out by the local community	• This kind of teaching was already a part of the educational system before the reform. • They include it in their teaching, by planning excursions to the local companies or having theme days or weeks, where a whole year group works together on the project of the theme.	• Local community have become harder to include than previously. • Before the reform, it was more informal, but now that the process has become formalized companies have started charging money for their time.
• The municipality support the “Team Classes” practice, which allows the teacher to split a class up in more hectic subjects or for learning demands, where additional attention and directions by the teacher is required.		• At Gl. Hasseris skole they work with the supportive teaching and extra tutoring hours integrated into the regular subjects • This means that where the pupils previously would have had 6 hours, they could now possibly have 7 hours in the same subject.
• Sees the value of utilising the outdoor areas	• A problem when incorporating activity into the classes have been the limitations of the facilities. • It takes too much time to go outside, because of how the school layout is.	• The exercise is integrated with the courses. • Some mornings they go for contemplative walks in the nearby green recreational area.
• In Aalborg, there is a great focus on the pupil’s level of absence from school and ensuring that the pupils want to come to school. • They incorporate help for the students who need it, to lessen the academic responsibility placed upon the parents. • Pupils all learn in various ways, and some lessons are better taught using specific teaching methods.		
	• They all have their own desks, because they are only allowed three hours of flex-time. • With the new office facilities, they almost don’t use the teachers’ lounge anymore, and instead mainly socialise with the teachers from their own team.	• The long work hours and increase in the teachers’ administrative duties have required the school to focus on the quality of the teachers’ facilities. • Many schools have had to rely on emergency solutions to find suitable office spaces. In this case, they merged the DUS (after-school centre) with the pre-preparatory classes, and thereby freed up enough space for team offices.
	• All students need iPads, and that has left the school with the problem of solving the increased need for powering devices on school premises. • The same goes for the older students’ laptop.	• They are working on phasing out the use of paper, and soon they will be completely digitalised.

ill. 18 - Table of the information of the interviews.

ill. 19 - Mood picture of children playing.

Sub conclusion

- A large space for instructions, and/or the ability to fuse classrooms into one. [Sørensen, 2017]
- Avoid scattered work stations along long hallways, to ease the teacher's supervision and teaching responsibilities. [Bækgaard et al., 2017]

- Inclusion of tutoring into subjects necessitates flexible classrooms, with room to focus individually, and have discussions as a group.
- Courses based on the Team Class practice could be smaller, to better make use of the square meters in some subjects, e.g. elective courses, woodwork classes, etc.

- A recreational path through the school grounds should be established, to reinforce the tradition of morning walks.
- Easy access to outdoor areas or flexible furniture/-areas designed to be used for specific activities, to make it easier for the teachers to plan exercises. This could for instance be done, by having activities in the hallways outside the classrooms or specific activity rooms. [Bækgaard et al., 2017]

- A layout that can be easily altered to suit an array of teaching methods. Examples could be to accommodates preferences regarding body positions when doing a task e.g. sitting upright, sitting laid back or lying down, different materiality, e.g. hard or soft surfaces, and different table positions for group work or individual tasks.
- Working with the indoor environment to make the school an encouraging and inspiring place. [Pejtersen, 2002]

- Depending on the flex arrangements of the school, it is necessary to have either shared workspaces, or an individual office space for each teacher.
- It is most efficient if the office spaces are divided into teams, based on the year group they teach, and that the team office is located close to the classrooms.
- They need a room to work quietly and focused, and a place to socialize that is only for teachers.

- The new demands for digital equipment calls for innovative solutions, on how to supply power for each table, while maintaining the flexibility of the room.
- Power stations for iPads, e.g. locked closets.
- Whiteboards to supplement the smart boards.

Sustainability

Sustainability has been defined in several ways, most of which are based upon the 27 principles defined by the UN in 1992. These principles should be the foundation of the future sustainable development. The principles are based on the concept that sustainability is comprised of three aspects: Environmental, Economic and Social. [United Nations, 1992] The way the world looks at sustainability today is still based upon the UN's definition, even though the way the three aspects are prioritized have changed over the years. In the 1990s, the social aspect had less influence than the others did, but in later years, the social impact and well-being of the people have become more important and today most would regard the three aspects as equally important. [Widok, 2009]

The first generation of certification schemes were BREEAM and LEAD and the main focuses were only the environmental parameters and indoor environment. In 2012 Denmark established a new version of certification schemes that took inspiration from the German sustainable certificate, DGNB. The DGNB is one of the few certifications that, apart from being an environmental certificate, is also a sustainability certificate. This means, that they judge the building equally regarding the three criteria.

Since the Danish DNGB-certificate is based on national values and ideas, this project will use their definitions of the term sustainability. [GBCD,2017] The DNGB uses the same focus points as the UN, where all their criteria are categorized under one of the three focus points. The categories and sub-categories can be seen in illustration 20. Based on the foci of the school reform, and the approach of the municipality, this project will primarily focus on the social- and environmental values.

Economic:

The economic aspects mainly concern the costs of a project and the solutions involving the lifetime of a building and whether it can be re-purposed. Another aspect is the buildings ability to withstand disasters and/or extreme weather situations. [GBCD, 2014]

Environment:

Environmental impacts are assessed in more than one way, e.g. the lifespan of the materials used, the pollution of the materials from cradle to cradle or cradle to grave and whether materials are reused or not. When calculating the environmental impact, the amounts and types of energy used is taken into account with the intent of minimizing the use of resources (electricity, heat and water). Finally the land is assessed, with the total area taken up by the building, and what qualities the building is taking away from the specific area being the primary concerns. [GBCD, 2014]

Social:

The social aspects are used to assess the well-being of the users and the indoor environment in general. This includes the effect the thermal- and atmospheric comfort, the architectural aesthetics, and the amount of art has on the users. The social aspects concern the outdoor areas and how well suited they are to all users. Social sustainability concerns all users in and around the building. The users need to be comfortable in the building and the building should make them want to be there. [GBCD, 2014]

ill. 20 - The sustainability categories of DGNB

ill. 10

Indoor climate

The indoor environment is a big part of sustainability and is crucial, when designing a work space or teaching environment. The research scientist Jan H. Pejtersen has done several analyses on studies of the indoor environment of schools. Pejtersen's research concludes that a good indoor climate can help decrease the number of sick days of the users, and increase general productivity. If there is a bad indoor climate, it can lead to poor health, asthma, a decrease in productivity and dissatisfied users in general. [Pejtersen, 2002] An unpleasant indoor environment can be caused by dust, draft, noise pollution, poor air quality and problems with the temperature. These can lead to problems such as fatigue, dizziness, headache, concentration problems and general discomfort in eyes, nose and throat. Investigations made at schools show that these symptoms decrease the pupils' productivity and ability to learn, and is consequently a big concern for the school-system. [Pejtersen, 2002]

This is one of the reasons that both the government and the municipality wants to increase the well-being in the schools; because it will increase the ability of the students to learn, and it will decrease the amount of student sick leave. [Aalborg kommune, 2015]

When looking at the indoor climate, four factors are examined in this thesis; thermal comfort, atmospheric comfort, acoustic comfort and visual comfort. These factors affect the feeling of well-being of the users.

Thermal comfort:
Thermal comfort is determined by the operative temperature, which is the combination of the users' activity level, the amount and type of clothing, the surface temperature, the air velocity and the air temperature. [Steen-Thøde,1997].
To achieve a thermal comfort, the activity level and amount of clothing of the users, along with the surface temp. must be considered when determining the need for heating in the specific rooms. In general, the air temperature needs to be adjustable, based on the need of the room functions. It is also important to consider the interior layout to prevent draft. [Steen-Thøde,1997]

Atmospheric comfort:
Atmospheric comfort is the general term for the parameters that affects the indoor air quality. [Steen-Thøde, 1997] In a school institution, three parameters are especially relevant: the CO2-pollution, the Olf and the relative humidity. Olf is a unit in which the odours and gases from people and furniture is measured based on the sense of smell. To achieve a pleasant environment the Olf and CO2-pollution must be as low as possible. [Steen-Thøde, 1997] The relative humidity affects for instance the growth of microorganisms and the comfort of the airways. The three parameters can all be managed by integrating plans for the ventilation into the design, and by making a regulated ventilation system. [Steen-Thøde, 1997]

Acoustic comfort:
The building acoustic, room acoustic and noise reduction is dealt with in the acoustic comfort. [Petersen, 1984] Building acoustics describe the measures that can be taken to reduce the sound from one room to another. Room acoustics deals with the actions that can be done to regulate sounds inside a room, from which the sound origin. When these three valuables are considered, and integrated into the design, they ensure acoustic comfort. [Petersen, 1984]

Visual comfort:
Visual comfort encompasses the quality and amount of daylight and the quality of artificial light in the building.
These parameters are determined based on measurements of the daylight factor, the possibilities for shading and for avoiding glare, and the contrast and representation of colours. [Christoffersen et al, 2002]

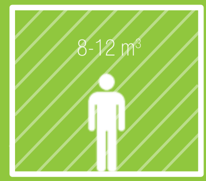
To increase the well-being of the users, the indoor climate must be designed in accordance to the teaching environment, and the interior of the school must stimulate the children's needs. [Pejersen, 2002] To insure the health and well-being of the users in public buildings the government has established basic rules and regulations for the indoor climate. When combining these rules with the analyses of Pejtersen, 2002, 7 basic requirements can be defined. (see ill. 22)

ill. 21 - Mood picture of students.

Sub conclusion

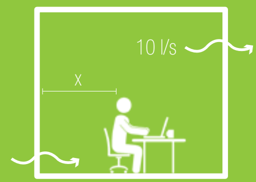
Minimum space

When working with a school there are some specific measurement for how many cubic meters each student should have per class room which will normally occupy around 28 pupils. [bygningsreglement1, 2015]



Ventilation

Displacement ventilation should be considered in all class rooms. The students should be placed at a respectable distance from the system to avoid draft. The general air flow should be at min. 10 L/s per person. [Pejtersen, 2002]

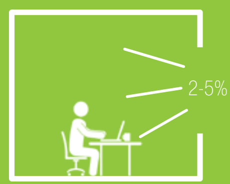


Maintains

All surfaces should be easy to maintain and clean. This will help minimize the overall dust and microorganisms on the school and should lessen the cases of asthma. [Pejtersen, 2002]

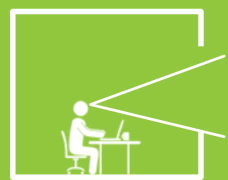
Daylight

In general, a room with plenty of daylight will improve the mood of the users, where a room where for study/work, should have a daylight factor of at least 2 % but preferable 5 %. [bygningsreglement1, 2015]



View

Another way to increase the well-being of the users is to have a window with a view to the outdoors. This orients the users and makes it easier to sense the time of day. [bygningsreglement1, 2015]



Psychosocial enviroment

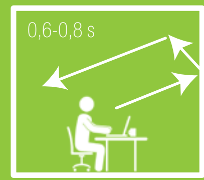
If the psychosocial environment is working well, the users will feel secure and wants to be in the building. It is therefore important to understand how different types of rooms are experienced (see page xx.). [Pejtersen, 2002]

Pollution

To achieve category 2, the Indoor air concentration of CO_2 must not exceed outdoor concentration with 500 PPM. [bygningsreglement1, 2015]

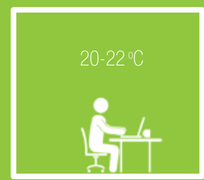
Reverberation time

Reverberation time should fit with the function of the room to achieve the optimal environment. When creating a class room the reverberation time should be 0,6-0,8 seconds. [Petersen, 1984]



Temperature

For the work to be as efficient as possible the air temperature needs to be between 20-22 degrees Celsius. [Pejtersen, 2002]



ill. 22 - Diagrams of the different indoor climate requirements.

Case study - Stjernen

When designing a sustainable building, it is important to integrate sustainable solutions with design solutions specialized to the function of the building. A good example of this is the newly build institution, Stjernen, which has replaced the municipal primary school called Tjørring Skole and the local kindergarten, Børnehuset stjernen. At Stjernen the architects and employees of Tjørring Skole worked in close collaboration to determine the key features of the new institution. Two of these features are the implementation of Sustainable solutions and the design of the outdoor areas.

Sustainable solutions

A sustainable approach has been integrated into the design from the very beginning, beginning with the decision to have an overhang, to minimize the upkeep cost of the building, and orienting the building volume, so that most of the windows face east and west, to prevent excessive temperatures and glare. [Johannesen, 2017]

When approaching the building the most noticeable sustainable feature is the green roof. The green roof absorbs most of the rainwater, and the rest is collected in water reservoirs used for the playground. [Røjkjær, 2017] While very effective, the roof also has esthetic qualities, from the choice of vegetation. Through the seasons the roof vegetation changes colours and expression, which connects the building to the surrounding nature. [Røjkjær, 2017]

In addition to plants, the roof also contains 60 m2 of heat collectors that contributes to the hot water supply, and 600 m2 solar panels providing panels providing a big part of the needed power for the ventilation system. [Røjkjær, 2017]

Sub-conclusions:

- Green roof collecting the rainwater
- Heat collectors for heating domestic hot water
- Solar cells powering the ventilation system
- A Playground with zones lessens the conflicts in the breaks

It is not only the roof that is sustainable. All building elements and materials have a Nordic Swan Ecolabel and have been chosen due to their durability and insulating abilities. [Johannesen, 2017]

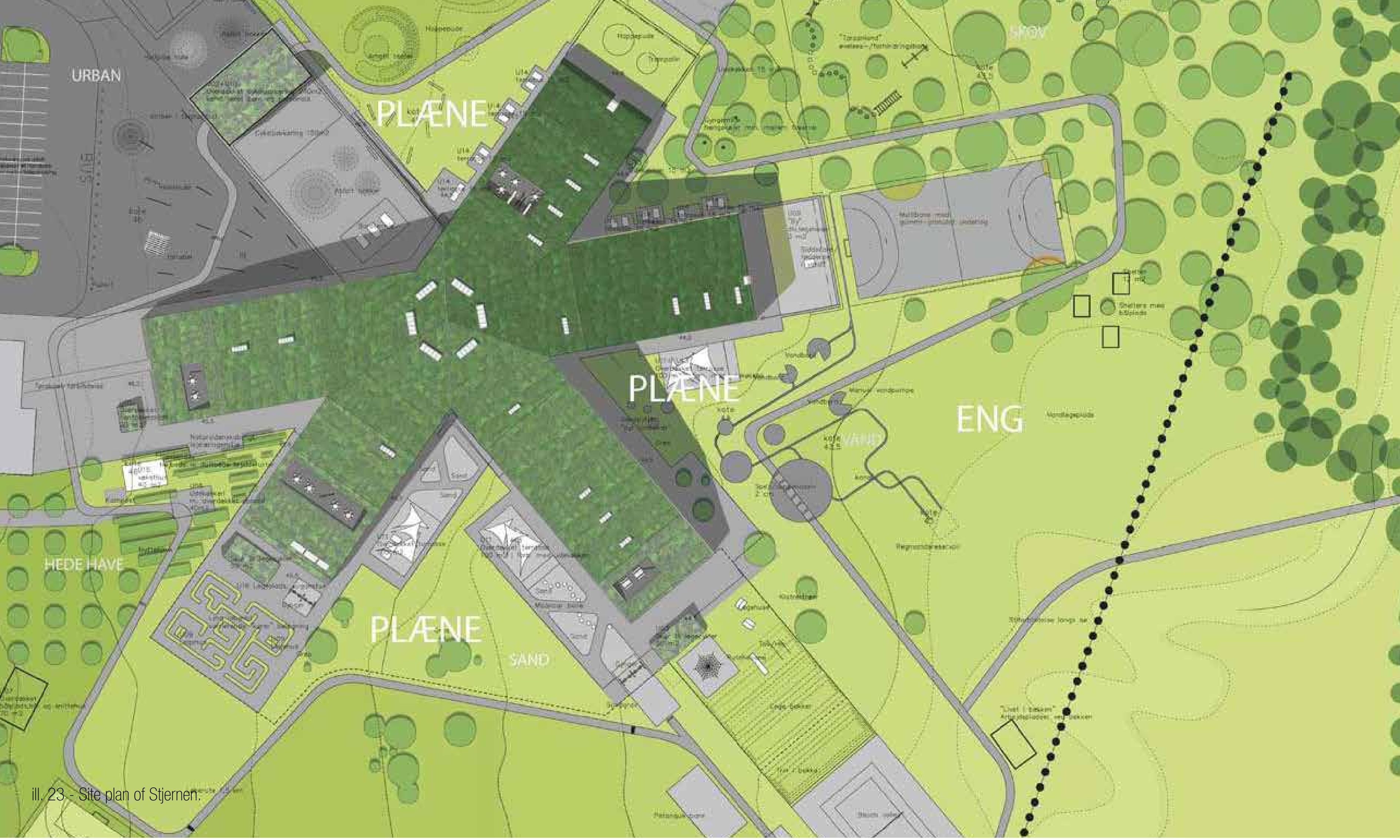
These Initiatives made Stjernen one of the first institutions in Denmark to reach energy class A, which is a class that defines a building with a very low energy and heat consumption. [Johannesen, 2017]

Outdoor Areas

The star-shape of the building naturally divides the surrounding area into smaller zones, which has been used to define areas for activities. Each zone has a theme, which relate to either a specific age-group or an element, such as water, sand, grass and forest, see ill. 23. This opens for the possibilities of diverse play, and provides the teachers with more opportunities for using the outdoor areas as an active part of their teaching. However, for this to work the classes must have a direct connection to the outside, which at Stjernen has been solved by having small outer stairs to the upper levels of the building. [Røjkjær, 2017]

The partitioning of the playground has furthermore resulted in less conflict between the children during the breaks. [Røjkjær, 2017] Because of the various places to play, it has become easier for the pupils to avoid tensions, by playing in different parts of the playground, compared to one big playground, where students having a conflict would be unable to avoid one another. [Røjkjær, 2017]

Stjernen is an exemplary example of a sustainable school, with a diverse outdoor area. When these approaches work as well as they do, it is because that they have been integrated into the project already in the early phases and had the children's needs as the main priority, which is one of the reasons that the school is so well-functioning. [Johannesen, 2017]



ill. 23 - Site plan of Stjernen.


ill. 24 - Picture of the nature huts.


ill. 25 - Picture of grass area.


ill. 26 -Picture of sand area.

Outdoor spaces

An important element of a school is the outdoor areas surrounding the building. This was established in the interviews mentioned earlier: [Bækgaard et al., 2017], [Thorhauge, 2017] and [Sørensen, 2017]. However, in order to fully analyse the essential elements of a school playground, it is necessary to examine the subject more thoroughly.

As a part of a Dutch examination of playgrounds [Dr. Maas et al., 2013], schools with different types of playgrounds were studied, to see the effects of green playgrounds against the effects of grey playgrounds. In this study, a green playground is defined as a playground using only natural materials such as grass, bushes, logs and sand. A grey playground is an outdoor space with elements such as asphalt, jungle gyms and multi-courts.
The examination shows a tendency that when children have a green playground the activity level for both boys and girls will generally be higher than for grey playgrounds. [Dr. Maas et al.,2013]
Yet, it is shows that the pupils use many of the elements of a grey playground frequently. The conclusion of the article is therefore that a playground is most optimal when containing both grey and green areas.

The Urban architect and author Jan Gehl briefly describes the incentives for interaction between children in his book: "Life between the houses". He theorizes that the biggest attractor for play is other children playing or more generally, that play happens when children are in the same place and that interactions happen when the surroundings invite the children to meet each other. [Gehl, 2007]
Studies made by the municipality of Aalborg [Andersen, 2008] also shows that pupils often begin their break by going to specific activity areas. By comparing this information, and keeping in mind that the playground is used for shorter periods of time, between 15-30 minutes during the children's breaks [Andersen, 2008], it can be concluded that defined grey and green activity zones, where children can gather and run to directly when the bell rings, are necessary.
A way to enable meetings between the children playing in different zones, is to work with visibility and natural pathways between the activity zones. With an increased visibility between the zones, the children will be able to survey the activity levels in each zone, and will be more likely start playing together. [Gehl, 2007]

When examining green playgrounds versus grey, the Dutch examination found that the green playground elements often led to higher upkeep and maintenance costs. [Dr. Maas et al., 2013] For instance, a green playground leads to a higher intake of dirt, which in turn increases the wear on the school. Newer schools such as Stjernen and Frederiksbjerg skole, have introduced the concept of shoe-free schools, to solve the problem. This means that all who enters the school must either use coating shoes, or take off their shoes and change to indoor shoes. However, for this solution to work, it needs to be integrated into the architecture.

To create a playground that address all the users and their needs, various elements and principles should be considered in the design. Ill.27 show some of the elements and principles that a playground should contain based on various references [Dr. Maas et al., 2013], [Gehl, 2007], [Andersen, 2008].

Sub-conclusions:

- Support primary movement
- Have sheltered areas on the playground
- Sense stimulating areas
- A mix between green and grey elements

Therm	Description	Suggestions
Mental Relaxation	There should be places with relaxation as the focus, a place with noise reduction where children can be alone.	• Green shielding and niches. • Smaller huts where children can be away from others.
Places for smaller groups	The playground should have places where smaller groups of children can meet and play, and allow them to be separated from the rest of the activities on the playground.	• Smaller huts where children can be away from others • Small niches e.g. with greenery
Places that invites play	The playground should encourage and help the children to start playing, both together and alone.	• Multi-courts • Sand box • Swing • Seesaw • Hopscotch • Jungle gyms
Support primary-movement	Primary movement are actions such as: running, jumping, walking, climbing. The playgrounds activity zones must stimulate these primary movements and challenge the children to move on the playground.	• Running-path around the school/playground • Balance board • Climbing net • Swing • Skipping rope • A jungle gym allows for climbing and jumping
Sense orientated	When playing with each other and exploring on their own children use all their senses to stimulate their creativity. it is therefore necessary to design the playground with all the senses in mind.	• Different textures on the playground such as: sand, grass, water, asphalt, wood • Plants with edible fruits • Flowerbed • Animals (mini zoo)
Independently of age and gender	To encourage children's development outdoor as well as indoor, a playground should be able to offer activities for all, independently of age and gender.	• A green playground is more adventurous and motivates the children's exploring • Boys are more attracted to fields for ball games, and areas that allows hiding and exploring

ill. 27 - Playground table. The table contains different elements that should be integrated in an outdoor area.

Color psychology

The colour of a room not only affects one's experience of a room, but it affects the mood, and even the behaviour. [Bjerregaard, 2005] The explanation for this is that colour consists of electromagnetic waves transported from the eyes as electrical impulses, ultimately reaching the glands of the brain. The glands regulate the hormone levels and other biochemical processes, and it is these chemical processes' that affects a person's mood, and causes certain physical reactions. [Bjerregaard, 2005] Besides this, the colours also affect the reflection of the light in the room. [Lysteknisk Selskab ,2004]

This makes the choice of colour in a room extremely important, especially in rooms where people stay for extended periods of time. Light colours have a higher reflectance than darker colours, and having darker colours on walls, ceilings and/or floors can increase the need for artificial light sources. Light colours also create softer shadows with less contrast. [Lysteknisk Selskab, 2004]

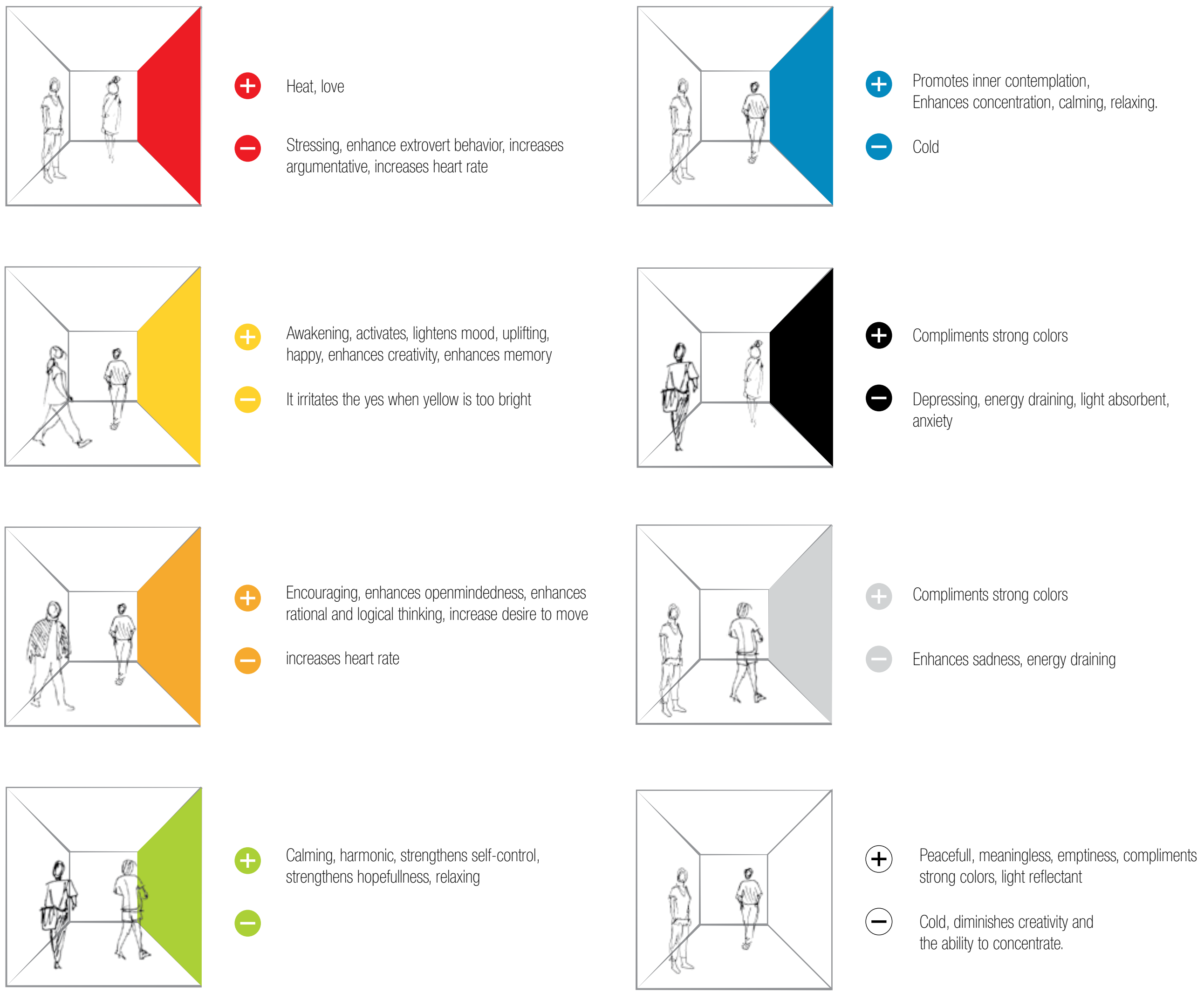
Garish colours on larger surfaces on the other hand, may feel dominating and strong colours in general can completely drown the senses, making it feel uncomfortable to stay in such spaces for a longer period of time.

In contrast, lighter colours generally feel more soothing and relaxing. Often people associates colours with objects from nature and the blue and green colours are therefore the colours most people favour, because it resembles the open sky or sea, and the swaying grass or forests. [Bjerregaard, 2005]

How a colour is experienced and how much people are affected is based on the individual's association with the colour, however, some effects are purely physical. In Norway, an experiment was made, showing that turning down the heat, would make the test persons feel the temperature drop sooner in a blue room compared to a red room, even though the temperature was lower in the red room. [Bjerregaard, 2005] In diagram 28 the effect of the various colours, both mentally and physically, is elaborated.

Sub-conclusions:

- Consider the effect of colours depending on the function.



ill. 16

ill. 28 - Colour diagram. Describes the different colours.

Child development

When approaching the field of child development studies, studies are often divided into three overall categories: the physical, cognitive, and emotional and social. [Berk,2013] The three categories explain the various changes a child goes through before reaching adulthood. To better discuss the development, and apply the knowledge, researchers divide the information into periods. Dr Laura E. Berk has, in her book; “Child Development”, described the major theories for different age groups of children. The age groups concerning children of school age are called; the Early Childhood (2-6 years), Middle Childhood (6-11years) and Adolescence (11-18). Children in Denmark start attending school when they reach 5 or 6 years of age, therefore the focus of this project is on the last segment of Early Childhood. These periods will be used as a basis in this study, along with Berk’s description of the developments happening in each period. The hallmarks of the advances in each period are illustrated in diagram 29.

Architecture

When designing a school, the development of a child should be considered. The architecture should not only support the child’s development but help encourage it, providing the children with the ideal environment to nurture their growth, both physically and mentally.

Using the above-mentioned age groups, the advances in each period have been combined concerning architectural initiatives that will promote the children’s’ development in a school environment. The nine headlines are described next to:

The early childhood

Active play

Space to run around, soft materials to lessen the impact of a fall.

Exploring

Places where their creativity is stimulated, making them think for them self - such as nooks and crannies.

Frames for imagination

Supporting make-believe scenarios with defined spaces that incite play. Playing together will let them establish ties to their peers, while expanding their thought and language capabilities.

Middle Childhood

Preparing for adolescence

Places for sitting and talking.

Athletic play

Places challenging their improving physics, with room for group based activities, such as climbing and outdoor ball games.

New challenges

Learning stimulated environments, e.g. black boards in hallways and zones for both playing and teaching.

Adolescence

Contemplative spaces

Places to think and talk about all the changes that are happening e.g. lounge possibilities, quiet spaces.

Flexibility & diversity

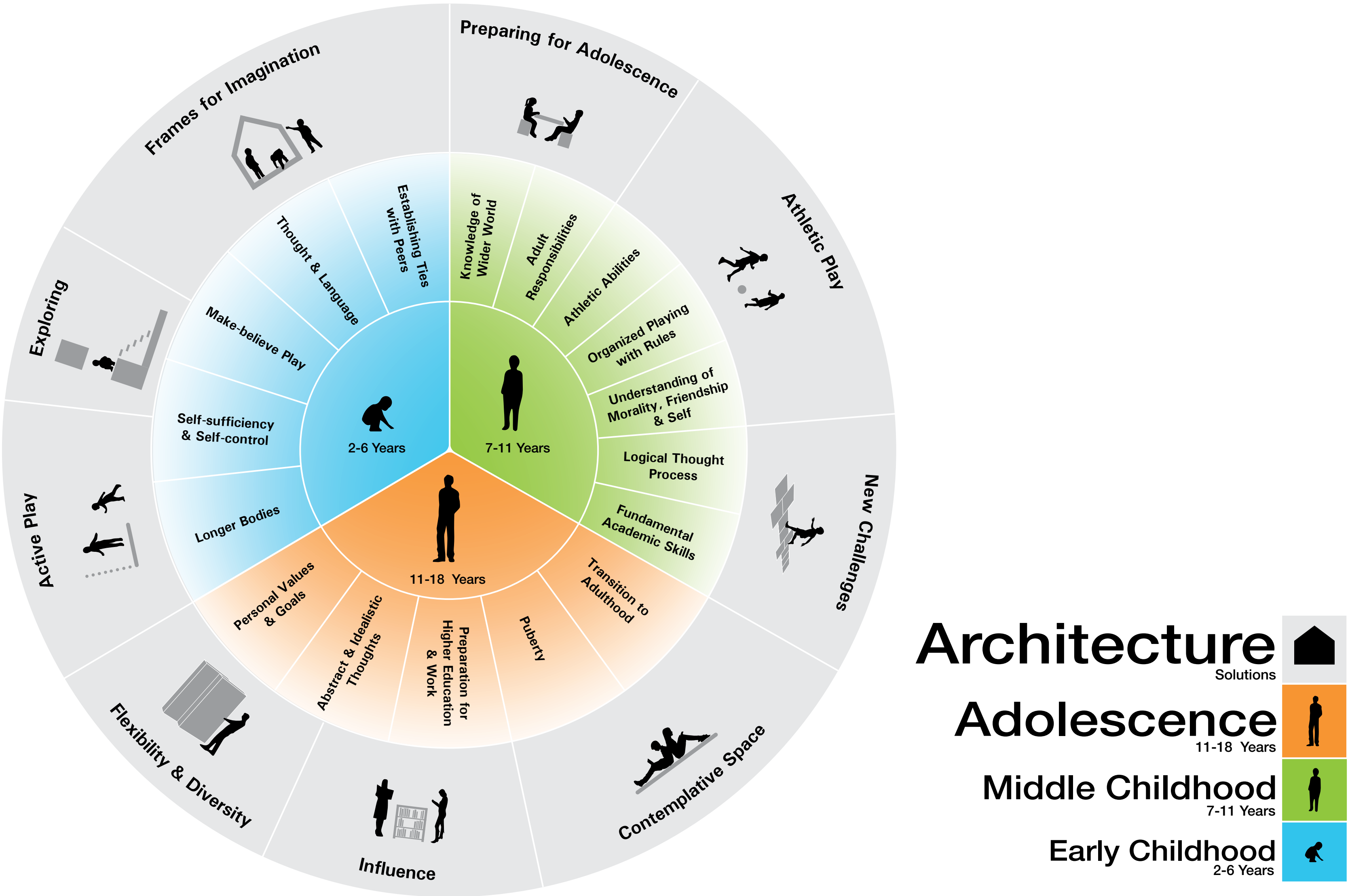
Less rigidity in their environment, with multifunctional and -purposeful spaces e.g. bringing the education into the hallways, spaces for being social and alone.

Influence

Influence on education and access to information on further education, through e.g. suggestion boards, library, informative sections.

Sub-conclusions:

- Creating spaces for the different stages of development.



ill. 29 - Child development diagram.
The diagram show the three categories a child goes through.

Learning environment

With the changing times and the implementation of the school reform, the approach to teaching has changed. [Grontmij A/S, 2010] The Danish public schools are hard-pressed to adapt their current facilities to the new theories on diverse learning methods. Meanwhile the technological development pushes the schools even further, challenging not only the way teachers are used to teach, the functions of the school. [Grontmij A/S, 2010]
Because of this, the mutual culture of older schools tends to focus on limitations, while the schools with newer buildings tend to create a culture that embraces opportunities. [Koral et al., 2010] What makes the difference is the building, classrooms, common rooms, and halls' ability to contain the new learning methods. [Koral et al., 2010]

The Four Learning Styles
Nowadays there is not only a heightened focus on flexible work areas, where it is possible to work individually, in teams or receive class instruction, but also on the fact that pupils learn best in different ways. [Grontmij A/S, 2010]
Research shows that there are four kinds of learning styles that the students learn by; visual learning, auditory learning, tactile learning and kinesthetic learning. [Borup, 2017] A visual student learns by using their eyes, reading texts, watching movies or looking at images, while an auditory student learns by conversation and by listening. A tactile student on the other hand, learns best by using their hands, e.g. taking notes or using tools to solve tasks, and a kinesthetic student learns with the entire body through movement and likes to move around while working.

Sub-conclusions:

- Creating flexible interior solutions

In an interview with the municipality, it was pointed out that especially younger pupils have trouble staying calm and seated for a whole day. They need to be taught by the concept of "learning by doing" or "learning by moving", to stimulate their need for exercise and activity. [Thorhauge, 2017] This complies with the theory of the kinesthetic student.

The four learning styles are a part of what makes differentiated learning methods and environments so important. For instance, an auditory student will respond better to a lecture or group-based tasks solved by conversations or discussions, than a kinesthetic student. A kinesthetic student may respond well to group-based tasks, depending on the freedom in movement, but would lose their concentration in a static lecture. They respond better to teaching based on active playing, or dynamic situations where the seating situation changes. [Borup, 2017]
A tactile student will learn more in a class that provides models or objects, or workshops, where they can work with their hands. For instance, a way to make a tactile student more interested in Geography, could be to have 3D-maps they can touch and feel.
The Visual student, like the auditory student, responds well to a lecture, but in this case, it would be important to include plenty of visual elements, such as images projected onto a screen, or drawings of figures or the like, on a black- or whiteboard.

A class will often contain students that learn by more than one of the above-mentioned learning styles, and it might also change with their age. [Borup, 2017] Consequently, the learning environment requires a high level of flexibility to enable teaching methods that suits all 4 learning styles. In ill. 30 various types of learning environment can be seen, where the benefits of the various learning styles are listed.

Teaching

Active teaching

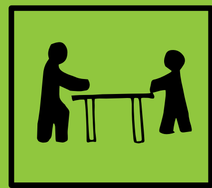
- Movement
- Kinesthetic and visual students

Could be:
- Orienteering race
- Hopskotch
- Large open space
- Activity rooms

Visual and tactile teaching

- Show and tell
- Light furniture, easily moved

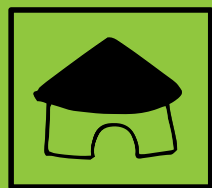
Could be:
- Centred teaching around desk
- Exhibitions
- Crafts tables



Outdoor teaching

- Focus on Nature
- Open outdoor environment

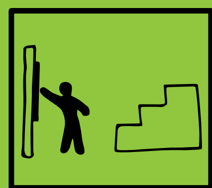
Could be:
- Nature huts
- Rooms that are both inside and out
- Garden beds
- Animal zoo



Lecture teaching

- Focus towards the teacher and a whiteboard

Could be:
- Classic teaching
- Lecture stair
- Use of media

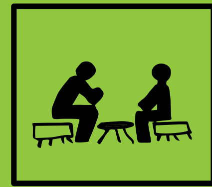


Group work

Debate/Conversation

- Dialog and conversation
- Eye-contact
- Freedom to move

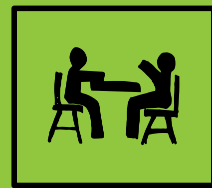
Could be:
- Niches
- Informel furniture
- Light furniture, easily rearanged



Problem-solving

- Contemplation
- Focus
- Well-lit area
- Low volume

Could be:
- Open area with screens
- Whiteboards

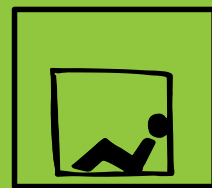


Individual work

Reading & listening

- Shielded/Sheltered
- Choices: lying/sitting, soft/hard

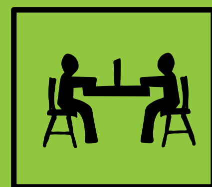
Could be:
- Window sill
- Fatboys
- Niches
- Quiet Rooms



Problem-solving

- Contemplation
- Focus
- Well-lit area
- Very low volume

Could be:
- Table seperators
- Movable or permanent screens
- Study rooms



ill. 30 - Learning environment

Frederiksbjerg skole

Frederiksbjerg Skole is a new school in Aarhus where the teaching environment is the key element. [Leick, 2016] The school has all throughout its building- and design process tried to incorporate the newest learning methods and ways to interpret the public school. The most visible way is in how the school embraces physical activities as an integrated part of the school, inviting the children to run, climb or jump, as a part of their regular movement through the school. [Leick, 2016]

The learning environment is based upon three main learning methods:

Communication and immersion

This learning method focus on how information is conveyed to the pupils, specifically through instructions. The Communication has a max. duration of 20 min. that should not be exceeded.

Team Work

The pupils can sit together in groups, while they work on different subjects and assignments.

Contemplation

The pupils are given the opportunity to immerse themselves into their assignments and sit undisturbed and work by them self. [Nielsen, 2017]

The three methods reflect the way the classroom and common area are constructed. [school visit 1, 2017] Each classroom has a niche used for the communication method (see ill. 32). The stair forces the pupils to sit close together, in a space with as little surroundings as possible, to decrease the amount distracting elements. Furthermore, this allows the teachers to be closer to the students, letting the teachers talk with their usual tone of voice, creating a more relaxed atmosphere. [Leick, 2016] [school visit 1, 2017] The rest of the classroom is designed for group work, with clustered tables for smaller groups (see ill. 34). the common area between the class rooms is a more informal space for group work, with small adjoining group rooms. Smaller groups of students can use the room to immerse them self into their work, or the room can be used to teach smaller groups of pupils. The hallways are used as small common rooms, where there is both areas for group work and contemplative work. [Nielsen, 2017]

As a part of the change from regular schools, the children do not have fixed classrooms. Instead they have academic environments, where each class is designed to a specific subject.
Without a regular class room, the students needed a place to stay in the break-periods. Frederiksbjerg skole solved this by making small activity rooms and various seating arrangements around the school, letting the students find their own favourite spot. [Nielsen, 2017]

All of these actions, have given the school a new way to interpret teaching. It has resulted in more activity during lessons and free-periods, given the teachers new tools to work with and made it easy for the teachers to apply different teaching methods [Nielsen, 2017]

Sub-conclusions:

- Play as a part of the movement through the building.
- Teaching environments based on three learning principles
- Academic environments


ill. 31 - The activity hall at Frederiksbjerg skole.


ill. 32 - The stair in the classroom at Frederiksbjerg skole.


ill. 33 - Activity element in the hallway at Frederiksbjerg skole.


ill. 34 - The group room at Frederiksbjerg skole.

The psychological effect of a room

Form and space affects people psychologically. [Kural et al., 2010] Everyone has experienced a room that has made him or her feel uncomfortable or joyful. To be able to design an ideal indoor environment for the users, it is necessary to know how to avoid, or achieve, these psychological responses.

In the former analysis, one of the requirements concern the psychosocial environment (Indoor Climate, p. 30). Psychosocial comfort is accomplished when the environment is both socially, and physically, suited to the users. It is therefore necessary to analyse which elements in a room affects the pupils and how.

In the research project APOS [Kural et al., 2010], concerning education and health, the study formulates 5 room categories; the sublime room, the qualified room, the indifferent room, the suppressive room and the unhealthy room. The 5 room categories, outlines the overall qualities that affects a person's experience of the specific room-category and the psychological responses that follows. They can therefore be used as guidelines, to understand the qualities and problems in different rooms. The categories can also be used as background knowledge for design decisions, to ensure that the design has the right effect on the users. [Kural et al., 2010] Illustration 35 shows a simple illustration of the different room types, their main elements and how they affect the users of the rooms.

When designing a school the goal should be to have either qualified- or sublime rooms. These rooms would give a positive effect on the users and support the function of the room. One of the main reasons that these types of rooms works well, is due to the light in the room. As mentioned in the section about the indoor climate light has a big impact on the people in the room. For a school, light in a room can improve the productivity and mood of the students in the room, but too much light can create glare, [Pejtersen, 2002] thereby creating the opposite effect. The sublime room could therefore create too much light for rooms such as class rooms, where a hallway or a common area would work with a larger amount of light.
Another factor the two room types have in common is the clarity of the room. It is easy to get an overview of the rooms; whereas rooms without clarity could give the uses an overwhelming feeling and lead to stress. [Carter, 2012] This is especially important for rooms where the pupils would spend long periods of time. The qualified room has an extra focus on this quality and it would therefore be a good match for classrooms.

Sub-conclusions:

- Create either qualified – or sublime rooms

The sublime room
- Aesthetically pleasing
- Clear bright light
- Often a large room
- Beautiful
- Magnificent
- Makes you feel:
    - o Inspired
    - o Solemn

The suppressive room
- Difficult to orient one-self
- Diffused light
- Confusing décor
- Makes you feel:
    - o Confused
    - o Disturbed

The qualified room
- Orderly
- Consistent
- Well-structured
- May have an invigorating colour
- Makes you feel:
    - o Safe
    - o Comfortable
    - o Exhilarated
    - o Welcome

The unhealthy room
- Dark
- Messy
- Confusing
- Smelly
- Makes you feel:
    - o Nauseated
    - o Unsanitary

ill. 23

The indifferent room
- Nothing special
- Makes you feel:
    - o Indifference
    - o Alienated

ill. 35 - Diagram of the 5 categories of rooms

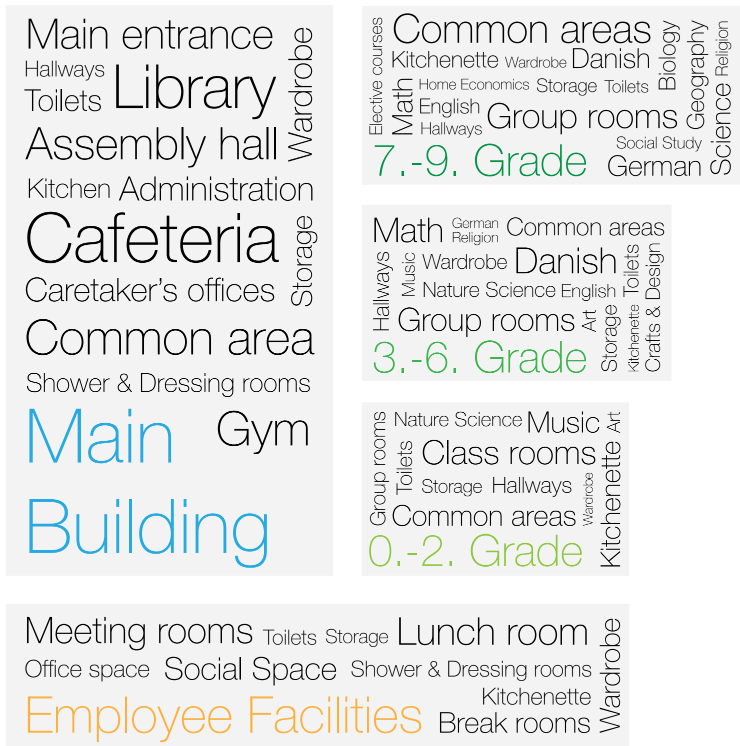
Room program

	Number	Area (m^2)	Collected area (m^2)	Activity	Daylight	Persons	CO_2 in the air (ppm)	Reverberation Time (sec)	Op. Indoor temp. Summer (C °)	Op. ndoor temp. Winter (C °)
Workshop Room	8	40	320	■■□	2-5%	26	500*	≤ 0,6	23,5-25,5	21-23
Class Room	43	40	1720	■□□	2-5%	26	500*	≤ 0,6	23,5-25,5	21-23
Common Area	10	40	400	■■□	2-5%	30	500*	≤ 0,4	23,5-25,5	21-23
Group Room	20	8	160	■□□	2-5%	5	500*	≤ 0,6	23,5-25,5	21-23
Toilet	53	2	106	■□□	—	1	500*	—	—	—
Office	5	8	40	■□□	2-5%	1	500*	≤ 0,6	23,5-25,5	21-23
Meeting Room	7	10	70	■□□	2-5%	10	500*	≤ 0,6	23,5-25,5	21-23
Warderobe	11	20	220	■■□	—	20	500*	—	—	—
Canteen	1	200	200	■■□	2-5%	200	500*	0,7-1,1	23,5-25,5	21-23
Canteen Kitchen	1	40	40	■■□	2-5%	5	500*	≤ 0,6	23,5-25,5	21-23
Library	1	80	80	■□□	2-5%	26	500*	≤ 0,6	23,5-25,5	21-23
Gym	1	250	250	■■■	—	40	500*	0,7-1,1	23,5-25,5	21-23
Dressing Room	2	20	40	■■□	—	15	500*	—	—	—
Teaher Workspace	45	3	135	■■□	2-5%	45	500*	≤ 0,6	23,5-25,5	21-23
Teacher Group Room	3	20	60	■□□	2-5%	10	500*	≤ 0,6	23,5-25,5	21-33
Teacher Break Room	1	60	60	■□□	2-5%	45	500*	≤ 0,6	23,5-25,5	21-33
Assembly Hall	1	350	350	■■□	2-5%	760	500*	0,7-1,1	23,5-25,5	21-33
Depot	5	10	50	■□□	—	1	500*	—	—	—
Caretaker Office	1	20	20	■■□	2-5%	2	500*	≤ 0,6	23,5-25,5	21-33
Collected Area			4321							
Collected Area With Hallways			6050							

*500 ppm over the outdoor pollution

ill. 36 - Room program table.
The information in the table will be used to design the school.

Function diagram



ill. 37 - Function diagram
The diagram show the different functions and how they should be connected to each other.

Design criteria

Environment

Interplay with surroundings:

- Strengthen the green zone of the local area
- Integrate entrance points
- Local typology
- Adjust to the typography

Outdoor:

- Easy access to outdoor areas
- Areas of the playground sheltered from sun and wind
- Different zones
- Supporting primary movement

Indoor:

- Flexible environment
- The requirements of the school reform
- Workspace solutions for the teachers
- Easy access to outdoor areas
- Consider the effect of colours - depending on room functions
- Integrate solutions from the phases of child development
- Create qualified- and/or sublime rooms

Sustainability:

- 2020-demands
- Focus on social- and environmental aspects
- Integrate passive- and active strategies
    - Utilise the wind direction for natural ventilation
    - Avoid direct sunlight
- Comply with the 9 indoor climate regulations
- Integrate solutions for further development of the school

Technical design criteria

Indoor environment				
Category	I	II	III	IV
Operative temperature (^0C)	21-25	20-26	19-27	
Temperature (^0C)	21-23	20-24	19-25	
Relative Humidity (%)	30-50	25-60	20-70	0-100
CO2 concentration (ppm)	750	900	1200	>1200
Airflow pr. person (l/s)	10	7	4	<4
Daylight factor (%) in 50 % of the area	>2	1,5-2	1-1,5	

Envelope qualities		
Insulation	Ceiling and roof constructions:	U-value = 0,10 W/(m2*K)
	Exterior walls and basement walls:	U-value =0,15 W/(m2*K)
	Ground deck, basement floors	U-value = 0,10 W/(m2*K)
	Windows, exterior doors and skylights:	U-value = 1,0 W/(m2*K)
Line Loss	Foundations:	psi-value = 0,12 W/(m*K)
	Foundation for buildings with 3+ floors:	psi-value = 0,30 W/(m*K)
	Seam between exterior wall and windows, doors:	psi-value = 0,03 W/(m*K)
	Seam between roof construction and skylight:	psi-value = 0,10 W/(m*K)
Transmission	1 floor	3,5 W/(m2*K)
	2. floor	4,5 W/(m2*K)
	3 floor	5,5 W/(m2*K)

ill. 38 - Table of technical design criteria.

DGNB criteria

As mentioned previously, the DGNB criteria will be used as a guideline for the definition of sustainability. [DK-GBC, 2015] However, this project does not aim to fulfill all aspects of DGNB, rather it is used to get clear guidelines and values that can support the integration of sustainable aspects into the project, and give measurable data to use as comparisons. The specific criteria that will be used as a part of the design process is:

TEC 1.1 - Fire protection

The most important aspect of this point is to ensure safety from fire in general and to prevent the fire from spreading. This is for instance, by planning escape routes and placing rescue openings for easy escape from the building.

TEC 1.2 - Sound conditions

Proper sound conditions are key for an efficient learning environment.

TEC 1.3 - The thermal envelope

The thermal envelope must secure a good indoor environment, by lessening the heat loss and protecting the building and construction from moist-damage.

TEC 1.5 -Maintenance and cleaning

Maintenance and cleaning is crucial to ensure a long life of the building materials. Clean-friendly materials needs to be integrated into the design, and it is necessary to make sure that all areas of the building can be easily accessed by the cleaning personnel.

SOC 1.1 - Thermal Comfort

Thermal comfort increase the health and welfare of the users. To achieve thermal comfort, the temperature, humidity and draught must be calculated and documented to accommodate the specific functions.

SOC 1.2 - Indoor air quality

This criterion is a knock-out criterion, which means that if the minimum requirement is not fulfilled then the building will not be able to be certified. The main part of this criterion is to make sure that the air change is efficient enough to remove smell discomforts and unhealthy substances from the air.

SOC 1.4 -Visual comfort

The main factor for the visual comfort is the amount and quality of light in the buildings. The light affect the mood and efficiency of the users, making light a significant factor the general comfort in the room.

SOC 1.6 - Qualities of outdoor areas

This criterion concerns the outdoor areas, which elements they contain, types of plants and how the sunlight conditions are. It also evaluate if the roof or facades are green and whether or not the roof can be used by the uses.

SOC 3.3 - Plan dispositioning

Plan dispositioning is crucial for the functionality and flexibility of the building, providing the possibility of having different applications for the same room, and giving the building additional spatial and architectural qualities.

SOC 2.3 - Bicycle conditions

The goal for this criterion is to promote and support the use of bicycles as a transportation method, by e.g. creating quality bicycle parking close to the entrance.

SOC 2.1 - Accessibility

Accessibility is also a knock-out criterion, because it is important that all parts of the building is accessible for all users. It should be as easy as possible for all users to move around in the building and independent movement for user with less functional capacity should be ensured.

ENV 2.3 - Efficient use of areas

It is important to consider the condition of the site, e.g. the pollution level, and deliberating the need for removing or adding extra soil to the area. Another factor for this criterion is also to incorporate which type of cover should be used in the outdoor areas e.g. grass, sand and asphalt.

ENV 1.1+2.1- Life circle analysis – environmental affect and Primary energy
A building affects the environment all through its life time, from the production of the material to the disposal. A life circle analysis evaluates the materials of the building both in concern of energy use and the effect on the environment concerning substances such as CO2.

ill. 39 - Diagram of DGNB categories.

Vision

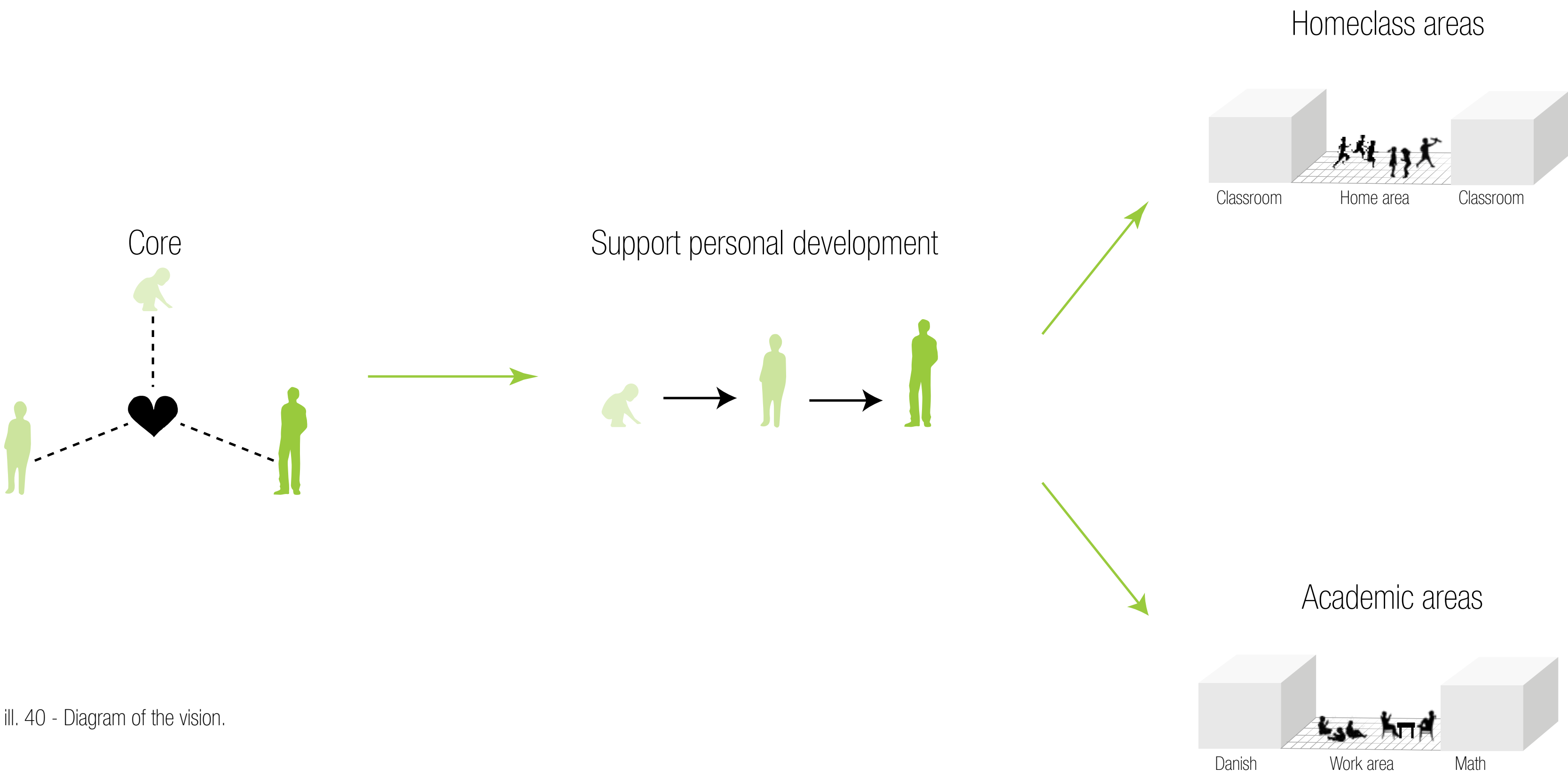
A school has a complex room program, with many users, each with specific needs. At the same time, a school is a community where the users benefit from interacting and sharing functions to strengthen the bond between them.

This project will focus on the meeting between home-areas and shared functions, by gathering the shared functions as the core of the building. The core will be a place that all users passes through and use several times a day. This will enhance the interaction between pupils of different age groups while maintaining a stable environment for the pupils, in their home-areas. The diverse needs of the children concerning their development, makes it vital to differentiate between their learning environments.

Where the youngest children need fixed boundaries and security, the intermediate and eldest students benefit from varying and dedicated environments.

Inspired by the case study of Frederiksbjerg skole (p. 42), this project will work with integrating academic classrooms for the intermediate and eldest students, and home-classes for the youngest pupils. The home classes allow the youngest pupils to adapt to the school environment, and the academic classrooms specializes the learning environment to each subject, and causes pupils to use the hallways and common rooms in the breaks.

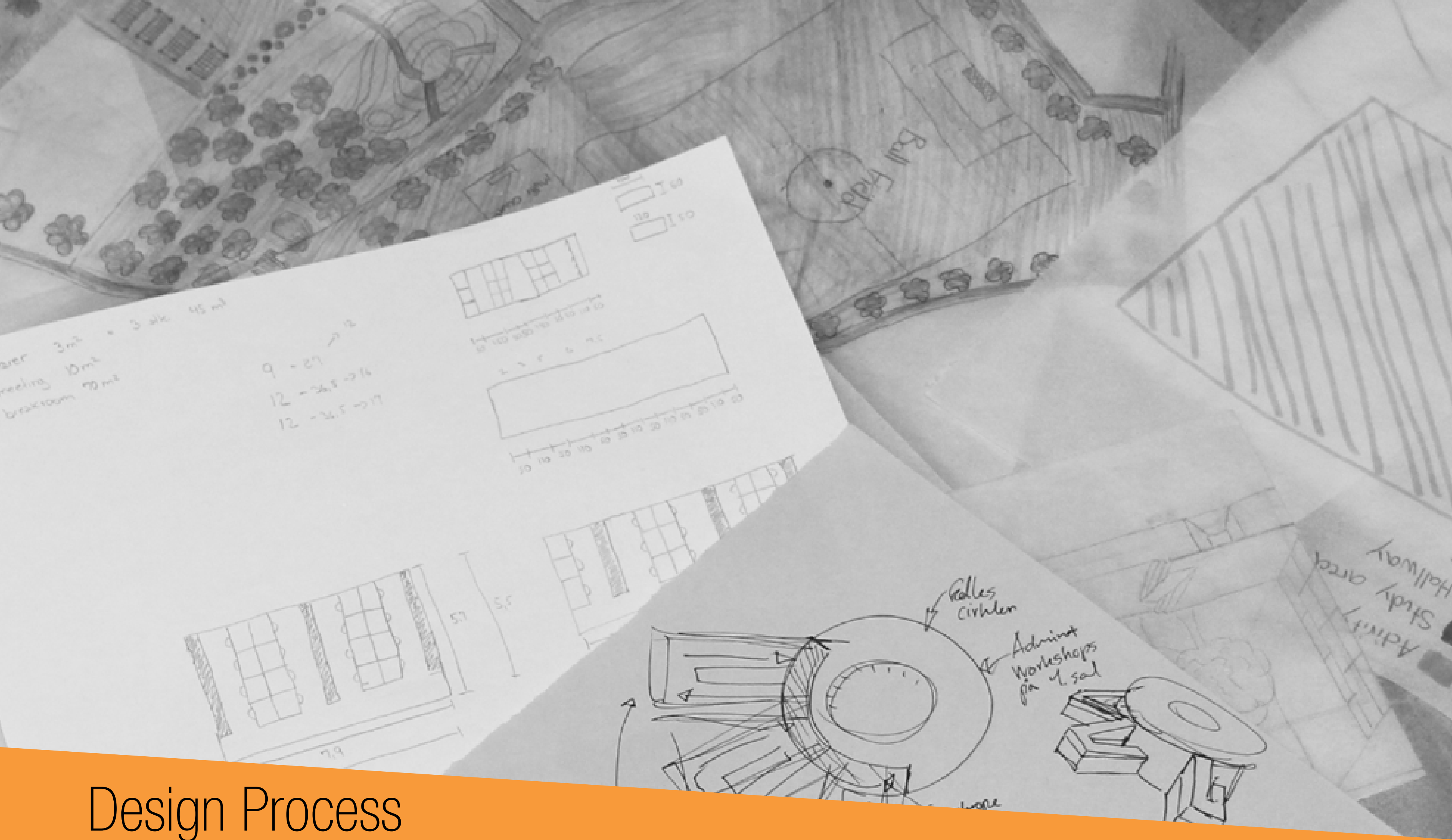
The focus of the project is to stimulate the pupils through activity and learning, by creating diverse environments and work situations that will support the pupils' unique needs.



ill. 40 - Diagram of the vision.

ill. 41 - Picture of some design process drawings.

02



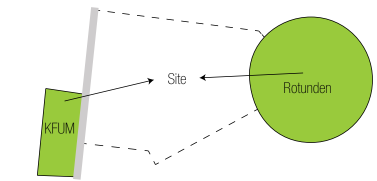
Design Process

This section contains a description of the process that have led to the final design of this project. The process includes in-depth analysis of the user requirements and functions. The design process proceeds with a study of room placement, various form creations, and analyses of design solution, leading to the final design.

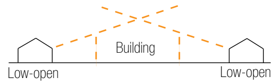
Design criteria

Interplay with surroundings

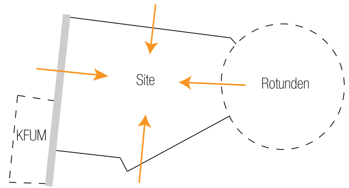
Green zone in the area



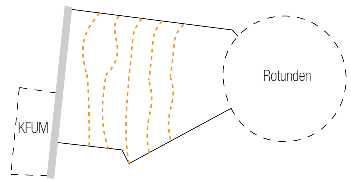
Local typology



Entrance from several points

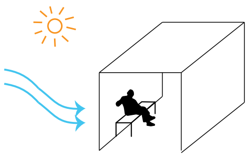


Adjust typography

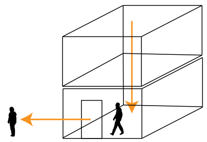


Outdoor

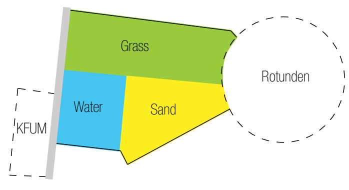
Shelters outside



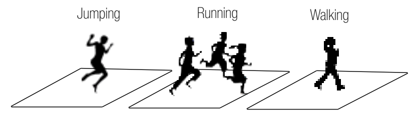
Easy access to outdoor areas



Different zones

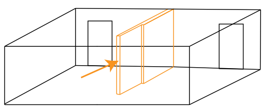


Supporting primary movement

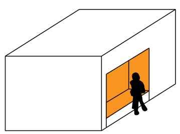


Flexible environment

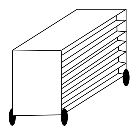
Rooms can be united



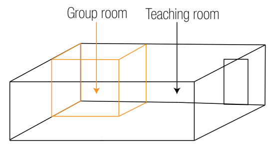
Niches

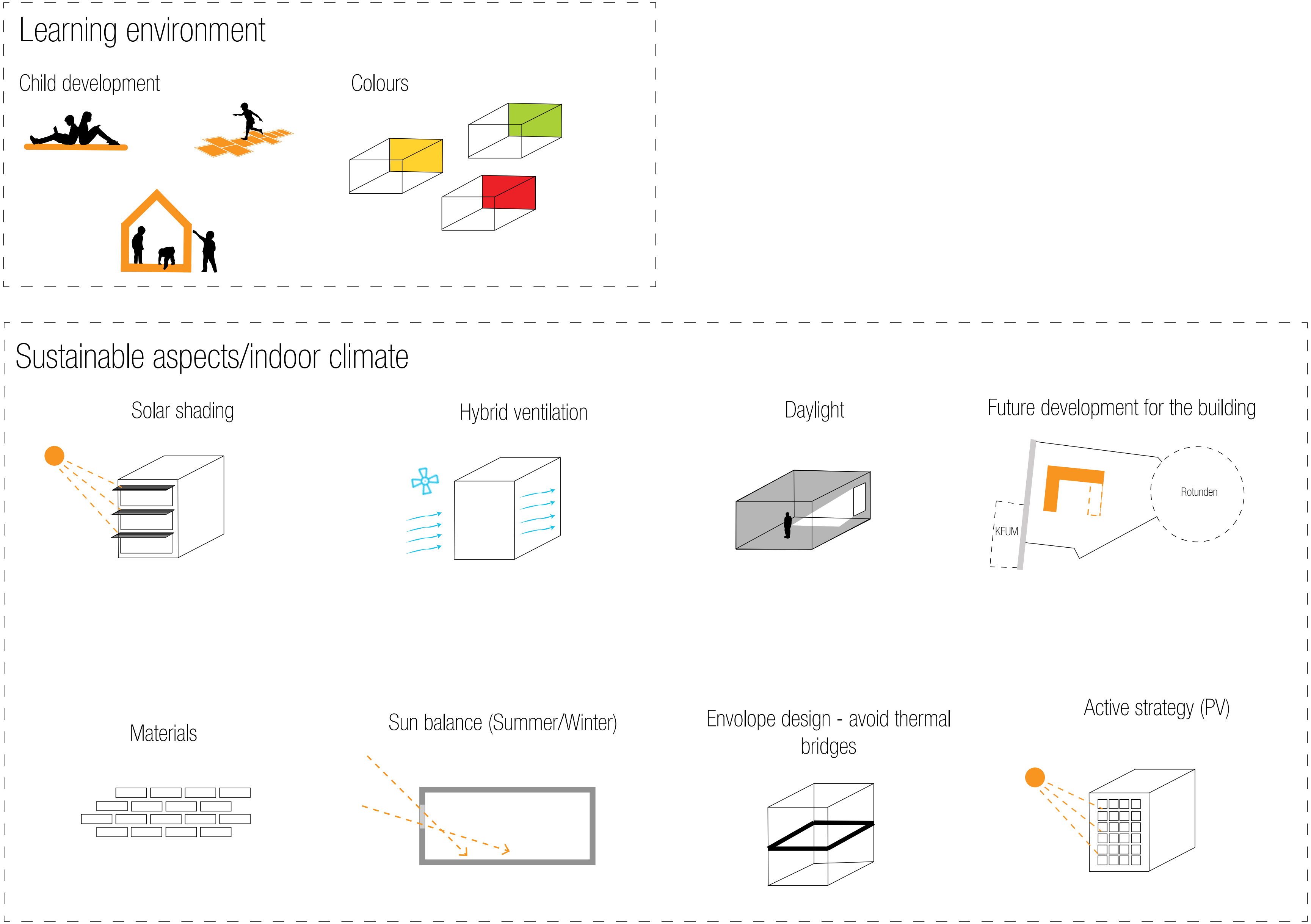


Movable funitures



Rooms with several function





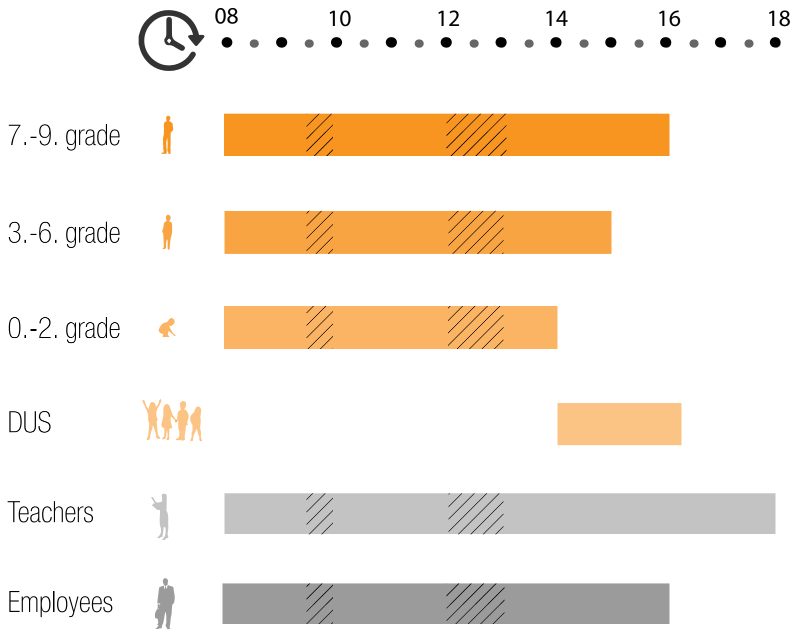
ill. 41 - illustration showing some of the design criteria made to initiate the design process

The design criteria showed on the previous pages can further be analyzed depending on their priority in the project.

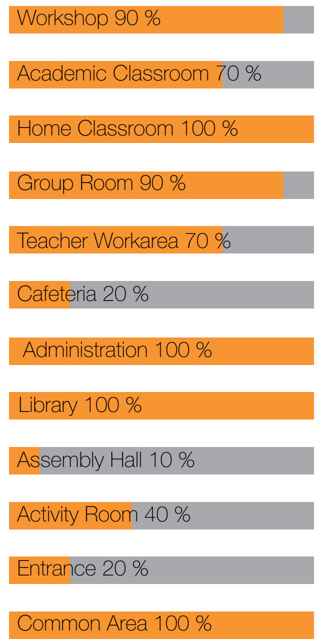
	Important			Most Important
General Criteria	Sustainable Aspects • Materials • Passive and Active strategies Rooms With Psychological Qualities • The rooms should be nice to stay in • The rooms should stimulate the pupils	Outdoor Areas • Shelter • Different zones • Supporting primary movement Interplay With Surroundings • Enforce the green zone • Entrance from several directions • Interplay with Rotunden Easy access to the outdoor areas from classes	Future Development • Possibility to expand the building Flexible Environment • Rooms that can be united • Movable furniture • Rooms with several functions • Using hallways for seating and smaller stays	Indoor climate • Daylight • Mechanical Ventilation • Natural Ventilation Child Development • Spaces on the children's terms School reform
Technical Criteria	Color and Material Reflectance Hot and Cold Rooms	Acoustic	Mechanical Ventilation Natural Ventilation Shadow on Surroundings	Thermal Comfort Daylight Fire Demands

ill. 43 - Table of the design criteria

User Schedule Analysis



ill. 44 The user's daytime schedule.
These schedules shows when the different user-groups are at the school, with their breaks marked in their bar.



ill. 45 - Occupancy of room types.
This diagram show the approximatly percentage each type of rooms will be occupied.

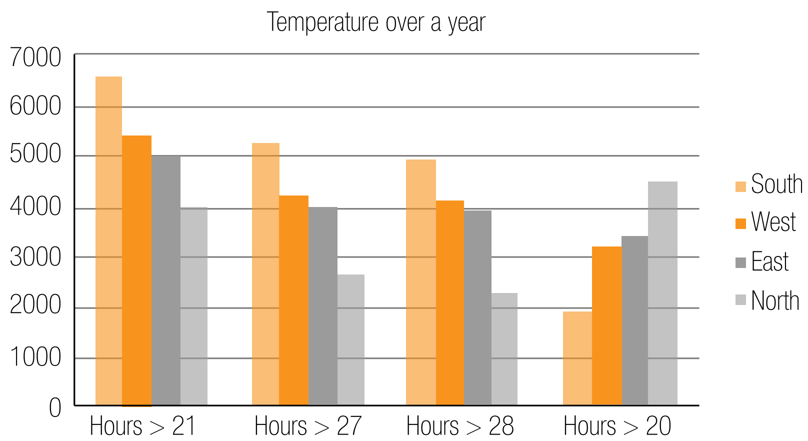
Room placement

In a building, every type of room has its own set of parameters, that influences the quality and comfort of a room. Many of these parameters, such as visual comfort and room temperature, are connected to the orientation and general placement of the room.

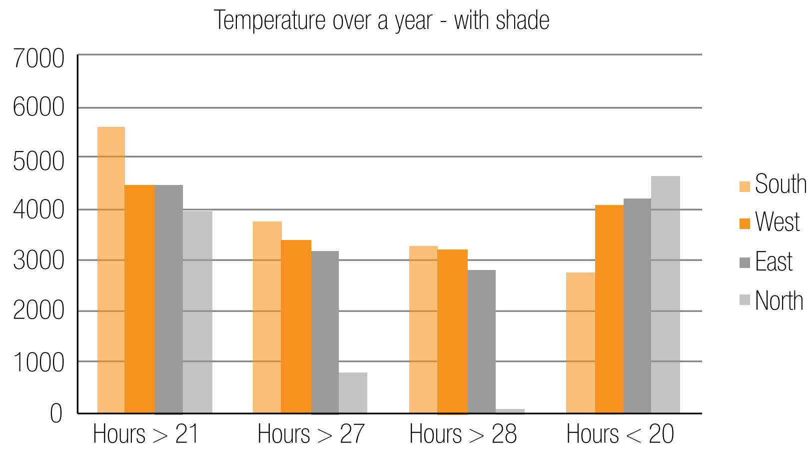
Orientation

To analyse the effect orientation of a room has on heat gain from direct sunlight, an analysis in Bsim was made. A test model of an appropriate sized classroom was made and tested with its windows facing due south, north, east and west. The results can be seen on the graph to the right ("Orientation data – without shading", ill. 46), which shows that the increase in temperature from direct sunlight is highest when due south, less due west and east, and least due north. It also shows that the orientation due north has the highest amount of hours below 20 degrees.

On the next graph, the result of the same orientations, but with solar shading, can be seen ("Orientation data – with shading", ill. 47). This shows that it is possible to reduce the influence of the room's orientation by shading the direct light intake. Thereby no orientation needs to be excluded, however it is important to think of the need for solar shading, to reduce overheating and glare, when placing the rooms.



ill. 46 - Orientation data - without shading.
The graph shows how many hours each orientation is above 21, 27, 28 and 29 degrees.



ill. 47 - Orientation data - with shading.
This graph shows how many hours each orientation with solar shading is above 21, 27, 28 and 29 degrees.

Shading and overhang

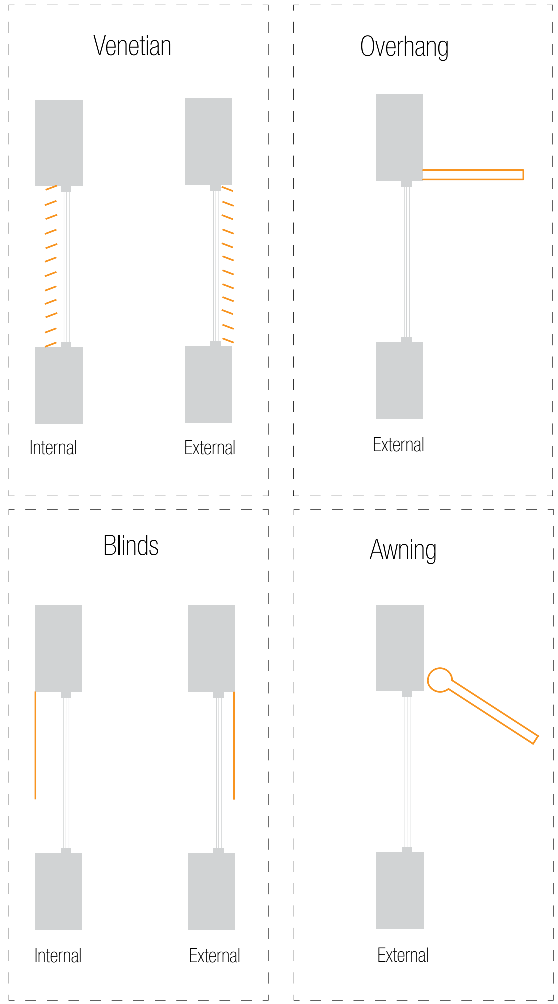
Choosing the right shading system is important for the visual comfort. The Solar shading diagram, Ill. 48, depicts the principles of generic shading systems: blinds, venetian blinds, awnings and overhangs. When choosing between the shading systems, the following parameters need to be considered:

- The reason for the shading system needs to be determined. To reduce the solar heat gain the shading needs to be exterior, to reflect the rays before they pass into the building. However, in the winter, where the solar heat gain is wanted, and the problem is glare from the low angle of the sun, interior blinds needs to be considered.

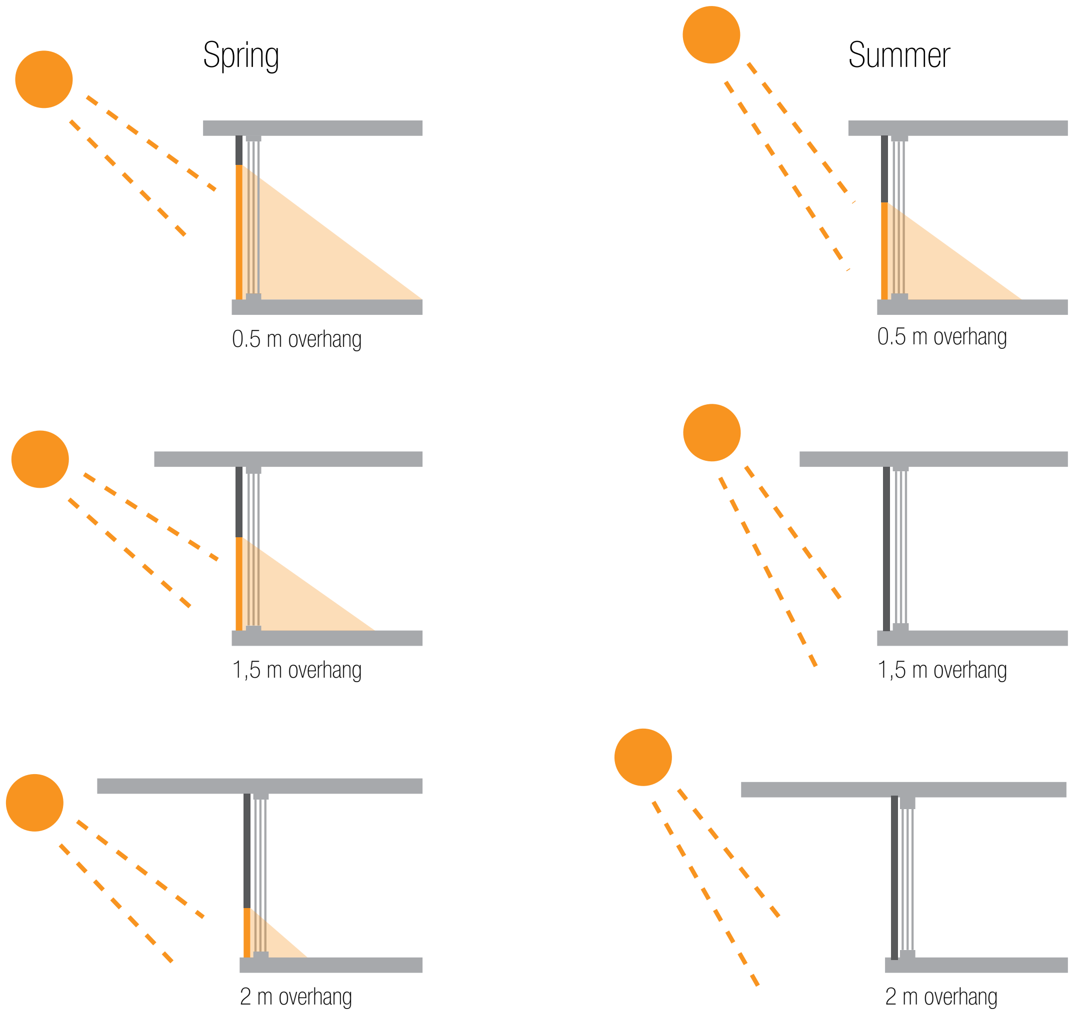
- The effect and quality of the view from the room. Venetian blinds and blinds disrupts the view into vertical or horizontal slits, respectively, when in use. A blind will offer little to no view, depending on the material, and the awning and overhang offers complete view, but if it is made as a fixed instalment it also reduces the daylight factor of the room.

- Other parameters to consider is the tactility of the materials, the facade aesthetics and the dexterity of the system.

Of shading systems such as the overhang, the effectivity of the solution is determined by its depth. The Overhang analysis diagram, Ill. 49, illustrates the results of an analysis made in Revit, to determine the depth necessary to shield most of the window (see appendix 2,2 for the original analysis from Revit). The analysis is done of a room with a height of three meters, and of all seasons. The study of winter has been removed, because it had little to no effect in this season, but the analysis is included in the appendix. To protect from glare other systems should be considered in this season, as previously mentioned.
The results showed that an overhang of 0,7m is sufficient in the summer, but to be sufficient in spring and fall, the depth needs to be 2m or more.



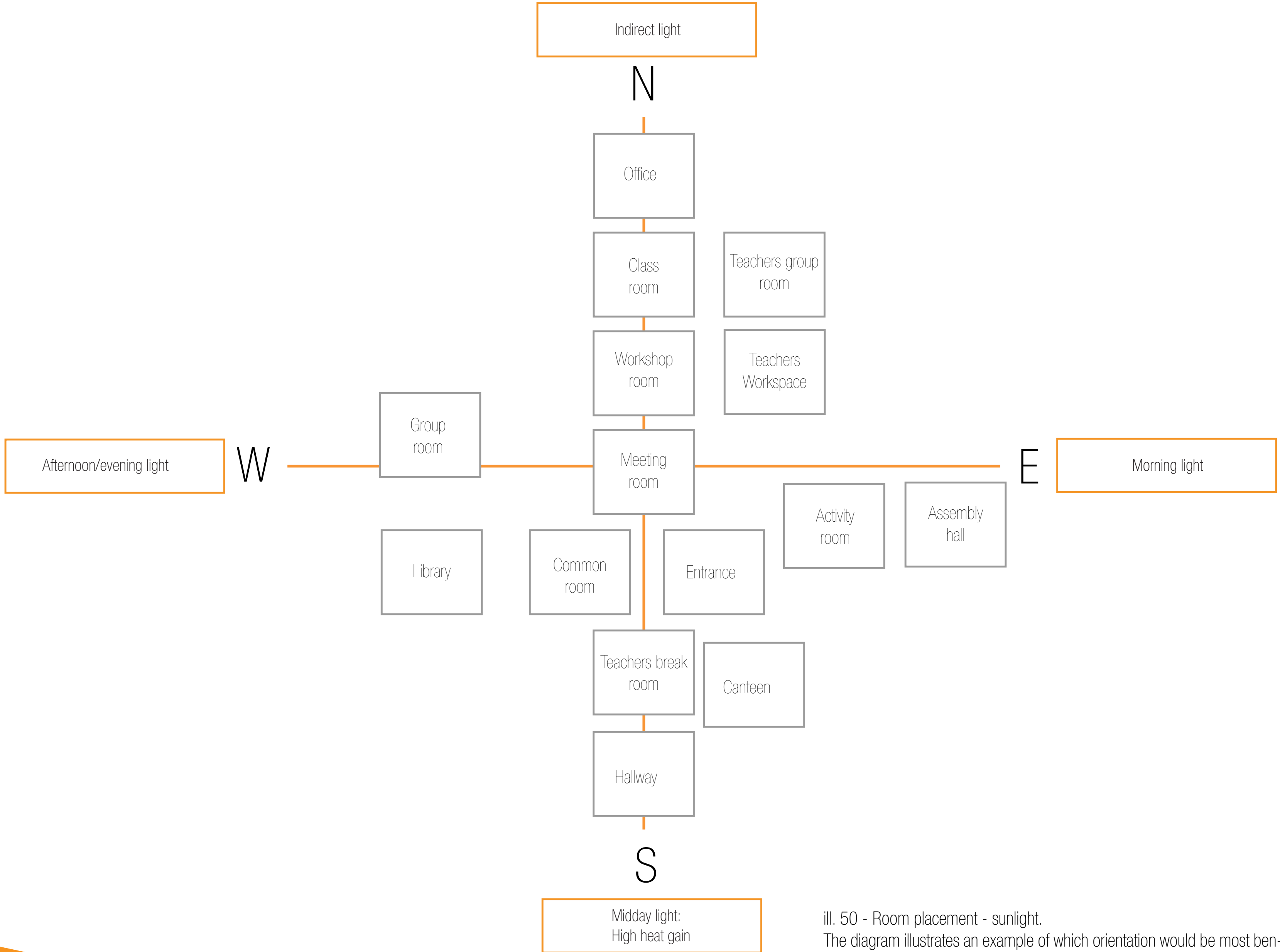
ill. 48 - Solar shading.
This diagram show 4 examples of solar shading - it can be seen that venetian blinds and blinds both have an external and internal edition where the overhang and awning is only external.



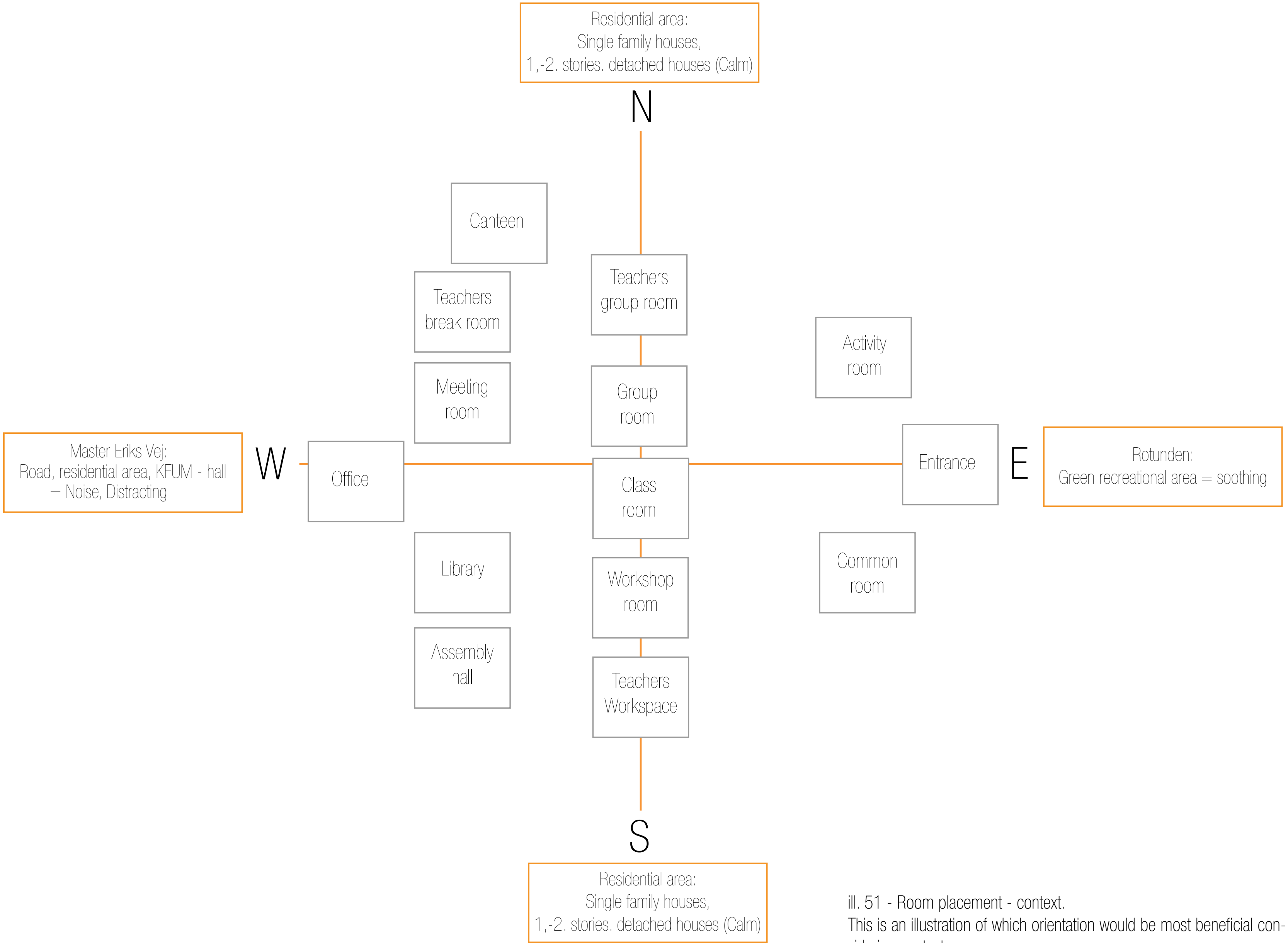
ill. 49 - Overhang analysis.
It can be seen on the diagram how the size of the overhang affect the amount of sunlight entering the builidng in a summer and spring situation.

Types of rooms

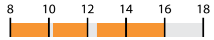
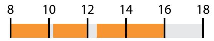
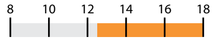
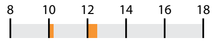
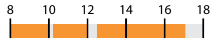
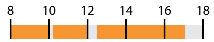
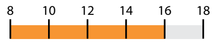
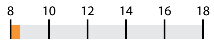
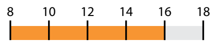
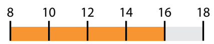
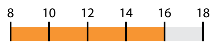
To further analyse the room type parameters, studies were made, of the most optimal placement of the types of rooms, concerning two parameters: sunlight (Room placement – sunlight, ill. 50) and the context (Room placement – context, ill. 51, p. 66). In situations where the types of room's needs overlapped, the importance of comfort was based on the rooms occupancy rate and the atmospheric load of the room. For instance, the class rooms were weighed as more important than the group rooms, which were used by fewer students and for less time than the class rooms.
The conclusion from the study can be seen on table 52 on page 67. These studies where used as the foundation for the following flow and shape analysis.



ill. 50 - Room placement - sunlight.
The diagram illustrates an example of which orientation would be most beneficial considering sunlight.



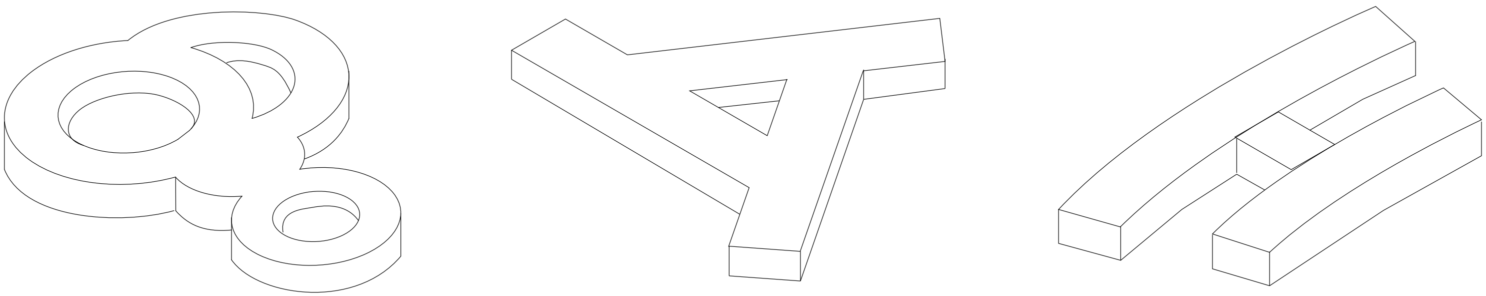
ill. 51 - Room placement - context.
This is an illustration of which orientation would be most beneficial considering context.

Room type	Occupancy	Conclusion
Class Room + Workshop Rooms		• North to avoid direct sunlight • Not a view towards west
Group Room (both Teachers and Pupils)		• Does not have a need for view • East due to the teacher's late schedule
Teacher Workspace		• North to avoid direct sunlight • East due to the teacher's late schedule
Cafeteria + Staff Break Room		• View towards east
Meeting Room		• Meetings room does not need daylight due to the short periods of occupancy. • Could benefit from a green view
Office		• North to avoid direct sunlight • View towards east
Library		• Could Benefit the atmosphere with a good view (east)
Assembly Hall		• Could benefit from a nice view towards east • Some direct sunlight is fine in this room
Activity Room		• Could be a sound barrier towards the road (east) • Could benefit with a more south placement for heat in winter
Entrance		• West to be visible from the road
Common Area		• May have direct light • Is not bothered by a distracting view.

ill. 52 - Room placement - conclusion.
The table contains which time of the day the rooms will be used and the conclusion from the corner context and sunlight diagram.

Shape studies

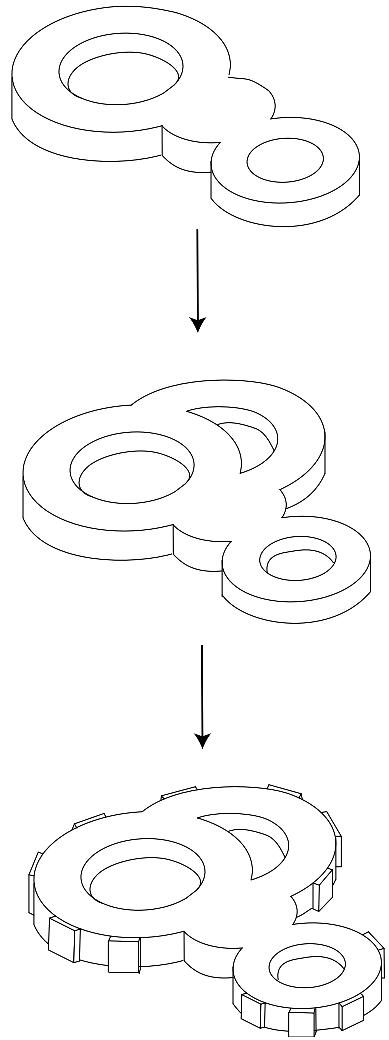
As mentioned in the vision, the concept is to create zones for the different users, with the mutual functions connecting them. Throughout the design process various sketching phases and inspiration searches were done. However, during the design there have been three main shapes (see Main shape developments, ill. 53), that have influenced the final design; the circular form, the triangular form and the half circles. These design proposals will be explained in the following pages.



ill. 53 - Main shape developments.
The diagram shows the three main shapes which have formed the project

Circular shape

The circular form was a shape-development based on the idea of having two separate enclosed outdoor areas, created by the architecture. The enclosed areas created a zoning of the outdoor areas. The youngest pupils had the small circle, the intermediate and eldest pupils the large circle and the area around the building were for everyone.
The shape evolved from 3- to 4 circles, creating a circle for each student age group and a centred circle with the mutual functions (see first step in Shape development of the circle, ill. 54). In the circular design the design criteria concerning the learning environment was integrated by implementing niches, achieved by dispatching some of the class rooms. (see second step of ill. 54)



ill. 54 - Shape development of the circle.
The illustration shows the circular shape developed through the process.

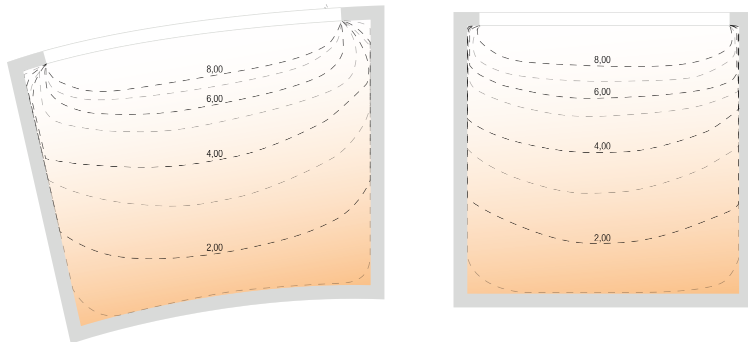
Reverberation time and daylight factor analyses

With the circular shape, all rooms would get a rounded wall, and to test if this had an effect of the conditions of the classrooms, an analysis testing room acoustic and the daylight factor of a square room and a room with two rounded walls, with approx. the same volume and measurements, was made. This test showed that the rounded wall had a very insignificant effect on the acoustic measures and had no effect on the daylight factor. It would therefore not be a problem based on these factors, to have rounded walls.

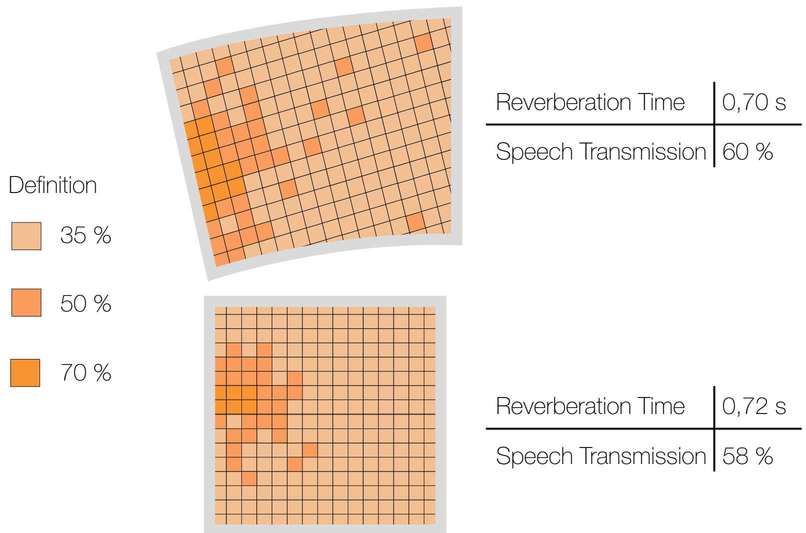
Evaluation of the circular shape

The Evaluation of the circle, based on the design criteria, resulted in the following table: Evaluation of the circle, ill. 55. This evaluation presented a clear image of the limitations of the circular form, while pointing out how most of the qualities were not dependent of the shape. For instance, the idea of having niches on the hallway, and a joined assembly hall and entrance could be transferred to another shape. The same goes for the idea of gathering the workshops with the rest of the mutual functions. This allowed the pupils to share the workshop rooms, thereby increasing the occupancy rate, and decreasing the number of rooms in total.

Ill. 55 - Models of the Circular shape.
Different compositions were tested.



Ill. 56 - Daylight test for classrooms both sqare and curved.



Ill. 57 - Acoustic study for classrooms both square and curved..

Evaluation of the Circle

Negative

- ÷ Rooms are fixed
- ÷ Big footprint
- ÷ Dominating compared to Rotunden, due to the circular shape
- ÷ Not easy to expand in the future
- ÷ “Waste room” in the classes
- ÷ Closed around itself
- ÷ Confusing - not simple enough
- ÷ Middle school pupils are attached to the big pupils
- ÷ East access to the outdoor for the eldest students have not been incorporated
- ÷ The topography is fitted to the building, instead of the building fitted to the topography.

Positive

- + Circular shape fits with the idiom of Rotunden
- + Possibility to join two class rooms
- + Enhances the core values of the vision.
- + Creates niches both indoor and outdoor by displacement
- + All Class rooms have good daylight
- + The transition between floors give a playful change to the flow
- + Activity area as a transition between floors create a active and playful way of moving and can be adapted to each age-group.
- + Each “academic group” is a fire-cell and a joint ventilation zone
- + Zones adapts the environment to the different need of the children
- + Possibility of skylight in all rooms
- + The hallway in the center of the circle’s sphere can give an easy flow through the building
- + Creates outdoor zones/courtyards
- + Green Roof enforce the green zone in the area
- + Entrance from two directions
- + A big part of the class rooms is in the ground floor giving them easy access to the outdoor
- + Landmark in the area

= due to the circle
= important

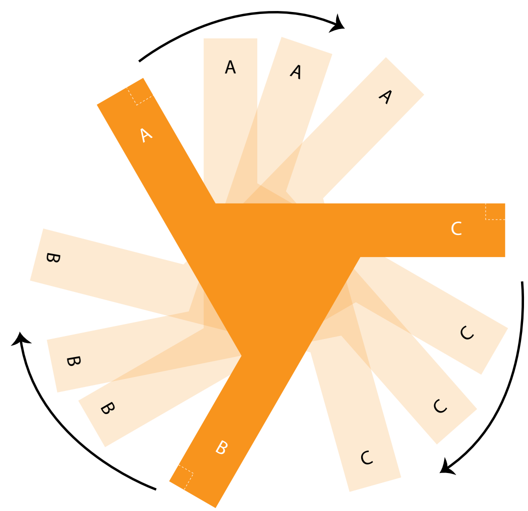
Ill. 58 - Evaluation of the circle.
The circular shape is evaluated based on the design criteria.

The Triangular shape

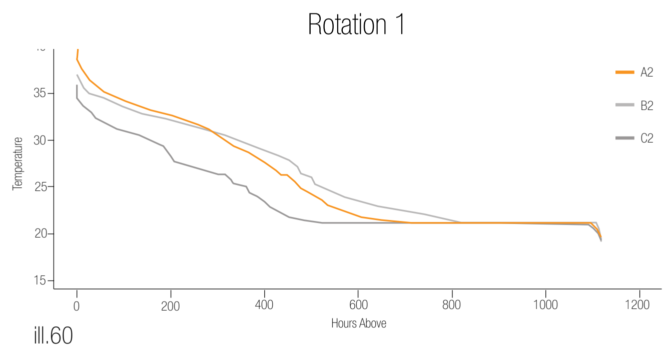
The deconstructed triangle shape was based on transferable qualities of the circular form, with focus on integrating the parts of the design criteria that were lacking in the circular proposal. This was, for instance, the criteria of future development and zoning of the outdoor areas.
The general idea behind this proposal was to divide the age-groups into separate wings of the building, with the common functions gathered in the centre. This shape had a more orderly layout and defined the spaces of the outdoor areas with its volume.
The wings also allowed the building volume to follow the existing slopes on the site. However, being positioned as they were, no matter how the building volume was turned, some classrooms would be oriented to the south.

Rotation study

To fully understand the impact on the classrooms and find the best position of the wings, concerning solar heat gain, to ensure thermal comfort as defined in DGNB SOC.1.1., various rotations with southern rotation were examined in Bsim. The Rotation of the building diagram, Ill. 59, shows the rotation combinations that were tested, for a room with windows facing south, with the approximate size of a classroom. For each rotation (1, 2, 3, 4) the building was rotated 20 degrees each time, and the room was tested for a position in each wing (A, B, C). The results of the study can be seen on the graphs to the right (Graph of rotations, ill. 60-63, and Comparison of the wings, ill. 64-66).
The results showed that it would be possible to lessen the solar heat gain, by rotating the wings to the optimal position. However, it became clear, that because of the wings angles, each wing would need to be regulated separately, and therefore require individual solutions to control the solar heat gain.
Furthermore, even with rotating the buildings, there would still be a considerable number of classrooms oriented partly south. The next step therefore became to look at the effect of glare.

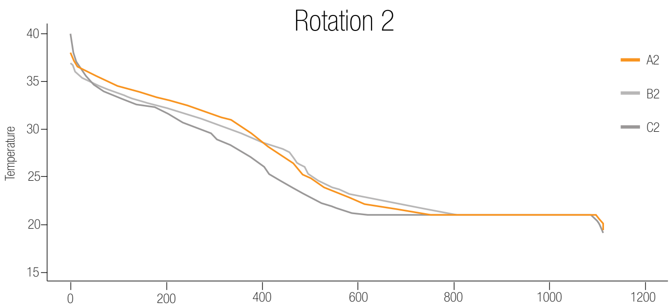


ill. 59 - Rotation of the building. This illustrates the 4 rotations tested in the analysis. The white boxes illustrates the placement of the classroom on each wing.

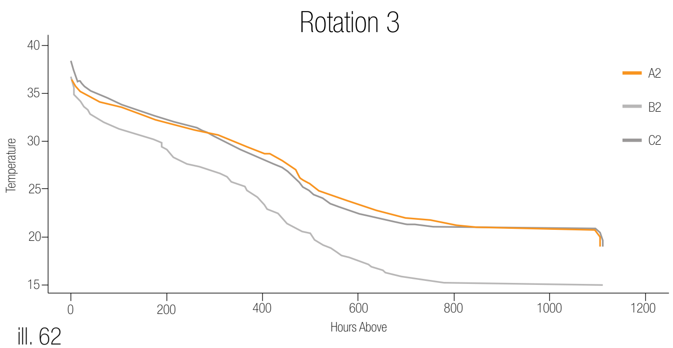


ill.60

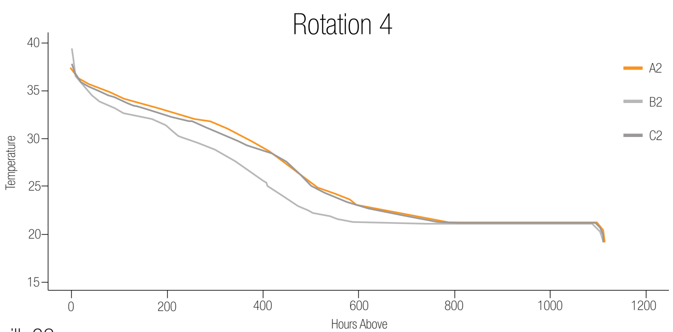
ill. 60-63 - Graph of rotations.
The graph show how many hours the temperature is above a certain value. A graph is made for each rotation, numbered 1-4.



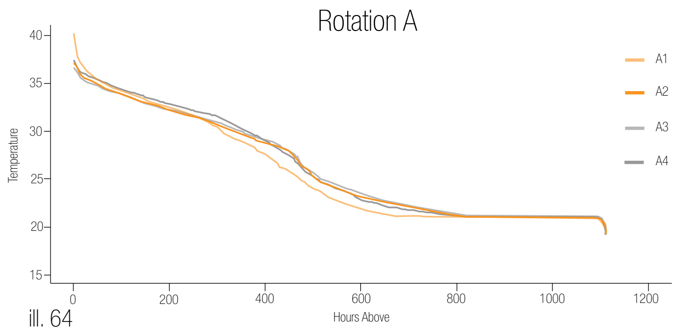
ill.61



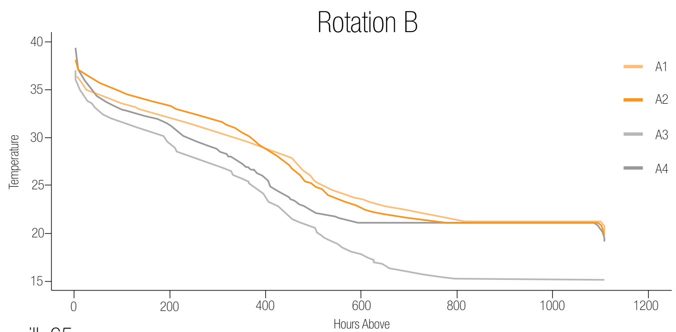
ill. 62



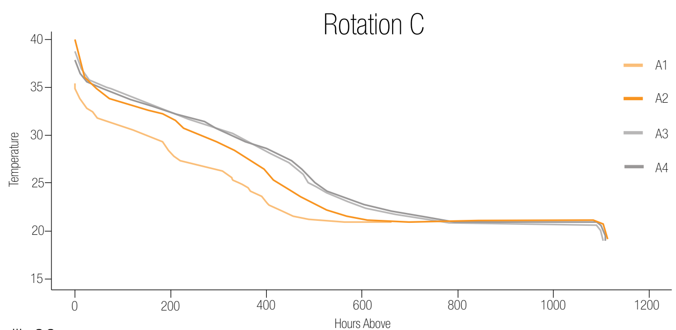
ill. 63



ill. 64



ill. 65



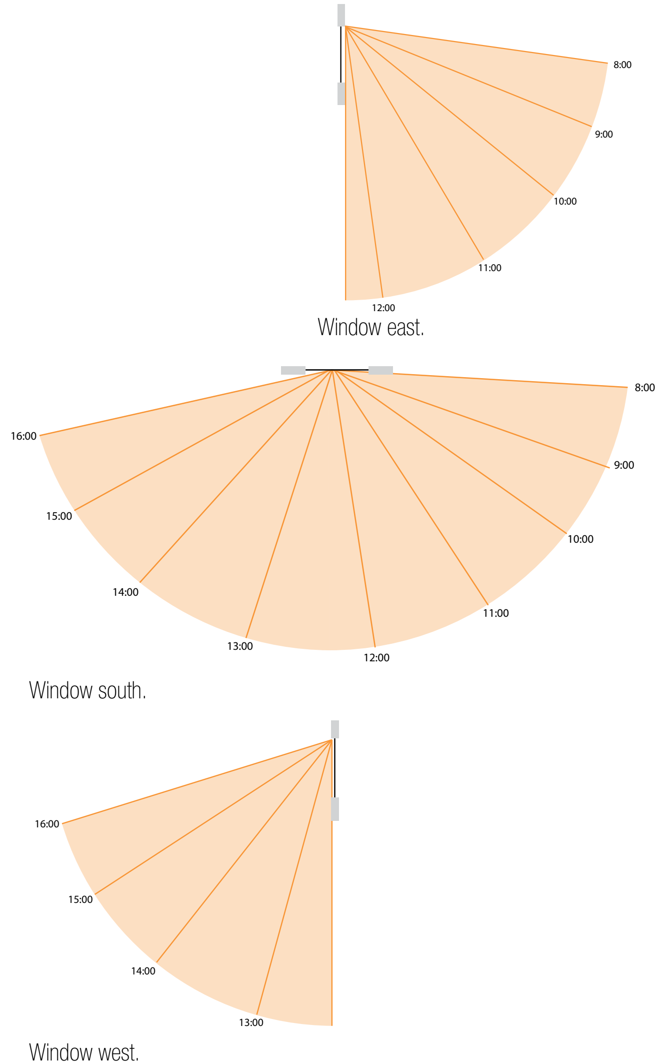
ill. 66

ill. 64 - ill. 66 - Comparison of the wings.
The graphs show how many hours the temperature is above a certain value. A graph comparing the 4 rotations of each wing is made and named after the specific wing (A, B, C)

Glare study

Having direct sunlight into classrooms makes the need for glare protection higher. As with the previous study, glare can be fixed by applying appropriate shading systems. However, it is important to consider how solar shading affects the quality of the room. When the solar shading is used, it protects from glare by minimizing the direct light entering the room, and the longer it has to be used, the longer the room will have a reduced daylight factor. The classrooms are used within the timespan: 08:00-16:00. Examining the path of the sun within this range gives an idea of how much of a school day the shading is needed. The Glare analysis, ill. 67, shows how much time a facade might need to use shading to protect from glare, for the example of a facade turning west, east and south. A southern facade would on a sunny day need shading almost all day, where west and east facades only need shading in the first or last half of the day. Based on the results, classrooms with a southern direction would need almost constant shading which would resolve in a decrease in the daylight intake and the view from the room as mentioned previously. Therefore, the most optimal place for achieving a visual comfort would be towards north where there is no direct sunlight. However, that would also mean no solar heat gain from the sun at all, and giving the needed number of classrooms it would not be possible to only have them in one direction. A west and east direction would give some hours of shading but still a big part of the day without and solar heat gain in the winter. This investigation also supports the DGNB criteria SOC 1.4 (Visual comfort) and help creating a good visual comfort for the students and employees at the school.

Because of this the triangular shape had to be re-evaluated based on the new considerations. As with the circular shape an evaluation scheme were made that listed both the negative and the positive elements, and considered which points were generic and which were determined by the shape. This shape has four important negative points which all are shape determined, two of them due mainly to the height and one concerning the southern position, which can't be avoided because of the triangular shape. As it was for the circle, this shape also has few qualities that are defined by the shape, and therefore most could be transferred and integrated into a new shape.



ill. 67 - Glare analysis.
Hours where the facade needs protection from glare, depending on its orientation. An eastward window may require glare protection from 8-12 o'clock. A southward may require shading from 8-16 o'clock, and a westward from 12-16 o'clock.

Evaluation of the Triangle

Negative	Positive
÷ Divides the site into three areas: two playground areas and one parking area	+ Defines spaces in outdoor area
÷ Always classrooms towards south	+ “Small” envelope
÷ Tall and compact - dominating	+ Possibility for expansion
÷ No easy access to outdoor area from class rooms	+ The core
÷ Less to no skylight due to the height of the building	+ Possibility for division of age-groups
÷ No integration of solar cells on the roof	+ The wings make it possible for flexible rooms

Shape determined
Important

ill. 68 - Evaluation of the triangle.
The triangular shape is evaluated based on the design criteria.

Half Circles shape

The last major shape study came as a product of the two previous proposals. In this shape, the qualities from the previous designs have been integrated, along with the knowledge gained from the rotation and glare study. They have been merged in a shape with ties to the circular shape, a shape that was inspired by Rotunden, an element that defines the site. The process of the shape is described further in the following steps (ill. 69):

Step 1: East/west placement

The last major shape study came as a product of the two previous proposals. In this shape, the qualities from the previous designs have been integrated, along with the knowledge gained from the rotation and glare study. They have been merged in a shape with ties to the circular shape, a shape that was inspired by Rotunden, an element that defines the site. The process of the shape is described further in the following steps (ill. 69):

Step 2: Topography

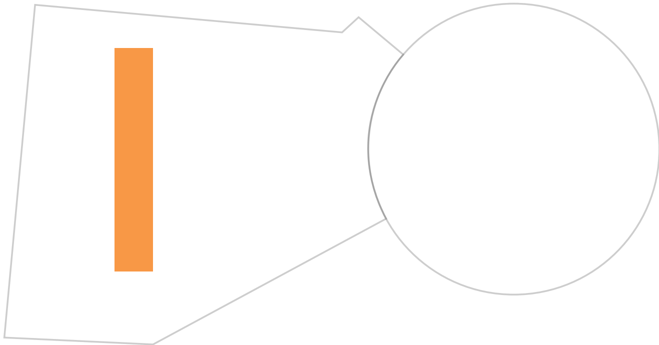
Assessing the topography on the site, it was found that while most of the site is increasing towards Rotunden, there is a rather level part in the middle of the site. To avoid levelling the topography the building is placed on this area. As it can be seen the two marked areas only have a 0,5m difference (Step 2: Topography, ill. 70).

Step 3: Context

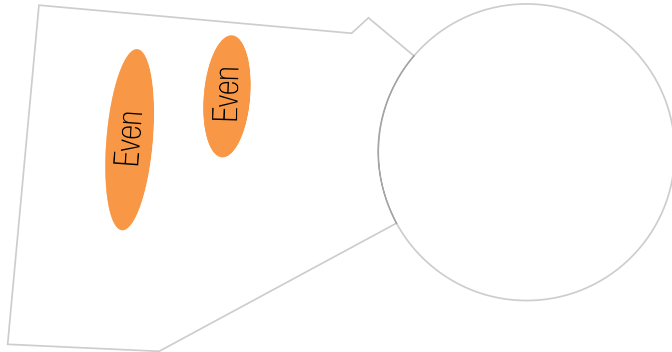
One of the qualities of the circular shape was the similarities of the idiom of Rotunden. Rotunden is a defining element of the site (see Site mapping, p. 14), and to work with this, the new shape should do the same. Using the perimeter of the circle of Rotunden and increasing the radius, serves as the outline of the building (Step 3: Context, ill. 71).

Step 4: Volume

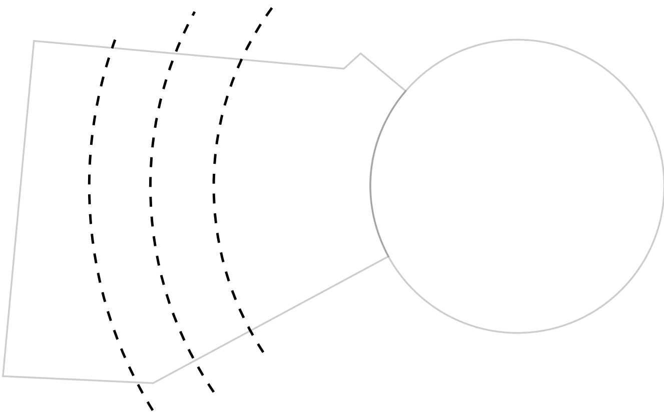
To keep the building from becoming too high, more than one building volume is needed. Still basing the shapes on the perimeter of Rotunden, two half circle volumes are placed, connected them with a smaller volume (Step 4: Volume, ill. 72).



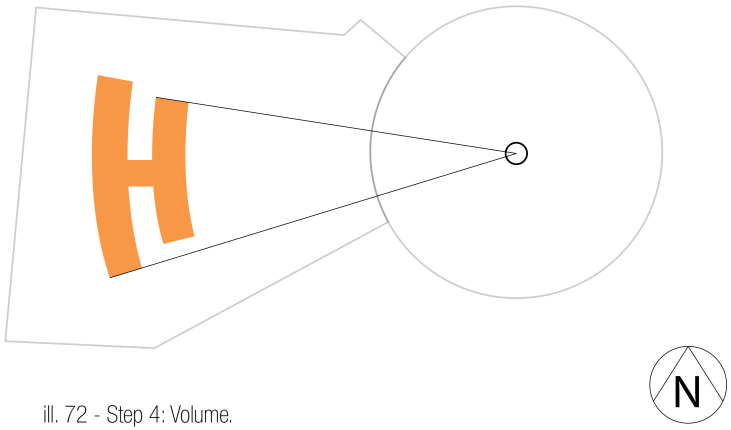
ill. 69 - Step 1: East/west placement.
The building is placed with the largest facade towards east/west.



ill. 70 - Step 2: Topography.
The two marked areas show the most even places on the site.

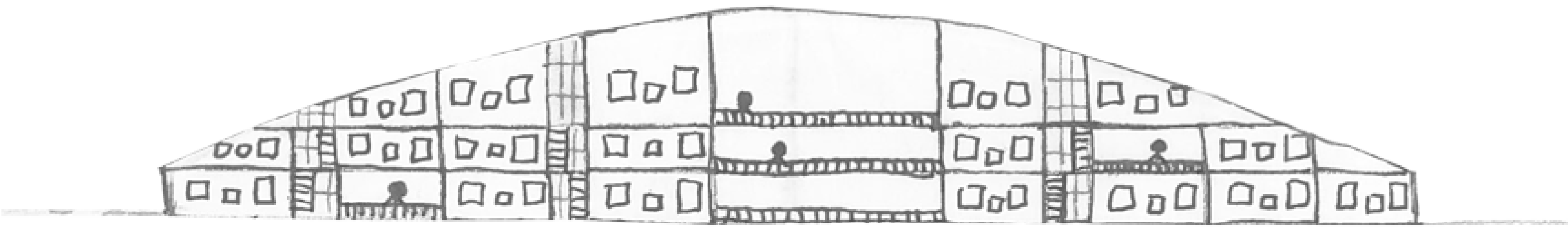


ill. 71 - Step 3: Context.
Circular spheres are drawn from the center of Rotunden.

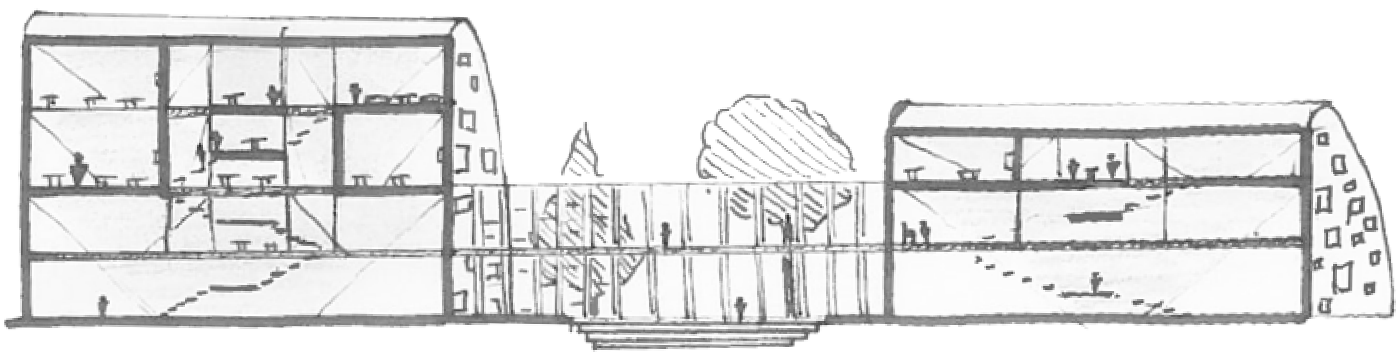


ill. 72 - Step 4: Volume.
The building is formed based on the three last steps.

This shape has a cleaner expression than the circular form, and is more flexible when it comes to adapting to the functions.
In the evaluation, it has mostly important positive features, yet, there is some design criteria that it does not integrate, such as having no easy access to the outdoor. On the other hand, many of the positive points are of higher importance, from the prioritisation of the design criteria, which can be seen in the Evaluation of the half circles – table, ill. 75, to the right.



ill. 73 - Section of the half circle.
Illustrates the idea of making the roof curved.



ill. 74 - Cross section of the half circle.
Illustrates the connection between the two buildings and the transparency of the cure.

Evaluation of the half circles

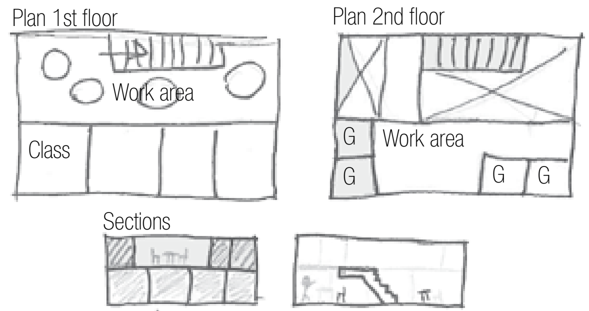
Negative	Positive
÷ Disperse the core-functions	+ Interact with Rotunden - low building volume - green zone = enforces
÷ Not Creating zones in the outdoor areas	+ Transparentsy - look to Rotunden
÷ Not easy access to outdoor	+ Flow - way finding =easy
	+ Assembly point
	+ Utilizes the typography of the site
	+ Create small outdoor areas between the building
	+ Small envelope
	+ Class rooms towards East and West
	+ Possibility for solar cells
	+ Possibility for division of age-group

ill. 75 - The half circles are evaluated based on the design criteria.

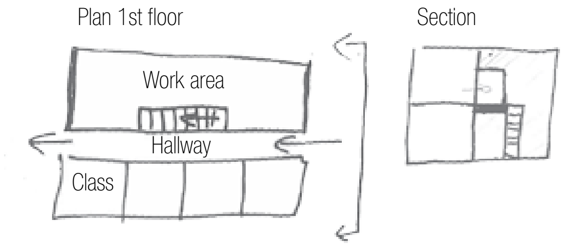
Layout development

General sketching phase

During the project the floor plan has been redeveloped several times, with every step influencing the next. Because of the scope of a school institutional building, the plan layout has been developed in sections, focusing on one type of function at a time. Subsequently a process was made where the different functions were pieced together as a whole (See ill. 76-80). During the early sketching phases, details such as sound proof inner walls, safety requirements and accessibility were integrated, using the demands and suggestions of the DGNB criteria TEC 1.2 (sound conditions), TEC 1.1 (fire protection) and SOC 2.1 (accessibility) as guidelines and inspiration.
The most pronounced ways they affected the process was by working with simple layouts with a high visibility, focusing on easy wayfinding, accessibility and measures of fire safety, to have clear overview of the nearest emergency exits. Test were also made on how the placement of rooms according to sound, e.g. placing quiet rooms, such as group rooms, in clusters.
Along the way some of these principles was put a side, but were easily re-implemented during the final stages of the floor plan development. For instance, many of the principles from the early phases were used to simplify the floor plans and increase visibility.

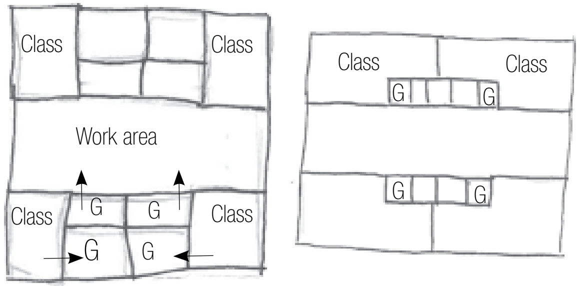


ill. 76 - 2 stories class module 1st idea.
This module has four classrooms on the 1. floor with a stair leading up to a group work area and group rooms. The hallway in front of the classroom can also be used for group work.

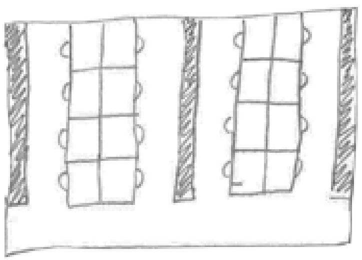


ill. 77 - 2 storeys class module 2nd idea.
In this suggestion the students enter the module from the 2. floor where the classrooms are placed. A stair leads down to the first floor where group rooms and work spaces can be found.

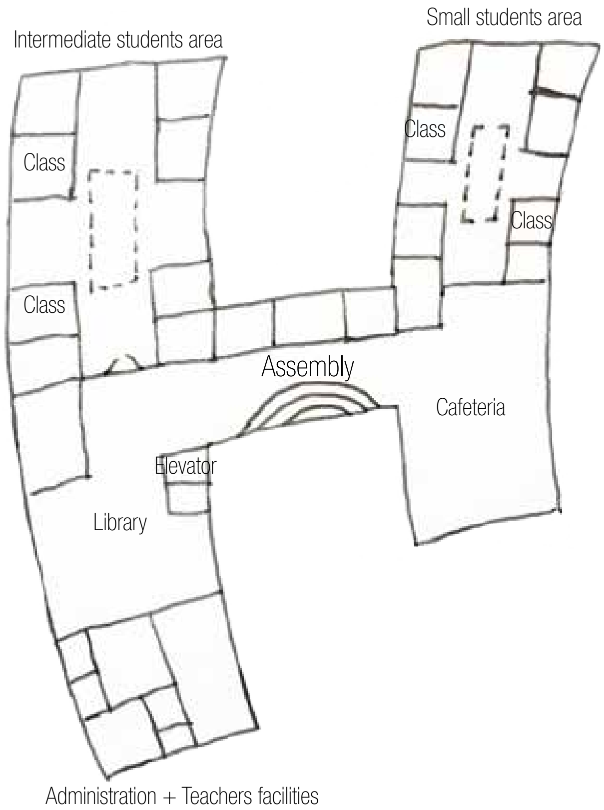
Suggestions 1 - plan. Suggestions 1 - plan.



ill. 78 - 1 storey class modules
These two modules illustrates two ways of having group rooms, class-rooms and a work area, all at one floor. To set daylight in the work area a skylight would be needed



ill. 79 - Teachers workplace.
The sketch shows a suggestion of how the room type could be for the teachers' workplace. The teachers need a storage and their own closet.



ill. 80 - Plan suggestion of layout.
In the beginning of making the plan layout, the different zones and a centered common area was integrated in the early phases of layout development.

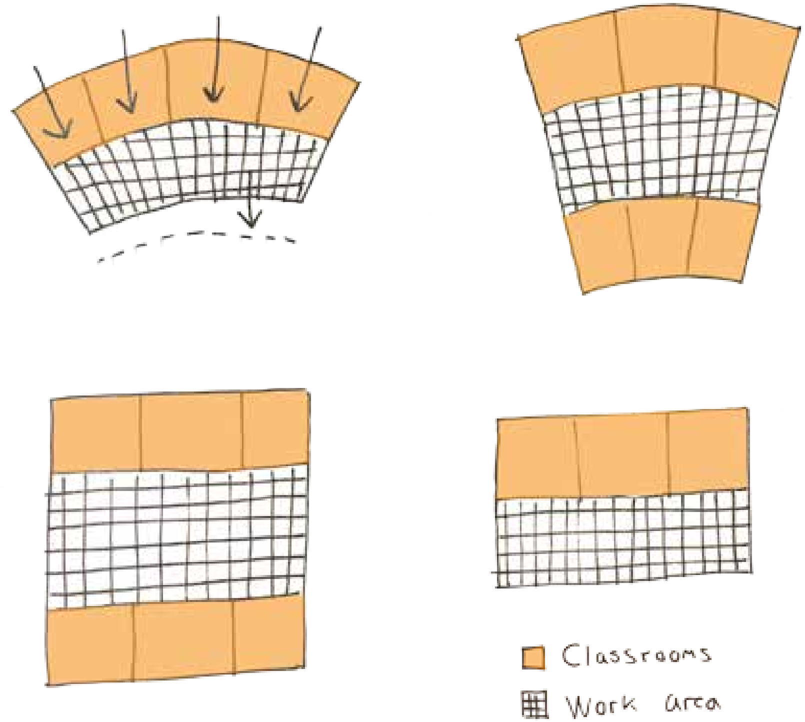
Academic zones

The vision of the project has been to work with subject-based work areas, where classrooms are connected to a shared area that supports both individual- and group work. This was therefore a part of the design from the start.

Working with academic zones gives a natural division of the building. Each subject needs a certain number of classrooms per year group to cover its occupancy rate. This led to the idea of a class cell (see Academic zones, ill. 81), where four classrooms shared a work space. The cell at the same time defined the fire cells of the building and a "ventilation-cell". The concept of the ventilation cell is to balance the intake and outtake of air within the cell, by blowing air into the less polluted classrooms, and having the outtake in the common work area, which has a higher pollution level because it is used as a common room in the breaks.

The classroom cells also made it possible to close the areas off from noise in other cells, which is an important part of the TEC 1.2 (sound conditions) of DGNB.

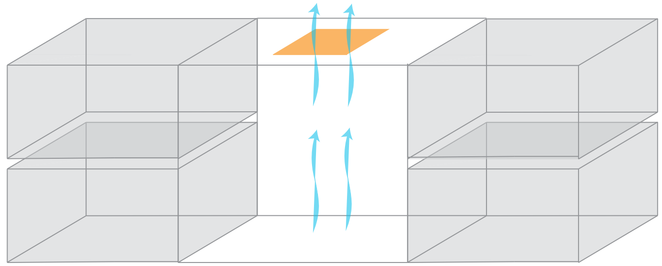
The concept of a classroom cell has been passed on and further developed throughout the design process. Ill.81 shows the development of the cell, and how the concept has changed to adapt to the changes of the project.



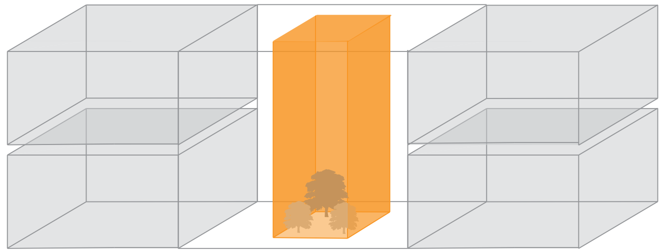
ill. 81 - Academic zones.
This diagram illustrates different wings to arrange the classrooms and the workarea.

Atria

Developing atria to bring light into the building became a part of the design, when the academic zone became more like the fourth development of Academic zones, ill. 81on the previous page, with classrooms on both sides of the work area. in the beginning, ideas of both interior atria and exterior atria was considered. The Internal atria diagram, ill. 82, and External atria diagram, ill. 83, shows the principles of both ideas. By having external atria, outdoor areas are brought into the centre of the building, and Nature has been proven to soothe stress and increase the comfort of people [Ulrich, 1984]. Additionally, the outdoor spaces could be used in the teaching.
The interior atria were considered, to bring light into the building and a connection between the floors. It also made it possible to consider the use of stack ventilation.
As the building increased in height, and the atria were reduced in size, the idea of the exterior atria was abandoned, because it would only have benefitted the 1st Floor, and taken up a lot of the air and open space on the rest of the floors.



ill. 82 - Internal atria.
An internal atrium give light into the building and creates a connection between the floors and the option of stack ventilation.



ill. 83 - External atria.
An external atrium brings green into the building and outdoor area that could be used in teaching. The green area could be used for teaching.

Classrooms

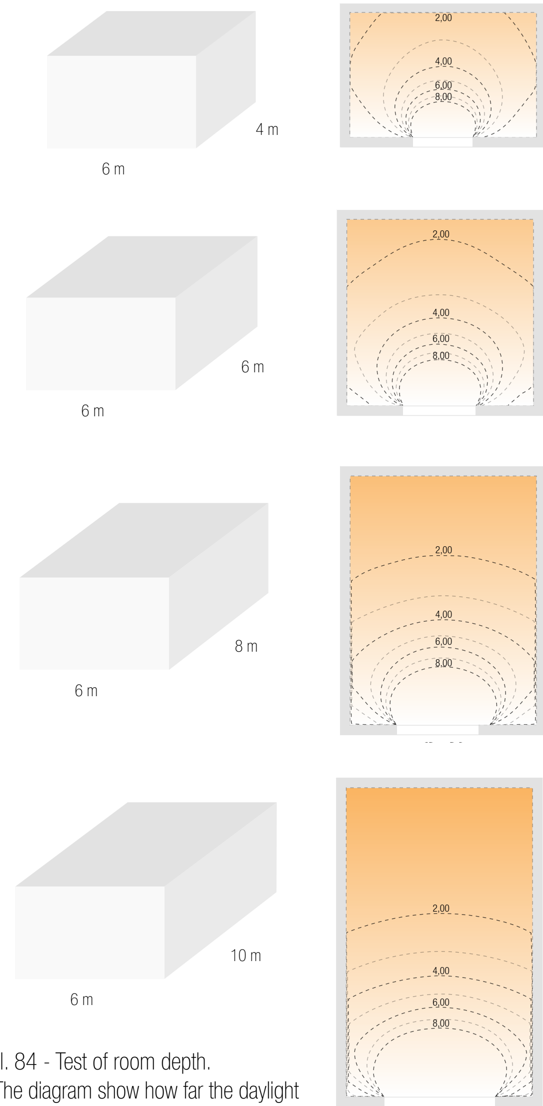
When designing the classrooms, the first thing that was examined was how deep it was possible to make the rooms, considering the daylight regulations of between 200-500 lux on work surfaces (further analysis of the daylight quality of the light can be seen in the section: Facade development, p. 100, where the process of the windows is described). One of the most important factors in a work environment is the visual comfort, and for this the amount and quality of daylight is key.

Depth analysis

The study was made in VELUX Daylight Visualizer testing four rooms with the same width, but with increasing depths. The glass area was regulated for each room, to a size of a 15% ratio of the floor area.

In the 2020 regulations the rule of thumb is a maximum 20% ratio of the floor area, for the entire building, to prevent a too high solar gain and transmission loss through the windows. At the same time the regulations states that areas of exterior glass in classrooms and common room must be a minimum of 15% of the floor area, if the light transmittance is greater than 0,75 [Bygningsreglementet.dk2, 2017]. The glass area is therefore calculated as the minimum allowable value, to make sure that the regulations are followed, and to keep below the max value. The results can be seen to the right, on the Test of room depth diagram, ill. 84.

In the room with a depth of 6m the daylight factor stays above 2% in the entire room. However, in the room with a depth of 8m, the last meter and a half is slightly below 2%. This means that the room depth should be no longer than 8m and preferably shorter.



ill. 84 - Test of room depth.
The diagram show how far the daylight can enter a room compared to the depth of the room. All the test have a window to floor ratio of 15 %.

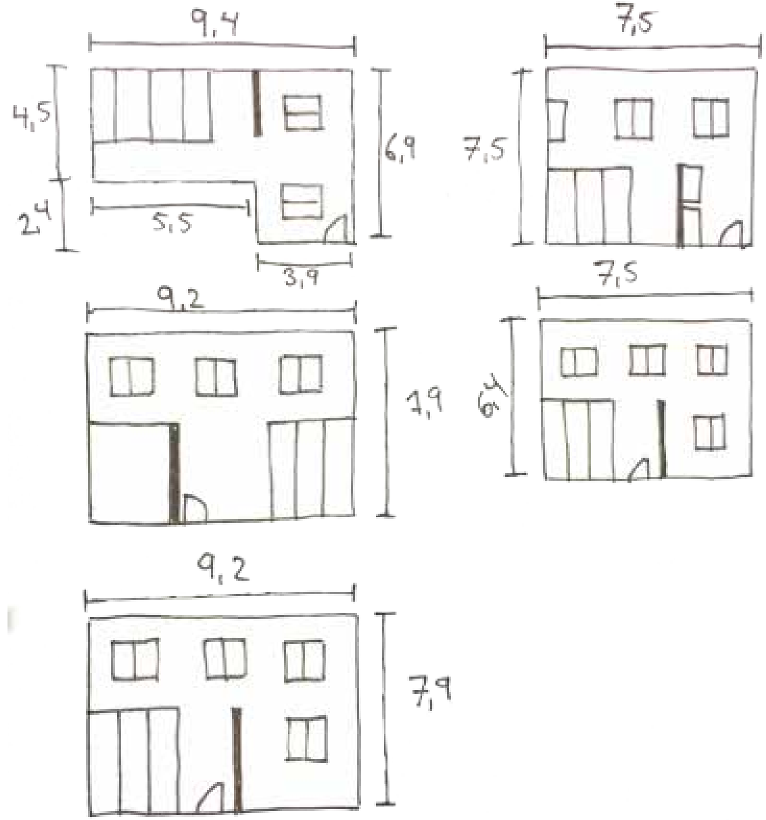
Classroom layout

Next step was to examine possible ways of integrating the learning environments described in the analysis chapter (p. 40). The most radical change of the common classroom is the implementation of a stair for lectures. In the vision the difference between the classrooms are described (p.52):

- The youngest students, 0.-2. grade, has home-classes. Because children of this age are more prone to distractions and are less independent, everyone needs to be seated in the classroom. This way the teacher is able to keep their attention.

- The intermediate- and eldest pupils, 3.-6. And 7.-9. grade, have academic classrooms instead of home-classes. With age, they become less prone to distractions and more independent, and to stimulate this growth half of their work spaces are placed in the shared academic zone, which is described in the previous chapter.

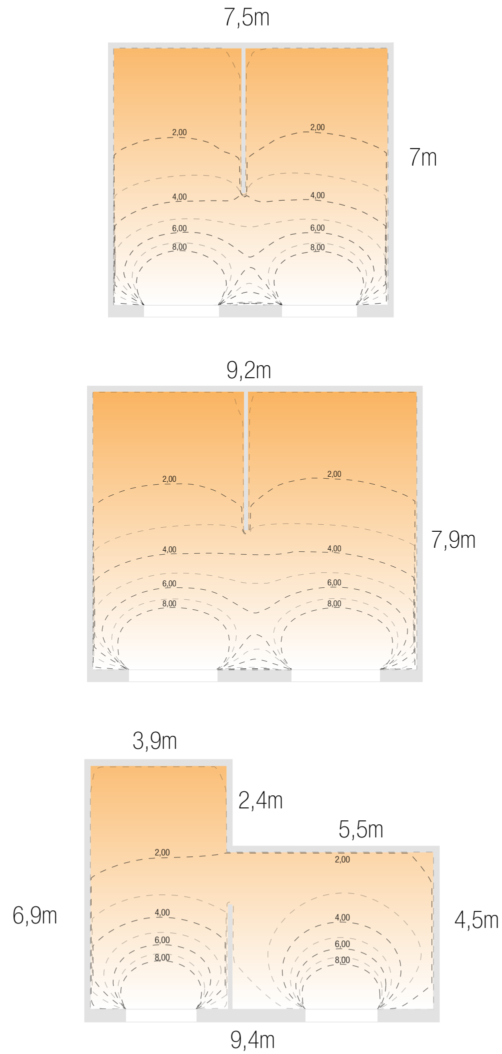
These considerations affect the layout and furnishing of the classrooms. On the sketches: Classroom layout suggestions, ill. 85, the various possibilities are shown. The sketches focus on how the lecture stair can be integrated.



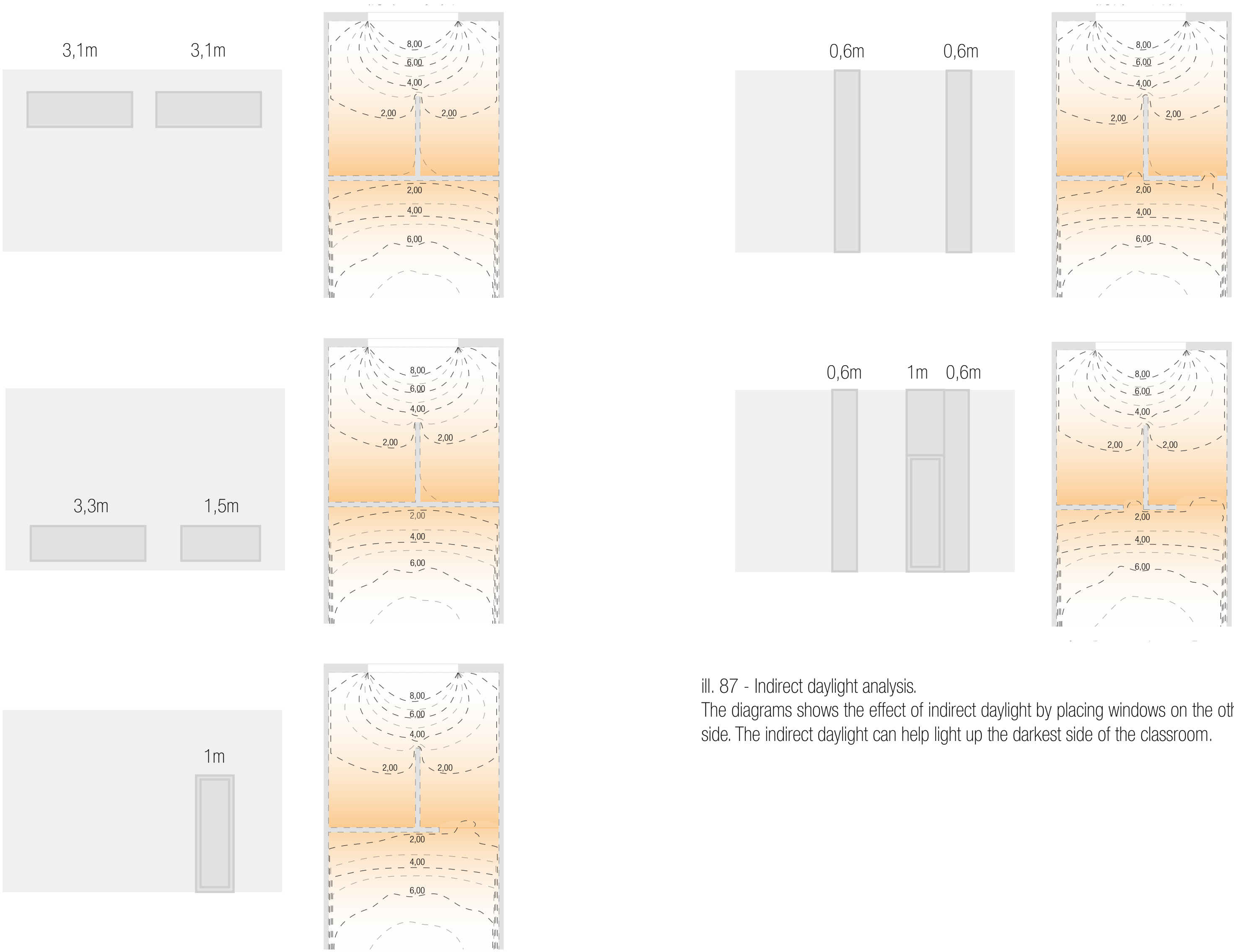
ill. 85 - Classroom layout suggestions.
This illustration shows various way to furnish and design the classrooms. The size of the stair various depending which age-group the classroom are meant for.

Daylight studies

The classroom suggestions were then tested in VELUX daylight visualizer, to evaluate the quality of the different shapes, and make sure that it was possible to achieve good daylight conditions with a 15% ratio of floor area (see Daylight analysis of classroom types, ill. 86). The studies showed that many of the classrooms would benefit from more light furthest from the windows. This led to the idea of using the indirect light from the atrium to raise the daylight factor in the back of the classroom. A model of the most critical classroom, placed on the 1. Floor, was made. The Indirect daylight analysis diagrams, ill. 87, shows a section of the process of testing various sizes and placements of glass surfaces. The surfaces had to be neither too small or too big. If too small the light would not have the wanted effect, but if the surfaces were to large, the hallways could become a distracting element in the class room. The results showed that the best results came from the floor to ceiling openings, or when the door to the class room were made in glass. The results also showed that the indirect light did improve the daylight factor, and at the same time it increases the visibility of the building



ill. 86 - Daylight analyses of classroom tyoes.
This illustration shows the result of the daylight analyses of three of the classrooms.



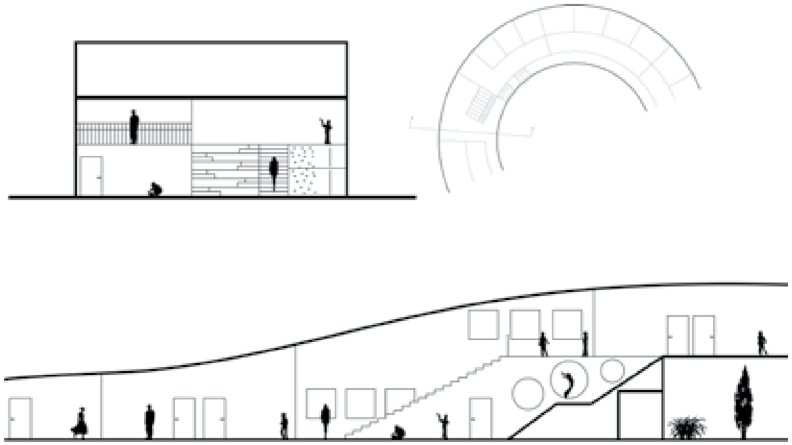
ill. 87 - Indirect daylight analysis.
The diagrams shows the effect of indirect daylight by placing windows on the other side. The indirect daylight can help light up the darkest side of the classroom.

Active environment

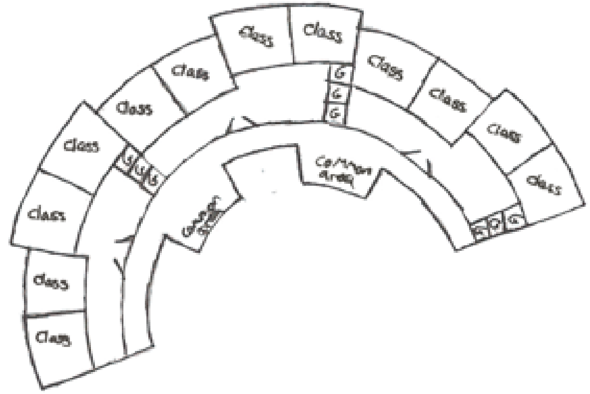
Many of the analysis of this project has emphasized the necessity of a stimulating and encouraging learning environment that makes activity a part of the everyday flow of the school. (see School Reform theory, p. 22 and Child development, p. 38)
The active environment is an essential part of a good learning environment, because children need to be active and use their energy to be able to sit down and focus during their lessons.
A model and sketching phase of how to bring activity into the natural flow of the school was made early in the process, to ensure that it was incorporated into the design from the beginning. The first ideas focused on creating movement through an atrium or assembly hall (see ill. 90-92). In the next phase, Nordstjernen, a newly built school in Frederikshavn, Denmark, and the case study of Frederiksbjerg skole(p. 42), where they have made hallway niches an element with both activating- and lounge elements, was used as inspiration (see reference photos, ill. 88-89). The concept of niches became a way to focus the learning environments to the needs of the specific age groups. This concept was implemented in various depictions along the way, as can be seen in ill. 93-94, sketches from the early stages of the circular shape proposal.

ill. 88 - Inspiration picture from Frederiksbjerg school in Aarhus.
An active element in the hallway at the school.

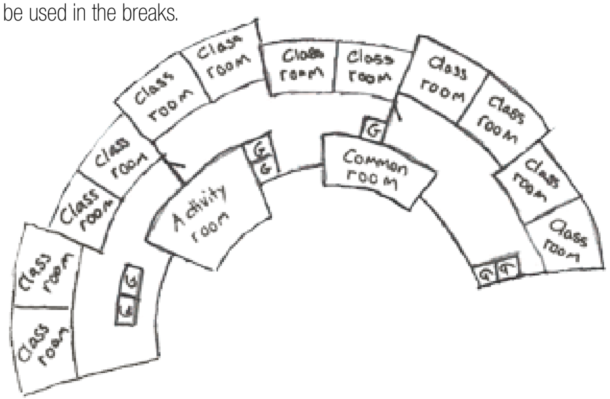
ill. 89 - Inspiration picture from Nordstjernen school in Frederikshavn.
At the pictures is a niche that can be used by the students.

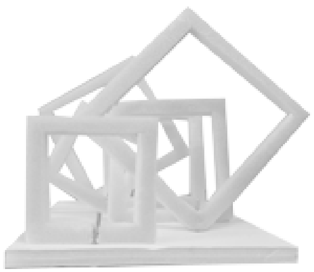


ill. 90 - Section of the circular shape.
The section shows the possibility for implementing active environments in the hallways.



ill. 93 - Plan drawing of niches in the hallway.
At the drawing the niches can be seen in the hallway and the idea is that the areas can be used in the breaks.





ill. 91 - Model of active elements.
The model shows squares in different angles that can be used to activate the students.

ill. 92 - Model of a climping element.
The model shows a net connected to the floor, which the students can crawl in it.

ill. 94 - Plan drawing of niches in the work area.
The niches creates different zones in the room.

Colour analysis

To bring more life and variation into the appearance of the rooms and hallways, it was decided to introduce colours or raw materials into the design.
Four colours were chosen, based on the colour physiology analysis, but as mentioned in the analysis, it is important to be aware of the colours reflective abilities. Therefore, the four colours, with the best qualities were examined, together with a range of other materials' reflective abilities, by measuring the reflected amount of lux.
The results are listed in table 95, where the amount of reflected lux is in one column with a percentage showing how reflective the colours are, compared to white.
This provides an understanding of the effect a material or colour has on the daylight factor. For rooms where the amount of daylight is higher than what is necessary, a twist of colour can be considered, but in rooms where the daylight factor is only just sufficient changing the colour will make the room worse.

	LIGHT REFLECTANCE	PERCENTAGE REFLECTED
WHITE	5200 Lux	100 %
ORANGE	3200 Lux	62 %
BLUE	2800 Lux	54 %
GREEN	2800 Lux	54 %
YELLOW	4100 Lux	79 %
GREY CONCRETE	4300 Lux	83 %
LIGHT WOOD	4050 Lux	78 %
DARK WOOD	3500 Lux	67 %
GREY WOOD	3400 Lux	65 %
RED BRICK	2400 Lux	46 %
GREY BRICK	2900 Lux	56 %
BEIGE BRICK	4000 Lux	77 %

ill. 95 - LUX colour test.
Table showing the result from the LUX colour test.

Mechanical ventilation system

To achieve proper comfort in the various environments of learning, the ventilation system must be able to regulate accordingly. This is one of the reasons why mechanical ventilation was thought of from the beginning, as mentioned previously. Despite this, the early concepts for solutions of mechanical ventilation, was not developed further until the final stages of the project.

Occupancy and use

To find out how to regulate the mechanical ventilation system the placement and use of the functions were analysed. To define this the information from the previous room placement study (p. 60) and the occupancy rate analysis (p. 59) was used. (see Day profile of the users, ill. 43, p. 59, and Occupancy of room types, ill. 44, p. 59)

Duct size and pressure loss

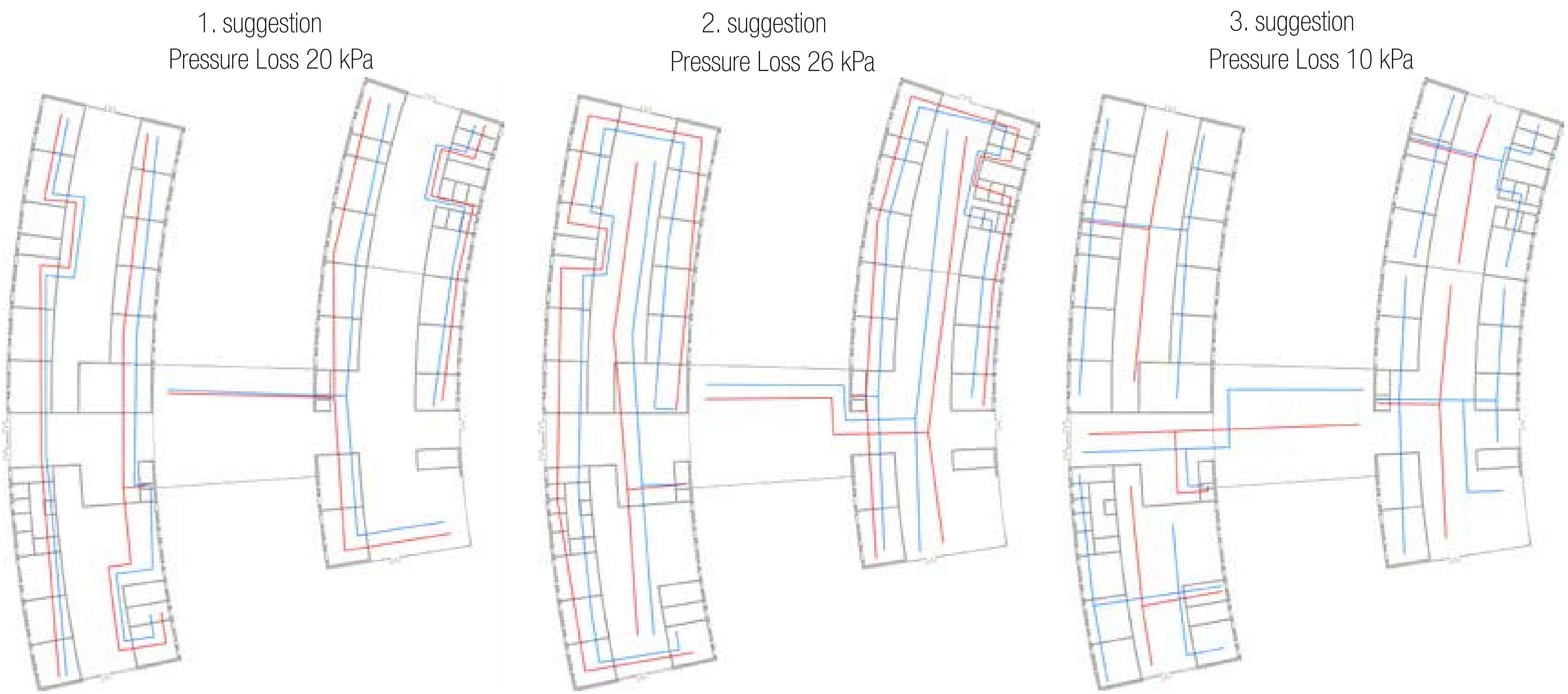
Next step was to determine the number of ventilation systems that would be most efficient. The analysis of the flow indicated, that there was more than one way to divide the building into ventilation zones.

The benefits of having several ventilation zones is the ability to regulate the zones separately, and the fact that if one system breaks, then a smaller part of the building is affected. Having small systems also means a smaller loss of air pressure through the pipes. On the other hand, ventilation aggregates are expensive in cost value and requires upkeep.

Different ways of partitioning the school were tested based on different factors. The first was based on the idea that the classes towards east would have their warmest period in the morning and the classrooms towards west would have their warmest period in the afternoon, and it could therefore be a consideration to have east and west separated from each other (Mechanical ventilation zones – duct length, ill. 96, no. 1). The second suggestion was to base the system on the use of the rooms. This meant all classrooms in one system and the work areas and hallways in a system by them self (see ill. 96, no. 2). The third and last suggestion was based on the idea of having smaller system within smaller fire sections and dividing the systems based on the occupancy. By doing this, the system servicing the teachers' area could be turned on within their schedule without having to turn on the ventilation of the rest of the building. (see ill. 96, no. 3) The longest pipe was then tested with estimate calculations of the duct size and pressure loss, the pressure loss is written in ill. 96, see appendix 6 for the full calculations. This analysis provided an overview of the possibility to avoid a too high pressure loss and too thick pipes. The most efficient results, that also accommodated the flow analysis was where the building split into 5 zones.

Conclusion/evaluation

Due to the analysis, no. 3 was chosen, where the building is split into 5 zones that fitswith the flow of the building, only compromising this in the teacher zone, connected to the workshops above.

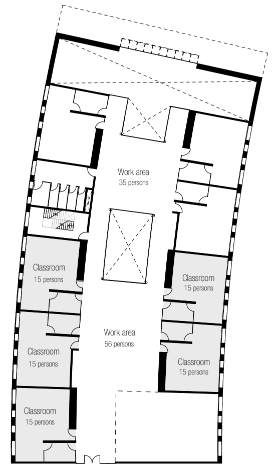


ill. 96 - Mechanical ventilation zones - duct length.

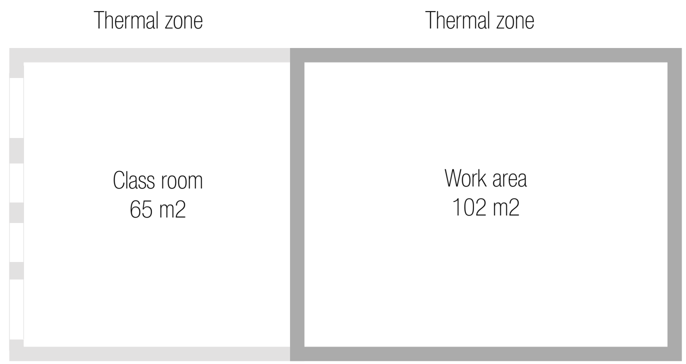
Ventilation cell

As previously mentioned, the principles of the ventilation cell, where the intake and outtake is balanced between the classrooms and the work areas, was incorporated into the design at an early stage. In the final stages of the design, this method was tested with the appropriate measurements of the classroom and work area (see Thermal zones in Bsim, ill. 98). The system was tested in Bsim for a classroom in the middle of a ventilation zone. Ill. 97 shows the assumed people load of both areas during lessons.

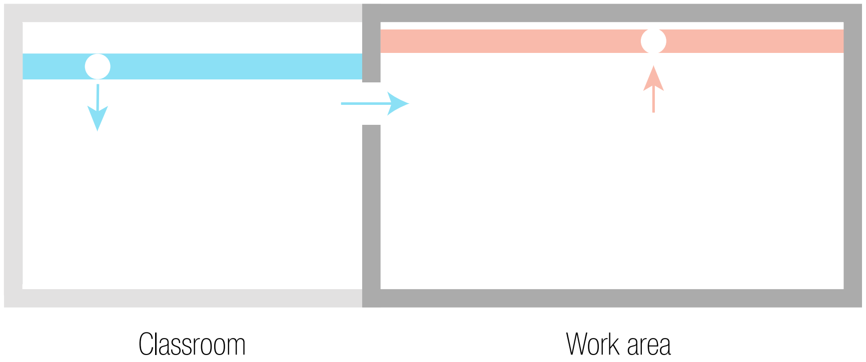
The analysis showed that the need for cooling through ventilation was too high in both rooms, to support this method of ventilation. This was the case no matter which room was made to hold the intake or the outtake of air. Only when the intake and outtake where balanced for each room separately, thermal comfort was achieved for both rooms.



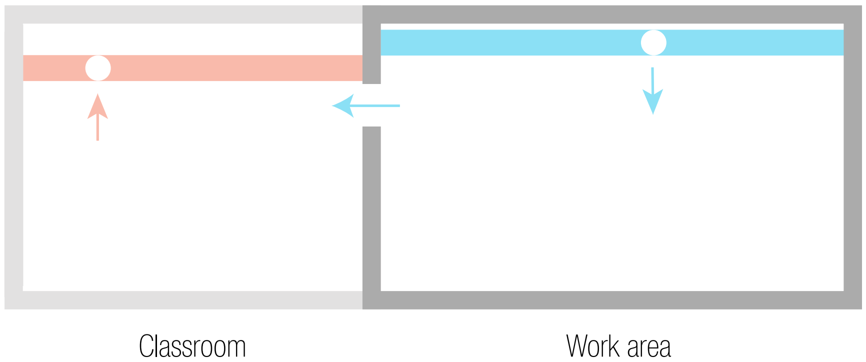
ill. 97 - People load.
The diagram shows how many people are assumed in the academic work area and classrooms during classes.



ill. 98 - Thermal zones in Bsim.
This diagram shows the thermal zones built up in Bsim.



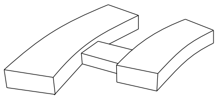
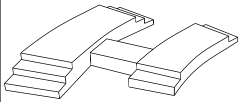
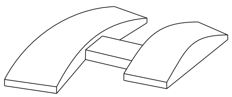
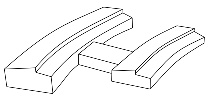
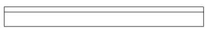
ill. 99 - First mechanical ventilation system.
The air supply enters into the classroom and flows into the work area, where the air is extracted.



ill. 100 - Second mechanical ventilation system.
The air supply enters into the work area and flows into the classroom where the air is extracted.

Roof and height

The roof design and height of the building was determined as part of a process where technical aspects was the focus. The shadows of the building was the determining factor for the height of the buildings. By placing the largest building to the west, it ensures the shadow of the building only affects a minimum of the outdoor area between the buildings, while the school is open.
Studies of different types of roof were carried out with the intent of comparing their technical and architectural aspects. The evaluation of these aspects can be seen on ill. 101: Evaluation table of the roof types. The analysis to determine the shadow on the surrounding residential area were made in the 3D-program Rhinoceros and the full analysis can be seen in appendix 12.
As a result, the curved roof was chosen, because it cast the least shadow on the neighboring residential areas, amplifies the green zone of the area and has an integrated solution to implementing solar cells.
To make sure that the curved roof cast less shadow than the existing school, both shadows of the buildings were compared (see Shadow study of the existing building and the new building, ill. 102, p. 98. For full analysis see appendix 13) the analysis shows that the curved roof cast less shadows on the surrounding residential areas, than the existing building.

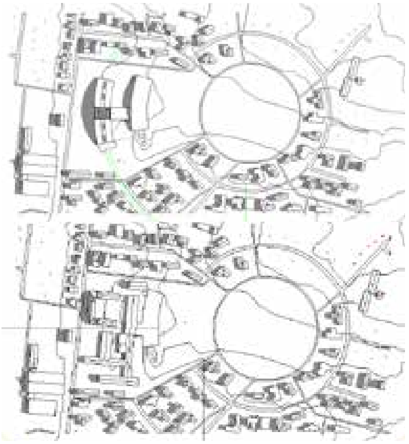
Roof types	Facades	Shadow on buildings	Function	Plan efficiency	Solar cells	Expression
		Winter: All day Spring/Fall: Morning Summer: Evening	Modern style, with full use of the plan	Each plan can be used fully, which makes the zoning of the building less dependent on the shape	Not easy to integrate as it is. They would have to be attached on the facade or on a angled frame on the roof.	The building is very dominating and heavy, and its sharp geometry makes it distinctive on the site
		Winter: All day Spring/Fall: Morning Summer: No	Outdoor areas available for all floors and classes	Each floor decreases in size but is instead directly connected to an outdoor area	Not easy to integrate as it is. They would have to be attached on the facade or on a angled frame on the roof.	The rising volume connects to the site, while its sharp corners makes it distinctive
		Winter: All day Spring/Fall: Morning Summer: No	A more organic building resembling the landscape	The arch makes each floor smaller, except for the first floor	Could be integrated along the curve on the southern part of the roof	The Arch relates to the movement in the facade and connects to the site, almost becoming a scenic element
		Winter: All day Spring/Fall: Morning Summer: Evening	Based on the stack-effect; with roof windows towards east, using the strong west wind to inforce natural ventilation	Each plan can be used fully, which makes the zoning of the building less dependent on the shape, as with the first	Could be placed on the East/West roof surfaces, which each have the needed minimum 10 degree angle	The facades become very simple, but from the site the roof create an interesting twist

ill. 101 - Evaluation table of the roof types.
The table show the different aspects that the roofs is evaluated on.

Shadows on surrondings

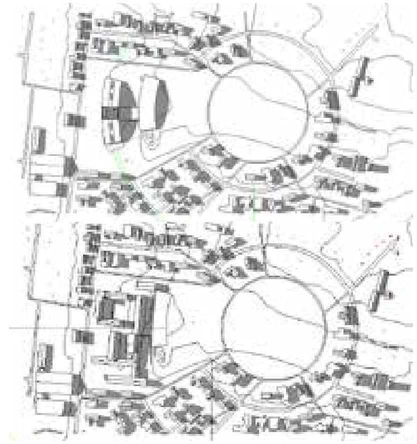
Summer

08:00



16:00

18:00

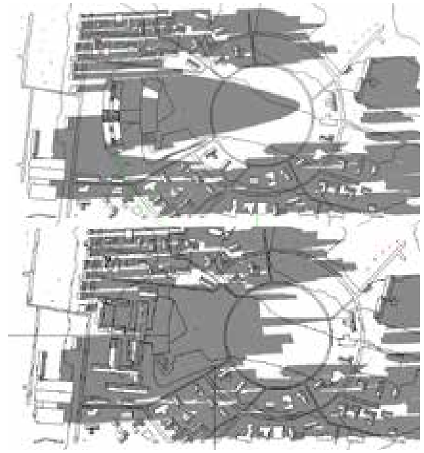


Spring/Fall

08:00

16:00

18:00



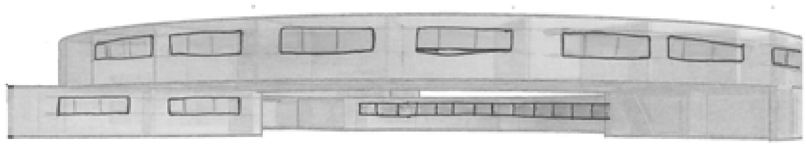
Winter 10:00 12:00 14:00

ill. 102 - Shadow study of the existing building and the new building.
The study shows that the new building cast less shadow than the existing building.

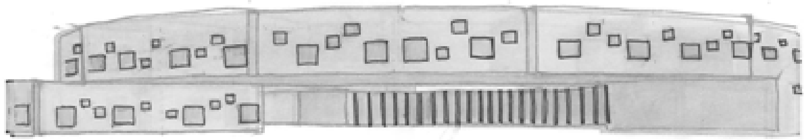
Facade development

Windows

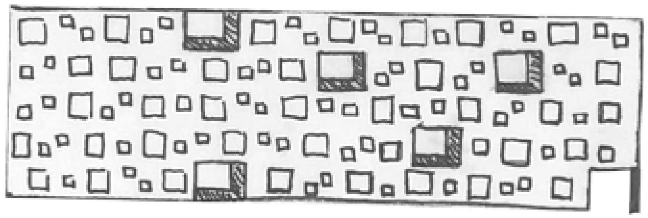
Throughout the process the facade of the building has changed with the shape, however, the principles of the windows have stayed the same (ill. 103-106). Three window types were chosen from an initial sketching phase, based on their individual qualities (see Window types, ill. 107). The three types of windows were then evaluated by the following analysis: the measurements of the windows and the effect on the daylight factor, indoor qualities, the need for artificial light, the efficiency of natural ventilation and the facade expression. The results of the analysis is described on the following pages, and the analysis evaluation can be seen on p. 104, ill. 110: Evaluation of window types.



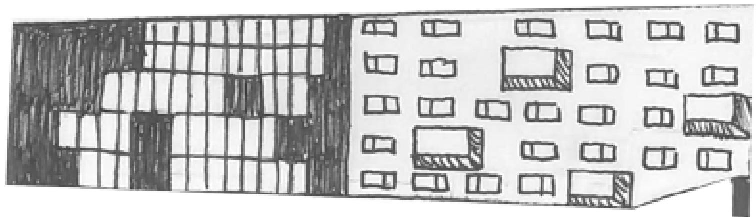
ill. 103 - Facade suggestions.
Collected windows create a band in the facade.



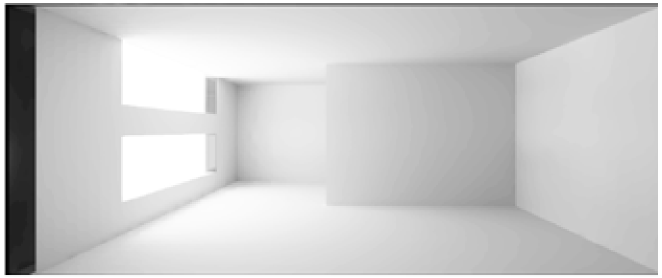
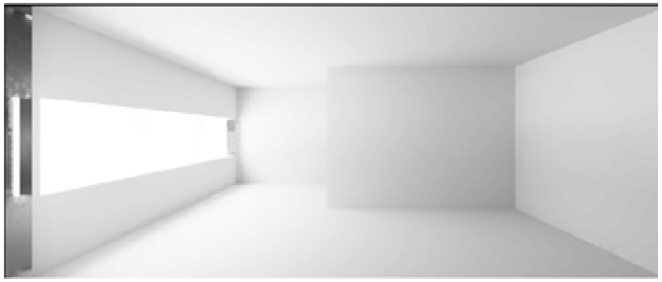
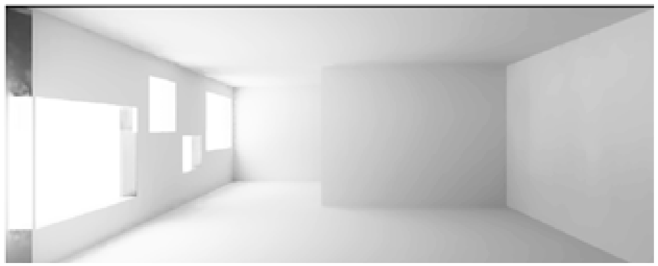
ill. 104 - Facade suggestions.
Playful windows, placed in different heights.



ill. 105 - Facade suggestions.
Playful windows, placed in different heights and terraces displaced into the facade.



ill. 106 - Facade suggestions.
Simple facade with small openings.

Average daylight 3,2 	+ Simple View from the tables Light far into the room No glare Natural ventilation (single sided)	- No view standing
Average daylight 3,7 	+ Well spread light Simple View all the time	- Glare
Average daylight 3,3 	+ Playful Well spread light Both No glare (different heights in windows)	- Can be too playful

ill. 107 - Window types.
The table describe the positive and negative for the different types.

Daylight analysis of measurements

Each type of window combination was tested in VELUX Daylight Visualizer with variations in measurements, to explore the impact on the daylight factor. As with the previous Daylight analysis, the windows were tested for a classroom, and the area was kept in a 15% ratio of the floor area. The complete analysis can be found in appendix 11, and the measurements that gave the best daylight factor for each type can be seen in evaluation. The analysis showed that a window with a height of 60cm or less was too narrow for the light to fully reflect into the room, due to the 50m thick outer walls. It also showed that windows placed closer to the ceiling could reflect the light further into the room.

Of the window types with the highest results the first and third type had similar results, with a 0,1 difference in favour of the third type. The second type had the highest daylight factor of 3,7.

Indoor qualities

As mentioned previously each type of window was based on a concept or idea on how it would affect the indoor qualities. Of the three types, the first and the third had the strongest concept.

Artificial light zone

Since daylight is only possible in one side of the classroom there will always be a noticeable difference in the light amount, from one side of the room to another. Dividing the artificial light sources in the classrooms into zones will therefore save energy. The critical part of the classroom is where the daylight factor falls below 2 %, and will have to use more artificial light. To define how much of the classroom is below the 2 %, a simulation testing the room in 1x1m squares was tested in Bsim. This way the border of the 2 % daylight could be found.

The results in Evaluation of window types, ill. 110, shows that 2% border of the first and second window type lies 3m from the back wall. In the third window type however, the 2% border lies 2m from the back wall, suggesting that light is reflected deeper into this room than the others.

Natural ventilation

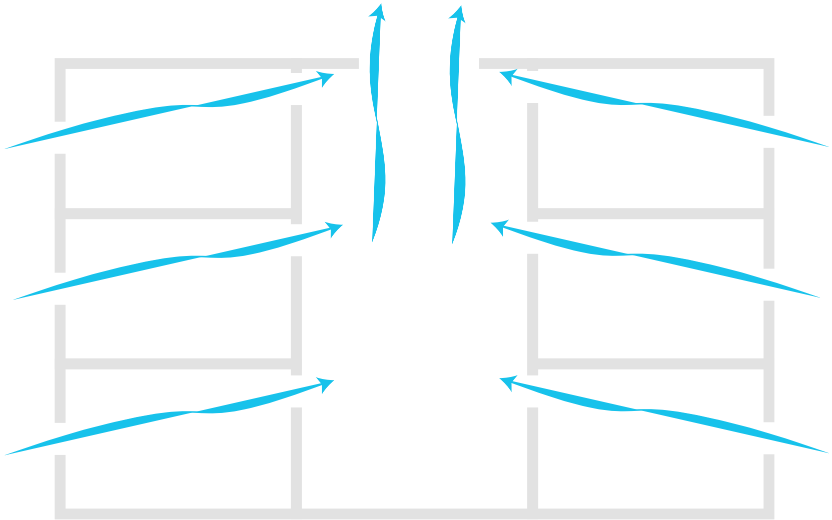
Single-sided ventilation was tested for each window type, the full calculations can be seen in appendix 8. During the evaluation of the window types the development of the plan led to the idea of using stack ventilation, by implementing sound absorbing wall elements between the classrooms and the work areas (see Principle of stack ventilation, ill. 108). This decision greatly impacted the results of this analysis, and the results of single-sided ventilation were therefore not considered in the final evaluation.

Facade expression

The suggestions to the three facade expressions led to the conclusion that all suggestions needed to be adjusted aesthetically, to soften the expression and keep a modern style.

Evaluation parameters

Based on the conclusions from the analysis the third window type was chosen. For the first and second type to work on the facade, the window bands would have to be changed. If they were made longer, they would have to be narrower to stay within the 15% ratio of floor area. This solution would worsen the daylight factor, see appendix 8. The third type gets daylight furthest into the room, which means that even though the value of the average daylight factor is lower than the second window type, the light is better distributed. At the same time its indoor quality is prioritised highly, however, it would need corrections to achieve an aesthetic facade expression.

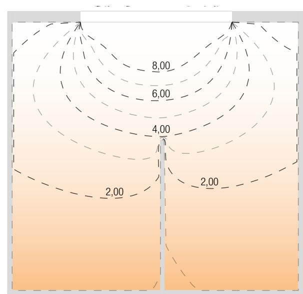
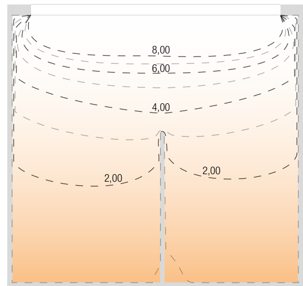
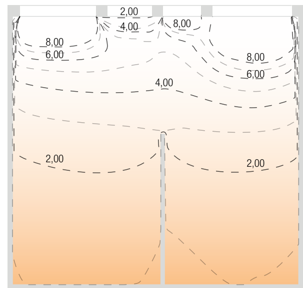


ill. 108 - Principle of stack ventilation.
The diagram illustrates the intake of natural ventilation into the classroom and the outtake in the atrium.

Two rows		Height above ground	Lenght	Height	Area	AFR m3/s	AFR - pr. class	Windward	Leeward	Roof	Internal pressure	Neutral plan
1- East	1. floor	2,68	0,62	0,64	11,904	14,05	2,81	-0,25	0,2	-0,5	-6,25	7,6
	2. floor	6,68	0,62	0,64	9,5232	8,89	2,22	-0,25	0,2	-0,5		
1- West	1. floor	2,68	0,62	0,64	11,904	14,05	2,81	0,2	-0,25	-0,5		
	2. floor	6,68	0,62	0,64	9,5232	8,89	2,22	0,2	-0,25	-0,5		
1- Roof	Roof	15	9	5,5	99	-45,87				-0,5		

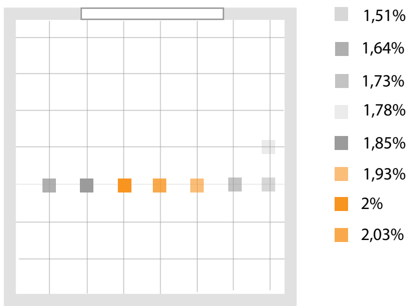
One row		Height above ground	Lenght	Height	Area	AFR m3/s	AFR - pr. class	Windward	Leeward	Roof	Internal pressure	Neutral plan
1- East	1. floor	2,68	0,62	0,32	5,952	7,40	1,48	-0,25	0,2	-0,5	-6,25	7,6
	2. floor	6,68	0,62	0,32	4,7616	4,82	1,21	-0,25	0,2	-0,5		
1- West	1. floor	2,68	0,62	0,32	5,952	7,40	1,48	0,2	-0,25	-0,5		
	2. floor	6,68	0,62	0,32	4,7616	4,82	1,21	0,2	-0,25	-0,5		
1- Roof	Roof	15	9	5,5	99	-24,44				-0,5		

ill. 109 - Calculation of natural ventilation.
The calculations is for one row and two rows of sound absorbing wall elements.

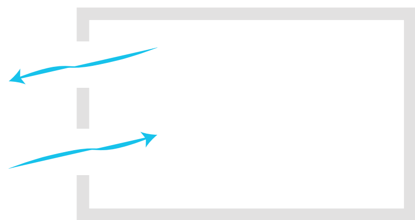
<table>
<tr><th>Window</th><th>Indoor Qualities</th><th colspan="2">Daylight factor</th></tr>
<tr><td></td><td>The concept of this window type is to have a high narrow window where to get light far into the room, and have a low narrow window, that the children can look out from without getting glare in eye hight.</td><td>3,2%</td><td></td></tr>
<tr><td></td><td>A longer window band placed centered in the wall, this give a good possibility for orientation and view in each room.</td><td>3,7%</td><td></td></tr>
<tr><td></td><td>These windows have a playfulness to them, with both higher and lower windows giving view and light further into the room. The larger windows can be used for seating in the classes.</td><td>3,3%</td><td></td></tr>
</table>

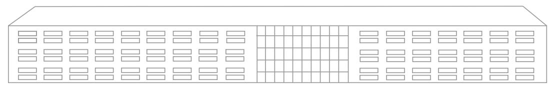
ill. 110 - Evaluation of window types.
The parameters for the evaluation is: indoor qualities, daylight factor, artificial light-zone, ventilation and facade expression.

Artificial light-zone	Ventilation	Facade expression
	needed ventilation for smell 6,3 needed ventilation for CO_2 0,8	

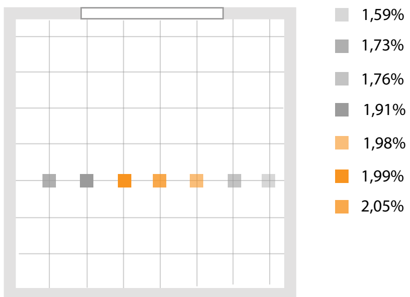


Possible ventilation 1,22

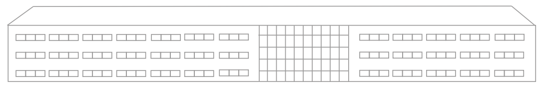




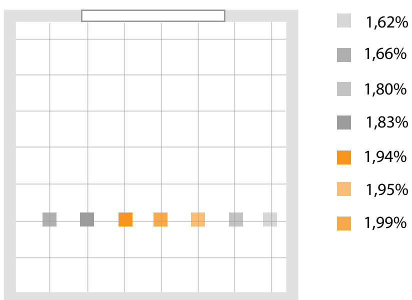
This facade becomes a little messy and not easy to get an overview over. Because the windows can't connect to one continues band, it feels like a lot is happening in the facade, even though the windows in principle are very simple.



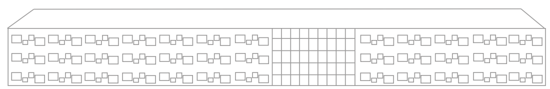
Possible ventilation 0,60



This facade becomes very static and easy to get an overview of the building. The simple bands makes et easy to read how each floor runs.



Possible ventilation 0,80



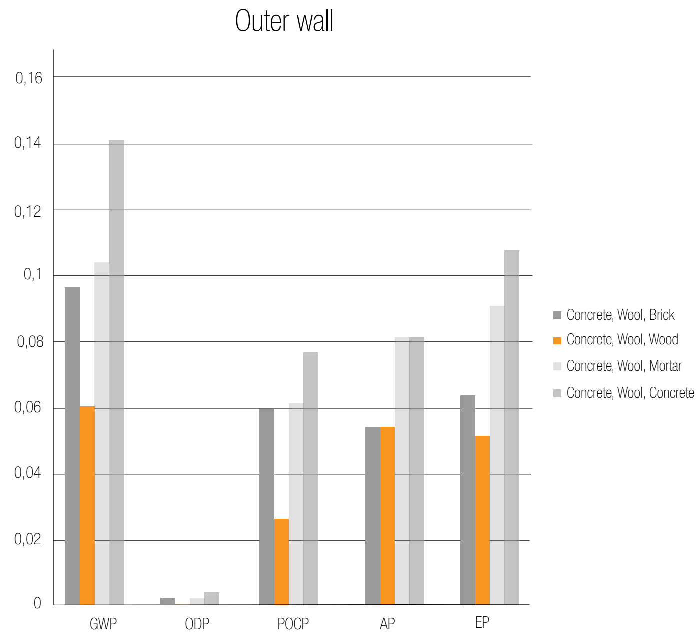
The playfulness of this suggestion get lost when the same combination is just repeated, and the facade becomes messy.

Material

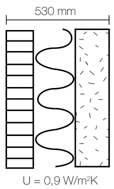
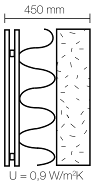
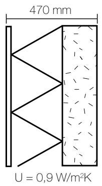
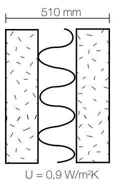
The choice of material impacts a sustainability of a building. This is considering the pollution-levels of its production, construction, lifespan and demolition. For the material considerations, a basic LCA-analysis was made to compare wall and floor constructions. The analysis of the floor constructions can be seen in appendix 1. The analysis for the wall comparison can be seen in the graph: LCA-results of outer walls, ill. 111. The results from LCA, together with analysis of material expression, net area, lifetime and maintenance, was evaluated, and is shown in the table: Evaluation of materials, ill. 112.

The long durability and low maintenance factor has a high priority when designing a public school. A public school needs to last a long time, with minimum cost. At the same time, the LCA – analysis also has a high priority, due to the demands of DGNB ENV 1.1 and 2.1 (life cycle analysis, and environment effect and primary energy). The nett area is also important for the cost of the building, and needs to be seen in comparison to the achieved u-value of the material, which is an important factor to secure a good thermal envelope and meet the conditions of the DGNB TEC 1.3 (the thermal envelope).

Of the tested wall constructions, the wall of concrete and wood has the best results in the LCA studies. However, when compared with the lifetime of the other materials, it has the shortest durability. subsequently, the concrete/brick wall construction has the second best LCA results, as well as the best durability along with low maintenance.



ill. 111 - LCA results of outer walls.
The different materials are compared with each other.

Wall	Expression	Nett area	Lifespan/ maintenance	LCA
Concrete/Brick 	- Structure - Gives play in the facades - Creates lines - Lot of possibilities of colour	- Thick wall, creates less area - Less light through the windows - Possibilities for exploita-tion of width frames	Long lifespan (100 years)	Second best
Concrete/wood 	- Heat / shades - Depth and create lines	- More area to the rooms - Better possibility for light through windows	- Short lifespan (30 years) - Can avoid maintenance	Best
Concrete/Mortar 	- Neutral facade - allows room to other elements - Different colours	- More area to the rooms - Better possibility for light through windows	- Middle lifespan (30 years) - Low maintenance	Third best
Concrete/Concrete 	- Both neutral and structure - Can create lines - Raw expression is possible	- Thick wall, creates less area - Less light through the windows - Possibilities for exploita-tion of width frames	- Long lifespan (100 years) - Almost no maintenance	Fourth best

ill. 112 - Evaluation of materials.
The parameters used for the evaluation; expression, Nett area, Lifespan/Maintenance and LCA results.

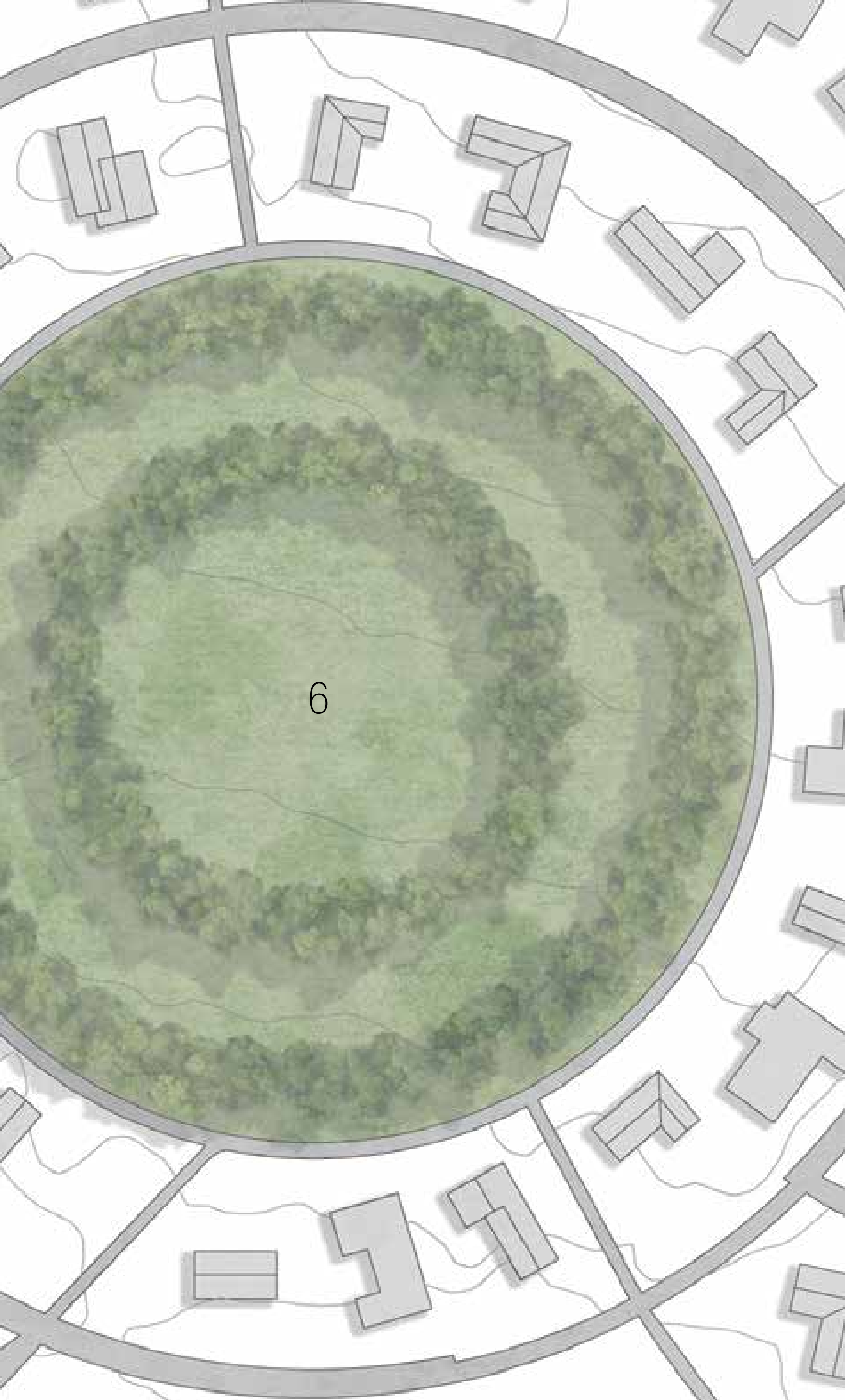
ill. 113 - Visualisation of the outdoor area from east.

03

Presentation

This section presents the project. At first, the overall master plan, including the master plan of the outdoor area, are presented. The technical aspect, such as details, construction and Br15, is then explained in-depth. After this the plans are presented, followed by function diagrams, fire diagram and mechanical ventilation. In the last part of this section the overall use and functions of rooms are shown. The section ends with a conclusion and further reflection of the project.

ill. 114 - Master plan 1:1250
The master plan gives an overall understanding of the site and how it interplay with the surroundings.
The number on the plan explain the placement of the different areas of the site.

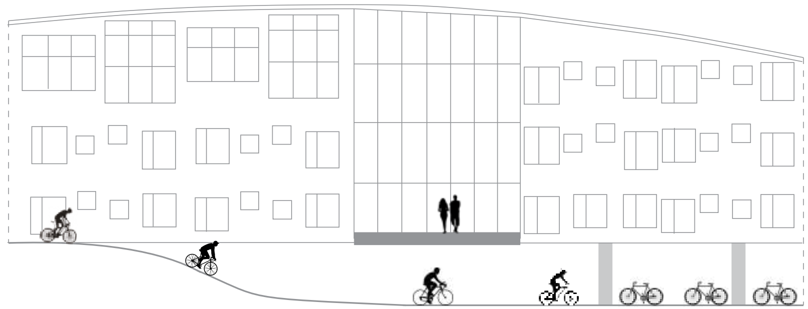


1: Entrance points
2: Solar cells
3: Delivery route
4: Bike parking (594)
5: Car parking (38)
6: Rotunden
7: KFUM hall
8: Turning area

Zones in the outdoor areas:
9: Hill area
10: Water area
11: Sand area
12: Assembly area
13: Multi area
14: Ball field
15:Gardening
16: Learning Huts

Master plan

The school and the surrounding area is the connection between the green park, Rotunden, and the green soccer area behind the halls of KFUM. From Rotunden the school is seen, surrounded by a green area, with grass and trees. From the residential areas on the southern and northern boundary of the site, the green roof will enforce the green connection, and from west the trees bordering the site and parking lot will hint of the green recreational area behind it. In this way, the site and building enforce the green zone in the area.
As a part of working with the DGNB criteria ENV 2.3 the outdoor area should consist of different coverings and avoid asphalt and tiles as much as possible; based on the amount of grass, trees, sand, water etc. the playground would get 7 out of 10 points.
As mentioned in the design process the main idiom for the building is inspired by Rotunden. To strengthen this bond between the site and the park, the surrounding playground has been divided into zones based on the same circle spheres. The paths work as borders defining the zones. Each zone has its own identity, based on a material's tactility and is placed close to the age group that it is designed for. None of the areas are closed off, which creates visibility between the activities and lets the children move easily between the zones. As described in the analysis: Outdoor areas, p. 36 most children will play where they can see activity or other children. The visual contact between the zones may therefore increase the desire to play in the other zones.
Each zone focuses to strengthen the development of children of specific ages, and has elements that may be used for teaching. For instance, the water- or sand zones, which tactile qualities stimulate the senses and instinct to explore, which is mentioned in the child development analysis as one of the phases of the early childhood. Additionally, the water area could also be used in subjects such as nature study or biology. The zones diversity in qualities relates to the criteria SOC 1.6 that among others, is about the design and number of different elements on the playground. Of the points addressed to the outdoor area and not the facade and roof, the project would get 32,5 out of 50 points.



ill. 115 - Section of entrance.
The section shows how the bicycle path goes under the entrance stair and down to the bicycle parking in front of the building.

A priority in the design of the outdoor areas has been to create an environment suitable for everyone. Allergy friendly trees and vegetation has therefore been implemented, and the "forest area" is made up of a selection of Larch-, pine-, rowan-, and fruit trees. (see inspiration pictures, ill. 116-119)

The building has two big entrance points: the main entrance towards west, where the car parking and the largest part of the bike parking is placed, and the exit from the cafeteria towards east orientated towards Rotunden (see visualization of the Main entry hall ill. 161, p. 138). The last entrance is connected to the surrounding paths from the surrounding residential areas, and has a smaller bike parking placed near it. The placement and amount of bike parking is based on the guidelines from SOC 2.3, which states that every pupil above fourth grade needs a parking space along with one per every fourth employee, and that they should be placed a max. length of 50m from an entrance. There is therefore 594 parking spots, giving a score of 91 out of 120 in those two parameters in DGNB.

The main entrance has an entrance stair with ramps due to the topography. On the south side of the stair, the ground is leveled with the road, to create a level place for parking and a bike parking level with the basement. This can be seen on the facade, p. 100, and the basement floor, p. 126. Cyclists coming from the north can get to the parking area by a path running parallel to the main building passing below the entrance-stair through a tunnel (see section of bike path).

In the integrated bike parking a door to the basement is placed for delivery of supplies and collection of refuge (see basement plan, p. 126).

ill.116 - Fruits trees

ill.118 - Pine trees

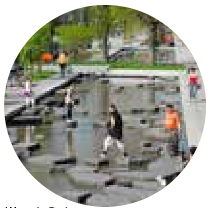
ill.117 - Larch tree.

ill. 119 - Rowan tree

Outdoor spaces


ill. 120

1. Garden area
• Small gardening boxes where the students can learn about gardening and plants in general.


ill. 121

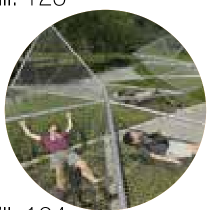

ill. 122

2. Water area
• The water zone has a big basin and a smaller water stream, where the children can jump on stepping stones, play with toy boats or the area can be used for teaching.

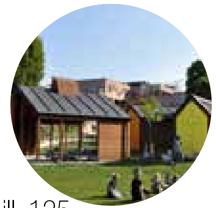
•The water zone is placed in the lowest part of the site, naturally collecting the excess water from the site. The basin has a depth of 10 cm, to ensure that the children cannot drown, see the section of the water basin (ill. 130.)


ill. 123

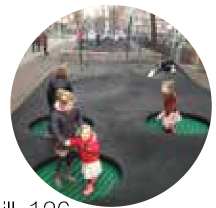
3. Sand area
• The sand zone is divided into two areas: one for climbing activities and the other as an unrestricted sandbox with swings.


ill. 124

4. Net seating
•A relaxing area, where students can lay or sit in both larger and smaller groups on nets raised from the ground.


ill. 125

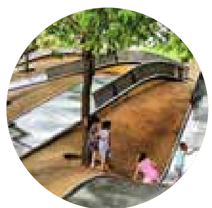
5. Huts
• Smaller huts for teaching. The huts can be equipped with a water supply or other functions, to support the teaching of various subjects in the nature.


ill. 126

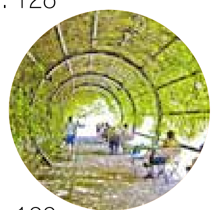
6. Trampoline area
• This area has small trampolines inserted into the ground. This type of trampoline is safer because they do not have holes the children can get stuck in, and are not above the ground, so the children can fall off it.


ill. 127

7. Climbing area
• A more challenging climbing area for the intermediate and older pupils, where they can improve their physical skills.


ill. 128

8. Slide hill
• The natural hill is used to create the inclination of the slides


ill. 129

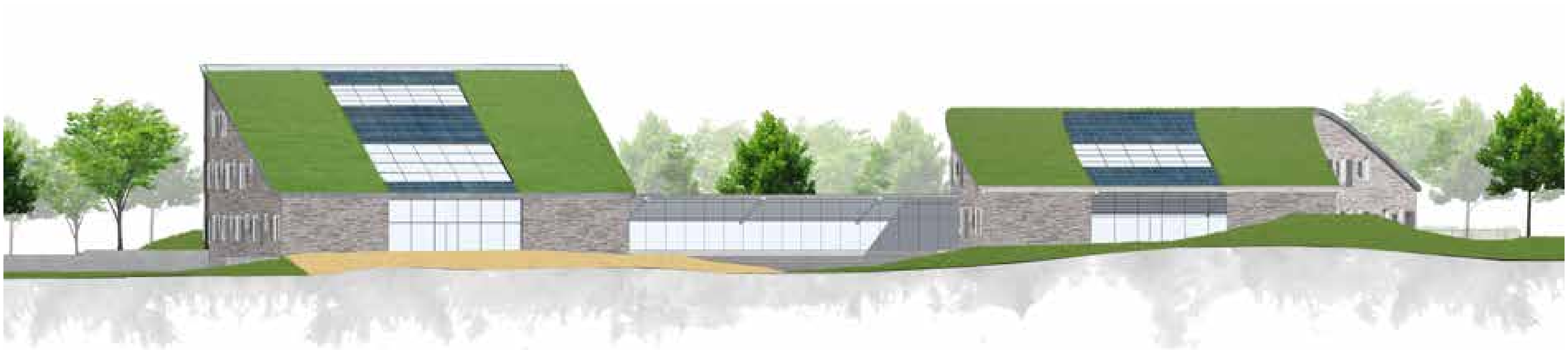
9. Sheltered seating
• As mentioned in the outdoor analysis sheltered areas are needed on a playground, this is done by placing a pergola, the same construction used as overhang above the large glass areas on the southern side of the building (see the southern facade, p. 117 and the visualization from the forest area, p. 110)

ill. 130 - Section of the water basin.
If needed the basin can take in more of the excess water from the site. In this case, the area can be closed off, or water tanks could collect the water, and use it to water the site. This measure is taken to consider the environmental increase in torrential rains, and future proof the site. (Brandt, 2015]

ill. 131 - Site plan 1:750.
The site plan gives a more detailed understanding of the function in the outdoor area. The numbers and reference pictures shows the idea behind the different areas.

ill.132 - West facade 1:500. The facade can be found in the technical drawing folder in 1:200

ill.133 - East facade 1:500. The facade can be found in the technical drawing folder in 1:200



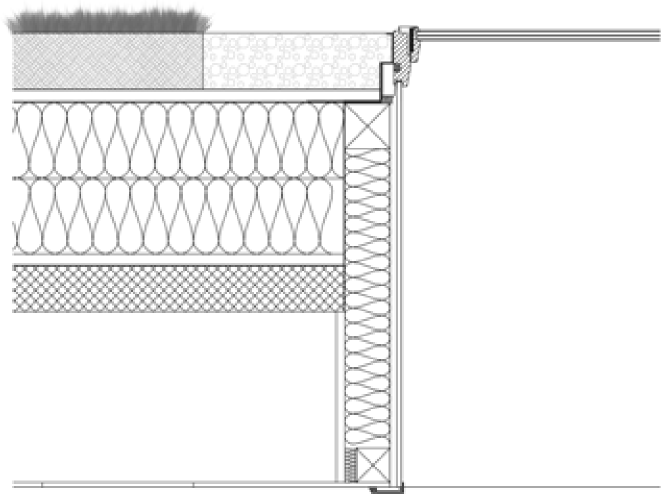
ill.134 - South facade 1:500. The facade can be found in the technical drawing folder in 1:200

ill.135 - North facade 1:500. The facade can be found in the technical drawing folder in 1:200

External features

The main exterior material is brick, with a pattern of grey nuances, making the building lighter and giving a depth to the facade. There are mainly two types of windows in the façade: larger lower windows and higher smaller windows.
To compliment the nuances of the brick-pattern the colour of the frame of the windows interchange in similar nuances of grey. The frame of the biggest windows is 150 mm in height and width, giving a depth to the facade and the exterior blinds, which can be seen on the detail (ill. 137), is integrated into the window frames. The largest of the windows are placed low, to use the inner window sill as a seating in the classrooms, as illustrated on the detail (ill. 137) The aesthetic qualities of the green roof were mentioned on the previous pages, however, other factors are the environmental qualities, such as improvement of the micro climate by moisturizing the air and slightly decreasing the temperature of the building. [ZinCo1, 2015] Additionally, 80 % of the rain water can be absorbed by the roof vegetation and the rest is delayed, thereby reducing the chance of flooding in a heavy rain fall. Studies at Melbourne University shows that a view of a green roof make people happier and more efficient at work, compared to a view of a regular roof. [ZinCo2, 2015]
The main vegetation on the roof is Sedum (see reference photo, ill. 143). This plant family variate in colour throughout the seasons, changing the appearance of the roof. Solar cells and roof windows are also integrated into the roof. Both elements need a minimum angle of 10 degrees to be cleaned by rain. To solve this the panels are raised from the roof to 10 degrees, when the angle of the roof itself becomes less. This can be seen on the western and eastern facades (ill. 132-133)

Roof structure:		**Skylight window:**
Dirt/rock layer 500 mm	150 mm	3-layer glass
Filler membrane		Alu frame
Drainage	30 mm	minimum angle at 100
Poly foam Eco Roof board	400 mm	
Water proofing		
Sceed laid to fals	30 mm	
Concrete roof deck	120 mm	
Expanded ceiling	500 mm	
Acoustic panel	12,5mm	



ill. 136 - Detail of the meeting between ceiling window and the green roof - 1:20.
In this detail the meeting between the roof and the skylight can be seen. The skylight on the roof which angle is below 10 degrees have been lifted to achieve this angle. Hence all windows can have the rainwater run of them and clean them.

Floor structure:

Linoleum	4 mm
Korck	17 mm
Battern	70 mm
Dobbelt Wedge	30 mm
Impact noise insulation	10 mm
Insulation	110 mm
Concrete deck	180 mm
Expanded ceiling	500 mm
Acoustic panel	12,5mm

Sound proof : L´ w = 58C
R´ w = 58 dB

Fire Resistence : REI 60

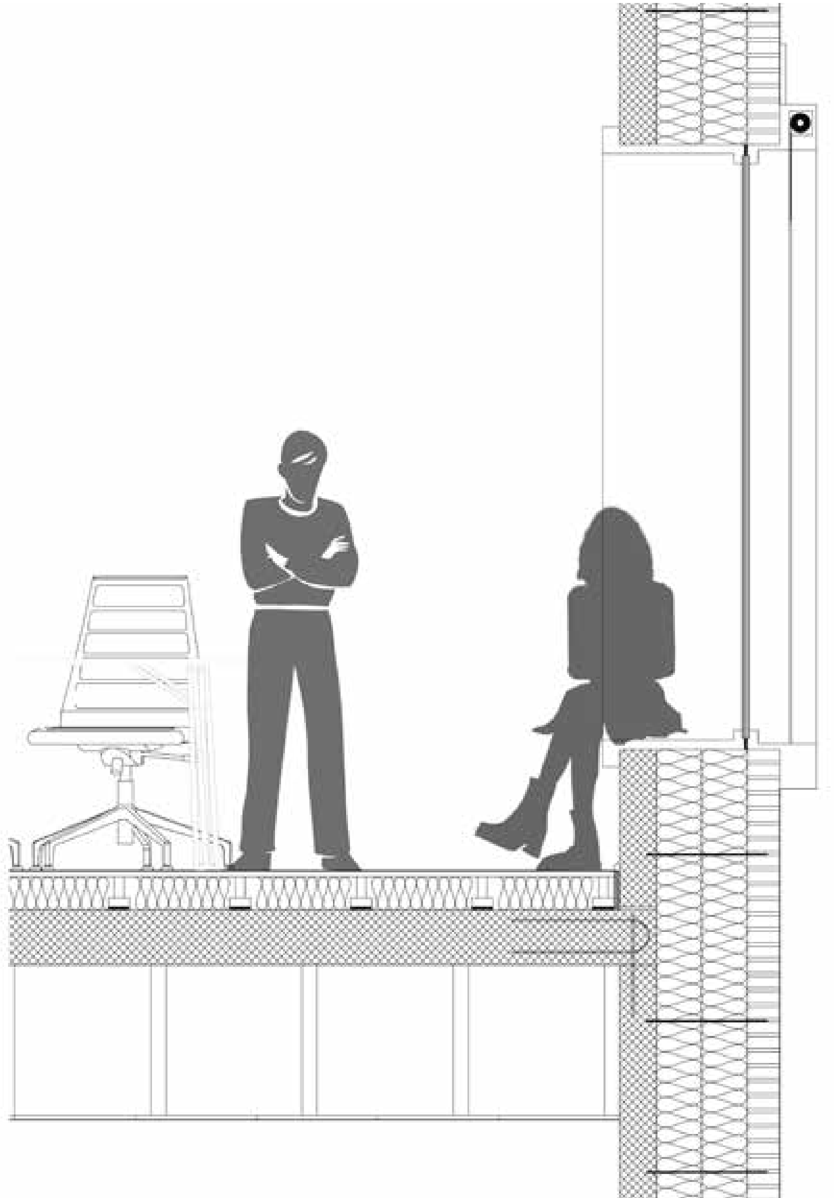
Exterior wall:

Brick	108 mm
Air	27 mm
Insulation	285 mm
Concrete	120 mm

Sound proof L´w= 53C
R´w= 55 db

Fire resistance: REI 60

Window:
3-layer glass
Alu frame
Mechanical blinds



ill. 137 - Window and ceiling detail - 1:50.
In this detail it can be seen how the deep windows can be used as a seating space. The solar shading blinds are hidden in the extruded frame of the window.

The energy demands of the building has been calculated in RockwoolEnergy, a program based on the calculations of Be15. The building complies with the 2020 demands, which states that a school should use no more than 25 kWh/m2 per year. This school uses 16,8 kWh/m2 per year. To comply with the 2020 demands, passive and active strategies have been used:

• Low U-values of building components lessens the transmission loss through the envelope, sealing the building, and reducing the need for heating.

• Natural stack ventilation through the atria reduce the need for mechanical ventilation in the summer.

• The percentage of the glass area has also been kept below 20 %, and turned mainly east and west. Windows allows the building to utilize the solar heat gain, but also increases the transmission loss. For this building the glass area is equivalent to 17 % of the floor area.

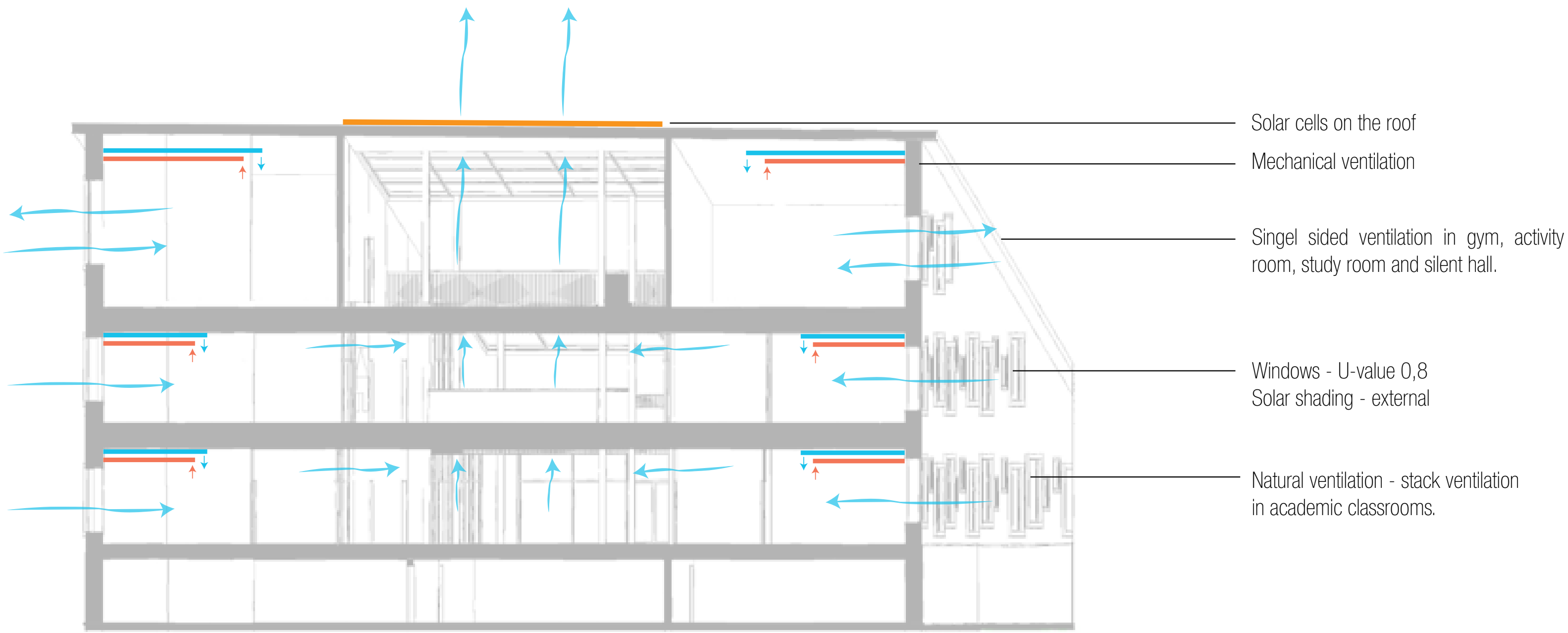
• To reduce the heat gain when necessary and prevent glare the integrated solar shading can be used (see the blinds on detail 137, p. 119). The shading is mechanical and continuous, meaning that it can be adjusted based on the need of the room.

• The active strategy used in this project is solar cells. The solar cells are placed in a band running cross each roof along with the roof windows, with an angle ranging from 28 to 10 degrees. The solar cells are also placed on the north side of the building. Although they are less efficient compared the ones angled south, they still produce a high amount of energy. With the current amount of solar cells the building produces energy to cover approximately 2/3 of the collected electricity use of the building. (see calculation of solar cell panels, appendix 5)

RockwoolEnergy Results

Collected Electricity Need	19,9	kWh/m^2
Room Heating	7,6	kWh/m^2
Energy Frame		
2020 Demands	25	kWh/m^2
The School	16,7	kWh/m^2
Transmission Loss		
2020 Demands	5,7	W/m^2
The School	2,7	W/m^2
Window to Floor Ratio	17	%

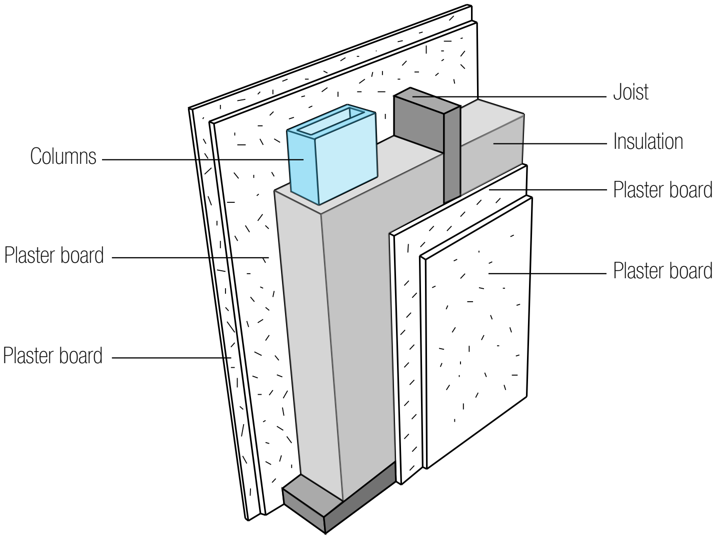
ill. 138 - Energy data from RockwoolEnergy.
The table shows how the building fulfill the 2020 regulation.



ill. 139 - Passive and active strategies.
This diagram show the different passive and active strategies that are used in the project. To avoid polluted air going into the room on the third floor, these room are ventilated with single sided ventilation where the rest of the building work with stack ventilation.

Construction

The construction principle of the building is loadbearing exterior walls with supporting columns placed in the inner walls, as shown on the Construction principle diagram, ill. 141. The inner walls can thereby be repositioned to the future needs of the school. The columns are made of steel, and although steel is not a very sustainable material, it has a long life-time and is more efficient than other materials, making it possible to have smaller columns with the needed strength. The profile is a closed square with the dimensions 140x220mm (see Inner wall construction, ill. 140) Columns are also placed around the atria in the centre of the building. These columns are made of wood, with the dimension of 200x200mm, because of the warmth and tactility of the material.
Stabilizing cores are made in each of the wings of the building. The stabilizing cores are made from the fire stair case and bathrooms.



ill. 140 - Inner wall construction.
This diagram shows the layers in the inner walls and how the columns are placed in the wall.

ill. 141 - Construction principle.
This section of a plan illustrates the main construction principle of the building. The load bearing walls and columns are marked.

Final room program

0.-2. Grade	Home Classes	9	51 m²
	Study Room	9	8 m²
	Toilet	2	26 m²
	Wardrobe	1	206 m²
	Work Area	2	195 m²
	DUS	1	54 m²
3.-6. Grade	Danish	5	58 m²
	Math	5	60 m²
	Study Room	10	8 m²
	Toilet	2	30 m²
	Wardrobe	1	123 m²
	Work Area	1	514 m²
7.-9. Grade	Danish	4	58 m²
	Math	4	60 m²
	Study Room	8	8 m²
	Toilet	2	30 m²
	Wardrobe	1	123 m²
	Work Area	1	330 m²
Practical Workshop	Art Workshop	1	72 m²
	Design Workshop	1	65 m²
	Wood Workshop	1	65 m²
	Home Economics	1	74 m²
	Media Class	1	72 m²
	Music Room	1	66 m²
	Elective Course	1	52 m²
	Work Area	1	213 m²
Cultural Workshop	Religion	1	58 m²
	Society	1	51 m²
	History	1	62 m²
	Study Room	1	8 m²
	Work Area	1	210 m²
Science Workshop	Biology	1	65 m²
	Science	1	72 m²
	Geography	1	48 m²
	Work Area	1	210 m²
Language Workshop	English	3	58 m²
	German	2	63 m²
	French/Spanish	1	63 m²
	Study Room	6	8 m²
	Work Area	1	210 m²
	Toilet	1	28 m²
Teacher	Break Room	1	346 m²
	Work Room	3	72 m²
	Group Room	3	22 m²
	Meeting Room	6	8 m²
	Wardrobe	1	70 m²
	Toilet	1	28 m²
Administration	Office	2	9 m²
	Caretaker Office	1	9 m²
	Secretary Office	1	21 m²
	Meeting Room	2	13 m²
	Wardrobe	1	5 m²
	Toilet	1	4 m²
	Kitchenette	1	4 m²
	Copy Room	1	5 m²
Shared Functions	Weather Porch	2	32 m²
	Entrance	1	280 m²
	Library and Assembly Area	1	516 m²
	Library Office	1	27 m²
	Cafeteria	1	335 m²
	Cafeteria Kitchen	1	77 m²
	Lounge	2	83 m²
	Activity Room	1	150 m²
	Gym	1	273 m²
	Gym Depot	1	107 m²
	Dressing Room	1	74 m²
	Silent Hall	1	196 m²
	Study Hall	1	275 m²
	Depot	1	42 m²
	Toilet	2	22 m²
	Cleaning Room	4	10 m²
Basement	Bicycle Workshop	1	57 m²
	Caretaker Workshop	1	99 m²
	Depot	4	96 m²
	Dressing Room	1	112 m²
	Hallway	2	611 m²
	Laundry Room	1	96 m²
	Refuse Room	1	57 m²
	Technical Room	3	86 m²
Total	Total Area	1	12319 m²
	Hallway Area	1	973 m²
	Hallway Ratio	3	8 %

ill. 142 - Final room program.
The table shows the different rooms and the sizes of them.

ill. 143 - Mood picture of sedum roof

ill.144 - Basement 1:600.
The plan can be found in the drawing folder in 1:200.

ill.145 1st floor 1:600.
The plan can be found in the drawing folder in 1:200.

3.-6. grade area
1: Danish
2: Group room
5: Math
6: Wardrobe area
7: Group room area

Office
8: Office
9: Meeting room
10: Copy room

0. Grade
11: 0. Grade (Classroom)
12: Work area
13: DUS
6: Wardrobe area

Common areas
14: Entrance Hall
16: Library office
17: Library
18: Assembly Hall
20: Cafeteria Kitchen
22: Cafeteria area

Practical workshop
7: Group room area
19: Music room
21: Home economics
23: Elective course
24: Wood workshop
25: Design workshop
26: Media
27: Art workshop

Teachers area
28: Teachers workroom
29: Teamwork room
30: Teachers break area

Other function
3: Bathroom
4: Fire staircase
15: Cleaning room

6-9. grade
1: Danish
2: Group room
5: Math
6: Wardrobe area

1-2. Grade
8: 1. Grade (Home-class)
9: 2. Grade (Home-class)
10: Work area

Cultural Workshop
13: History
14: Religion
15: Society

Language workshop
16: Spanish/French
17: German
18: English

Science workshop
19: Biology
20: Geography
21: Science

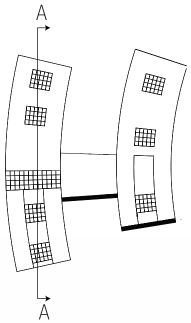
Other function
7: Academic work area
3: Bathroom
4: Fire staircase
10: Cleaning room
11: Common area
21: Depot

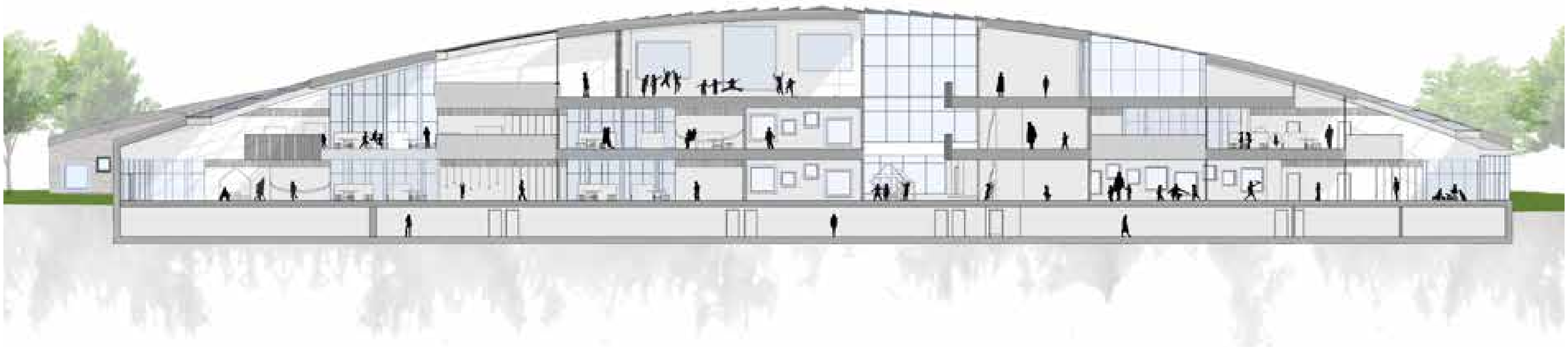
ill.146 - 2nd floor 1:600
The plan can be found in the drawing folder in 1:200.

Common function
2: Dressing room
3: Activity room
4: Gym
5: Gym depot
6: Study room
7: Silent hall

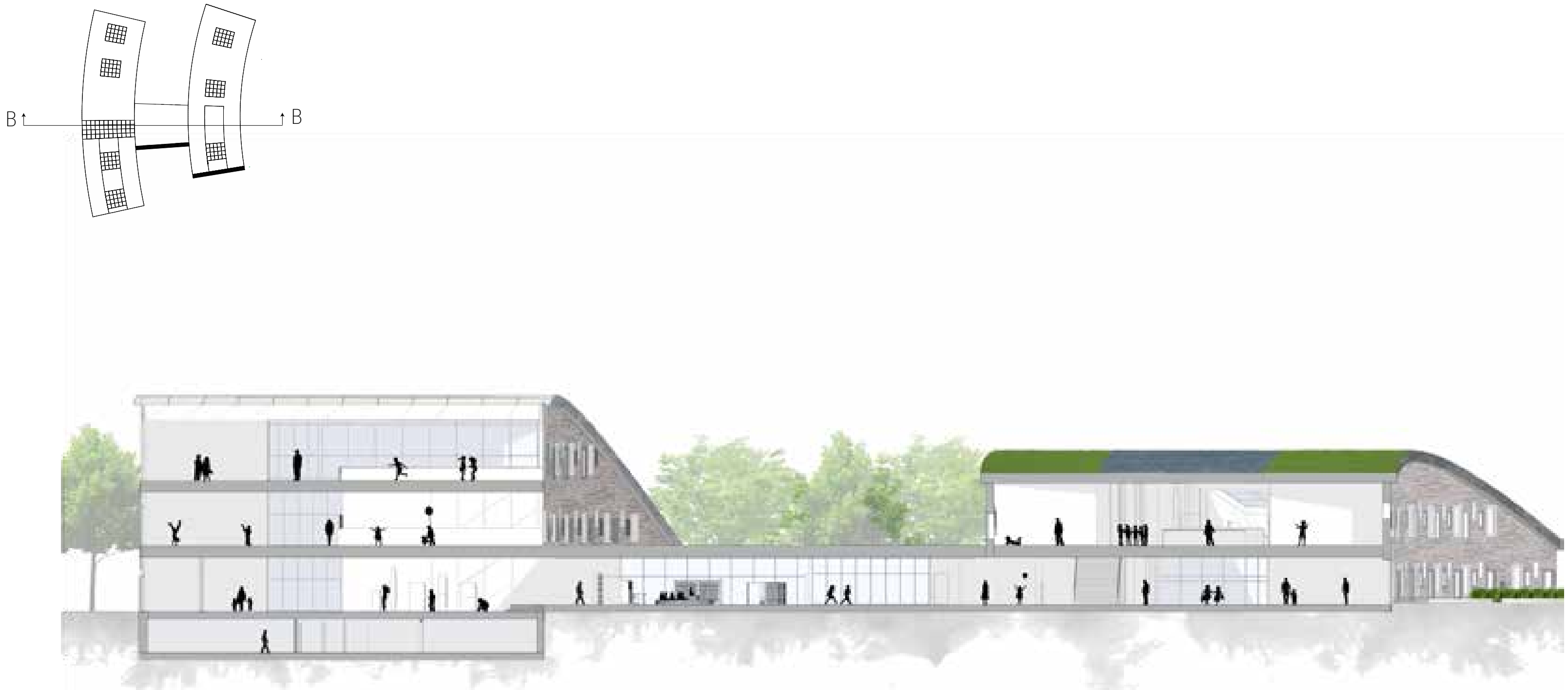
Other functions
1: Fire staircase
8: Common area
9: Cleaning room

ill. 147 - 3rd floor 1:600.
The plan can be found in the drawing folder in 1:200.





ill.148 - Section AA 1:500.
This section is made through the atria in the west building. The niches, play area and study areas can be seen. The section can be seen in the drawing folder in 1:200.



ill. 149 - Cross section BB 1:500.
This cross section shows how the two buildings are connected and the core of the building.

All the teacher functions are next to the cafeteria, with a glass wall separating the areas. This way the teacher facilities are still visible to the pupils, while providing the teachers with secluded areas where they can fully concentrate on work.

All subjects besides Danish and Math are in the workshop area, allowing students of different ages to share classes of subjects they have in common, such as English, history and biology. A colour is chosen for each function to define the area. It is mainly used in the niches and the floor of the group rooms. Orange is chosen as the colour of the workshop area and shared functions, due to its high reflectance of light, and its psychological effects: enhancing creativity, activity and uplifts the mood. (see Colour Psychology, p. 36)

The youngest childrens' home classes are placed on the 1. and 2. floor, with easy access to the outdoor. They are also placed on the south side, close to the main playground area. The green colour defines their wing, because the colour is calming and strengthens self-control. (see Colour Psychology, p. 36)

The DUS (after-school care) is a part of the youngest pupils' home-area, and shares the facilities. The DUS includes a kitchenette in the work area, and a classroom with storage, specifically for DUS activities.

The intermediate pupils have their main home-area and main subjects (Danish and Math) on the ground floor in the northern part of the building, which also have easy access to the outdoor areas. The colour of their home-area is Yellow, because of its high reflectance, and how it enhances logical and rational thinking and the desire to move. (see Colour Psychology, p. 36)

The home area and main classes of the eldest students are placed on the second floor (see concept sketch of the academic work areas p. 156). Their home area is defined by the colour blue, because of its ability to strengthen the inner contemplation and concentration, and its calming effect. (see Colour Psychology, p. 36)

On the third floor lies the activity rooms the youngest students use for gymnastics (see concept sketch of the activity floor p. 147). The intermediate and eldest students will continue to use the halls of KFUM, located across the road.

Next to the activity rooms lies two study halls, that can be used after school, in free periods or in the breaks.

The administration is next to the entrance, which makes it easy for visitors to find.

The library and assembly hall is in-between the two main buildings. The cafeteria is a continuation of the assembly hall and library. With the main entrance, these four functions make up the core of the building, the place where all the users meet. (see visualization of the entrance hall p. 138, and concept sketch of cafeteria p. 144

1st floor 2nd floor 3rd floor

ill. 150 - Placement of the functions in the school
The diagram explains where each function is placed and give a brief description of each function. The colour on the diagram refers to the text on the page 132.

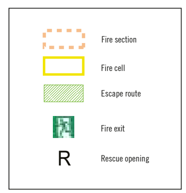
Fire regulations

The building is divided into two fire sections, and each fire cell consist of 2 or 3 classrooms, since the classes can be merged into one (see Fire diagram ill. 151-153). Fire stairs are placed in the end of each wing, which is two per fire section. Each classroom has two large windows that functions as rescue openings.

ill. 151 - Fire plan over 1st floor.

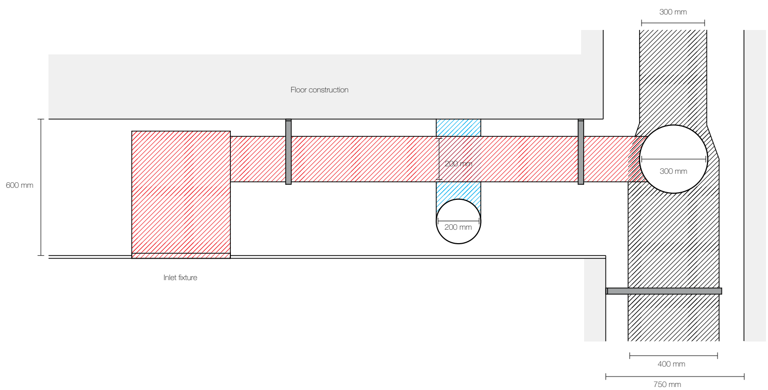
ill. 152 - Fire plan over 2nd floor.

ill. 153 - Fire plan over 3rd floor.



Mechincal ventilation

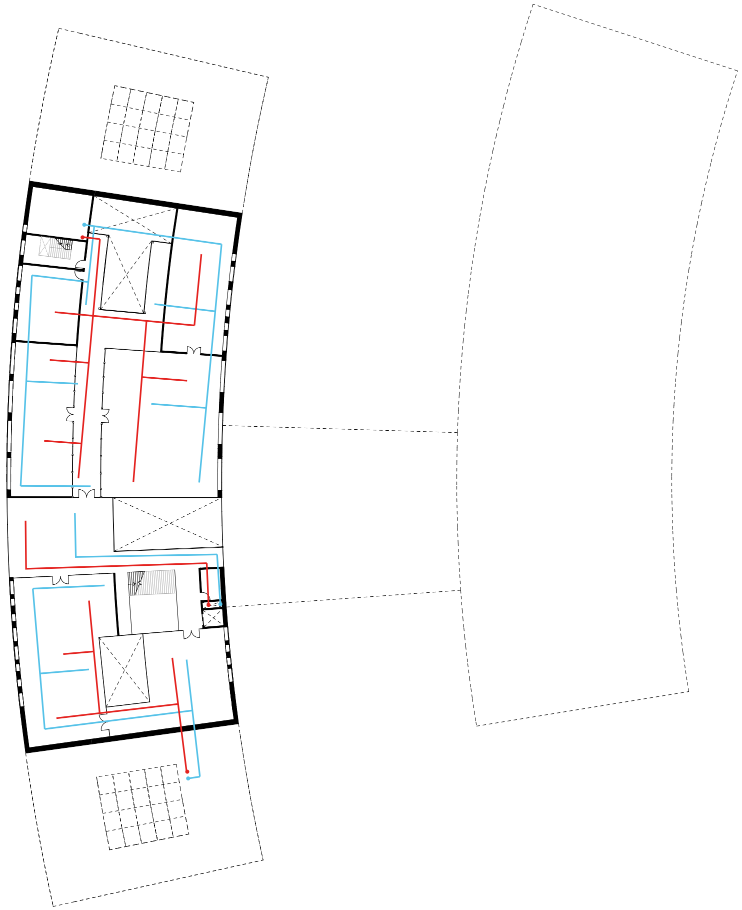
The mechanical ventilation system is divided into five zones based on the functions of the building. Each fire section holds one ventilation system, and the east building has a system for the workshops and cafeteria, and a system for the teacher functions. Each room has an intake and outtake system to maintain the atmospheric comfort. The size of the ventilation ducts are mainly 100mm for the pipe closest to the fixtures and up to 400mm closest to the central device (section of Ventilation pipe, ill. 154)



ill. 154 - Ventilation pipes. Show how the ventilation pipes are placed in the ceiling.

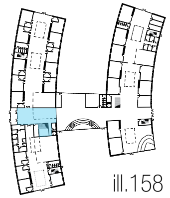
ill. 155 - Ventilation plan 1st floor.
A plan over the intake and outtake systems.

ill. 156 - Ventilation plan 2nd floor.
A plan over the intake and outtake systems.



ill. 157 - Ventilation plan 3rd floor.
A plan over the intake and outtake systems.

Walk-through of the building



ill.158

The Entrance

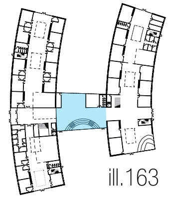
Upon entering the school, the visitors have a clear view through the core (Visualisation of the entrance, ill. 161). The visibility makes it easy for visitors to orientate themselves and find their way through the building. The school is shoe-free, which means that the visitors are met with a seating area, where they need to take of their shoes or put on reusable plastic coverings. The pupils need to take off their shoes when entering, and carry them to their wardrobes in their home-area, where each pupil has his/her own locker. The main staircase for the children's home-areas is located on the right. This stair is designed as an activity stair, which means that it functions as a regular stair, as well as offering an alternative way to move through the building. The pupils can either walk up the stairs or climb their way to the next floor. An example of such a stair can be seen on the inspiration picture, ill. 159-160. Directly to the right, is the administration offices. The first room upon entering is the secretary office and waiting room, through which a hallway leads to the rest of the administrative offices. The sculptural squares further down the entrance hall, which can be seen on the visualization, illustrates the concept of mixing art with an element that invites the children to climb and play around it.

ill. 159 - Activity stair reference. This picture illustrates the concept of the main stair in the building

ill. 160 - Activity stair reference- This picture is used as inspiration when designing the main stair in the building.

ill. 161 - Visualisation of the entrance.
This visualisation show the view through the building, and the transition between the two main wings. the squares in the corners works as an active element in the entrance.

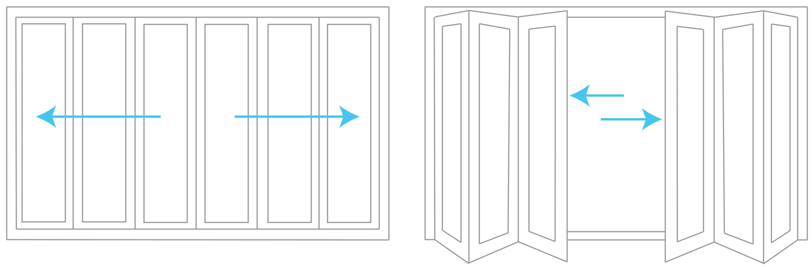
ill. 162 - Visualisation of assembly hall area
This visualisation shows a rainy day and how the assembly hall atmosphere can be seen through the windows.



ill.163

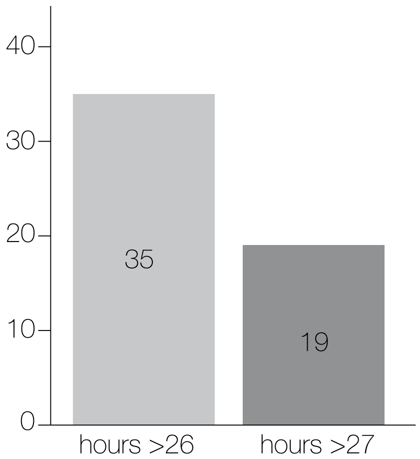
The assembly hall and library

Moving further into the core of the building, the next area is the assembly hall and library. The assembly hall and library has been combined as a part of the main hallway of the building. Placing the library in the centre of the building is a calculated decision, to create awareness, by becoming a visible area that the children walk through several times a day. This was suggested by both the teachers of Hirtshals skole [Bækgaard et al., 2017], and [Røjkjær, 2017]. The tribune area is used for assemblies and other gatherings, and the rest of the day it can be used as a reading area for the library or a meeting place for the students. (see Visualization of the assembly hall area, ill. 162) The tribune is based on the topography of the site and continues outside. The glass wall can be folded open, which extends the assembly hall to the stage outside. (ill. 164), which can be used for plays, concerts and gatherings in general. For the same reason, the music room is placed in the core, close to the tribune to make it easy to move instruments for assemblies or concerts.



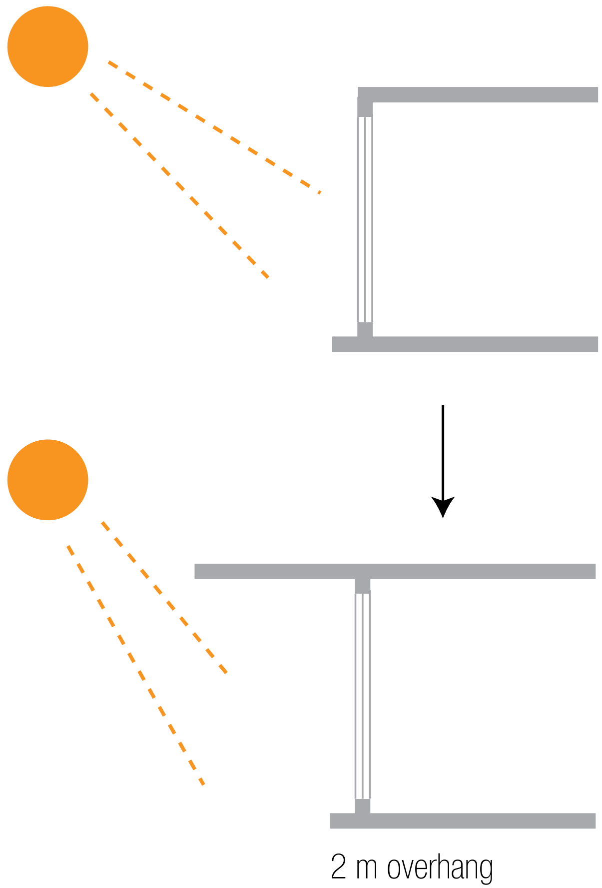
ill. 164 - Folding window.
The lowest part of the south glass facade, can be folded together as this illustration.

Overheating was a concern in the assembly hall and library, due to the large amount of glass to both north and south. To document the thermal comfort, the room was analysed in Bsim, where it was found that overheating was a problem, until the 2m deep pergola overhang on the south facade was integrated. The overhang can be seen on the 2. Floor plan (p. 128), and the detail, ill. 167. The results can be seen on diagram 165-166. The plants on the pergola creates a complete cover in the summer semester and lets some light through in the winter semester.

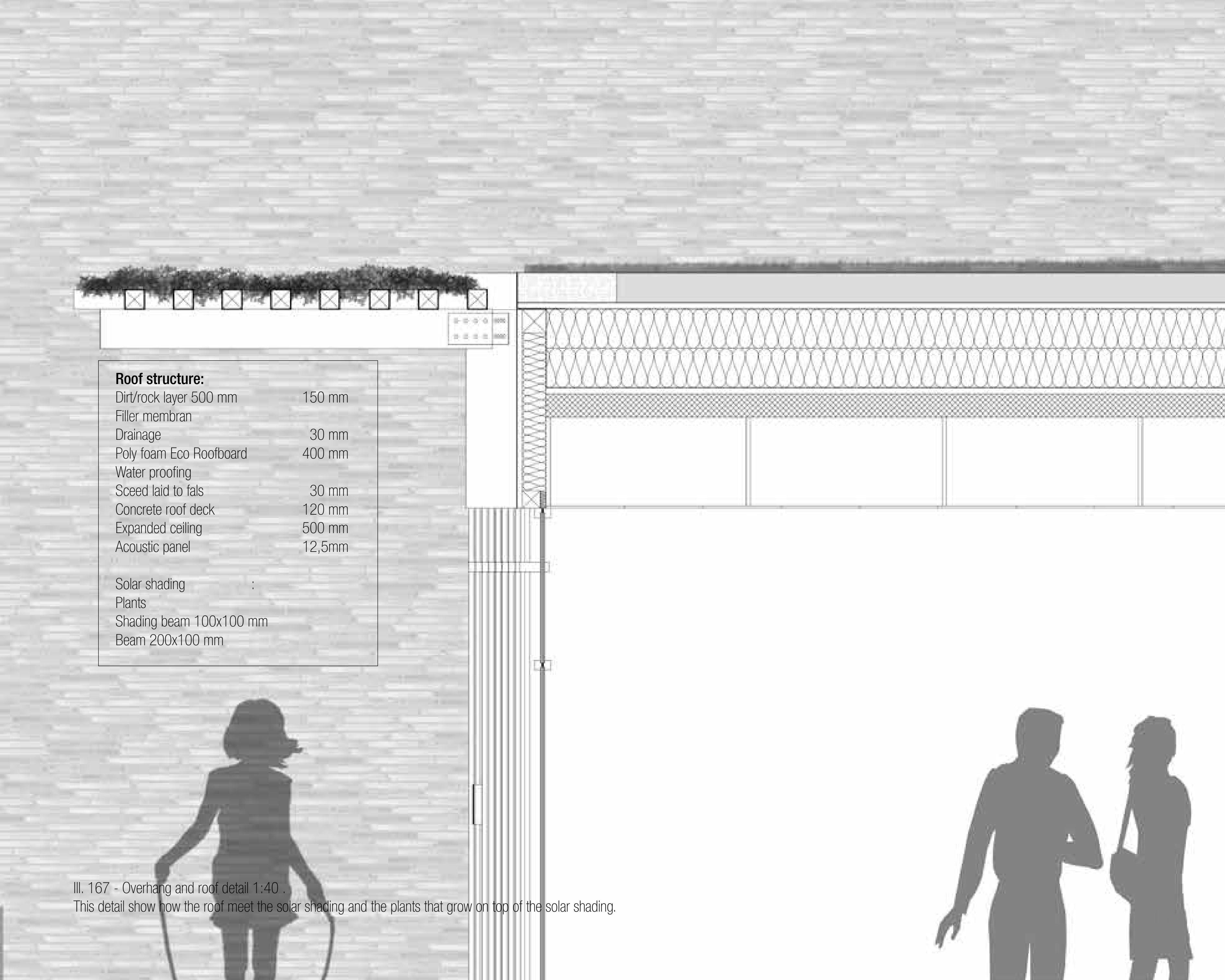


Hours above 26 degrees	Hours above 27 degrees
Max. 100 hours	Max. 25 hours

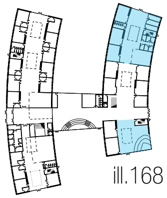
Ill. 165 - Results from overhang simulation.
The graph shows how the glass core can be cooled by using an overhang as solar shading.



Ill. 166 - Solar shading.
The illustrations shows how the solar shading affect the direct sunlight in the room.



Ill. 167 - Overhang and roof detail 1:40 .
This detail show how the roof meet the solar shading and the plants that grow on top of the solar shading.



ill.168

Cafeteria

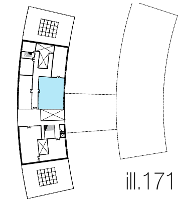
After the assembly hall and library is the cafeteria, and the first floor of workshop classes. The cafeteria has 150 seating at tables and a stair with additional seating, that imitates the topography of the site, and becomes an interior extension of the Slide hill. The cafeteria kitchen is next to the cafeteria, with a serving area directly connected (see visulisation, ill. 169). The home economics class is placed next to the cafeteria kitchen, which allows them to share storage. The other workshops on this floor is the practical workshops; the crafts and design classes, art class, media class and a classroom for elective courses. The rest of the workshop classes are on the second floor, divided into three zones; the science-, cultural- and language workshops, each with a shared academic work area.

Teacher facilities

The next section of the eastern wing is the teacher facilities, which as mentioned previously, is separated from the cafeteria with a glass wall. The glass wall allows the pupils to see the teachers when they are in the teacher lounge, but when a teacher draws back to his or her office space, they can work undisturbed. The teachers share an open office, based on the age group they teach. When they need to work together in groups or talk privately, they can use the group rooms, to not disturb each other (see School reform applied, p. 24)

ill. 169 - Visualisation of the cafeteria.
This visualisation give an idea about the atmosphere in the cafeteria and serving area.

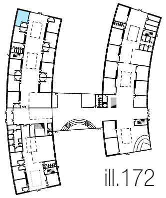
ill. 170 - Visualisation of the 3rd floor gym.
Here the atrium and entrance to the third floor can be seen. The windows to the right gives a view into the gym.



ill.171

Gym and study rooms

The rest of the shared functions are placed on the third floor of the western wing, on top of the pupils' home-areas. In one side of the wing, there are two activity rooms, for when a teacher needs to activate his or her pupils during a class, or as a gym for the youngest pupils, as mentioned previously (see ill. 170) Two study halls are placed in the other part of the floor. One is a group-work area, where the students can work together and arrange a homework club. The other is a silent room for individual focused study or for the students who needs a quiet place during the day.

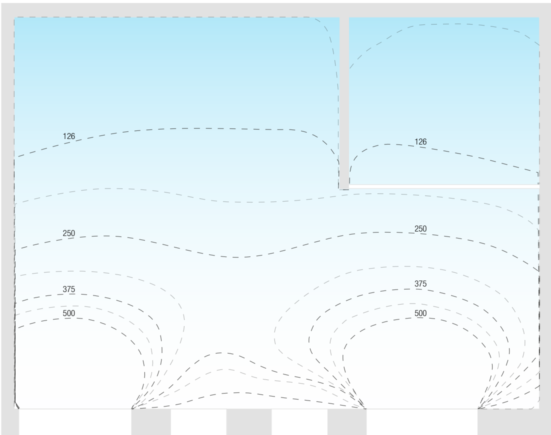


ill.172

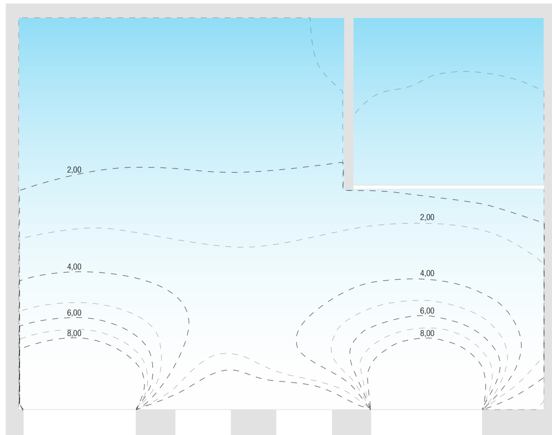
The classroom

The home classes and academic class rooms are very similar, and the main differences are the sizes, and the number of seating. Each classroom contains grouped tables with room for up to 28 students and a lecture stair for short lectures and adjoining classrooms can be merged if more than one class needs to work together in a secluded area. The layout of the classrooms is adjusted to the specific age group. Examples of different types of classrooms and ways to place the interior can be seen on ill. 176-180. The indoor environment has been one of the main focuses during the design process, which is reflected in the results of the simulations of the class rooms. One of the simulations is the Velux daylight simulation. This shows an average daylight factor of 3,1 % for the entire room and an average of 300 Lux at the work tables (daylight diagram, ill. 174-175). The light does not reach the back of the room, however, this is fine for the lecture stair, where the use of a smartboard makes the dimmer light more suitable. Sound is also a crucial factor for a classroom. An acoustic calculation is made for the classroom calculating the reverberation time of 1,7 s. (appendix 9) The Building regulations states that the reverberation time for classrooms should be between 1,6-1,8 s, which puts this classroom in the middle of the range.

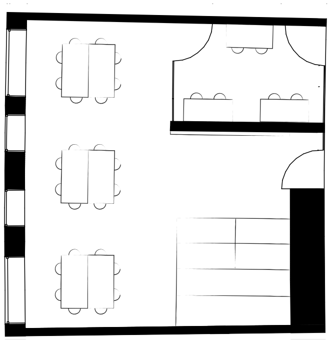
ill. 173 - Visualisation of the classroom.
This illustration show a classroom situation. It can be seen how the stair, and window frames both can be used as different seating arrangement.



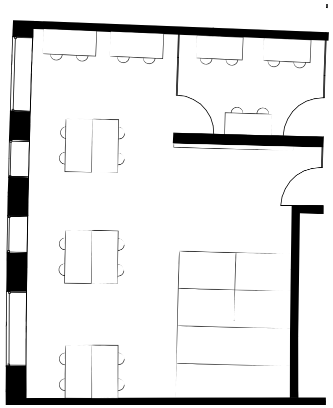
ill. 174 - LUX result of a academic classroom. I
n the classroom there will be sufficient light on the workstations.



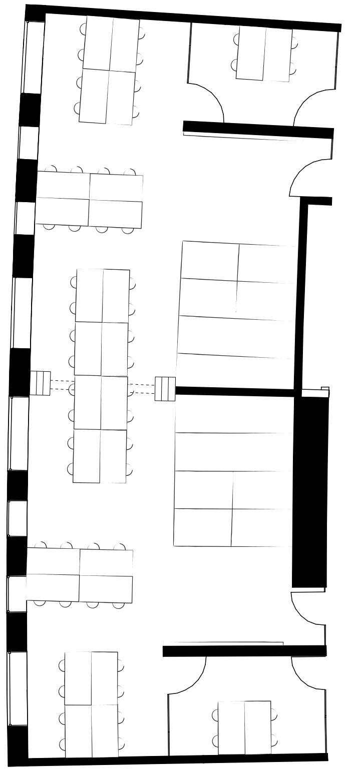
ill. 175 - Daylight factor results of a academic classroom.
In the classroom there will be sufficient daylight on the workstations.



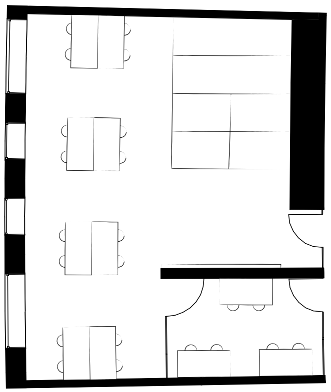
ill. 176 - Plan layout 1:200.
A plan layout for a home-class for 0th-2nd grade.



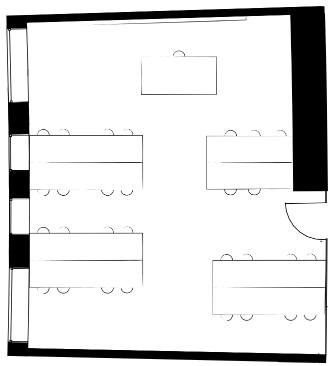
ill. 178 - Plan layout 1:200.
A plan layout for an academic classroom for the students in 3rd-6th grade.



ill. 180 - Plan layout 1:200.
A plan layout for two classrooms that are connected.

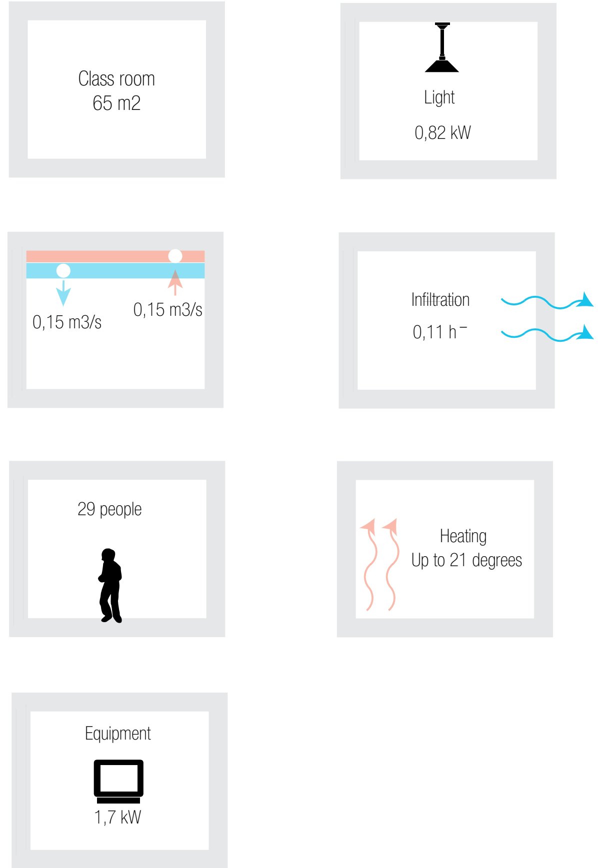


ill. 177 - Plan layout 1:200.
A plan layout for an academic class-room for the students in 7th-9th grade.

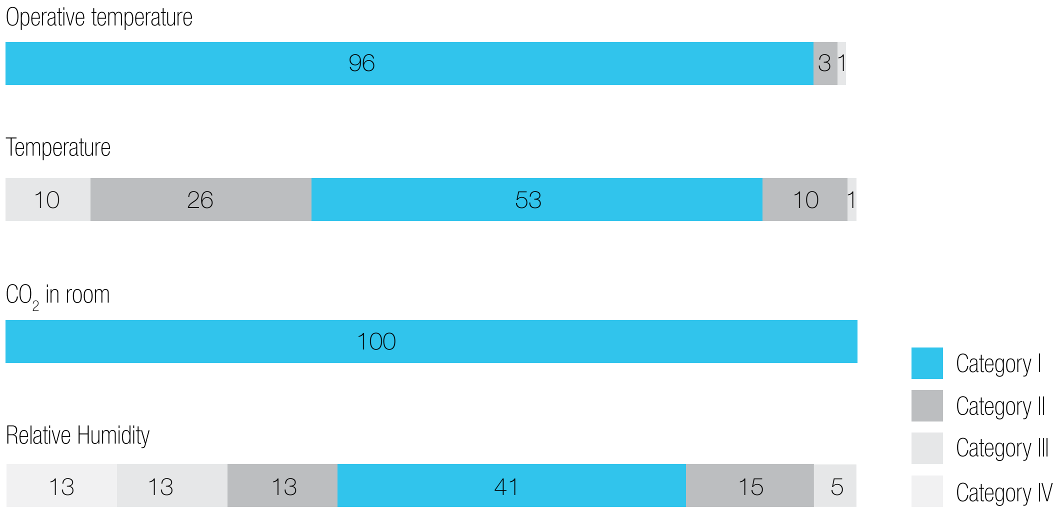


ill. 179 - Plan layout 1:200.
A plan layout for one of the workshop classes such as science.

Another simulation made for the class is a Bsim indoor environment simulation, analysing relative humidity, operative temperature, room temperature and CO2 level. A diagram of the model is shown on ill. 181. Overheating was assumed to be the biggest problem because of the substantial number of people in the room.
Because of this, a classroom on the second floor, with classes to both sides is chosen for the simulation, due to its danger of overheating.
The test is done for both a classroom towards east and west, to make sure that both situations work. The following results are taken from the simulation of a classroom turned west, but both results can be seen in appendix 4.
The results from the simulation is compared to DS EN 15252:2007 and DGNB to determine the quality of the indoor environment. The goal of the project was to make a category I building. The category values and results can be seen in the table, ill. 182-183.
The average values are all within category I. The average values gives a basic idea of the conditions in the room, but to fully understand how much of a year each parameter stays within category I, the data must be further analysed. Ill. 182 shows how big a percentage of the year the values are within each category.
For the DGNB these results give a score for the thermal comfort (SOC 1.1) of 60 out of 65 and for the air quality (SOC 1.2) it would get 50 out of 50 points.



ill. 181 - Bsim classroom parameters.
The diagram shows the parameters used in the Bsim simulation. The classroom also have venting, which is calculated based on the window openings .



ill. 182 - Result percentages in school hours.
The percentage of each year that the classrooms stays within each category. The percentages have been divided to specify how much the values are above or below category I.

Category division	IV	III	II	I	II	III	IV
Operative temperature (°C)	–	<20	20-21	21-25	25-26	26<	–
Temperature (°C)	–	<20	20-21	21-23	23-24	24<	–
Humidity (%)	0-20		25-30	30-50	50-60	60-70	70-100
CO2 (ppm)	–	–	–	<750	<900	<1200	>1200

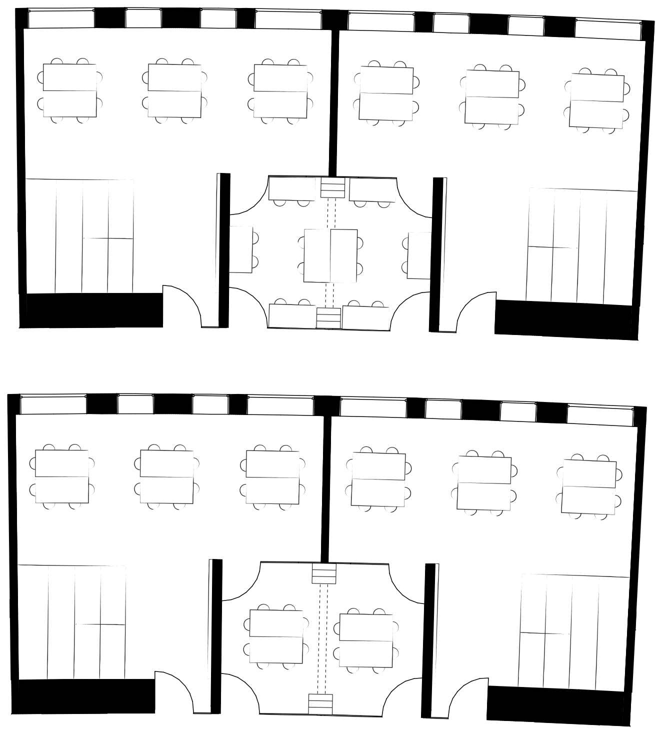
ill. 183 - DS-EN 15251 Categories.
The values defining the DS-EN 15251 categories, devided into sections describing when the results are above or below category I.

	l/s pr. pers	>26	>27	Op. temp	CO2	Hum
Classroom	10	9	3	22	<750	36

Avarage results for a classroom.
The tabel shows the avarage result for each tested parameter.

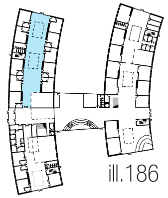
Study room

All classrooms, except the Practical- and Science workshops, have an adjoining study room, which can be used for students who needs a calm environment to work in. As with the classrooms, two adjoining study rooms also has the possibility of being joined. This creates the possibility for teachers to work together with smaller groups of students from both classes. See ill 184 for an example of how the study rooms could be changed.



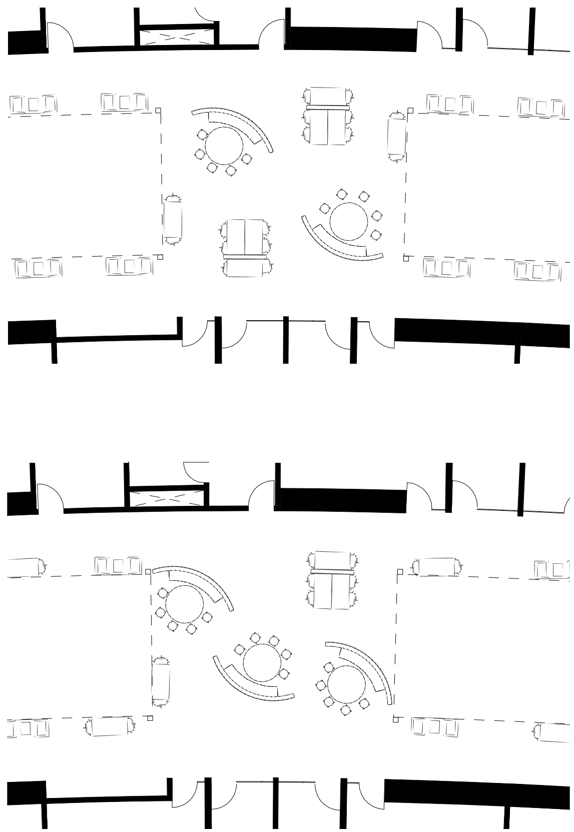
ill. 184 - Merging study room 1:200.
The plan shows two ways of how the study room can be merged and funished.

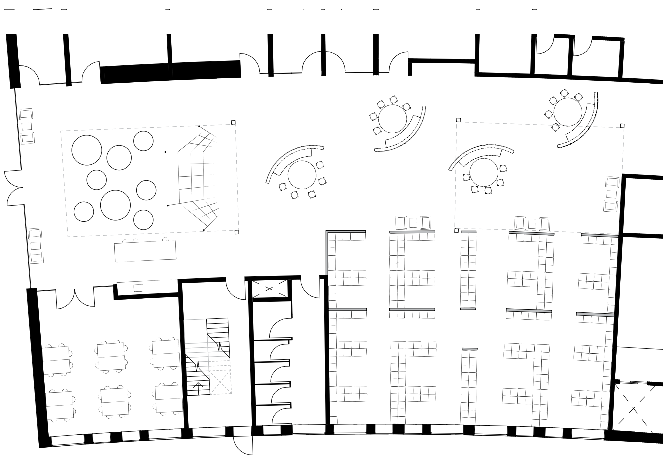
ill. 185 - Mood pictures of children


ill.186

Work area

For the intermediate and eldest pupils, the academic work area is an area of study, but for the youngest pupils the area is for play, which can be seen on the plan suggestion ill. 187. In the academic work area, the students can work in groups with their own classmates or their parallel classes or individually. A diverse selection of furniture and seating arrangement support various environments that stimulates the needs of the individual child (see analysis of the learning environment, p. 40). The furniture is movable, and the power connection runs in the wall separators that can be connected to power sockets integrated in the floor in a grid. The movable furniture can be placed in several ways to create different environments, see. Ill. 188. This form of flexibility gives a score of 61 out of 80 for the plan disposition SCO 3.3



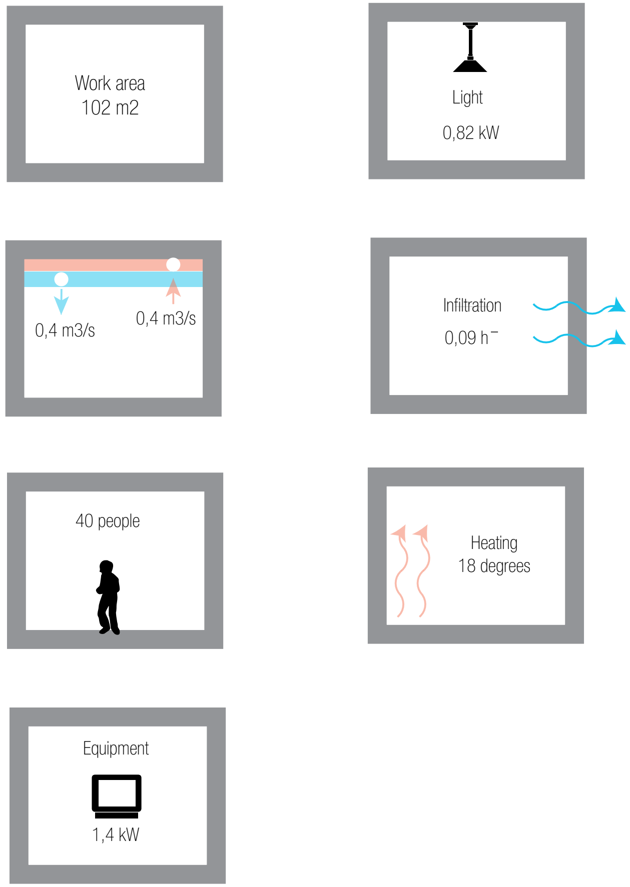


ill. 187 - Home area layout 1:400.
The plan illustrates a layout for the home area with the smallest students.

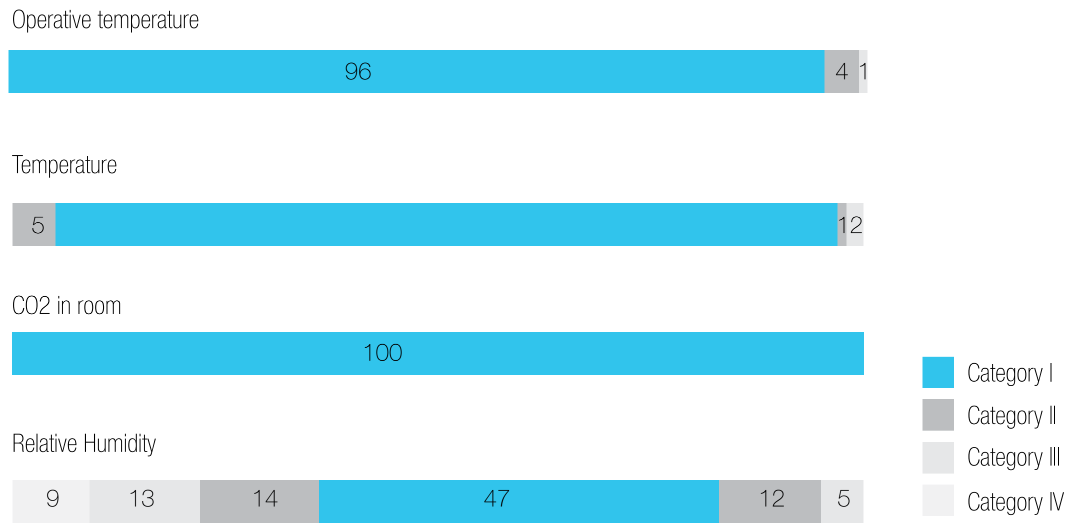
ill.188 - Academic work area layout 1:300.
The plan show two different ways to furnish and use the academic work areas

ill.189 - Visualisation of a academic work area.
The visualisation gives an idea about the furniture and atmosphere of the academic work areas.

A section of the academic work area is simulated in Bsim, from the same position in the middle of the wing, as the previous study of the academic classroom.
Like the academic classrooms, the work area also complies with category I, with its average values. The general temperature is slightly higher than in the academic classrooms, however the people load is also higher than the previous case (see ill. 181 p. 152).



ill. 190 - Bsim parameter from work area.
The diagram show the parameters used in the Bsim simulation. The class-room also have venting, which is calculated based on the window openings .



ill. 191 - Result percentages in school hours.
The percentage of each year, in which the work area stays within each category. The percentages have been divided to specify how much the values are above or below category I.

Category division	IV	III	II	I	II	III	IV
Operative temperature (°C)	–	<20	20-21	21-25	25-26	26<	–
Temperature (°C)	–	<20	20-21	21-23	23-24	24<	–
Humidity (%)	0-20		25-30	30-50	50-60	60-70	70-100
CO2 (ppm)	–	–	–	<750	<900	<1200	>1200

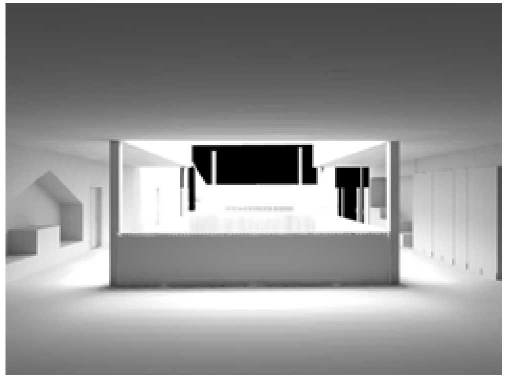
ill. 192 - DS-EN 15251 Categories.
The values defining the DS-EN 15251 categories, devided into sections describing when the results are above or below category I.

	l/s pr. pers	>26	>27	Op. temp	CO2	Hum
Work area	10	18	15	23	<750	34

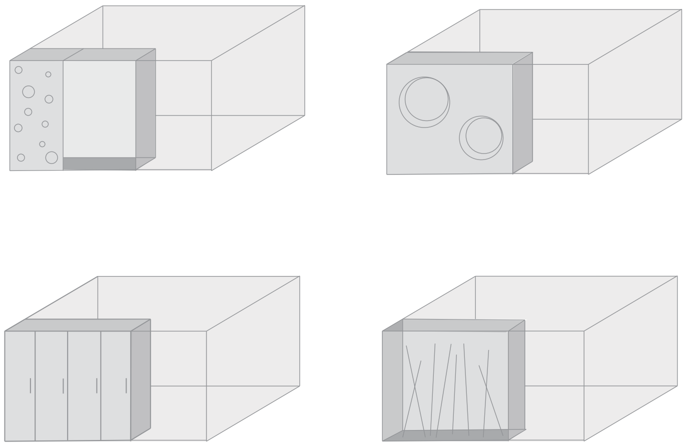
ill. 193 - Average results for a work area.
The table shows the average result for each tested parameter.

Atrium

Atriums has been integrated through the floors to ensure proper daylight conditions in the work areas and increasing the amount of daylight in the classrooms and study rooms. (ill. 195-196) The Atria also improves the natural ventilation of the building. Each classroom has a sound reducing ventilation opening, which can be seen on the detail of the atrium area 197. The opening is 400 mm high and 640 mm wide and makes it possible to use stack ventilation between the classrooms and the atrium. The opening requires a depth of 700 mm to properly reduce the sound. The space beneath the openings is used for storage and niches with various kinds of activating element or seating (ill. 194) The element of the niches varies depending on the age group it is meant for. The younger pupils have more niches meant for play, where the eldest pupils have more niches with seating.

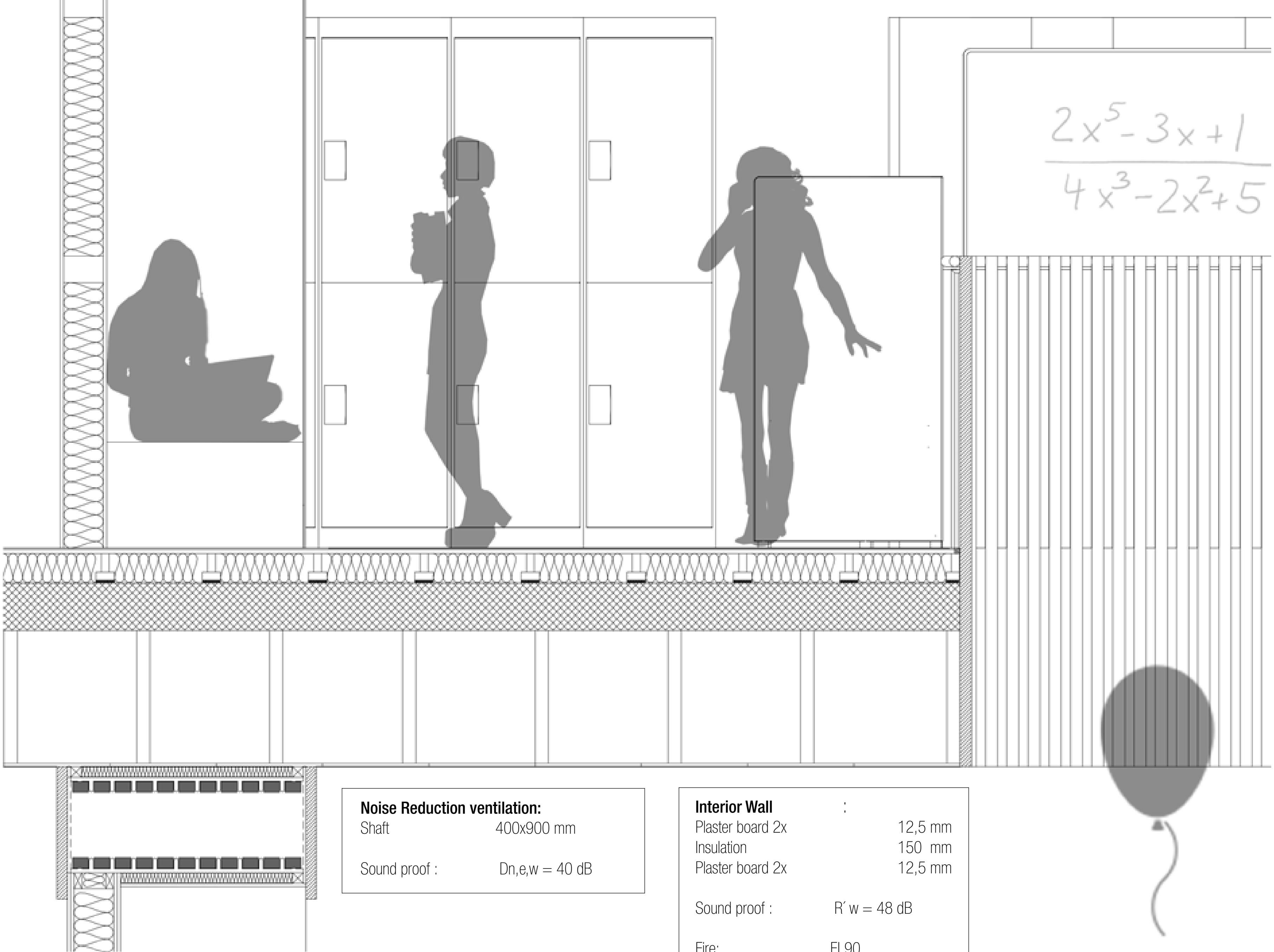


ill. 195 - LUX rendering of the atrium.



ill. 194 - Niches examples.
The diagram shows four examples of the niches, that the natural ventilation duct create is shown. These can both work as storage, activity zones or seating areas.

ill. 196 - LUX rendering of the atrium.



Noise Reduction ventilation:

Shaft	400x900 mm
Sound proof :	Dn,e,w = 40 dB

Interior Wall :

Plaster board 2x	12,5 mm
Insulation	150 mm
Plaster board 2x	12,5 mm
Sound proof :	R´ w = 48 dB
Fire:	EI 90

ill. 197 - Detail of the horizontal division 1:20.
The detail shows the inner walls and the ventilation system between the classrooms and the work area. The Sound reducing ventilation opening(for natural ventilation) can be seen in the walls. In the space between the linoleum and the concrete deck the electrical installation can run and that way the power sources can be placed multiple places in the room.

Conclusion

The final project is built on an evidence based design. As it has been shown through the project, a continues documentation of different technical results has influenced the design and lead to a project that in most values fulfill category I over 50 % of the year. These results document a good indoor environment and will help insure the well-being of the users and create an environment that stimulates learning.

The new school reform has laid the baseline for a big part of the design. Hence the shifting learning environment; letting the students learn in the way that best fit their needs, the preparation areas for the teachers, where they both alone and with other have the room to plan their lessons. As a way to support the increasing activity need, the school have a diverse range of outdoor areas and both rooms and minor installations indoor that lets the students be active throughout the day.
The school embraces all students and is adapted to the specific needs of the unique age groups. The zones are design to fit the development level of the age group using it, and the outdoor area contains tactile, athletically, open, closed and sense stimulating areas. This ensures activity for all students independence of age and gender.

The site and the building support and underline the green zone in the area. The height and placement of the building is adjusted to ensure that the building would not be too dominating in the area. The project has also improved the sunlight condition for the surrounding dwellings compared to the current building.

Reflection

The learning environment and how to create optimal conditions and environments suited to the individual pupils' needs, have been the main focuses of this report. This has meant that other elements have been deprioritized and needs further detailing.

One of these elements is the mechanical ventilation system. Despite concept-ideas of mechanical ventilation solutions being a part of the earliest sketches, the planning of the actual implementation was pushed to the final stages of the process. Because of this, elements such as the placement of technical rooms and the main duct system was less integrated, and the solutions less elegant than if it was integrated earlier in the process. As it is, the solutions have resulted in excess space in the basement.
Additionally, further work in Bsim have shown that it might have been beneficial to integrate separate ventilation systems for classrooms and work areas. The people load is higher in the work area and would benefit from a lower air intake temperature than the classrooms.

The fire safety regulations should have had a higher priority in this project. Smaller fire sections would have been desirable, as well additional fire staircases. Smaller fire sections mean a lower strain on the fire exits, and a smaller part of the building to which the fire can easily spread to.
The placement of high-risk rooms such as the wood workshop and science room might also have been placed together in a smaller fire section, to reduce the risk of the rest of the school, and enhance the precautions of this area.
The detailing of the workshop area has generally been deprioritized in this project, and has been designed as types, instead of individual rooms. To detail these rooms further, in-depth analysis of the specific subjects and their teaching methods should be made.

Another element that should be detailed further is the construction principles. In the beginning of the design process, several construction principles were discussed and a column-plate system were chosen, to work with flexible inner walls. But as the design evolved, the concept of the construction was not redeveloped to the new design. If they had been more closely integrated into the design, they could have been a part of shaping the atria and defining the work area.
The next step, in the atria design, would have been an iterative process between daylight analyses, to develop the atria and work areas further. For instance, a higher number of smaller atria might have spread the light more evenly.

Throughout the process the possibility of expanding the building has been a priority. However, to expand the school in the same idiom of Rotunden, a new wing would have to be build, which means that a small expansion is not an obvious choice for this building.

With more time, and further detailing, all of these elements could be integrated into the design, and improve the final result.

Reference list

Links:
Aalborg Kommune1, [2017], " Legepladser i Aalborg Kommune" [Online]
http://www.aalborg.dk/miljoe-energi-og-natur/drift-af-groenne-omraader/legepladser
Visited: 25-02-2017 21:37

Aalborg Kommune 2,[2017]"Noget at have det I" [Online]
http://fremtidensfolkeskole.aalborg.dk/media/2380995/vision-for-folkeskolerne-i-aalborg-kommune.pdf
Visited: 17-03-2017 20:01

Aalborg Kommune [2015] "Kvalitetsrapport 2015" [Online]
http://www.aalborg.dk/media/4280002/samlet-rapport-11-februar.pdf
Visited: 07-02-2017 11:13

Aalborg Kommune, [2006], " Kommuneplan - Hasseris" [Online]
http://www.aalborgkommuneplan.dk/kommuneplanrammer/vest-aalborg/hasseris/default.aspx,
Visited: 09.02.2017 15:32

Andersen , Lise Nevstrup [2008]"Den gode legeplads ud fra børns perspektiv" [online]
http://www.aalborg.dk/media/390575/den-gode-legepladsredigeretfeb2009-1-.pdf
Visited: 18-03-2017 17:50

Brandt, A., [2015], "Her er det første tegn: Global opvarmning kan give Danmark koldere vejr" [Online], http://vejret.tv2.dk/2015-10-01-her-er-det-foerste-tegn-global-opvarmning-kan-give-danmark-koldere-vejr visited: 12-05-2017 15:16

Bygningsreglement1, [2016] "Indeklima" [online]
http://bygningsreglementet.dk/br15_01_id89/0/42
visited: 19-03-2017 20:55

Bygningsreglementet2, [2014] "Fælles bestemmelser for bygninger omfattet af bygningsklasse 2020" [online] http://bygningsreglementet.dk/br10_04_id5181/0/42 -
Visited: 11.05.2017 09:39

Borup, Marianne [2017], "Læringsstile" [online]
http://www.mangeintelligenser.com/l_stile/d4l.html
Visited: 17-02-2017 10:24

Cappelen, John; Jørgensen, Bent [1999] " TECHNICAL REPORT 99-13" [Online]
https://www.dmi.dk/fileadmin/user_upload/Rapporter/TR/1999/tr99-13.pdf
Visited: 27-02-2017 15:10

Carter, Sherrie Bourg [2012] "Why Mess Causes Stress: 8 Reasons, 8 Remedies" [online]
https://www.psychologytoday.com/blog/high-octane-women/201203/why-mess-causes-stress-8-reasons-8-remedies
visited: 18-03-2017 16:18

Gaisma.com, [2017] "Aalborg, Denmark – Sun path diagram" [Online]
http://www.gaisma.com/en/location/aalborg.html,
Visited: 09-02-2017 12:18

Green Building Council Denmark(GBCD), [2017] "DGNB I Danmark" [Online]
http://www.dk-gbc.dk/dgnb/introduktion-til-dgnb/dgnb-i-danmark-historisk-rids/
Visited: 10-02-2017 14:19

Green Building Council Denmark (GBCD), [2014] "Mini-guide til DGNB" [Online]
http://docplayer.dk/7598434-Mini-guide-til-dgnb-certificering-af-baeredygtigt-kontorbyggeri-i-danmark.html
Visited: 10-02-2017 14:42

Nørgaard , Mariann, [2013], "Trafiksikkerhedsplan – det handler om liv!" Aalborg Kommune [online]
http://www.e-pages.dk/aalborgkommune/858/html5/
Visited: 26-02-2017 19:29

Regeringen [2013]"Aftale mellem regeringen (Socialdemokraterne, Radikale Venstre og Socialistisk Folkeparti), Venstre og Dansk Folkeparti om et fagligt løft af folkeskolen"[Online]
https://www.kl.dk/ImageVault/Images/id_62271/scope_0/ImageVaultHandler.aspx
Visited: 08-02-2017 10:22

Secher, Mikkel [2016] " Se listen: Disse 115 danske skoler har problemer med arbejdsmiljøet", tv2 nyheder [online]
http://nyheder.tv2.dk/samfund/2016-08-15-se-listen-disse-115-danske-skoler-har-problemer-med-arbejdsmiljoeet
visited: 09-02-2017 14:38

Books:
Bjerregaard, Lene [2005] "Den nye helhedsfarvelære – en syntese af naturvidenskab og filosofi", byggecentrum

Berk, Laura, E. [2013] "Child Development", Illinois State University, International edition, 9. Edition, Pearson Education, Inc.

Christoffersen, Jens; Johnsen, Kjeld; Petersen, Erwin [2002] "Beregning af dagslys i bygninger", By og byg anvisning 203,

Dr. Maas et al. [2013], "Groene schoolpleinen - Een wetenschappelijk onderzoek naar de effecten voor basisschoolleerlingen" Vrije Universiteit te Amsterdam, Amsterdam

Green Builidng Concil Denmark (DK-GBC), [2015] "DGNB System Denmark manual for Undervisnings- og institutionsbygninger version 2015 pilot", pilot version 2015 1.2

Frandsen et al. [2009] "Helende arkitektur". Aalborg: Institut for Arkitektur og Medieteknologi. (Institut for Arkitektur og Design Skriftserie; Nr. 29).

Gehl, Jan, [2007] “Livet mellem husene”, 6. Edition 2. ”oplag” Arkitektens Forlag, Copenhagen

Grontmij A/S et al. [2010] ”Modelprogram for Folkeskoler”, Erhvervs- og byggestyrelsen og Realdania

Kural, René; Jensen, Bjarne Bruun; Kirkeby, Inge Mette [2010] ”Apropos, arkitektur, pædagogik og sundhed” Kunstakademiets Arkitektskolens forlag.

Heiselberg, P. [2006], Design of Natural and Hybrid Ventilation, DCE Lecture Notes, nr. 5, Aalborg University. Department of Civil Engineering, Aalborg.

Kafla, N. P. [2011], ” Hermeneutic phenomenological research method - simplified” - Bodhi: An Interdisciplinary Journal, 5, Kathmandu University, Nepal

Knudstrup, Mary- Ann, [2004], “Integrated Design Process in Problem-Based Learning”, Article in the Aalborg PBL Model, red. Kolmoes, A & Fink, K F & Krogh, L. Aalborg University Press 2004. Denmark. [Online] Available at: VNB : Aalborg Universitets forskningspotal.

Leick, Claus,[2016] ”En skole bevæger sig”, Frederiks Bjerg Skole, Lasertryk

Lysteknisk Selskab [2004]”Godt lys i boligen”, ELFOR Ð dansk eldistribution og Elsparefonden, 1. udgave, 1. oplag 03. faglig bistand af udgiverne samt VELUX Danmark og DELTA

Pejtersen, J.[2002],” Indeklimapåvirkninger i skoler” DTKommuikation A/S, Copenhagen

Petersen, Jørgen [1984] ”Rumakustik”, SBI-Anvisning; 137

Rasmussen, Jens; Holm, Claus; Rasch-Christensen, Andreas [2015] “Folkeskolen-efter reformen”. Hans Reitzels Forlag, 1 edition, 1 copy. [p. 12-30]

SolData Instruments v/Bason, Frank, og Kræftens Bekæmpelse v/Schønau, Lisbet, [2009], ”UV-index”, pamphlet with educational material, Kræftens Bekæmpelse og TrygFonden smba, [online] available at: https://www.cancer.dk/dyn/resources/File/file/0/200/1385247459/uvindexgray.pdf, 14.05.2017 16:58

Steen-Thøde, Mogens [1997]”Indeklima” chapter from ”Grundlæggende klimateknik og bygningsfysik”, Aalborg universitet, institut for byggeri og anlæg, [page 8-42]

Ulrich, R. S. [1984] View through a Window May Influence Recovery from Surgery, Science, New Series, Vol. 224, N. 4647 [27th April 1984],[p. 369-378.]

United Nations, [1992] “Rio Declaration on Environment and Development 1992”, Lexmercatoria.org

Widok, Andy,[2009] “Social Sustainability: Theories, Concepts, Practicability" in Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools, Shaker Verlag 2009, Berlin

ZinCo1 [2015] "Miljøfordele ved grønne tage" [Online]
http://www.zinco.dk/Hvorfor-gr%C3%B8nne-tage-/Milj%C3%B8fordele
visited: 10-05-2017 20:32

ZinCo2 [2015]"Grønne tage er en vigtig faktor i klimatilpasningen…" [Online]
http://www.zinco.dk/Hvorfor-gr%C3%B8nne-tage-
visited: 10-05-2017 20:32

Reference Persons:

Bækgaard, Hanne R. (craftsmanship and design- and nature), Normann, Karina (danish), and Hald, Louise (math) – 2017, Teachers of the intermediate stage

Johannesen, Kurt, 2017, Headmaster of Tjørring Skole, he was one of the main participants in the design process and planning of Stjernen.

Nielsen, Søren Torp, 2017, Administrative leader of Frederiksbjerg Skole, he was one of the main participants in the design process and planning of Frederiksbjerg Skole.

Røjkjær, Kaj, 2017, Guide for Stjernen a School in Tjørring. He is a former teacher for the old school of Tjørring and is now retired after having worked many years as vice-principal at Gjellrupskole.

Sørensen, Michael, 2017, Headmaster of Gl. Hasseris Skole

Thorhauge, Lene, 2017, Pedagogical consultant of the school administration of Aalborg municipality, specialised in aesthetical learning principles and competency development.

School Visits:

1.visit:
Frederiskbjerg Skole in Aarhus.

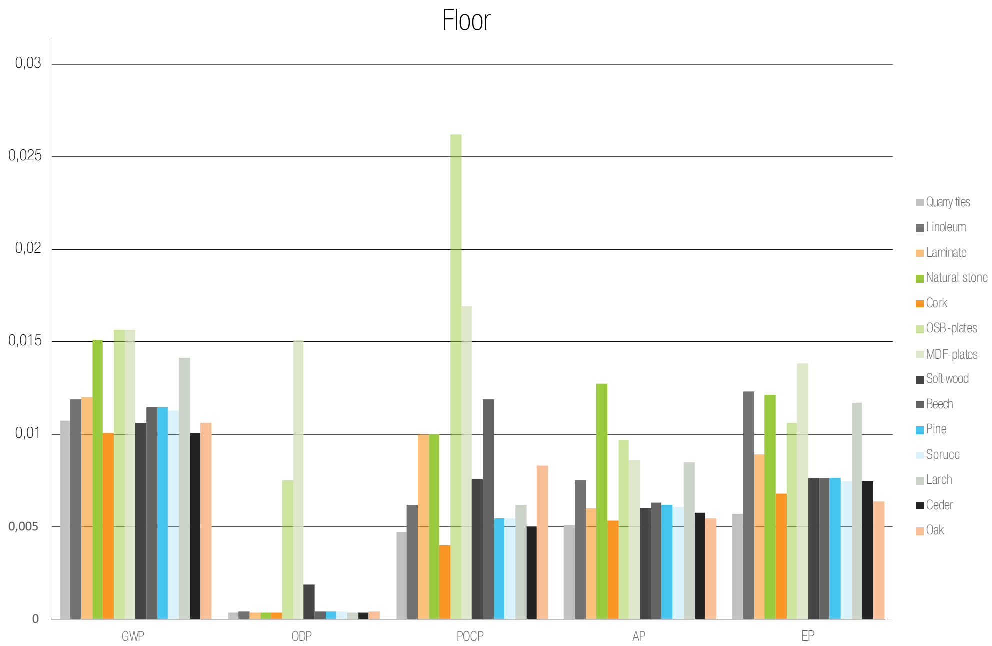
2. visit:
Stjernen Tjørring Skole in Tjørring.

Illustration list

Sørensen, Michael, 2017, Headmaster of Gl. Hasseris Skole
Thorhauge, Lene, 2017, Pedagogical consultant of the school administration of Aalborg municipality, specialised in aesthetical learning principles and competency development
Ill. 19 – mood picturehttp://da.henninglarsen.com/media/1458363/henning-larsen-architects_frederiksbjerg-skole_aarhus_denmark_virklund_sport_02.jpg
Ill. 20 – The sustainability categories of DGNB based on http://docplayer.dk/7598434-Mini-guide-til-dgnb-certificering-af-baeredygtigt-kontorbyggeri-i-danmark.html
Ill. 21 – Mood picture https://imageservice.nordjyske.dk/images/nordjyske.story/2014_02_18/ed39eb7d-77bf-4a92-94c5-de13d7e1dd3f.jpg?width=880&scale=both&bgcolor=black
Ill. 22 – Different indoor climate – based on Pejtersen, J.[2002]," Indeklimapåvirkninger i skoler" DTKommuikation A/S, Copenhagen and http://bygningsreglementet.dk/br15_01_id89/0/42
Ill. 23 – Site plan of Stjernen - http://mgarkitekter.dk/media/articles/src/article63_image2.jpg
Ill. 24 – Picture of the nature huts -http://www.randersradius.dk/upload/images/referencer/tjoerring/top.jpg
Ill. 25 – Picture of glass area - http://mgarkitekter.dk/index.php/projekter/63-tjorring-skole-institutioner
Ill. 26 – Picture of sand area – own picture
Ill. 27 – Playground Tabel - Dr. Maas et al. [2013], "Groene schoolpleinen - Een wetenschappelijk onderzoek naar de effecten voor basisschoolleerlingen" Vrije Universiteit te Amsterdam, Amsterdam
Gehl, Jan, [2007] "Livet mellem husene", 6. Edition 2. "oplag" Arkitektens Forlag, Copenhagen
http://www.aalborg.dk/media/390575/den-gode-legepladsredigeretfeb2009-1-.pdf
Ill. 28- Colour diagram - Bjerregaard, Lene [2005] "Den nye helhedsfarvelære – en syntese af naturvidenskab og filosofi", byggecentrum
Ill. 29 - Child development diagram – based on Berk, Laura, E. [2013] "Child Development", Illinois State University, International edition, 9. Edition, Pearson Education, Inc.
Ill. 30 – Learning environment diagrams – own illustrations
Ill. 31 – The activity hall - http://www.virklund-sport.dk/media/171774/multirum_frederiksbjerg-skole-_1_.jpg
Ill. 32 – The Stair in the classroom - http://da.henninglarsen.com/media/1450041/henning%20larsen%20architects_frederiksbjerg%20skole_aarhus_denmark_huftoncrow_4.jpg
Ill. 33 – Activity element in the hallway - http://www.virklund-sport.dk/media/171834/organiske-ribber_frederiksbjerg-skole-_3_.jpg
Ill. 34 – The classroom – own picture
Ill. 35 - Diagram of the 5 categories of rooms based on Kural, René; Jensen, Bjarne Bruun; Kirkeby, Inge Mette [2010] "Apropos, arkitektur, pædagogik og sundhed" Kunstakademiets Arkitektskolens forlag.
Ill. 36 – Room program table – data from DS-EN 15251-2007
Ill. 37 – Function diagram – own illustration
Ill. 38 Table of technical design criteria – data from DS-EN 15251-2007, DGNB and http://bygningsreglementet.dk/br15_01_id89/0/42
Ill. 39 – Diagram of DGNB categories – based on http://docplayer.dk/7598434-Mini-guide-til-dgnb-certificering-af-baeredygtigt-kontorbyggeri-i-danmark.html

Appendix 1

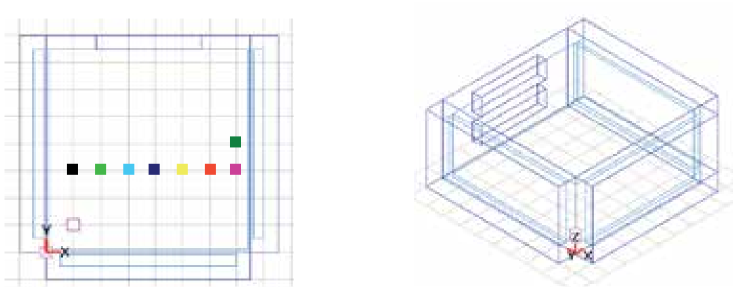
LCA results from floor materials.



Appendix ill. 1 - results from LCA.

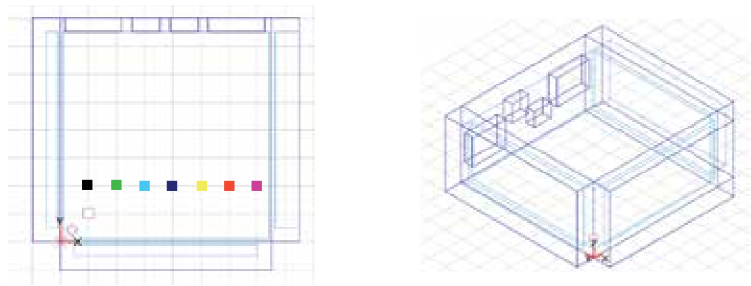
Appendix 2

Artificial light test in Bsim.



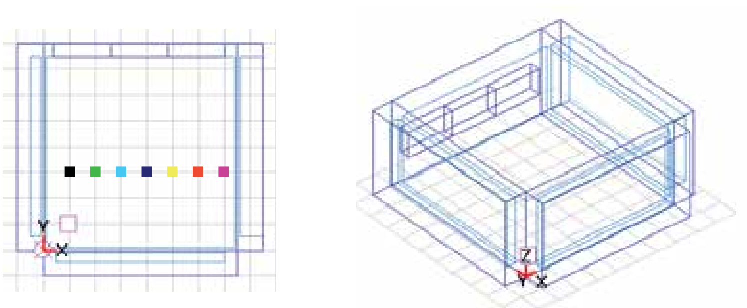
- 1,64%
- 1,85%
- 2%
- 2,03%
- 1,93%
- 1,73%
- 1,51%
- 1,78%

Appendix ill. 2 - results from bsim of the 1. window type.



- 1,66%
- 1,83%
- 1,94%
- 1,99%
- 1,95%
- 1,80%
- 1,62%

Appendix ill. 4 - results from bsim of the 3. window type.

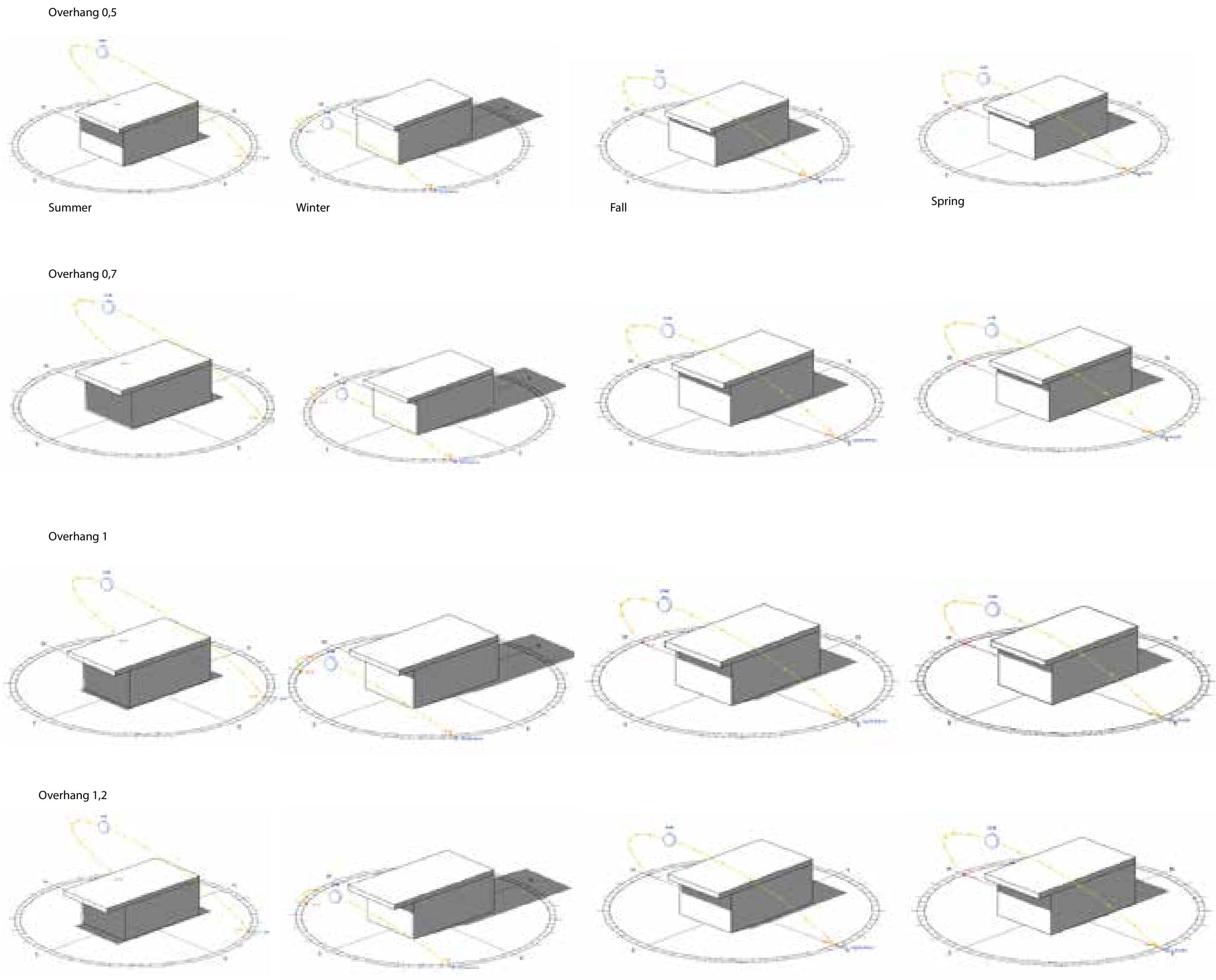


- 1,73%
- 1,91%
- 1,99%
- 2,05%
- 1,98%
- 1,76%
- 1,59%

Appendix ill. 3 - results from bsim of the 2. window type.

Appendix 2,2

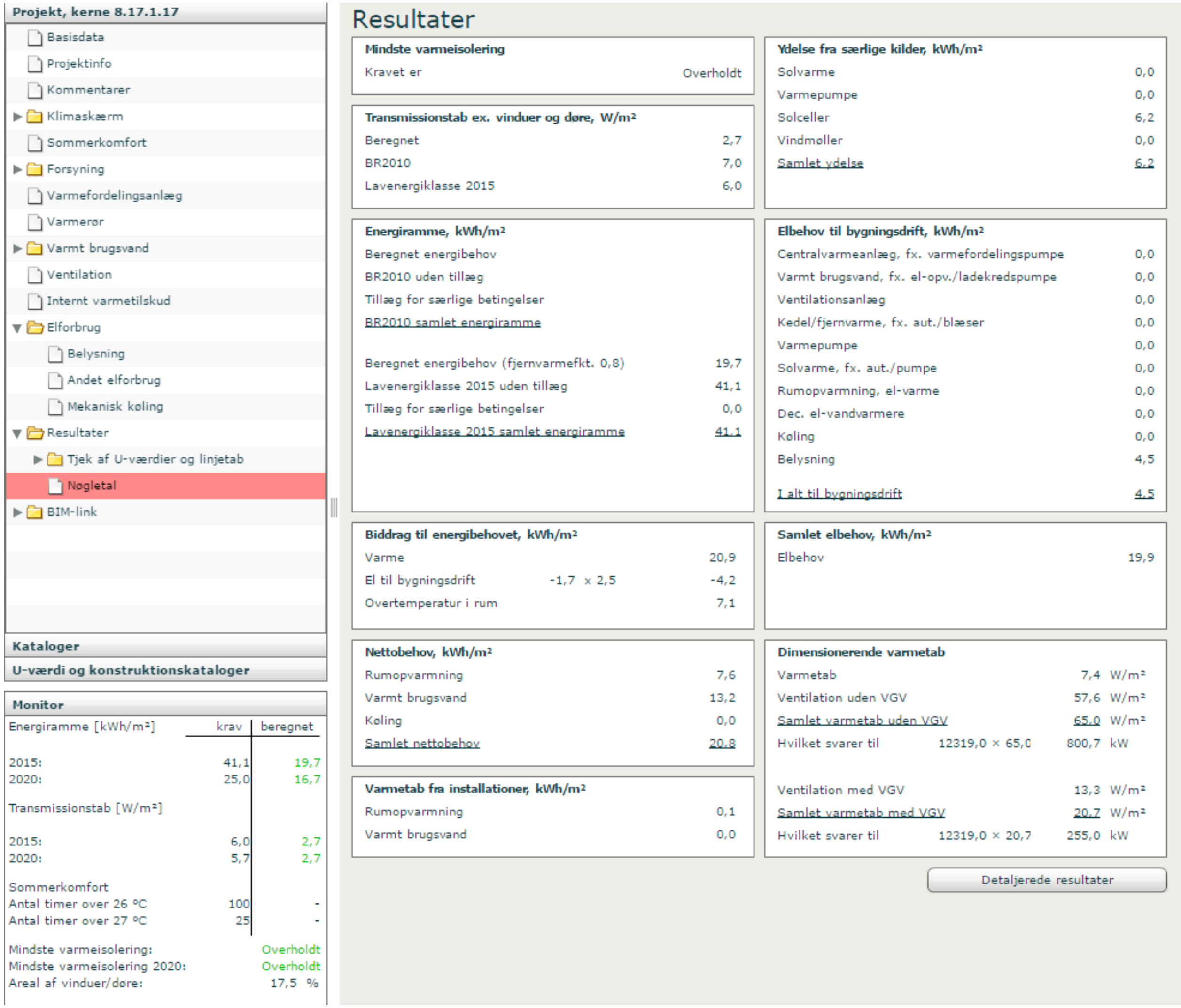
Overhang



Appendix ill. 5 - Study of different sizes overhang and the effect of them in summer, fall, spring and winter.

Appendix 3

RockwoolEnergy

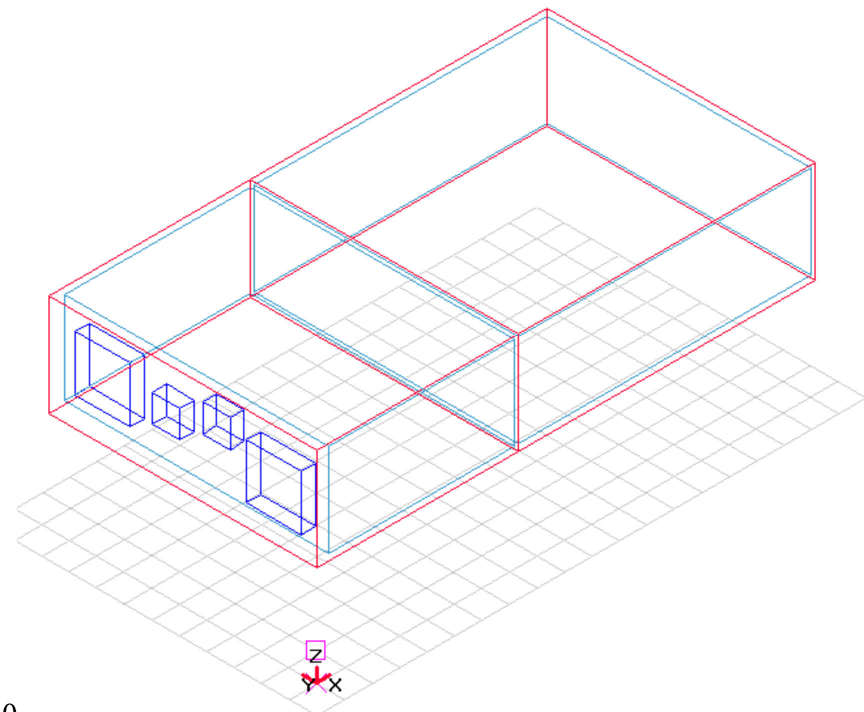


Appendix ill. 6 - sceenshot of the results from RockwoolEnergy

Appendix 4

Bsim simulation for presentation

In this appendix can the results be seen for the indoor simulation of a classroom and the work area. The classrooms have been tested both for one turning west and one turning east.
The illustration underneath shows the model build in Bsim.



Appendix ill. 7 - picture of Bsim model

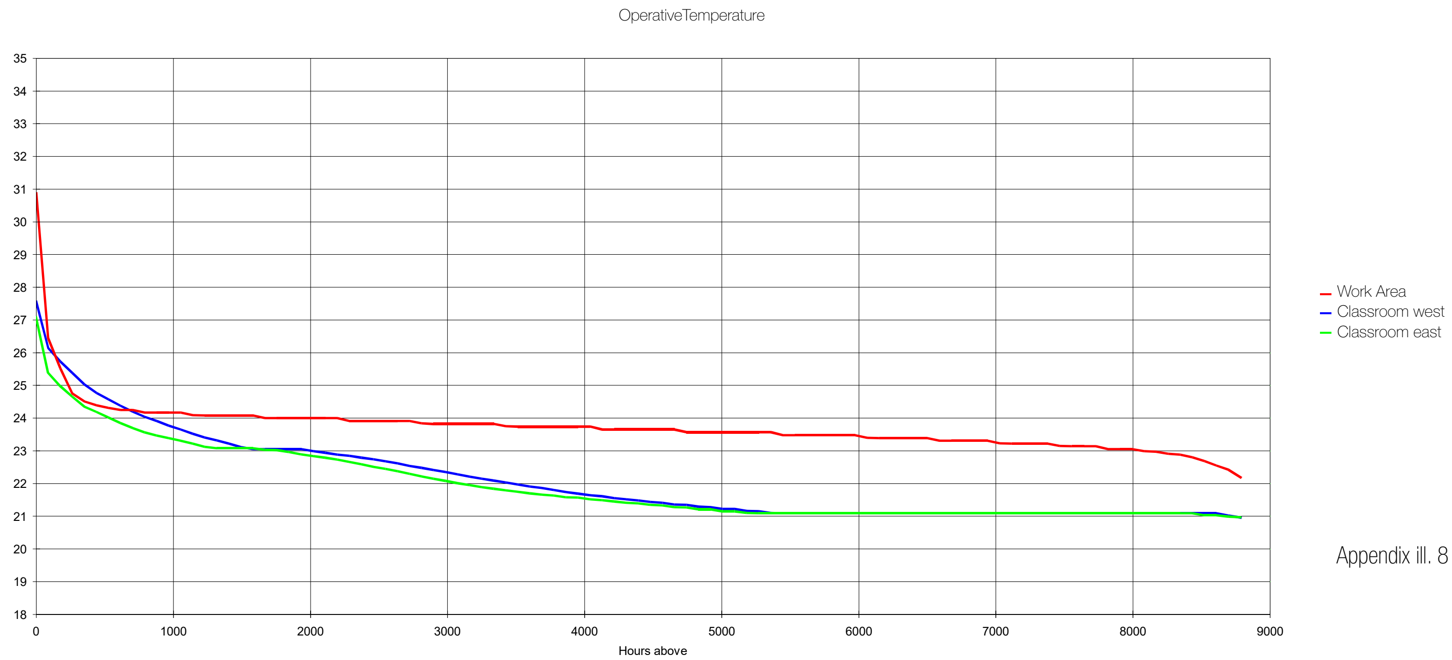
Results
Operative temperature:
The operative temperature is important because the airs temperature is a significant factor for the comfort in the room.

Temperature:
The temperature varies depending on the temperature outside, the direct sun, ventilation and heating.
Passive strategies can be used to adjust the temperature, such as window placement and solar shading. In this project are the windows in the class rooms either turned east or west and the solar shading will be active when the temperature gets over 21 degrees.

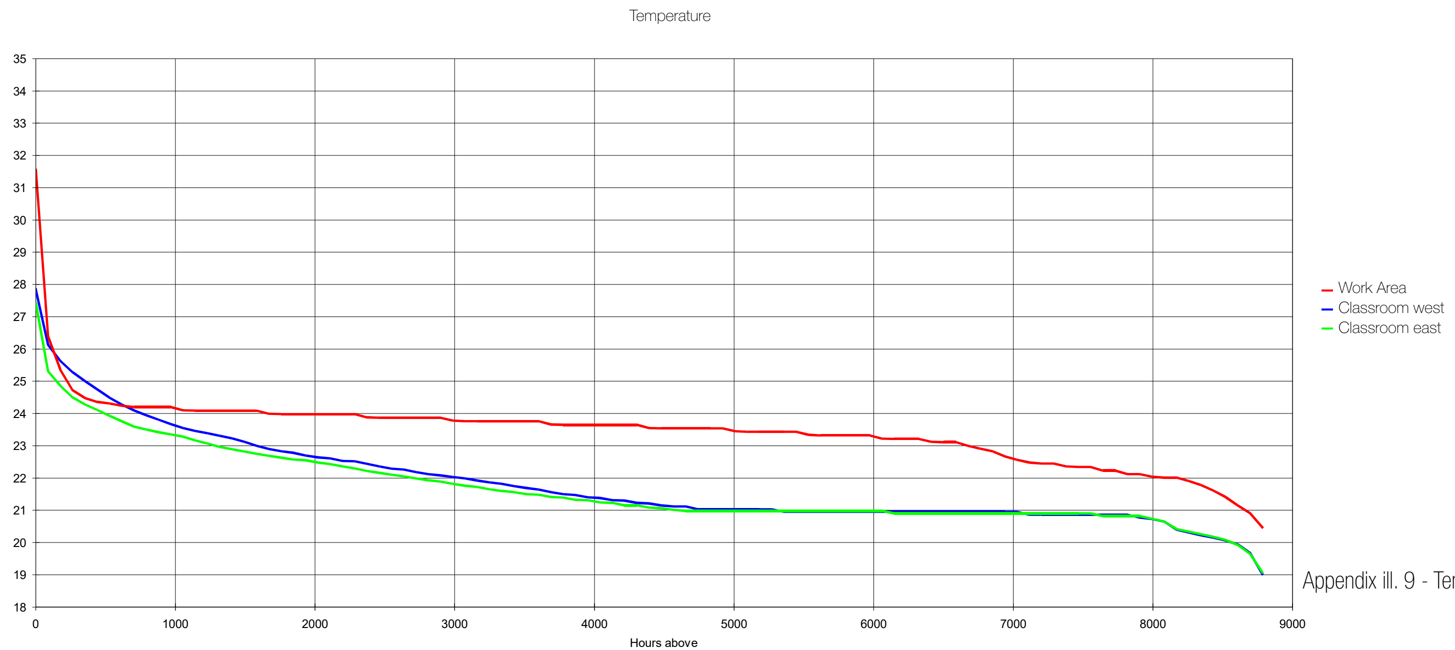
Ventilation:
Mechanical ventilation was added in the summer depending on the pollution levels – which is therefore only turned on if the pollution level is higher than 850 ppm.

CO_2:
The CO_2 pollution varies depending on the students and the equipment in the rooms. The students are set to be in the classroom 50 % of the time because some of the students that will be in the group work area. The work areas are set to have 40 people 100 % of the time, because of the children going out from the class rooms

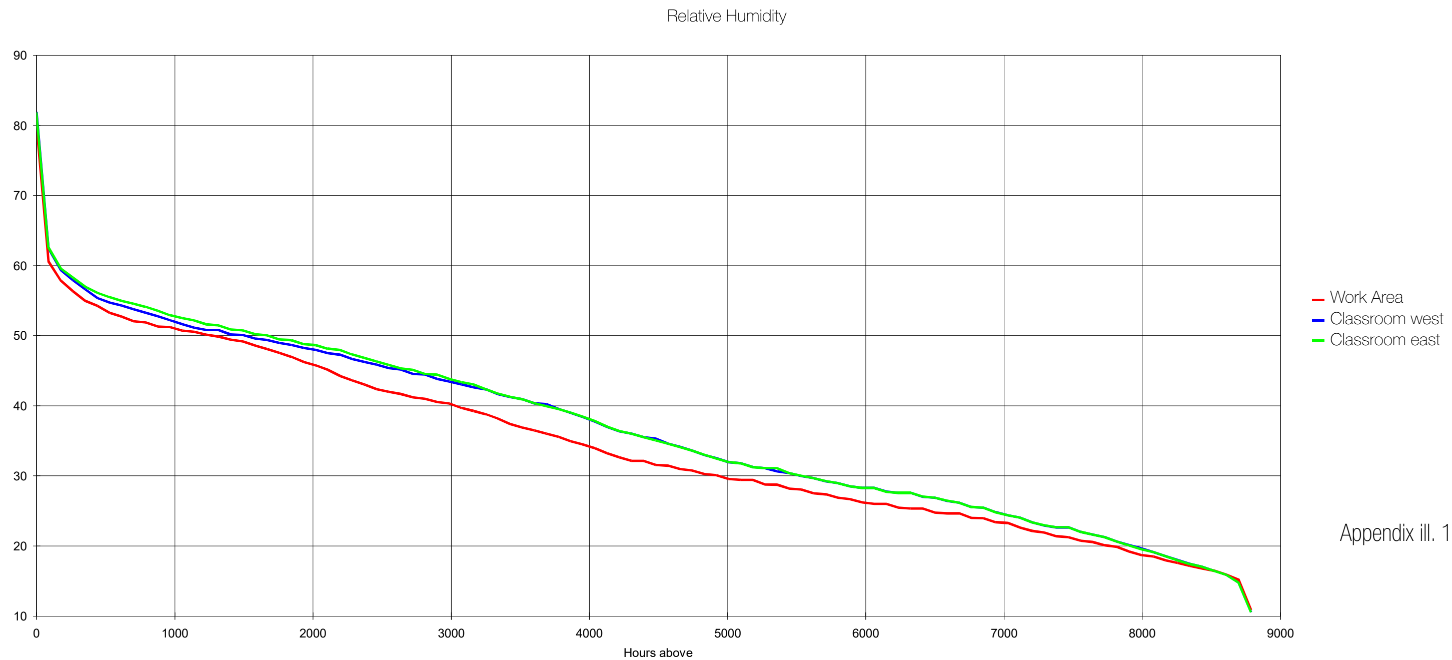
The following diagrams shows the hours above graph for, operative temperature, temperature, relative humidity and CO_2 level in the air.



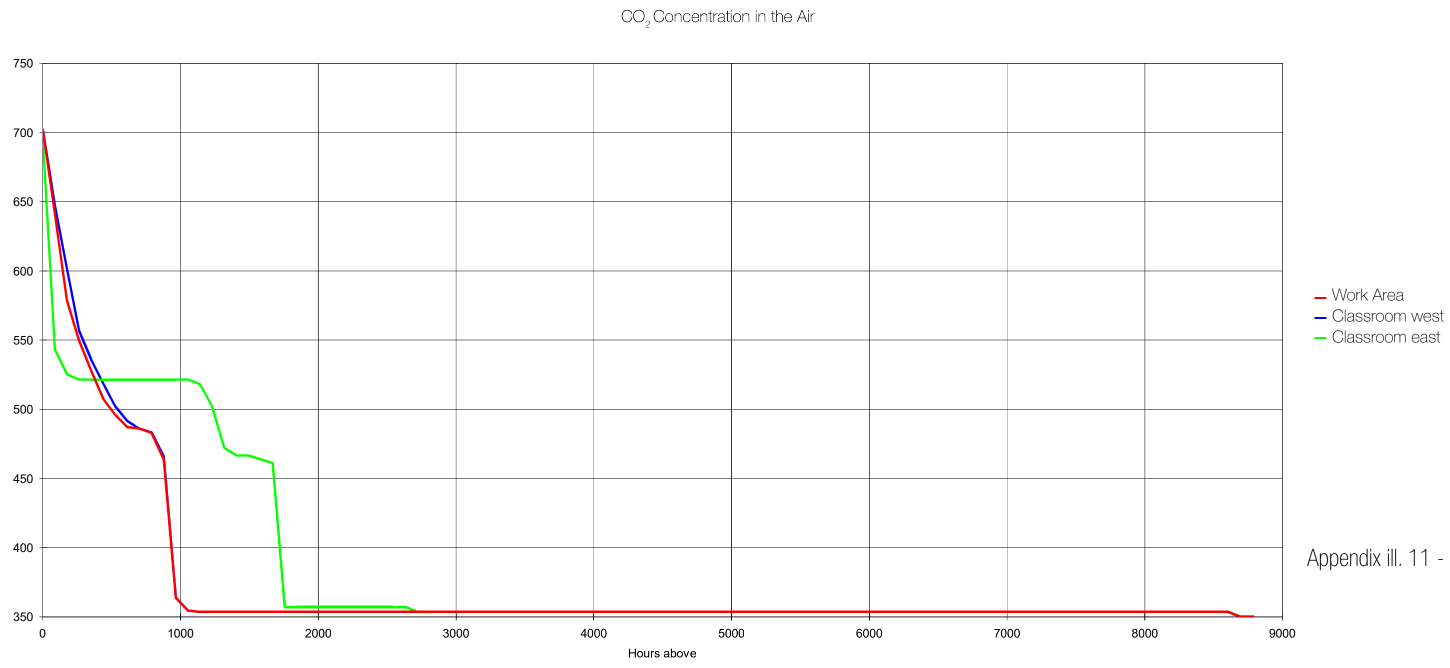
Appendix ill. 8 - Operative Temperature graph



Appendix ill. 9 - Temperature graph



Appendix ill. 10 - Relative Humidity graph



Appendix ill. 11 - CO_2 concentration graph

Appendix 5

Solar cells calculation

	PV calculation for south	PV calculation for north
Area (A)	270 m^2	270 m^2
	220 m^2	220 m^2
	490 m^2	490 m^2
Module efficiency (B)	15	15
Install power (C)		
C=A*B/100	73,5	73,5
Evaluation of system (D)	0,75	0,75
Solar ration (E)		
10 degrees	1097 kWh/m^2	999 kWh/m^2
25 degrees	1125 kWh/m^2	726 kWh/m^2
Annual yield		
C*D*E		
10 degrees	30236 kWh	27535 kWh
25 degrees	31008 kWh	20010 kWh
Sum	61244 kWh	47545 kWh
Total energy		108789 kWh

Appendix ill. 12 - The calculation of the energy produced by the solar cells

Appendix 6

Mechanical ventilation pipe length and pressure loss

To calculate the duct size and pressure loss an excel file (tryktabsberegning) has been used to estimate the results for the three tested system. These systems are testes only for the 1. floor.

Data for system based on east and west

Diameter (m)	Length (m)	Airflow (m^3)	Speed (m/s)	Total Pressure Loss (kPa)
0,4	5	2550	5,6	9
0,4	20	1020	2,3	9
0,4	10	935	2,1	10
0,4	10	850	1,9	11
0,3	10	765	3,0	15
0,3	20	680	2,7	16
0,3	10	595	2,3	17
0,3	10	510	2,0	19
0,3	20	425	1,7	20
0,3	10	340	1,3	20
0,3	9	255	1,0	20
0,3	10	170	0,7	20
0,3	10	85	0,3	20

Appendix ill. 13 - The results from the east/west system

Data for system based on work area and classroom

Diameter (m)	Length (m)	Airflow (m^3)	Speed (m/s)	Total Pressure Loss (kPa)
0,4	5	1435	3,2	1
0,4	4	1435	3,2	1
0,3	3	1295	5,1	3
0,3	8	1295	5,1	7
0,3	10	1140	4,5	11
0,3	10	985	3,9	14
0,3	10	830	3,3	16
0,2	3	675	6,0	19
0,2	8	590	5,2	26

Appendix ill. 14 - The results from the work area and classroom system

Data for system based on small fire sections

Diameter (m)	Length (m)	Airflow (m^3)	Speed (m/s)	Total Pressure Loss (kPa)
0,4	5	3875	8,6	5
0,4	1	1550	3,4	5
0,3	15	775	3,0	8
0,3	10	465	1,8	9
0,3	10	325	1,3	9
0,2	10	185	1,6	10

Appendix ill. 15 - The results from the fire section system

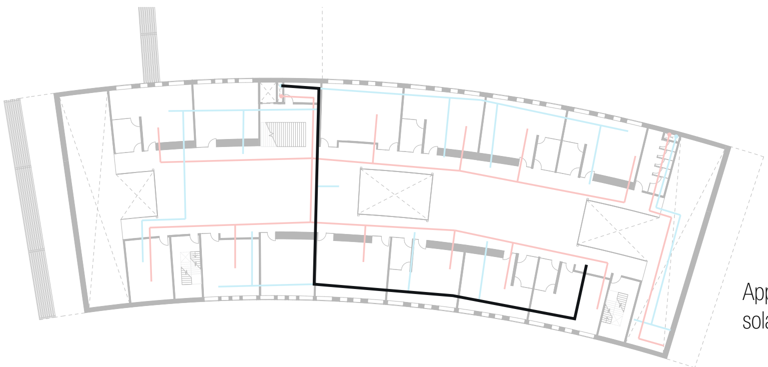
Appendix 7

Mechanical ventilation pipe pressure loss

To calculate the duct size and pressure loss an excel file (tryktabsberegning) has been used to estimate the results for the final system. The data can be seen in the table underneath. The calculation have been made for the longest pipe route, which will be the route that the system would be design after. This route is in the east wing of the building going from the basement to the 2. floor, which can be seen on the illustration

Diameter	Length	Airflow	Speed	Roughness	Friction coefficient	Reynolds' number	Resistance	Dynamic pressure	Total Pressure Loss
[m]	[m]	q [m³/h]	v [m/s]	k [m]	lambda [-]	Re [-]	R [Pa/m]	½ρv² [Pa]	SumΔP [kPa]
0,4	8	4456	9,8	5,0E-06	1,0E-02	3,0E+06	1,2E+03	4,8E+04	10
0,3	6	1570	6,2	5,0E-06	1,1E-02	1,4E+06	7,2E+02	1,9E+04	14
0,2	2	1062	9,4	5,0E-06	1,2E-02	1,4E+06	2,5E+03	4,4E+04	19
0,2	9	781	6,9	5,0E-06	1,2E-02	1,1E+06	1,4E+03	2,4E+04	32
0,2	12	741	6,6	5,0E-06	1,2E-02	1,0E+06	1,3E+03	2,1E+04	48
0,2	5	506	4,5	5,0E-06	1,3E-02	6,9E+05	6,4E+02	1,0E+04	51
0,2	8	408	3,6	5,0E-06	1,3E-02	5,5E+05	4,3E+02	6,5E+03	54
0,2	9	271	2,4	5,0E-06	1,4E-02	3,7E+05	2,0E+02	2,9E+03	56
0,1	12	134	4,7	5,0E-06	1,4E-02	3,6E+05	1,6E+03	1,1E+04	76
0,1	7	36	1,3	5,0E-06	1,8E-02	9,8E+04	1,5E+02	8,1E+02	77

Appendix ill. 16 - The calculation of the energy produced by the solar cells



Appendix ill. 17 - The calculation of the energy produced by the solar cells

Appendix 8

Natural Ventilation for Window test

To calculate the natural ventilation an excel document (Natural_ventilation_calculator) has been used. The result from the window evaluation diagram can be seen in the tables below.

1. window type										
Single sided ventilation	Height from ground	Length	Height	Area	AFR (m^3/s)	Windward	Leeward	Roof	Internal pressure	Neutral plan
East										
	0,5	3,9	1	3,9	1,22	-0,25	0,2	-0,5	-3,83	1,7
	2	3,9	1	3,9	-1,22	-0,25	0,2	-0,5		
West										
	0,5	3,9	1	3,9	1,22	0,2	-0,25	-0,5	3,06	1,7
	2	3,9	1	3,9	-1,22	0,2	-0,25	-0,5		

Appendix ill. 18 - The results from the 1. window type.

2. window type										
Single sided ventilation	Height from ground	Length	Height	Area	AFR (m^3/s)	Windward	Leeward	Roof	Internal pressure	Neutral plan
East										
	0,9	6,6	0,4	2,64	0,603	-0,25	0,2	-0,5	-3,83	1,3
	1,7	6,6	0,4	2,64	-0,603	-0,25	0,2	-0,5		
West										
	0,9	6,6	0,4	2,64	0,603	0,2	-0,25	-0,5	3,06	1,3
	1,7	6,6	0,4	2,64	-0,603	0,2	-0,25	-0,5		

Appendix ill. 19 - The results from the 2. window type.

3. window type										
Single sided ventilation	Height from ground	Length	Height	Area	AFR (m^3/s)	Windward	Leeward	Roof	Internal pressure	Neutral plan
East										
	1,1	2	1,5	3	-0,497	-0,25	0,2	-0,5	-3,83	0,9
	0,7	1	0,8	0,8	0,126	-0,25	0,2	-0,5		
	1,6	1	1	1	-0,305	-0,25	0,2	-0,5		
	0,5	2	1,5	3	0,676	-0,25	0,2	-0,5		
West										
	1,1	2	1,5	3	-0,497	0,2	-0,25	-0,5	3,06	0,9
	0,7	1	0,8	0,8	0,126	0,2	-0,25	-0,5		
	1,6	1	1	1	-0,305	0,2	-0,25	-0,5		
	0,5	2	1,5	3	0,676	0,2	-0,25	-0,5		

Appendix ill. 20

Appendix 9

Acoustic calculation of the reverberation time in the classroom

Equation for reveberation time	T=(0,16*V)/((Sa*s)+(Sn*A)+(4*m*V))
Equivalent absorption area	(Sa*s)
where	
α = absorption coefficient	
and	
S = surface area	
Absorption from persons	(Sn*A)
where	
n = number of persons	
and	
A = absorption coefficient for person	
Absorption in air	(4*m*V))
where	
m = air absorption	
and	
V = volume of room	

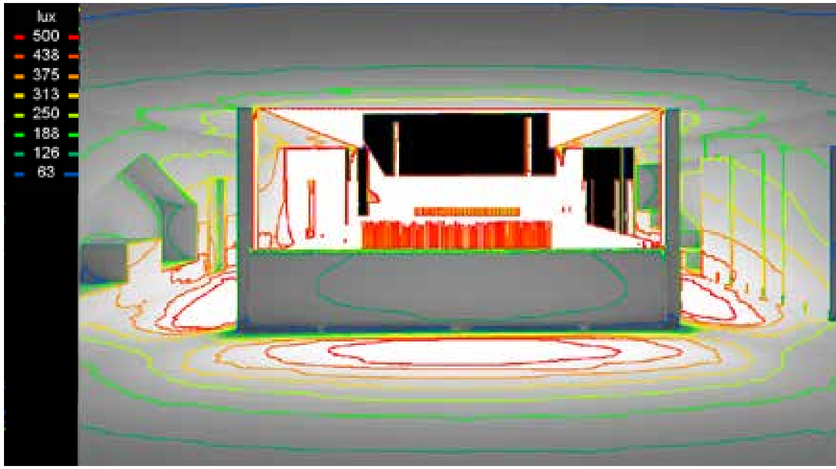
Appendix ill. 21 - calculation methods for reverberation time

Equivalent absorption area	Material	Areal	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S(m^2)	a	Sa	a	Sa	a	Sa	a	Sa	a	Sa	a	Sa
Floor	Linoleum or vinyl	43,4	0,02	0,868	0,02	0,868	0,03	1,302	0,04	1,736	0,04	1,736	0,05	2,17
Ceiling	Plasterboard	43,4	0,15	6,51	0,11	4,774	0,04	1,736	0,04	1,736	0,07	3,038	0,08	3,472
Front and rear walls	Painted concrete	19	0,1	1,9	0,05	0,95	0,06	1,14	0,07	1,33	0,09	1,71	0,08	1,52
Front and rear walls	Whiteboard	2	0,1	0,2	0,07	0,14	0,05	0,1	0,04	0,08	0,04	0,08	0,04	0,08
Side walls	Painted concrete	18,6	0,1	1,86	0,05	0,93	0,06	1,116	0,07	1,302	0,09	1,674	0,08	1,488
Absorption from persons		Antal	Sa/stk	Sa	Sa/stk	Sa	Sa/stk	Sa	Sa/stk	Sa	Sa/stk	Sa	Sa/stk	Sa
Persons	People	0	0,18	0	0,23	0	0,28	0	0,32	0	0,35	0	0,35	0
chairs	Benches	27	0,5	13,5	0,56	15,12	0,66	17,82	0,76	20,52	0,8	21,6	0,76	20,52
Absorption in air		Volumen	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		[m3]	m	mV	m	mV	m	mV	m	mV	m	mV	m	mV
v/ 50% RF		130,2					0,0004	0,052	0,001	0,1302	0,0024	0,31248	0,0061	0,794
Total absorp-tion				24,8	1,1	22,8	1,2	23,2	1,3	26,7	1,5	29,8	1,4	29,3
Reverbera-tion time	T=(0,16*V)/ ((Sa*s)+(Sn*A) +(4*m*V))			0,8		0,9		0,9		0,8		0,7		0,7

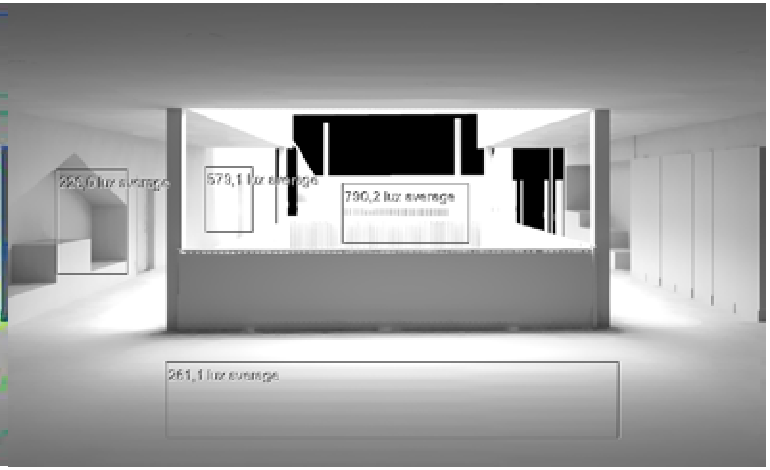
Appendix ill. 22 - calculations for reverberation time

Appendix 10

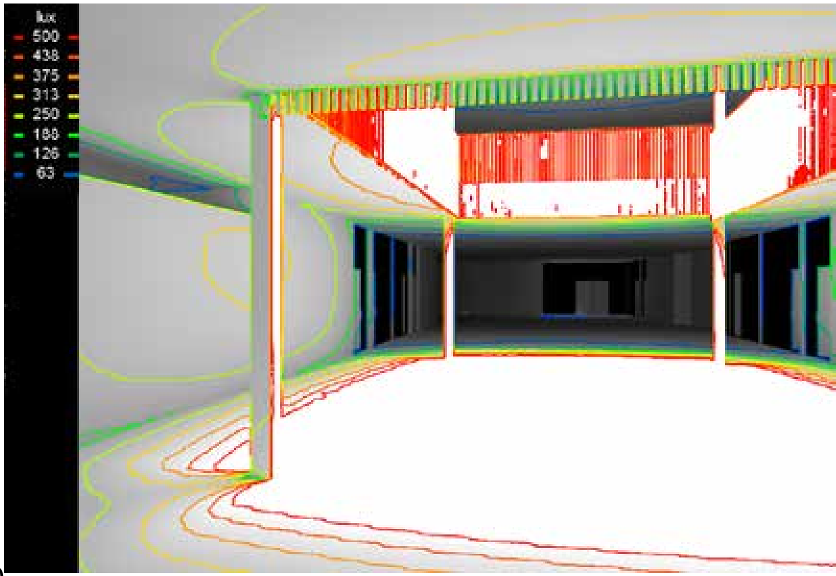
Daylight in Atrium



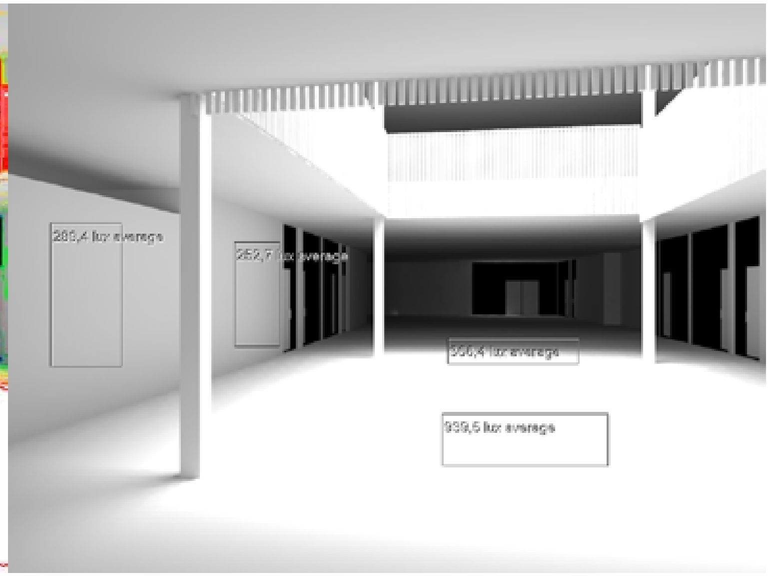
Appendix ill. 23 - Diagram showing Light in the atrium



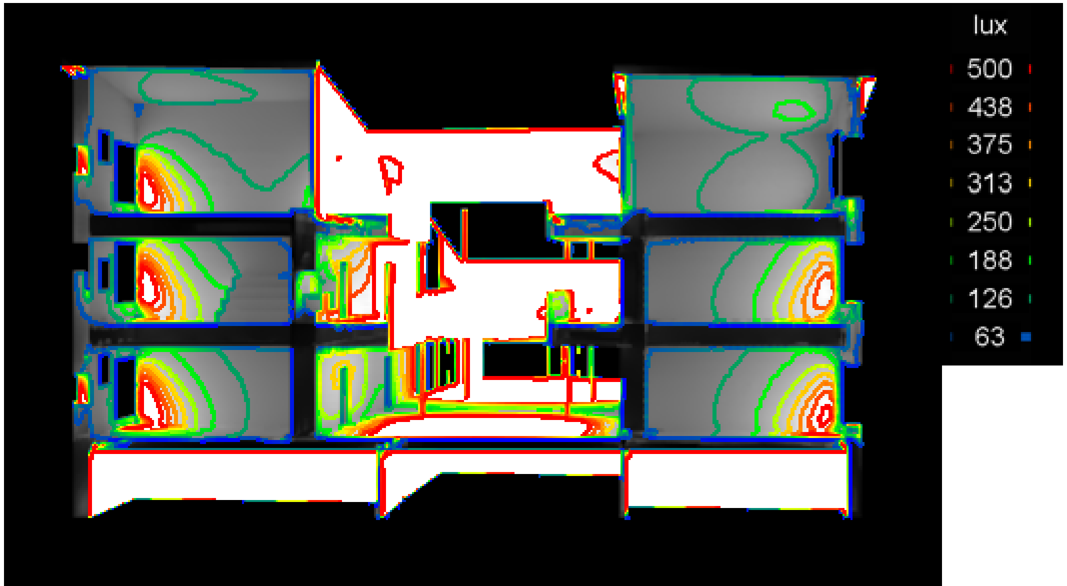
Appendix ill. 25 - Diagram showing Light in the atrium - average lux



Appendix ill. 24 - Diagram showing Light in the atrium



Appendix ill. 26 - Diagram showing Light in the atrium - average lux

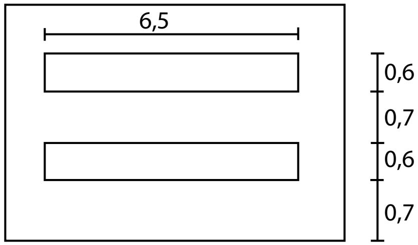


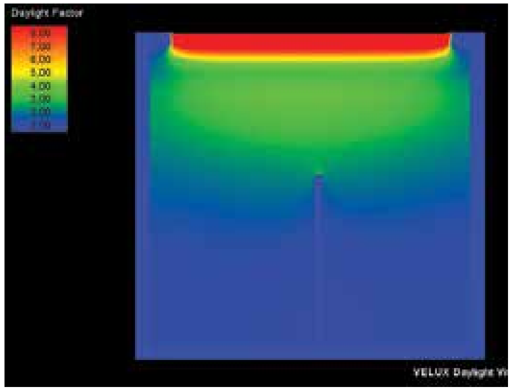
Appendix ill. 27 - Diagram showing Light in a section of the atrium

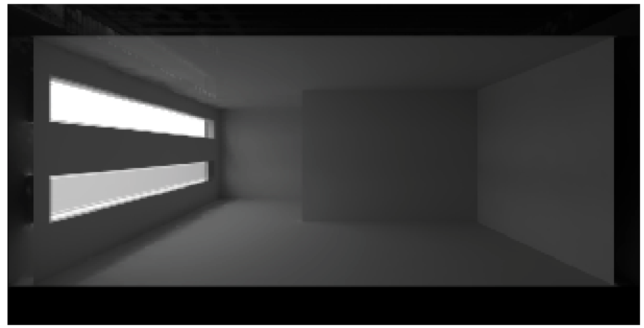
Appendix 11

Daylight for different window types

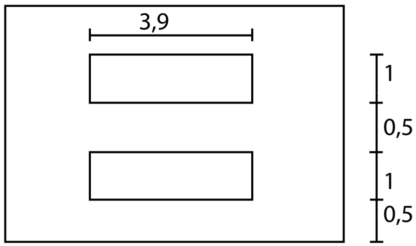
Daylight 1,7

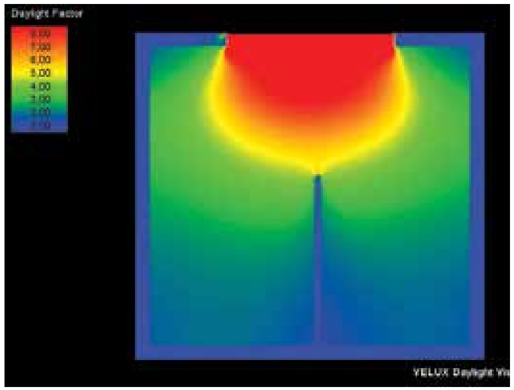


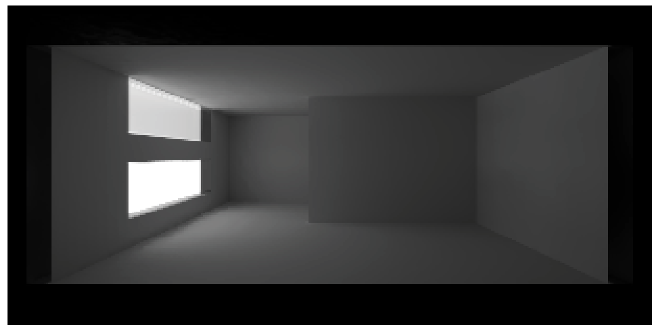




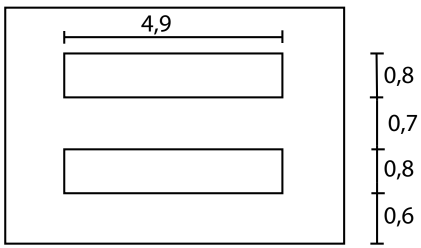
Daylight 3,2

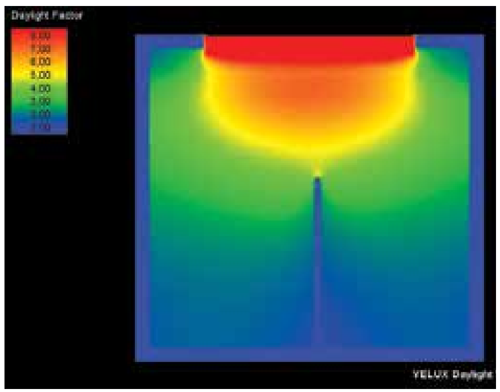


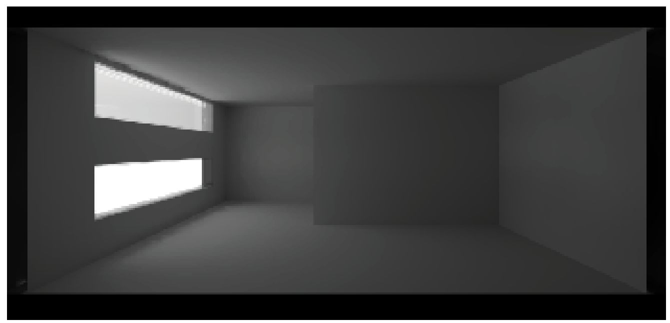




Daylight 3

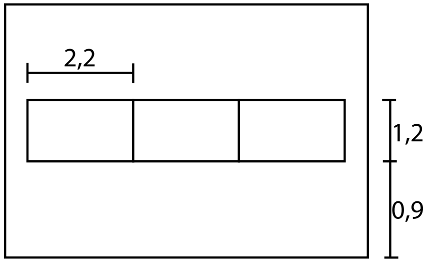


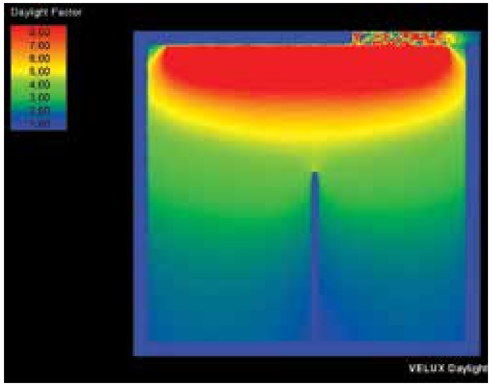


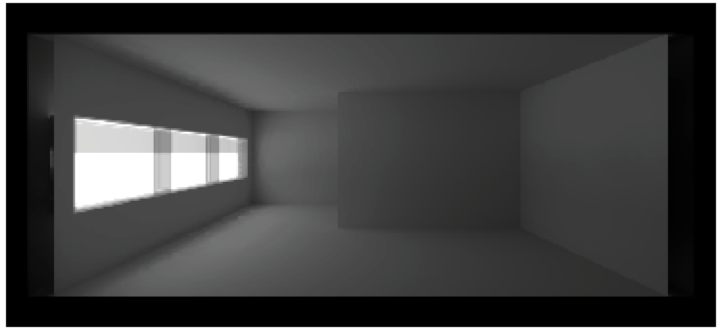


Appendix ill. 28 - 1. window type in three different versions

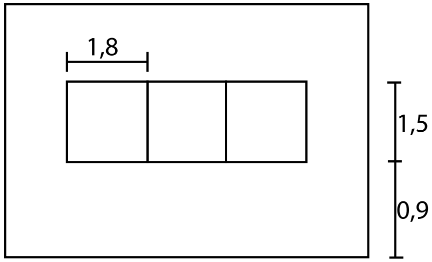
Daylight 3,9

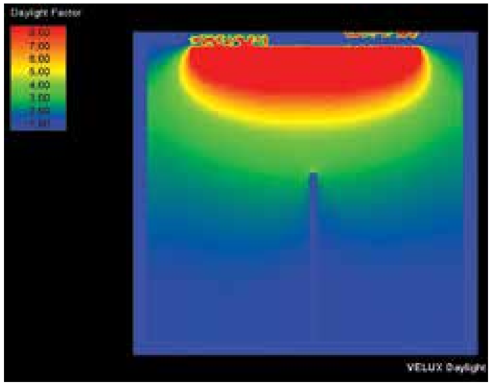


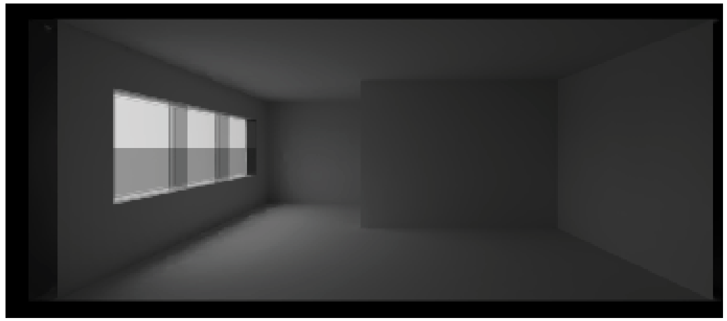




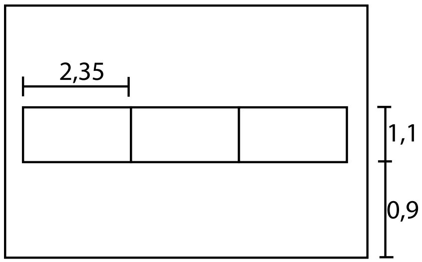
Daylight 2,9

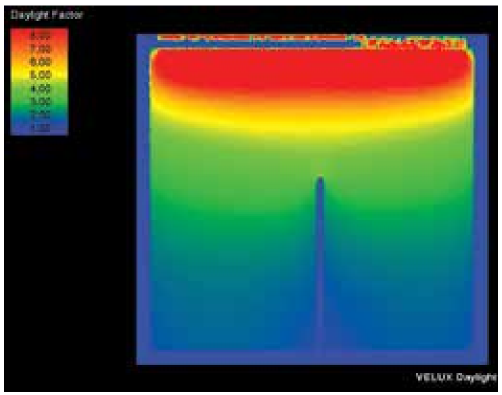


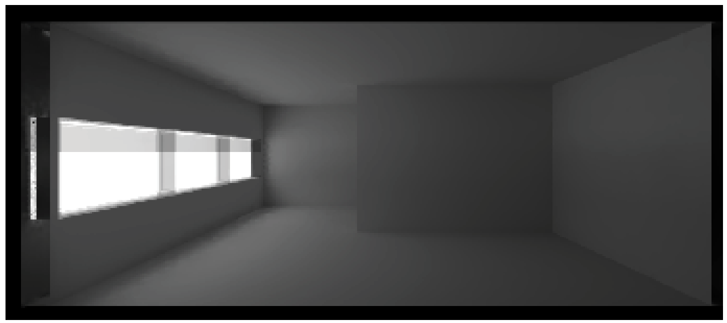




Daylight 3,7

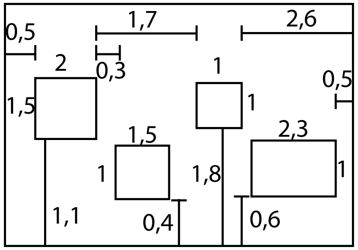


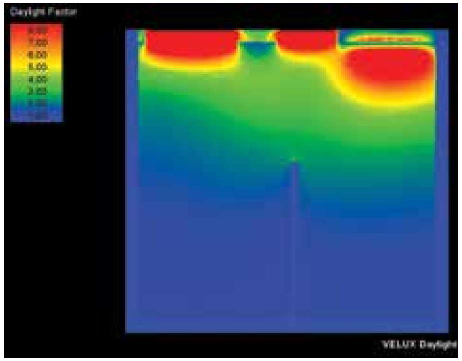


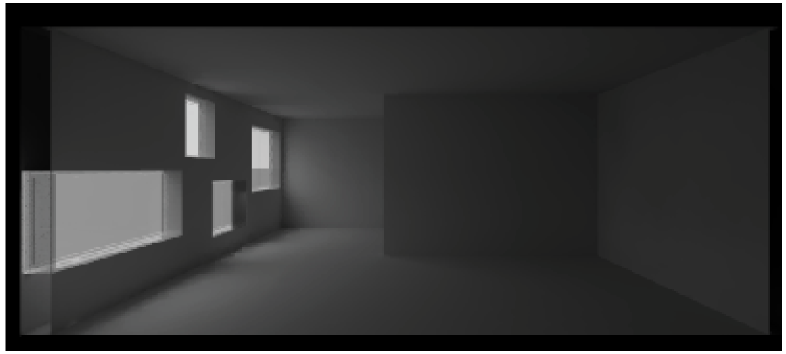


Appendix ill. 29 - 2. window type in three different versions

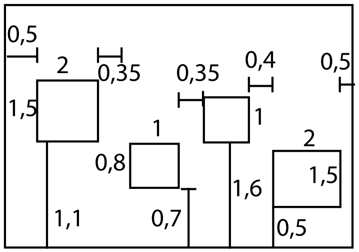
Daylight 2,1

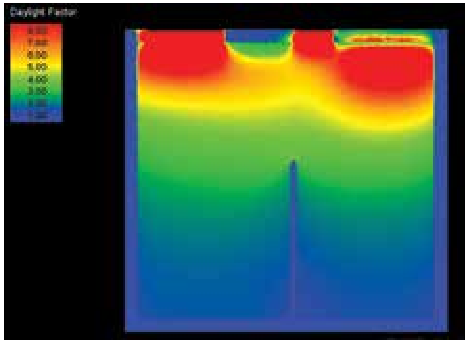


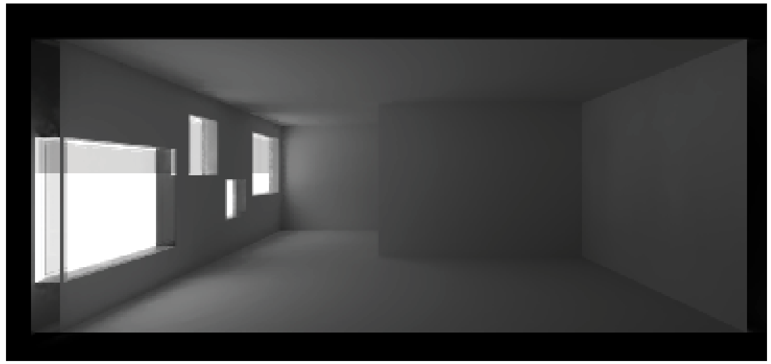




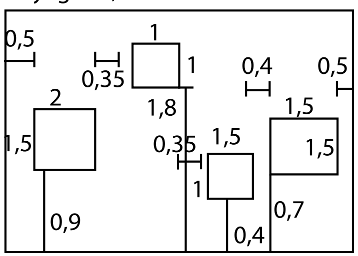
Daylight 3,3

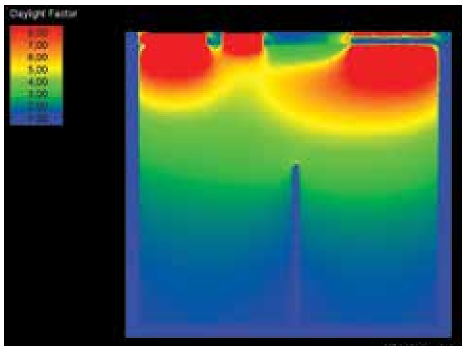


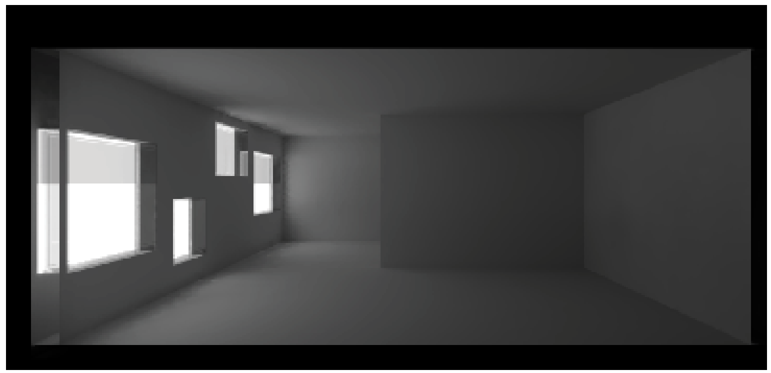




Daylight 3,2



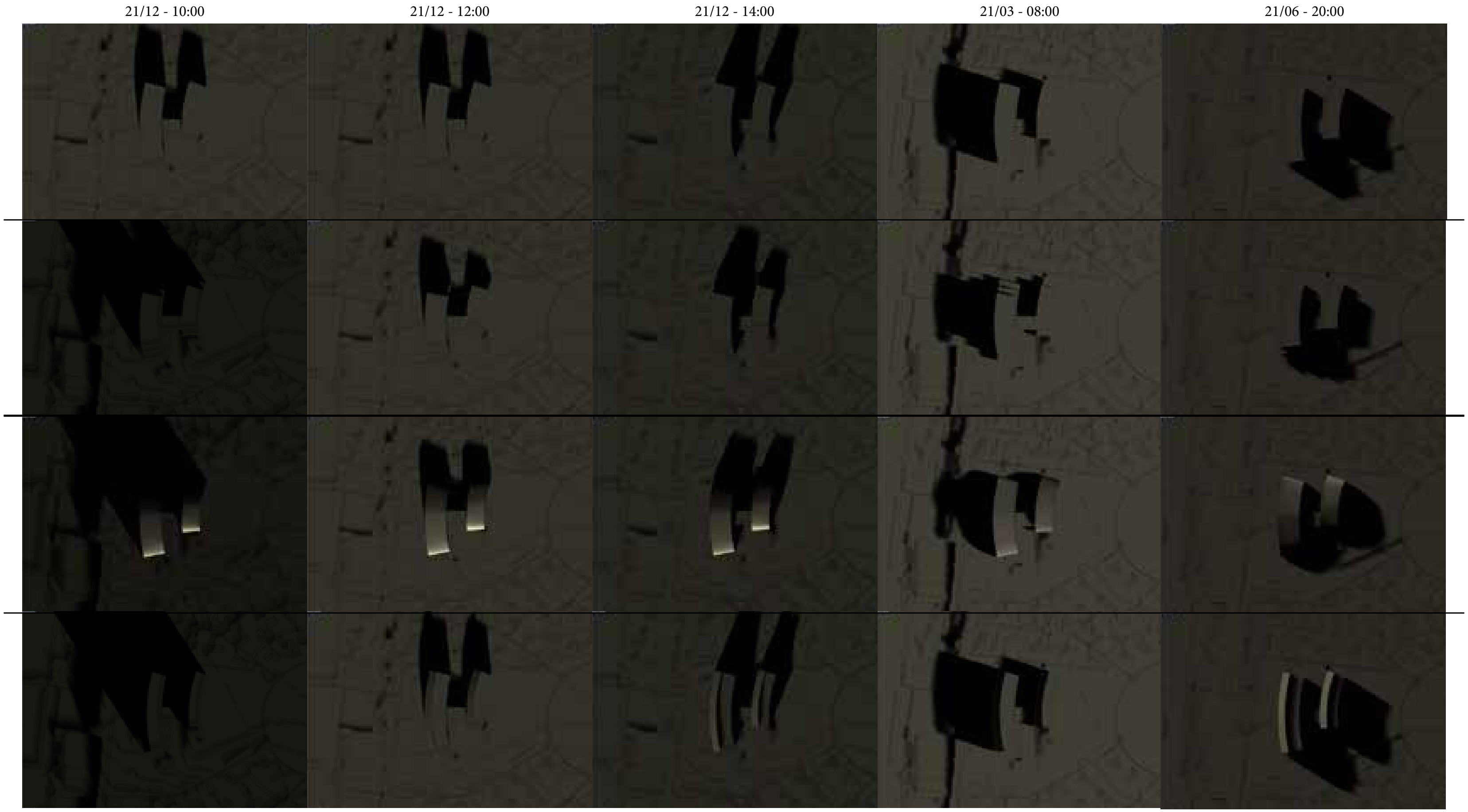




Appendix ill. 30 - 3. window type in three different versions

Appendix 12

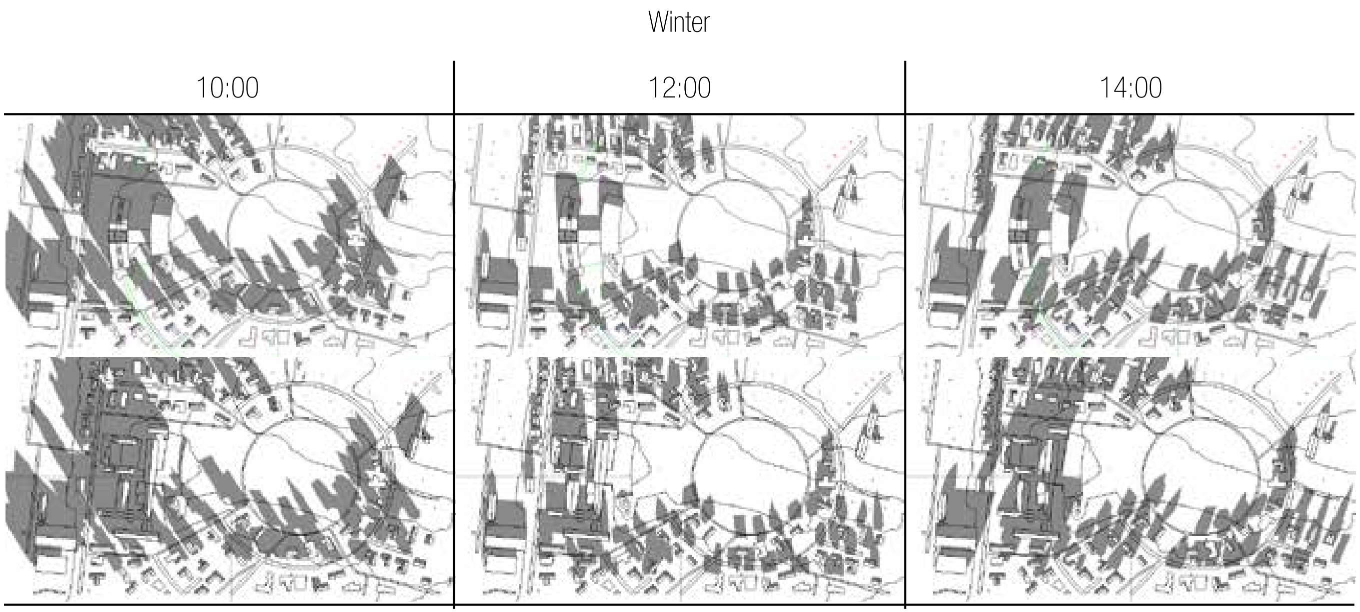
Shadow studies for the different roof suggestions



Appendix ill. 31 - shadow diagram for the roof types

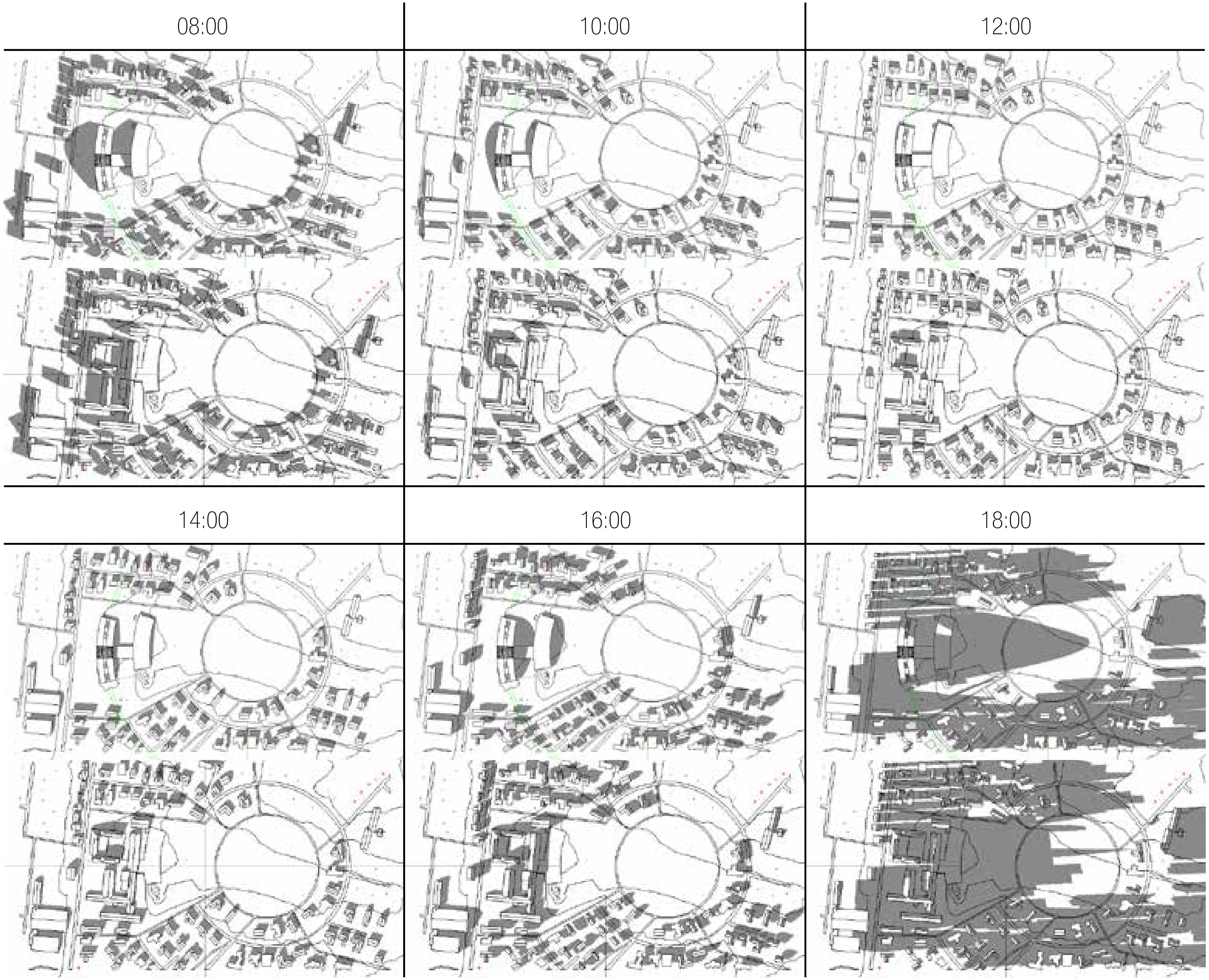
Appendix 13

Shadow study for the current school and the project design



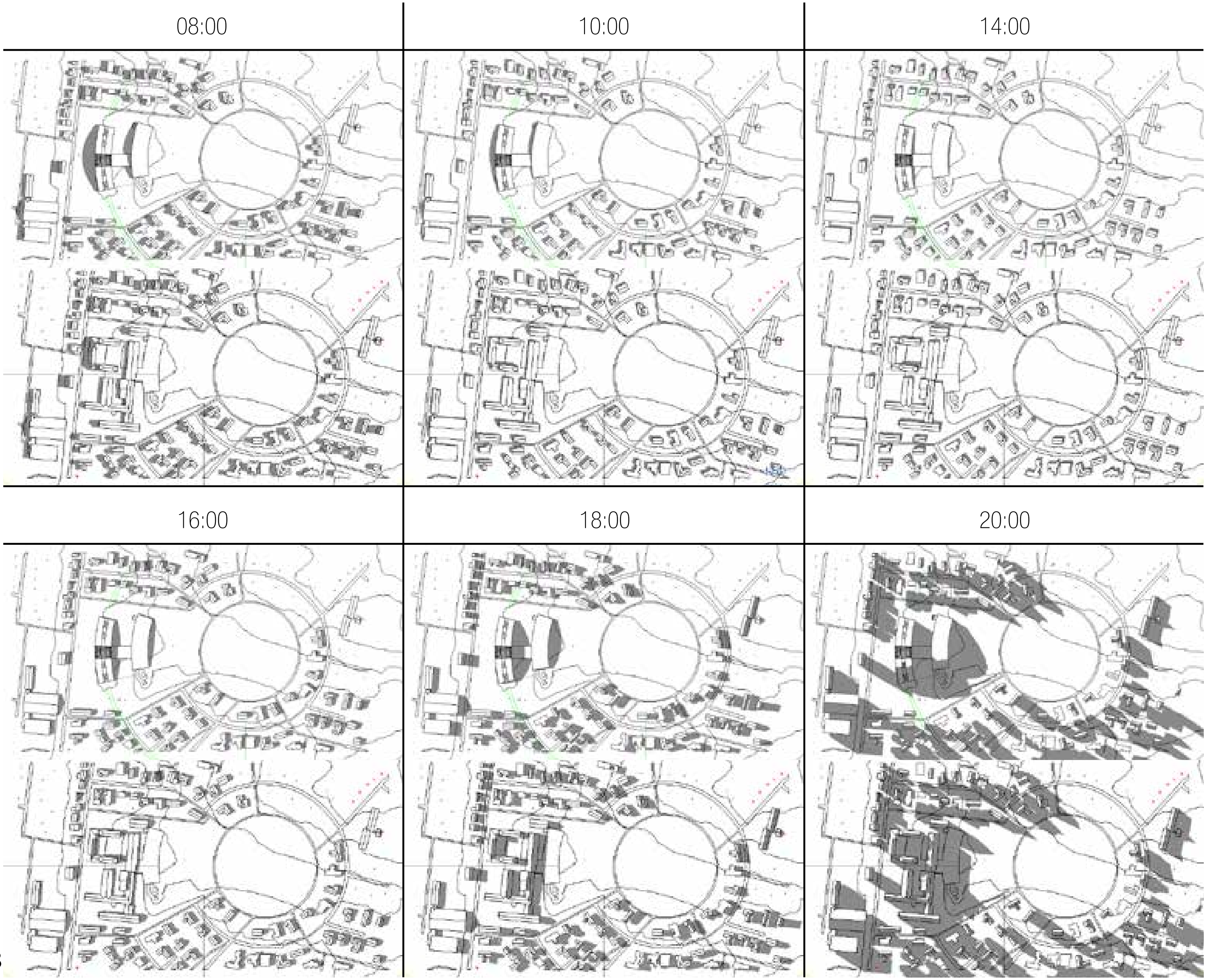
Appendix ill. 32 - Winter solar study

Fall/Spring



Appendix ill. 32 - Spring /Fall solar study

Summer



Appendix ill. 33 - Summer solar study