The School of Tomorrow

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READING GUIDE
This report communicates the analysis, process and ending results of the development of a new "Folkeskole" (the Danish expression for a public school containing students from 0th to 9th grade) in Aalborg, focusing on modern learning environments, social and environmental sustainability. The methodological approach of integrated design is used to organize the project phases. The project is initiated with a program containing the four chapters: site analysis, case studies, research, energy and sustainability, where each chapter is ended with a sub conclusion to sum up the important parameters that will influence the further design. The chapters will within a Danish contest concern objects as modern pedagogical teaching strategies, how to improve better indoor working environment, and how to insure low use of energy.
After the program this report will present the final proposal including plans, sections, diagrams and 3d visualizations. Then the design process with focus on progress and discoveries of different design solutions that led up to the final design proposal will be presented and summed up with an overall conclusion of the project.
An appendix, including results of simulations and document of the municipality's master plan for the area and design process, can be found on the last pages. In accordance to the Harvard references method, for literature and illustrations are carried out.

ABSTRACT (ENGLISH)
This Master's Thesis will concern the design proposal of a new Folkeskole for the Aalborg municipality, which is to be located close to Gigantium in the new Master Plan for Gigantiumkvateret. With a point of departure in the new Skolereform, the school will be designed with longer school days, more exercise on a daily basis and the upcoming digital era pupils will have to face in mind.
As rising concerns is focused on the sustainability of both the environment and on human wellbeing the school will incorporate engineering and architectural solutions in order to deal with this concern. Social aspects regarding how to incorporate public use of the school as a multi-purpose school that is available around the clock and can be used by the local neighborhood in Gigantiumkvateret will also be addressed.
In order to create modern educational facilities with a focus on alternative education for children, theory must be studied. Places for contemplation and group work will be a big part of everyday in modern schools.

RESUMÉ (DANSK)
Dette kandidat afgangsproject omhandler et skitseudkast til en ny folkeskole til Aalborg Kommune tæt på Gigantium planlagt i henhold til den nye masterplan for Gigantiumkvarteret. Med udgangspunkt i den nye Skolereform skal arkitekturen skræddersyes til at tilpasse de længere skoledage, mere motion i hverdagen og den digitale dagligdag elever kommer til at møde.
Med stigende omtanke på bæredygtighed for både miljøet og menneskets velvære skal skolen indarbejde ingeniør mæssige og arkitektoniske løsninger for at tage hånd om denne problematik. Sociale aspekter om hvordan borgere skal kunne bruge skolen til afbenyttelse for nabolaget i Gigantiumkvarteret døgnet rundt er behandlet.
For at udforme moderne læringsfaciliteter for børn som understøtter de forskellige læringsmetoder er der anvendt teoretisk viden om læring i folkeskolen. Dette har bl.a. resulteret i områder hvor fordybelse og gruppearbejde kan foregå uden for klasselokalerne.

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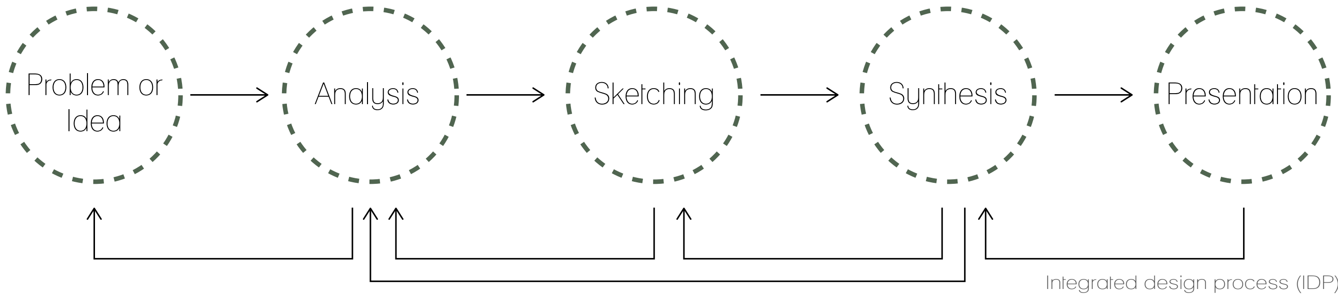
MOTIVATION

The Danish "Folkeskole" is a compulsory primary education, which is aimed at children of the age six to sixteen and covers kindergarten through ninth grade; this resulted in 1,013 schools and 558,581 students in 2014 [uvm.dk, 2015]. Within these ten years, Folkeskolen will play an important role in developing the pupils' ability to take action, their decisiveness, their responsibility and prepare them to enter and be part of society as well as achieve the essential knowledge that is needed in order for further education [uvm.dk, 2015 B]. Altogether, Folkeskolen plays an important role in our journey from childhood to adulthood.

"Dansk Erhverv" and shifting Danish governments agree that Denmark is a society based on knowledge and that Denmark has to continue improving the educational sector, and in terms of knowledge, in order to keep a wealthy society [Forretningsplan Danmark 3.0, 2008], [Ufm.dk, 2012]. Unfortunately, the latest PISA study from 2012 reveals that Danish students are internationally only placed as the 22nd, 25th and 27th best in math, reading and science respectively [uvm.dk, (n.d.)]. This, however, did result in a political ambition of modernizing and improving education and was concretized/precipitated in 2014 with the introduction of the new "Skolereform" [Uvm.dk, 2015]. Skolereformen brought with it changes to some of the physical and pedagogical environments. Following this line of thought, the architecture should reflect this change as well in order to support the learning environment in the best way possible. Skolereformen states that every child should learn as much as possible. Considering this, the indoor environment will also play an important role in this; however, 56% of already available classrooms in Denmark have bad indoor environments [Welin, 2014].

There is a need for new and better-designed schools that does not look like traditional schools but have a shape and architecture based on supporting modern teaching methods and ensures a good indoor climate that improves the pupils' well-being and performance. This ambition will only be possible by using a combination of research, technical knowledge and creativity.

Because Danish educational facilities tend to produce students with an affinity toward studies within the humanities rather than engineers, it is decided that the school should have a scientific profile. Educational facilities with a focus on science will then be exposed in an interesting way in order for pupils to find it more appealing and, hopefully, be interested in pursuing a higher education within the sciences.



Integrated design process (IDP)
Ill.: 1

METHODOLOGY

Throughout the project, PBL and IDP will be used to solve technical and architectural issues and make the project's foundation.
More methods have been used to solve different upcoming challenges.

As a start, the interview form described by Kvale has been used to gather data and knowledge from other schools. By having references of different schools with different approaches to both the Skolereform and sustainability, which we focus on, will initiate a discussion on how to design with a focus on children's ability to learn and how to give inspiration to it.

To analyze the context and the site different mappings to investigate possibilities and restrictions in the area are used.

The digital tools Bsim and Be10 will be used to analyze and specify the needs necessary to fulfil the energy and sustainability requirements for future building.

PROBLEM BASED LEARNING (PBL)

With this learning method, the students' own skills are tested by requiring them to obtain the necessary knowledge needed to solve the specific problem statement assigned in the project themselves. In this way, there is a constant workflow between practical knowledge and theory, which leads to a solution-orientated project. Furthermore, it takes its departure in a problem statement within the field as well. In this project, the project group works with different methods in order to solve the specific problem statement while new knowledge is achieved simultaneously. The goal of PBL is for students to gain knowledge of diverse and interdisciplinary fields of subject areas and thereby allow them to give an answer to the given problem. Within the context of this project, the focus will be on how to build a school with emphasis on good architecture and rational, calculated engineering. By working with PBL, it gives a wide range of academic methods in different areas of expertise [Aau.dk, 2015].

INTEGRATED DESIGN PROCESS (IDP)

This method is a combination of PBL and professional knowledge from engineering and architecture. With this method, the project goes through five phases; problem or idea, analysis, sketching, synthesis and presentation (see Ill.: 1).
- In the analysis phase, one uses all the acquired knowledge to construct a program, which contains vision, parameters, demands etc.
- During the sketching phase, the acquired knowledge is used as the facilitator for the design and is continuously adjusted throughout the work process when newer knowledge is gained.
- In the synthesis phase, the architectural aspects and demands of the functions come together.
- The presentation phase is when the final report and presentational material is made and visualized.

In IDP, the design is continuously optimized through new iterations, which creates a more complex circular process. It works toward solutions and integrates all aspects of both architecture and engineering, which complement each other in order to solve technical and architectural issues and design in unity [Knudstrup, M. 2003].

I

SITE ANALYSIS

SITE
ACCESSIBILITY & SURROUNDINGS
TOPOGRAPHY
NOISE
SUN
WIND
SUBCONCLUSION

SITE ANALYSIS

In cooperation with Aalborg municipality, it has been decided that the location of the school will be based on a master plan proposal in a future dwelling complex placed 6 km outside Aalborg center. A site for the school has already been incorporated in this master plan, as well as an outline proposal for how the surrounding dwellings will be shaped; this chapter will present the analyses that are relevant for the site, which is the master plan, accessibility, topography, nearby facilities and climate conditions.

Vandkusten visalisation of new buildings in Gigantiumkvarteret
Ill.: 2

SITE

Currently the site is placed in an open field area with lots of green surroundings. The area is dominated by grass fields only disturbed by bus, bicycle and car roads going across. The site's topography is slating downwards from the new established Thomas Manns Vej to Bertil Ohlins Vej wtih 8 meters.

With departure in the winning master plan proposal for Gigantiumkvarteret by Vandkunsten the context is used here. Gigantiumkvarteret located between Gigantium and Aalborg University campus and will be a primary area of development with up to 1800 new dwellings with special focus on families (see appendix 2).

With this new amount of residents in the area a nearby school has to emerge. From open fields the whole area will be transformed into 2-4 stories housing and office area. A nearby golf driving range will be built and Gigantium will be extended with an international sports center just south of it. The small streams and lakes, from the campus area, will continue into Gigantiumkvarteret. The site area will be of 21.000 m2 (see appendix 1).

Aeriel view of site
Ill.: 3

Nearby functions
Ill.: 4

- Gigantium sports halls
- Gigantium indoor swimming pool
- Supermarket
- Campus

Roads
Ill.: 5

Green areas
Ill.: 6

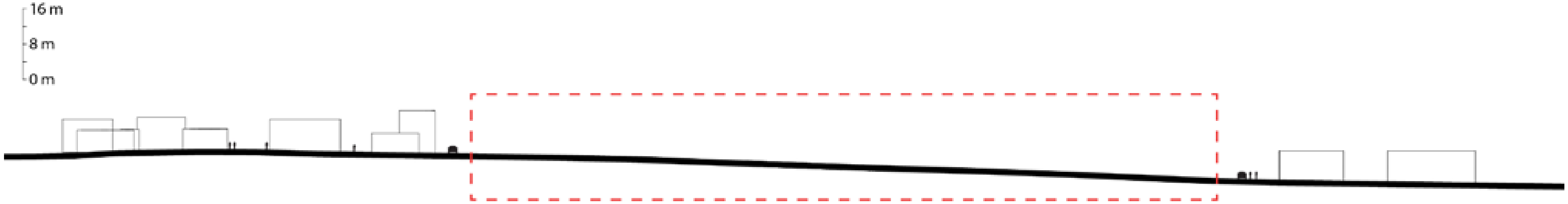
ACCESSIBILITY & SURROUNDINGS

The site is located in the center of the new Gigantiumkvarter is, despite one five storey building, surrounded by 2-3 stories family dwellings and office buildings.

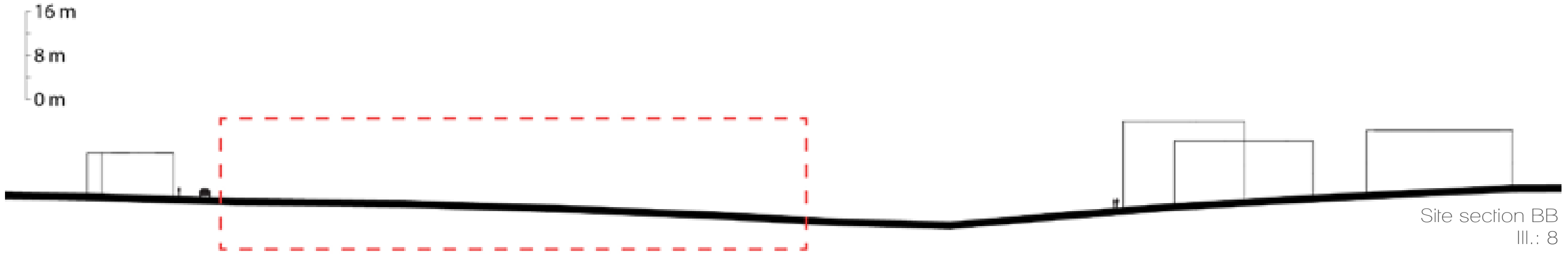
Gigantium just north west of the site attracts people from Aalborg to sport events several times a week and is a focal point for the city's sportsmen and women. A new sportscenter on the other side of Bertil Obels Vej will emerge to attract even more people to the site (see ill.: 4).
The small streams running through the campus area continue in the new residential area, to make rainwater drainage with ponds scattered around in Gigantiumkvateret.

As Bertil Obels Vej is an bus exclusive route with stop just at the site public transport is ideally placed for the kids at the new school. Larger roads, Hadsundvej, Universitetsboulevarden and E45 as well make easy and fast access for private motorists.
The new established Toppentuestien is a bike road going from Gigantium by the site and into campus. This makes it an easy and fast way for transportation in Aalborg, especially in rush hour periods as when pupils take time off from school (see ill.: 5).

A lot of green areas, water and recreational areas is located around Gigantiumkvateret: a new golf driving range, a football field, city gardening and play grounds for kids (see ill.: 6).



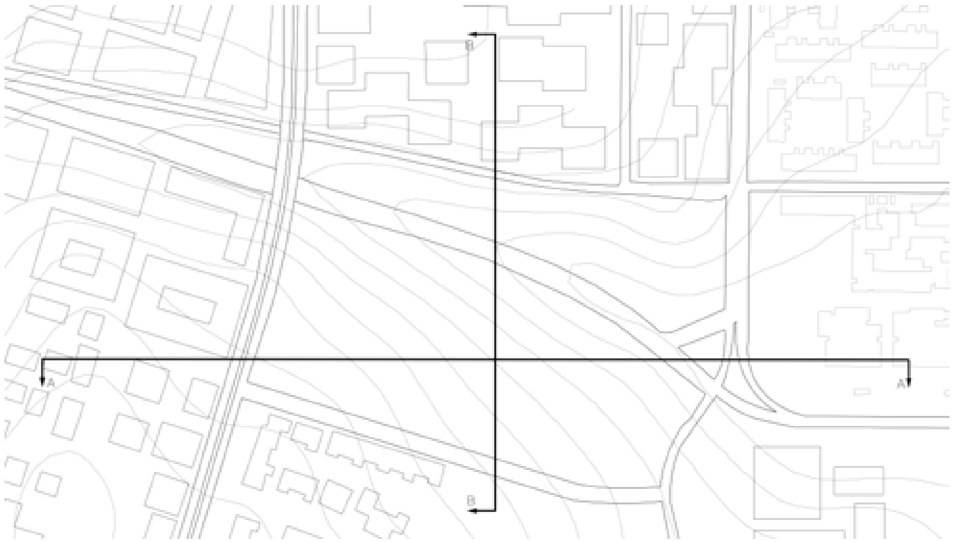
Site section AA
Ill.: 7



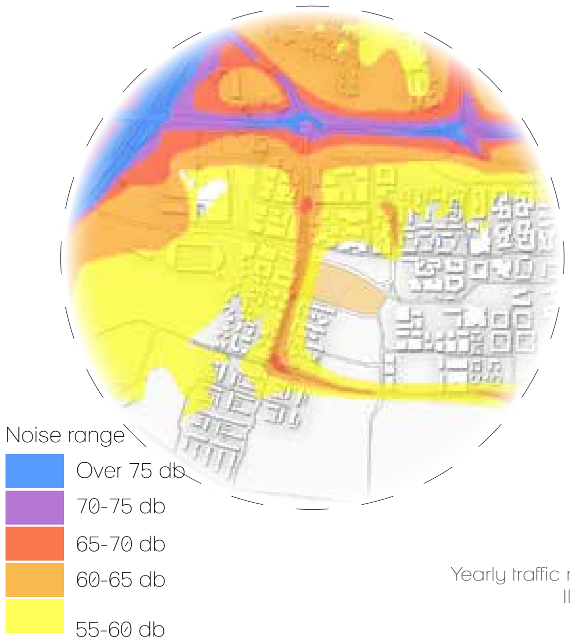
Site section BB
Ill.: 8

TOPOGRAPHY

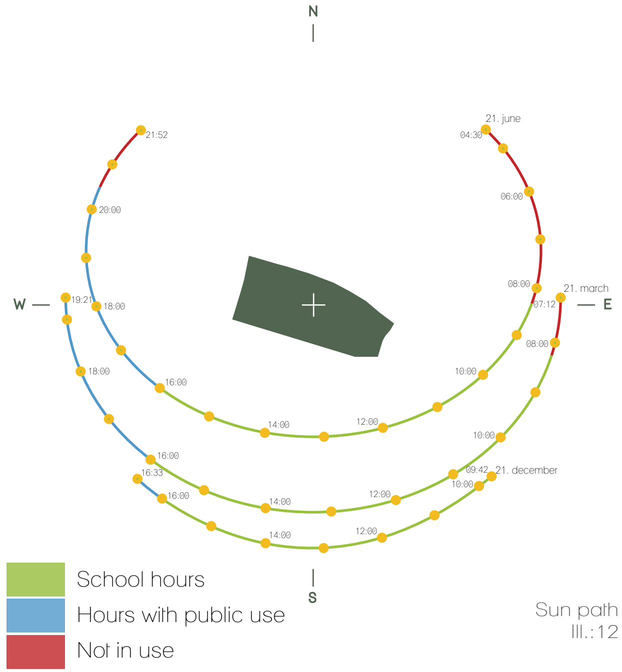
The topography on the site is sloping down from the south west corner to the north east corner by 8 meters. The steepest slope is at the west end of the site and most flat at the south east part. This means that when standing on Thomas Manns Vej one have an undisturbed view to the site and most of Gigantium-kvarteret.


Site section map
Ill.: 9

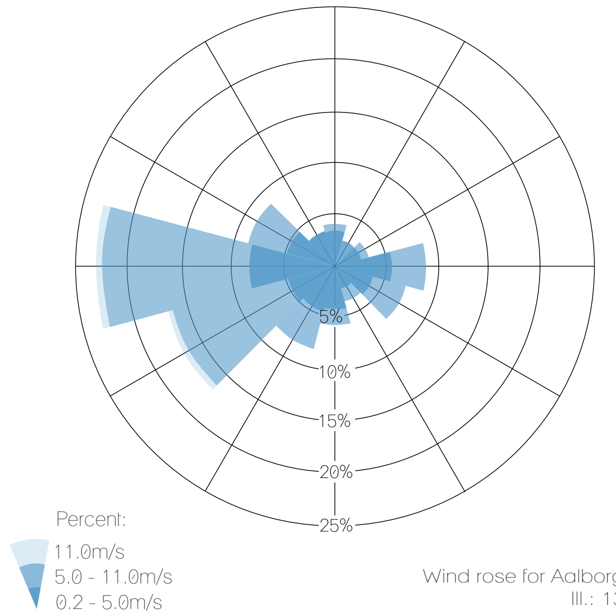
Open field on site
Ill.: 10



Yearly traffic noise
Ill.: 11



Sun path
Ill.:12



Wind rose for Aalborg
Ill.: 13

NOISE

As shown on ill: 11 the site is not exposed to average high decibels. This registration might change when more dwellings will be build close to the site. However, except from dwellings, only smaller local roads will be added in the area. Meaning that the primary noise will still occur from the main roads. It is predicted that the increased noise will not cause problems for the school, however it is worth mentioning that there will be most quiet in the eastern part of the site.

SUN

As seen on the sun path diagram the position of the sun changes a lot through out the year. To maintain good indoor environment and optimize energy savings for electricity, considerations of how to orientate functions is necessary.
A day at school starts at 8.15 and ends latest at 16.00 as seen on ill.: 12 (see ill. 186).
As class rooms and office functions tries to avoid direct sun light, due to risk of overheating and glare, it's important to know the sun path. Other functions like outdoor areas, hallways and canteen area where direct sun light contributes to the spacial and architectural feeling, can be located towards south. As no high buildings is nearby, nothing shades for direct sun on the site.

WIND

When designing, especially outdoor areas, wind can be a noteworthy factor to take into consideration. To avoid wind tunnels and turbulent spaces where occupation is scheduled is essential to obtain comfortable playgrounds and other outdoor activities. In Aalborg wind from west is dominating and may possibly affect the comfort of staying in areas exposed to the this (see ill.: 13).

SUBCONCLUSION

As the site currently is placed on a spacious open green area with no near context buildings besides Gigantium the departure will be taken from the winning proposal from Vandkunsen regarding Gigantium-kvarteret. The upcoming residential area will have lower two-to-three storey buildings, which will not affect the school site much in terms of shadow.

The site's topography is slanting 8 meters downward from South-West to North-East and will influence the programming of the building.

The passing by bus route will give easy access to the site by public transportation and major roads near the site secure good access by private transportation. These roads, however, does not have major noise impact on the site.

As Gigantium is close to the site it will be integrated for sports facilities to the school. The nearby university campus gives the opportunity to collaborate and enhance the science profile on the school with external lectures and visits.

The predominant west wind will affect how possibly the outdoor areas' organization.

II

CASE STUDIES

BIRKERØD SKOLE
SKOLEN I SYDHAVNEN
VIBEENGSKOLEN
SUBCONCLUSION

CHOICE OF CASE STUDIES

As a first step to gain knowledge and inspiration to the project, three case studies have been made. This chapter explores the potential of how architecture within a context of modern Danish schools can work with: pedagogical principles, the new Skolereform and sustainability. This is done by analyzing these three subjects on three different newly build Danish schools. Birkerød Skole is based on an interview with the principal, janitor and own observations. In the two other cases it was not possible to visit the buildings, or get an interview, instead they are based on literature; Skolen i Sydhavnen has, however, been visited but only from the outside.

BIRKERØD SKOLE (2013)
Architects: Bplus
Location: Birkerød, Denmark

SKOLEN I SYDHAVNEN (2015)
Architects: JJW Arkitekter
Location: Copenhagen, Denmark

VIBEENGSKOLEN (2014)
Architects: Arkitema Architects
Location: Haslev, Denmark

First day in school
Ill.: 14

BIRKERØD SKOLE(2012-2013)
Architect: Bplus
Location: Birkerød, Ruderstal Kommune
Size: 8.500m2
Students: 700 (0th.-9th. grade)


Auditorium classroom
Ill.:15


Smaller library in hallway
Ill.:16


Aquariums and stuffed animals in science area
Ill.:17

ARCHITECTURAL AND PEDAGOGICAL PRINCIPLES
Birkerød Skole is a newly renovated School where two older schools were merged together to form one big public school that fulfills the new requirements for Skolereformen [Graatang (a),(b), 2015]. The class sizes differ from 20-28 students per class.
Together with the renovation phase the school had an extension building, that works as the ASP (after school program). Throughout the school there has been worked with transparency as one of the key parameters. Because of that all rooms have major or minor area of glass connected to the hallways, and in that way all activities on the school is exposed.

Birkerød Skole gives each student an Ipad from first grade, and all teachers have Ipad's and MacBook's as well. These digital tools, together with white smart-boards in all rooms, are used in teaching regards to present, chat and include the students in the lessons. However, they experience glare problems with direct sunlight at whiteboards and screens. When designing a new school the architecture have to take these new glare issues into account, power supply is also important. At Birkerød Skole power supply is available from most areas of the school and all students have their own cabin, to backpacks, laptops e.g.

The school is divided in different learning areas, this is visible from the corridors where e.g. the science area is equipped with taxidermy (see ill.: 17). The learning areas also have their own small library only containing books within this field (see ill.: 16).

A functional division in the school separates the 0-5 grade as phase 1, 6-9 grade as phase 2, the canteen, science area and the language area to organize activities. In phase 1 all classes have their own classroom, and access to different classroom setups from individual learning to group activities and a room furnished as a lecture hall with seats in stepped levels (see ill 15). These different furnish layouts encourage teachers to adapt the

Open wall storage
Ill.:18

Students personal lockers
Ill.:19

Creative road sign
Ill.: 20

room for optimal learning environment. In phase 2 the students does not have a specific classroom, but move around from room to room according to what lesson they attend to. [Graatang (a), 2015]. In this way the school doesn't need to have as many empty classrooms, but rather have to schedule how students move around in the rooms.
A new special room spacious enough to accommodate three phase 1 classes was built with view towards the grass area just south west of the school. Even though the spacious quality in this room is high, it lacks to fulfill its purpose as if three classes attend in this room the acoustics is less good and it's hard for teachers to control that many pupils together in one spot [Graatang (b), 2015].

APPROACH TO THE NEW SKOLEREFORM

Birkerød Skole was establish before the new Skolereform, however it still fulfills the Skolereform's criteria because it's visions and architecture, like the new Skolereform, is based on John Hattie's studies of how pupils can improve learning outcome in school. Birkerød Skole has worked out a vision for the new school with 12 points e.g.; Better opportunity for contemplation, visible learning, work with individual learning style and progression, higher flexibility, [Graatang (b), 2015]
With the new Skolereform all teachers went to courses of how to teach in a modern way, with digital tools and the new mindset of how children best learn. This new way of teaching is still in the startup phase, and some teachers still have a hard time adjust to this new way [Graatang (a), 2015].

SUSTAINABILITY

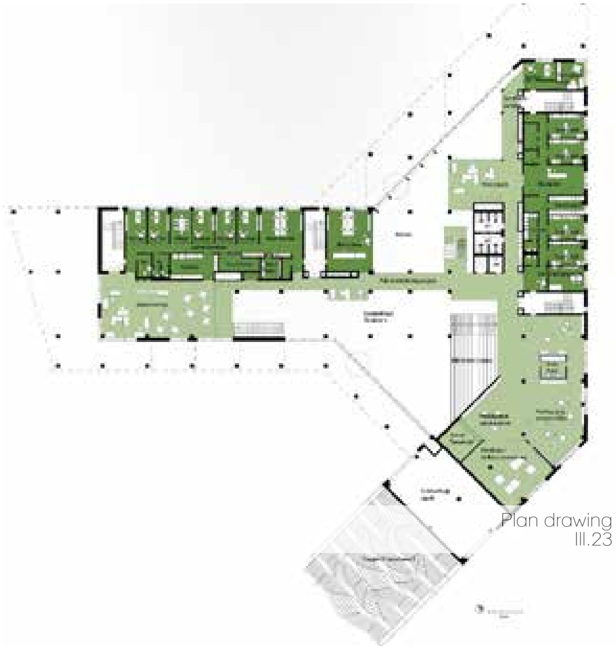
When designing for the renovation the architect took indoor climate into consideration. All floors and ceilings is sound absorbing and big skylights in classrooms and offices adds extra natural daylight. Mechanical ventilation was installed and gives an acceptable temperature inside most of the year. In summertime teachers still ventilate sometimes by opening windows. With these new improvements they experience problems with direct sunlight making glare at white-boards and screens. The ventilation as well makes a bit noise and the new temperature control system is still being adjusted. A 1000m2 sports hall is used all through the year to different purposes and the school kitchen is used by local associations.

SKOLEN I SYDHAVNEN (2009-2015)

Architect / Engineer: JJW Architects / Niras
Location: Sydhavnen, Copenhagen (SV)
Size: 9.500m2
Students: 900 (0th-9th grade)

Roof of Skolen i Sydhavnen
Ill.21

Playground
Ill.22



Plan drawing
Ill.23

ARCHITECTURAL AND PEDAGOGICAL PRINCIPLES

Since Skolen i Sydhavnen is placed at the harbor front, it has been decided that the school should have a profile focusing on water and science, and use the water from the harbor as an active part of the education.

The architecture is supporting this profile due to its materiality where metal, wood and concrete have been used to create a maritime harbor atmosphere. As a contrast, the floors are colored in strong and playful colors (see ill.: 21).

Due to a limited site area, almost the entire roof have been included as outdoor area, and is being used as a playful mountain area going from ground till 5th floor. Only a smaller area on the 5th floor is not used for outdoor space but instead as a closed off area for solarcells (see ill.: 22).

Skolen i Sydhavnen is programmed so the ground floor is used as internal schoolyard and public meeting place where functions that can be used by the public in the evenings (e.g. music room) is incorporated, the 1st floor is where the administration, staff room and school dentist are placed, at 2nd floor all the rooms for 0th-3rd grade is placed, and at 4th floor is the facilities for 4th-9th grade.
The different floors and internal schoolyard have a visual contact due to the open atrium.

APPROACH TO THE NEW SKOLEREFORM

Only the younger pupils from 0th-3rd grade have permanent classrooms, all the older students do not have a permanent classroom but is switching between different kinds of rooms depending on what and how they are supposed to learn in the specific classes. There is also many different sitting areas throughout the school. Including a "stair for sitting" (see ill.: 24), different kinds of smaller niches inside as well as outside the classrooms. Small playhouses are placed in the open areas, they function as niches and working areas (see ill.: 25), but also as play areas in the breaks and after school time. All together this diversity allows the students to choose different kinds of working spaces according to the type of work and the personality of the students.

Stairs and working area
Ill.24

Working niche in open space
Ill.25

Window in classroom
Ill.26

SUSTAINABILITY

Skolen i Sydhavnen meets the demands for the DGNB bronze certification (an acknowledged certification within sustainable buildings). According to the DGNB system, the building is preforming best in the field; social sustainability, here is it almost for fulfills the standards for gold certification [Kiesslinger, 2015]. The strong performance in social sustainability is a combination of the social aspects mentioned on the previous page, and a good indoor climate. Elements of how this indoor climate are designed is described below.

To ensure good indoor air quality, both mechanical and natural ventilation are used. There are automatically controlled driven windows and doors in both the facades and inner walls, and the system will automatically open at night to insure a clean air in the morning. As supplement to the automatically driven ventilation, each classroom have a window that can be manually opened. This window are placed on the inner side of the envelope with a deep external window frame padded with acoustic plates to minimize noise from the outside to enter (see ill.: 26).

There have been worked with the acoustic on all the inner surfaces; the ceiling is made of wavy metallic lines with 100mm acoustic bats above. The walls are covered with wooden battens with an acoustic absorbent material behind, and other places there are used the same metallic system as used for the ceiling, which is magnetic and therefore can be used as message board. The floors is made of sound absorbent polyurethane.

It has also been a goal to allow the daylight to enter deep into the buildings volumes, this have been achieved by using highly placed windows [Kiesslinger, 2015].

Social sustainability is important when designing a new school, but it includes many parameters, where only some of them are mentioned here. To get some inputs of how to assess the importance of different elements, DGNB will be further investigated in the research chapter.

VIBEENGSKOLEN (2012-2014)

Architect / Engeenirs: Arkitema Architects / Søren Jensen, Cenergia
Location: Haslev
Size: 6.430m2
Students: 450 (0th.-6th. grade)

Aeriel view
Ill. 27

Playground and facades
Ill. 28

Classroom for pupils with loft
Ill. 29

ARCHITECTURAL AND PEDAGOGICAL PRINCIPLES

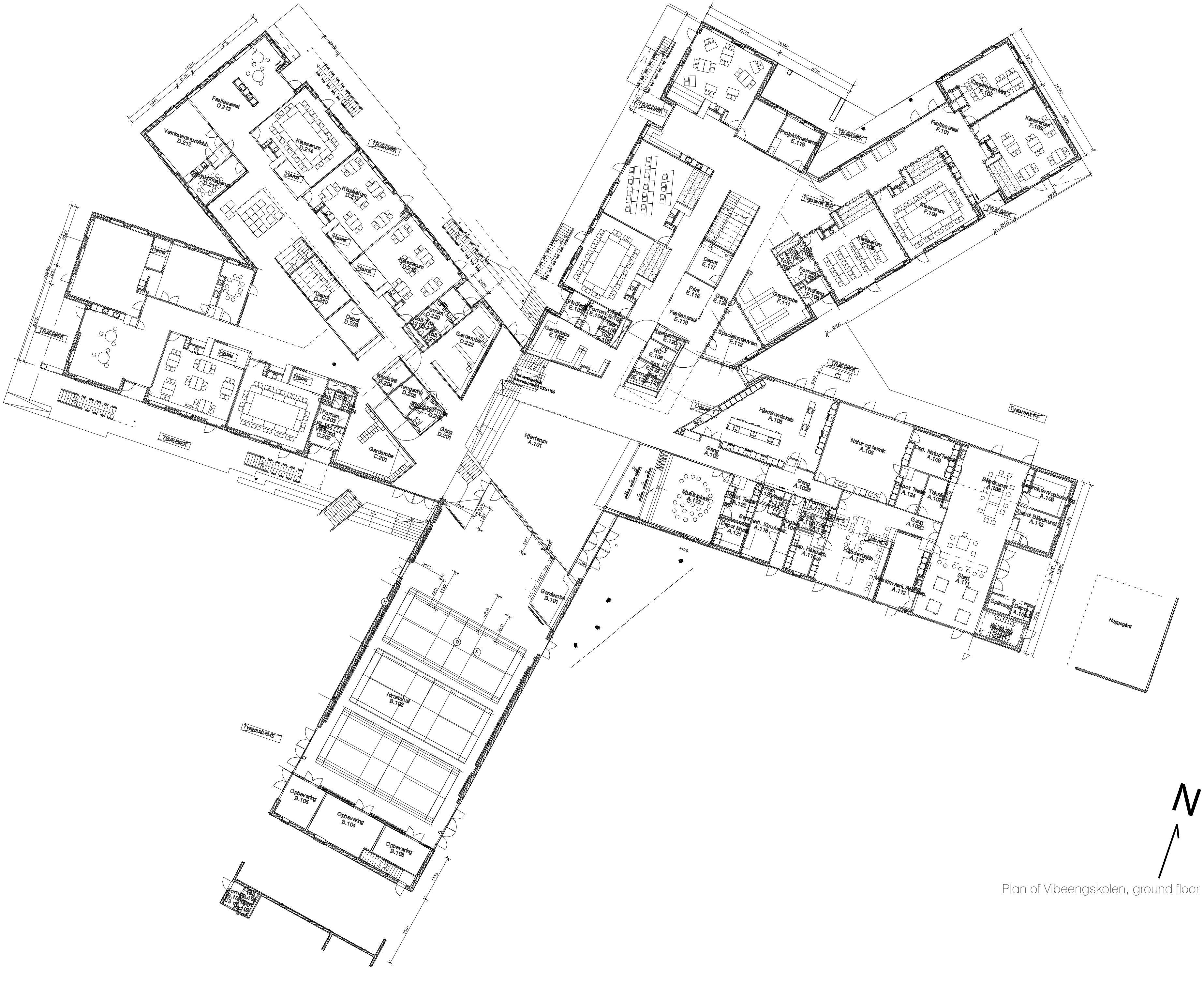
Vibeengskolen is shaped as a star with a big common room in the center and more divided functions in the 6 "legs" meaning all functions is located close to the central common room. The classes for primary school are gathered around a "v-shaped" corridor forming two of the legs, another v-shaped corridor gather the classrooms for the early middle age pupils, and separates them from the younger pupils. Another leg contains the facilities for design and science, the last leg contains a gymnasium (see ill. 30). The two-storey building has a pitched roof that insures the feeling of a low scale building. The strong red color on the facades gives the building a strong identity but also a playfulness that the young users can relate to (see ill. 28).

APPROACH TO THE NEW SKOLEREFORM

Great outdoor facilities are insured with a total outdoor area on 40.000 m^2 including kitchen garden, fruit trees, exercise route, ball areas and playgrounds. There is also a pedagogic ambition of including the outdoor areas as part of the learning environment [Modelprogram.dk, 2014].
There have been a focus on diversification of volumes, division of age and the fact that the students are individuals with different needs. Resulting in classrooms for the youngest pupils with an incorporated loft (see ill. 29), and other classrooms for the older students where stairs and niches are incorporated, so the classrooms offers a variety of different sitting and learning opportunities.

SUSTAINABILITY

To lower the heating demands, the building is shaped with relative compact and deep volumes. Meaning, all the volumes have a depth between 14,3-18,3 m. The pitched roof is a modern variation consisting of smaller rectangles. Here the roof surfaces that are facing towards north are used for roof windows that insure good daylight conditions in the deep volumes, and the surfaces pointing south are used for solar cells (see ill. 27). Vibeengskolen was the first energy neutral (zero energy) primary school in Denmark, and it is possible for the neighbors to use the outdoor areas [Schafranek, 2014].



Plan of Vibeengskolen, ground floor 1:500
Ill. 30

SUBCONCLUSION

The case studies have shown different design solutions and proposals on how architecture can support new teaching methods and learning environments. The proposals that will be a part of the further design process are mentioned below.

-Glare and direct sunlight should be avoided in the classrooms because it can disturb new teaching media.

- Facilities for public use should be placed close to the entrance and if possible on the ground floor

-Offer a variety of work areas both in and outside the classroom. It might be a good idea to offer lofts for the young pupils and sitting stairs and lounge areas for the older students, which both are seen in Vibeengskolen and Skolen i Sydhavn.

- Deep volumes up to 18 meters can be used to lower the heating demands, however skylights might be needed.

- Use highly placed windows in the classrooms to insure good daylight conditions.

- Combine mechanical ventilation with manually and automatically controlled venting to insure good air quality.

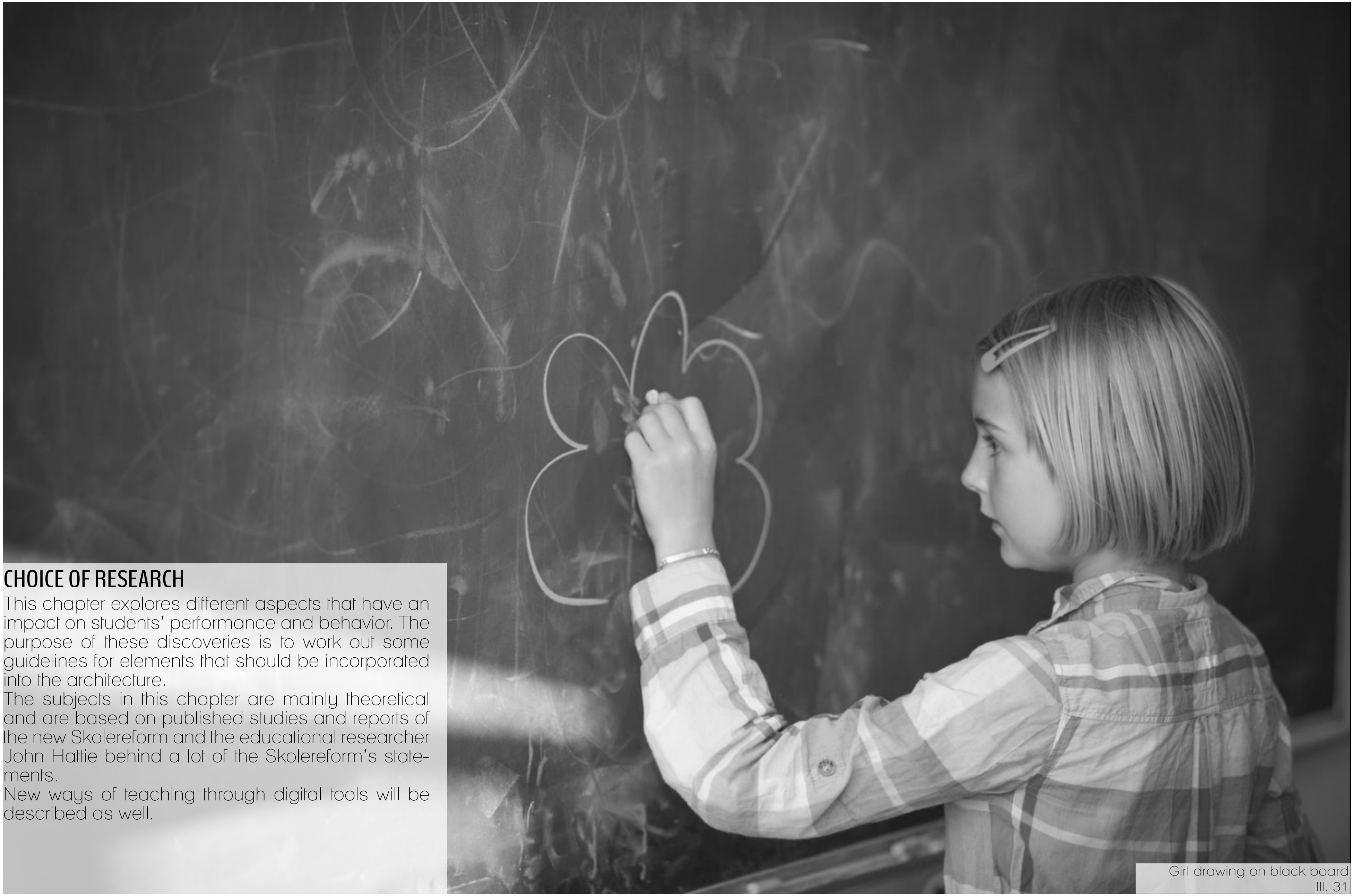
- Division of age levels and reduced numbers of classrooms for the older students can give space for good work areas outside the classrooms.

- Investigate DGNB's instructions of social sustainability and John Hattie's studies to achieve more knowledge that can help set up criteria that will improve the indoor and learning environment.

III

RESEARCH

SKOLEREFORMEN
JOHN HATTIE STUDIES
DIGITAL TEACHING TOOLS
SUBCONCLUSION



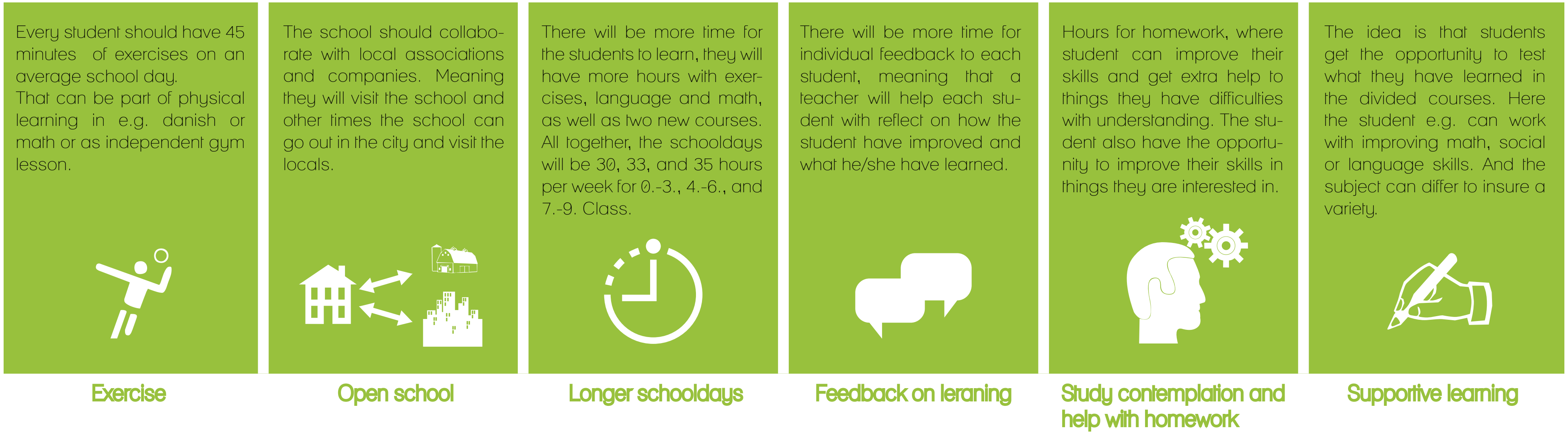
CHOICE OF RESEARCH

This chapter explores different aspects that have an impact on students' performance and behavior. The purpose of these discoveries is to work out some guidelines for elements that should be incorporated into the architecture.

The subjects in this chapter are mainly theoretical and are based on published studies and reports of the new Skolereform and the educational researcher John Hattie behind a lot of the Skolereform's statements.

New ways of teaching through digital tools will be described as well.

Girl drawing on black board
Ill. 31



New elements from the new school reform
Ill.32

SKOLEREFORMEN

The new Skolereform was adopted in the summer 2014. The purpose was to improve the academic level, which is concretized in three goals:

- Folkeskolen has to challenge all students so everyone become as skilled as they possibly can.

- Folkeskolen has to reduce the influence social background have on academic results.

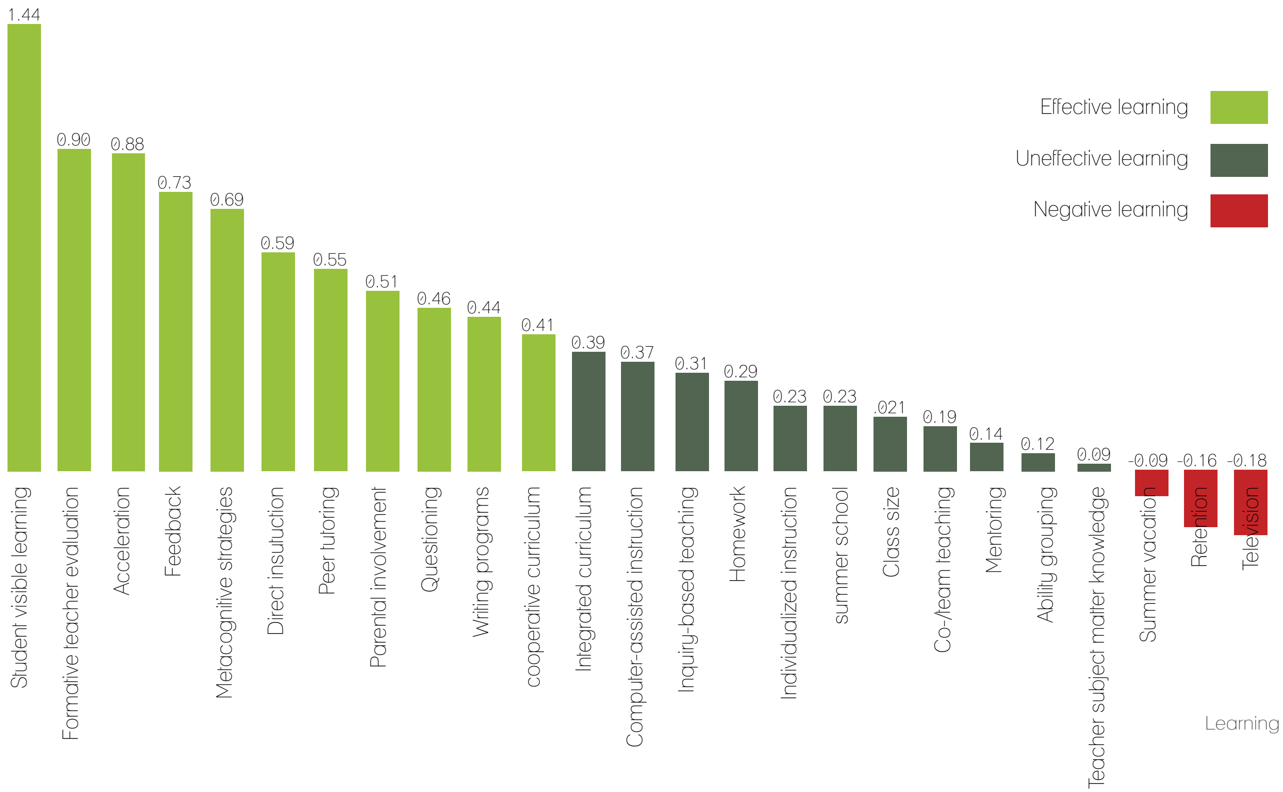
- The trust we put in Folkeskolen have to be stronger, and it should happen through respect for professional knowledge and practice. [Undervisningsministeriet, n.d.].

The approach to achieve these goals is a transformation of the learning and teaching methods into more effective and modern methods, where the school will be focusing more on feedback to the students, visual learning goals and incorporation of IT based learning.

The school will also change physically due to requirements of more time for exercises, longer schooldays, more focus on visiting and inviting local associations and companies in to the school as extern teachers, and a more varying teaching. The illustrations above show the main impact the new school reform have given [Undervisningsministeriet, n.d.] (see ill. 32).

ARCHITECTURAL APPROACH TO THE REFORM

When the new school reform is transformed into architectural solutions, three relevant approaches are found:
It is ideal to include an open indoor area that can gather classes for external lectures and be use for short physical exercises when the weather is too bad to use the outdoor facilities.
The school might choose to combine classes for help with homework and study contemplation. To support this possibility, two classrooms should be able to transform to one big room, e.g. using a folding wall system.
If the students should be as skilled as they possibly can it is essential to have a good indoor climate and an architecture that supports the teaching principles.



Learning efficiency based on John Hattie's studies
Ill. 33

JOHN HATTIE STUDIES

John Hattie is an educational researcher famous for his comprehensive meta study of factors that affect students learning results, this study involves an analysis of 60.000 international studies based on a total of 245 million students and teachers and was published in 2009 [Gymnasieskolen, 2013]. Parts of the results can be seen in the diagram above (see ill. 33).
Hatties studies are not focusing on the architectural environment but on how to improve teaching methods. However, Hattie's studies might also have an indirect influenced on physical environment.

Based on the results, Hattie have concluded that the students should have greater responsibility of their own learning, more feedback, evaluation and be aware of why they are doing what they are doing. He also points out that it is important that the students have a good relationship to the teachers, and that teachers should use more dialog based learning instead of todays learning where the teacher talks 70-80% of the time, and a "fishing" for answers rather than being in a real dialog [Folkeskolen.dk, 2013].

ARCHITECTURAL APPROACH TO JOHN HATTIES

From an architectural perspective it is interesting to see that the size of the class only have a tiny influence, meaning that it might be preferred to have big classes with many student to save space and money. It is also seen that individual feedback and visible learning (where the student can see how much he/she has improved) will have an high influence on the learning results. Therefore, it will be beneficial to have areas where the teacher can talk with smaller groups/individual with the students.
The architecture can also help increasing the student's willingness to participate in dialogs and have a good relationship with the theater, by restricting the institutional expression and creating a homely atmosphere.

Classroom with smart boards
Ill. 34

DIGITAL TEACHING TOOLS

Digital media will be an fundamental part of the Danish school system in the future, this is already made clear by political decisions, the severity of these decisions can e.g. be seen in the period 2012-2015 where an extraordinary allocation of 500 million kr., where given by the Danish Folketing to improve the digital media in Folkeskolen.
The government and KL have also developed specific goals for how to include digital technology in the school system:

- The students have to use digital technology in such a manner so digital media can replace notebooks and photocopies

- There have to be good Wi-Fi conditions everywhere on the schools

- The digital system have to support a BODY (bring your own device) strategy

[Den digitale Vej til fremtidens velfærd, 2011], [IT i undervisning og læring, n.d.]

THE PURPOSE

The purpose of using digital media is a cohesion of; making the education more interesting for the students, improve the children's skills of using digital technologies, and teaching the children on a more individual level so everyone can learn as much as possible. It is also an ambition that the digital media is a visual way to help the student, parents and teacher on evaluate how well the student are improving, and how the student can improve further [Brugerportalsinitiativet, 2015].

STRATEGIES

In 2014 the Danish government and KL made an agreement that every municipality will have to acquire a digital learning platform, here each municipality is free to choose their own system, but the media have to support the goals from the new Skolereform, meaning that leaning goals, and improvements should be visible for the student. There is already several digital learning systems available [Brugerportalsinitiativet, 2015]. The two following sub

Pupils from Essa academy
Ill. 35

chapters will shortly enlightened some of the solutions.

IPADS AND APPLE

Essa academy was one of the first schools to implement Ipads for every students, there are also Apple TVs in classrooms, meaning that it is easy for the teacher and students to show their tasks in a visual way. According to Apple, Essa academy have improved the number of students that pass exams from 28% to 100% and the school saves money because less students needs private teaching and less money are spent on papers and books [Apple.com, n.d.]. However Apples solutions are also criticized for being expensive, and according to the Telegraph many schools have tried to follow Essa's example, but not all of them have succeeded because the teaching strategy and culture did not follow as well. It is also important to mention that Essa academy not only invested in Apple products but also new staff and teaching strategies [Lee, 2015].

SMARTBORDS

Smartboards is a relative expensive solution, but it is also becoming more normal in the Danish schools. There are indications that smartboard have a positive effect on the educations [Tor Arne Wølner, 2012].

SUBCONCLUSION

The Skolenreform's purpose is to improve pupils' learning. To do this it tries to include more students, have daily exercise and implement exercise during teaching. Furthermore, an awareness of how different students learn in different ways will result in a school that has to be suited to comprehend different types of group work, individual work and learning while being psychically active. This demands a flexible school with ever-changing furnishing and spacial layouts, e.g.:

- Two adjacent classrooms should be able to transform to one big room

- Implement a small assembly hall that can gather classes for lectures and exercises

-Creating a homely atmosphere in the classrooms

-Areas where the teacher can talk with smaller groups of students

- John Hattie speaks about new learning methods where teachers rather than normally teaching through one-way communication instead initiates dialogs with the students as a new way to teach. This will lead to less conventional teaching methods where the teacher speaks from a desk to more open environments where the architecture supports moving around in smaller groups.

As digital appliances are used in Folkeskolen, students will now need lockers for their devices, chargers and other relevant electronical equipment.

It is important to minimize the amount of glare disturbing monitors and smart-boards as well.

IV

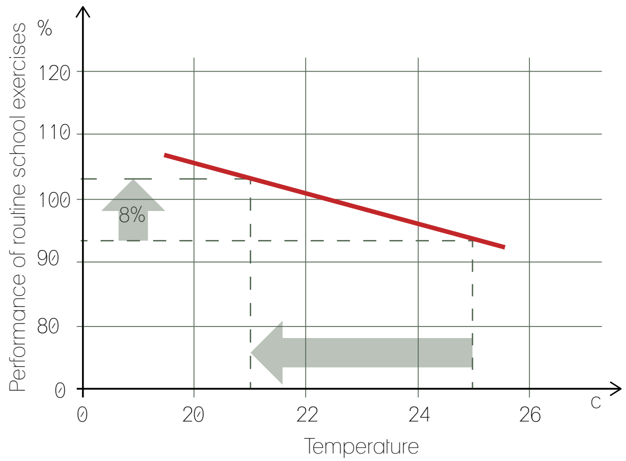
SUSTAINABILITY & ENERGY

AIR QUALITY & TEMPERATURE
DAYLIGHT
ACOUSTICS
DGNB
SOCIAL SUSTAINABILITY
THE EFFECT OF A GREEN VIEW
COLOR'S IMPACT ON PERFORMANCE
ENERGY STRATEGY
SUBCONCLUSION

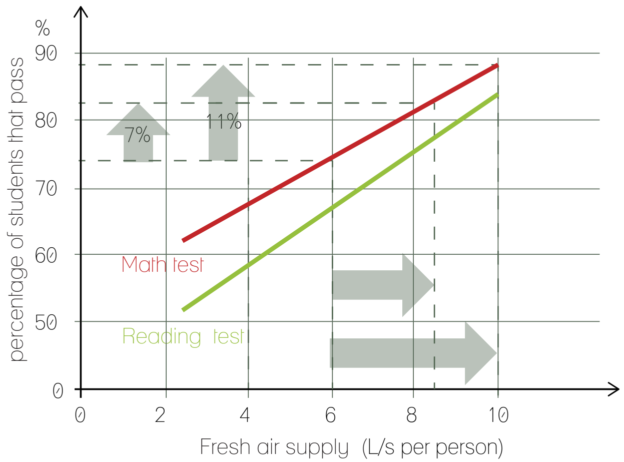
SUSTAINABILITY & ENERGY

With focus on designing teaching facilities with a good indoor environment that can improve the student's performance and wellbeing, this chapter explores how thermal, atmospheric and visual comfort have an important impact. Instead of focusing on the requirements this chapter will use studies and instructions from SBI, DTU and DGNB on how to insure a good environment meaning that these demands often is higher than the official requirements. The sub chapter "Energy strategy" will based on the achieved knowledge develop on a strategy of how the building should meet the high requirements for indoor climate without using too much energy.

Kids playing
Ill. 36



Relation between student performance and temperature
Ill. 37



Relation between students who pass tests and fresh air supply
Ill. 38

AIR QUALITY AND TEMPERATURE

To ensure the students have a good working environment, it is essential to maintain good operational temperature and a good supply of fresh air. Therefore it is important to integrate efficient ventilation systems whether it is natural, mechanical or a combination of these that can maintain good indoor air quality even if the amount of students change during the day [Engelund Thomsen, 2006].

To fulfill BR 20 fresh air need to be provided without causing draft from either natural or mechanical ventilation and in classrooms and have both supply and extraction further more keep a maximum CO_2 level of 900 ppm inside classrooms and offices.

Research published from FOA shows if the ventilation rate is increased from 6 l/s to 10 l/s per person the amount of students who passes tests are increased by 11 % [Clausen, Toftum & Wargocki, 2011]. FOA as well guide to keep a temperature between 20-24°C for light activity, not to exceed 25°C and not below 18°C. [Engelund Thomsen, 2006] Research shows that if the temperature instead is stable in winter periods on 21 degrees the student's performance is raised by 8 % (see ill. 37) [Clausen, Toftum & Wargocki, 2011].
According to DS 1752 different categories has been set up as guidelines to create good thermal comfort. The categories is A, B and C where A is best [DS 1752, 2001].

As category B corresponds to FOA's studies about thermal comfort and performance inside classrooms this will be used, but the project will strive to stay in the low end off the advised temperature guideline.

As (ill. 38) shows the benefit of increasing ventilation rate to 10 l/s per person is substantial. This corresponds to category A as the project will fulfill. This will as well put up demands to the school to implement effective mechanical ventilation and when possible in summer months good strategies for natural ventilation will be used to save energy.

" Research shows if the ventilation rate is doubled from a low level it leads to an increase in performance of school work on ca. 10 percent. It corresponds popular said to those students with good indoor environment in the classroom can save almost one full year of education. – translated quote [Welin, 2014].

Well lit working area
Ill. 39

DAYLIGHT

By designing rooms with good daylight, research shows that children are able to progress 20 % faster in math tests, 26 % faster in reading tests and have 7 % - 18 % higher scores at school [Heschong Mahone Group, 1999].

Natural daylight is an important factor when it comes to performance based professions, although it is an office or a school. As the DS 12464 tells a minimum 300 lux in class rooms is required on workspaces [Lys og Belysning - Belysning ved arbejdspladser - Del 1].

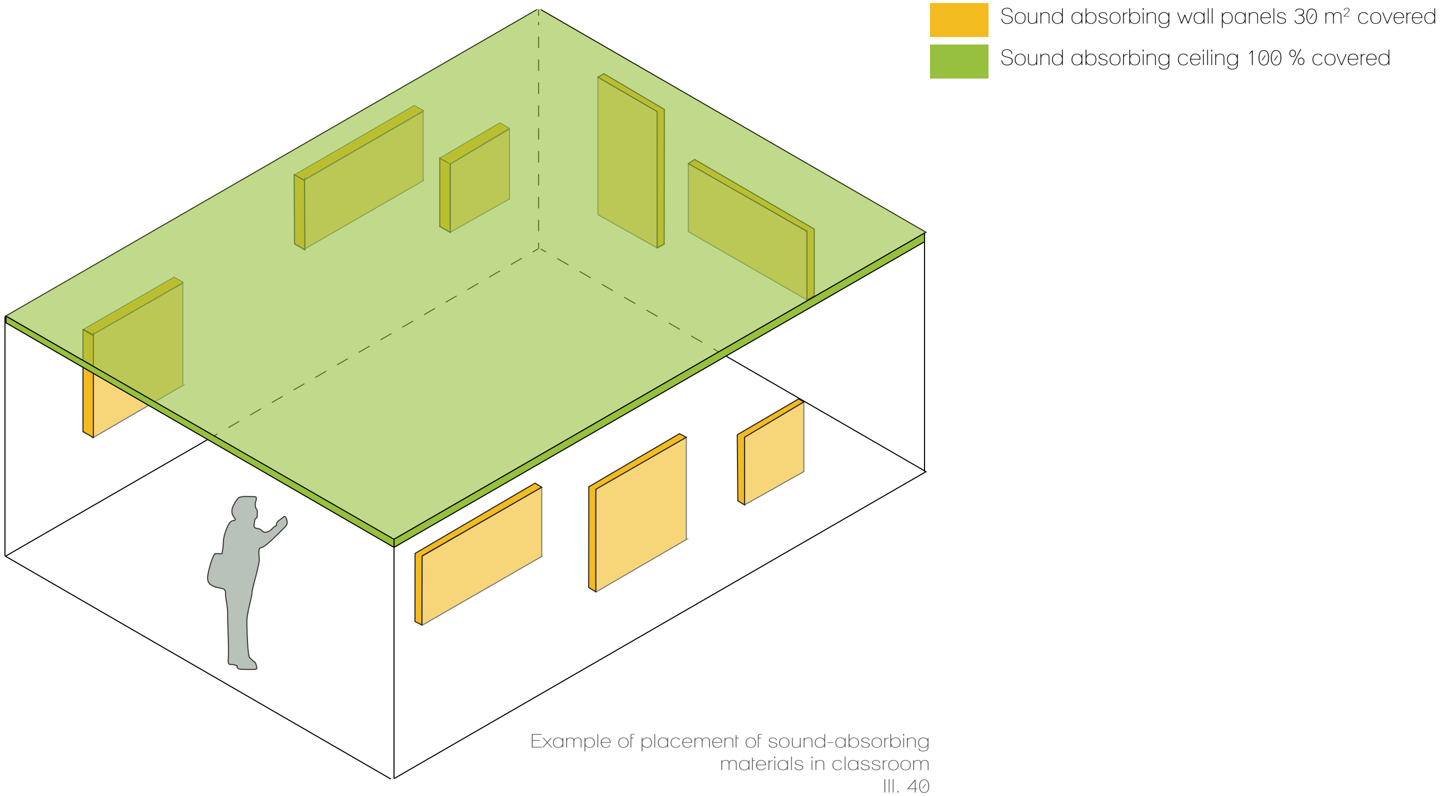
By optimizing the conditions for natural daylight into the classrooms savings on electricity to artificial light is possible. Different rules of thumb can be used when designing rooms to optimized the use of natural daylight:

- Normally 25 % - 35 % glass.
- Investigate possible view from chosen window placement.
- Avoid wide dark areas between windows.
- Divide windows into view window and highly placed daylight windows.
- How can daylight be used without causing troubles with glare and reflections from surfaces and screens

Different strategies to placement of facade windows can be used according to functions of the room. Some of these strategies could be:

- Room illuminated from two sides.
- Divided view window and highly placed daylight window.
- Skylight window.

[Engelund Thomsen, 2006]



Example of placement of sound-absorbing materials in classroom
Ill. 40

ACOUSTICS

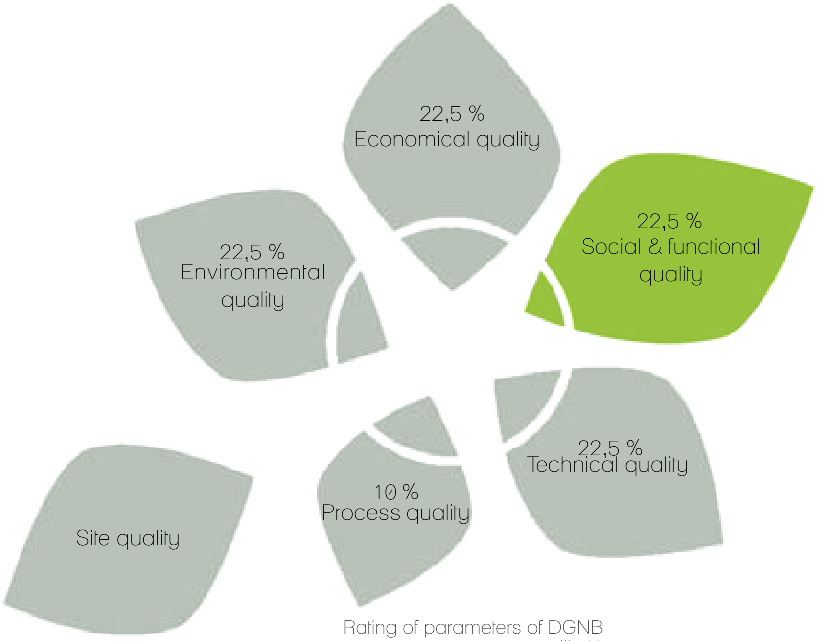
In public school sound conditions are often an issue, with pupils making noise whether it is from playing, talking or moving around the acoustics affect all. To have a good learning environment it is crucial to keep reverberation time low by designing with acoustics in mind.

To fulfill requirements large areas with sound absorbing materials often need to be used, such as acoustic ceiling, sound absorbing floor and acoustic surfaces on the walls. It is recommended to install at least 10-15% sound absorbing material on the wall area to obtain suitable distribution of the sound. (see ill. 40)

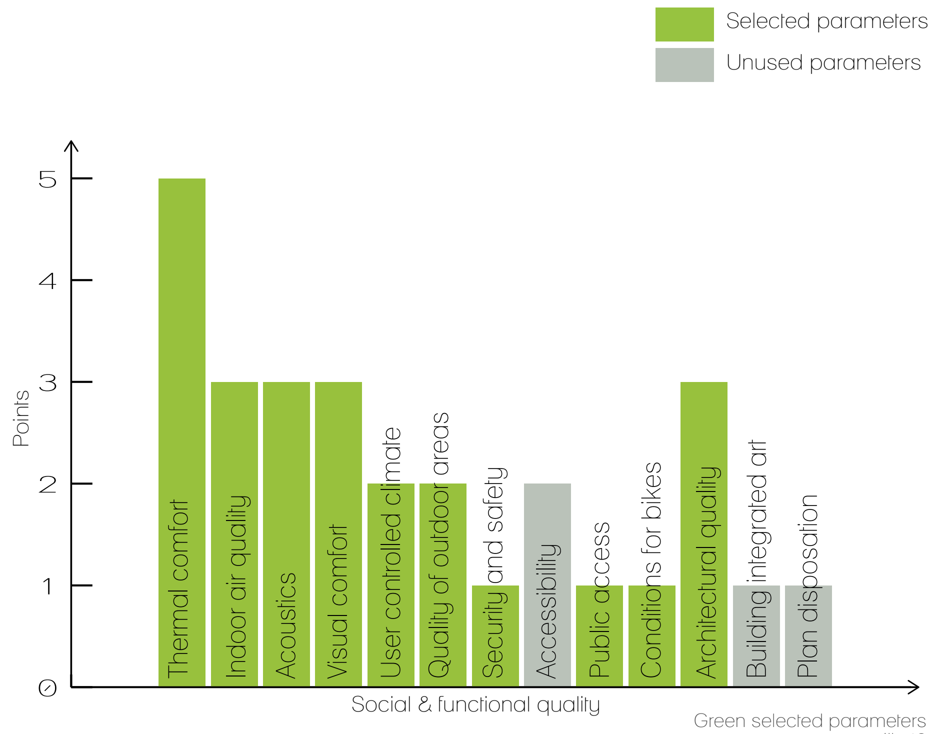
To divide noisy and quiet areas with good sound insulated walls it is important to maintain proper indoor acoustic comfort and learning environment.

By covering large areas with sound absorbing material thermal accumulation can be an issue with less good operational temperature as result. This demands strategies to mostly cover light walls which have lower thermal mass and to expose heavy walls. Therefore it is important to have a holistic balance between acoustic, temperature, energy, light and overall learning environment as pros and cons follow decisions made due to acoustics [Engelund Thomsen, 2006].

As large areas need to be covered by sound absorbing material the interior will be affected. Large surfaces which normally could be used for decorational or teaching purpose has to be covered and there fore thoughtful placement of these elements will be used.
Another factor on acoustics is furniture that absorbs sound and people in general as well contribute to a lower reverberation time.



Rating of parameters of DGNB
Ill. 41



Green selected parameters
Ill. 42

DGNB

DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) is a certification system used to work towards sustainable architecture. It takes its departure in 5 major subjects (see ill. 41), with several subtopics (see ill. 42). DGNB was established in 2007 in Germany and has been translated into a Danish context which mostly is used for pilot green buildings and is the most used certification system for green buildings in Denmark. In this chapter some of the quantitative subtopics will be described and the more qualitative subtopics is more straightforward to work with as principles and guidelines can be followed as examples of how to built.

To build sustainable one as well need to take social parameters into consideration. DGNB has as one of five parameters scheduled how and what a building should fulfill in social aspects to be able to be certified. In the social category it is shown how the different topics is rated. This social subtopic is as well divided into health, comfort and user satisfaction, functionality, aesthetics and plan disposition.

The thermal comfort is a crucial parameter to secure health and satisfaction for the user, whatever it is at home, at the job or in school. Therefore it is an important, highly rated, aspect to secure the general impression of the building and the building's construction.

The thermal comfort is measured on 4 different criteria; operative temperature that cannot exceed 25,5⁰C more than 50 hours a year, draft for natural and mechanical ventilation, radiation and floor temperature and the humidity.

Indoor air quality has to stay below 1000 ppm on CO_2 level to ensure health and well-being.

Visual comfort determines how the daylight has to be in the building. Sunlight have a huge impact on human well-being both on a physical and psychological level. By having a daylight factor of 3% in 80% of the work area grants the building full points [Green building Council Denmark, 2012].

Kids playing music
Ill. 43

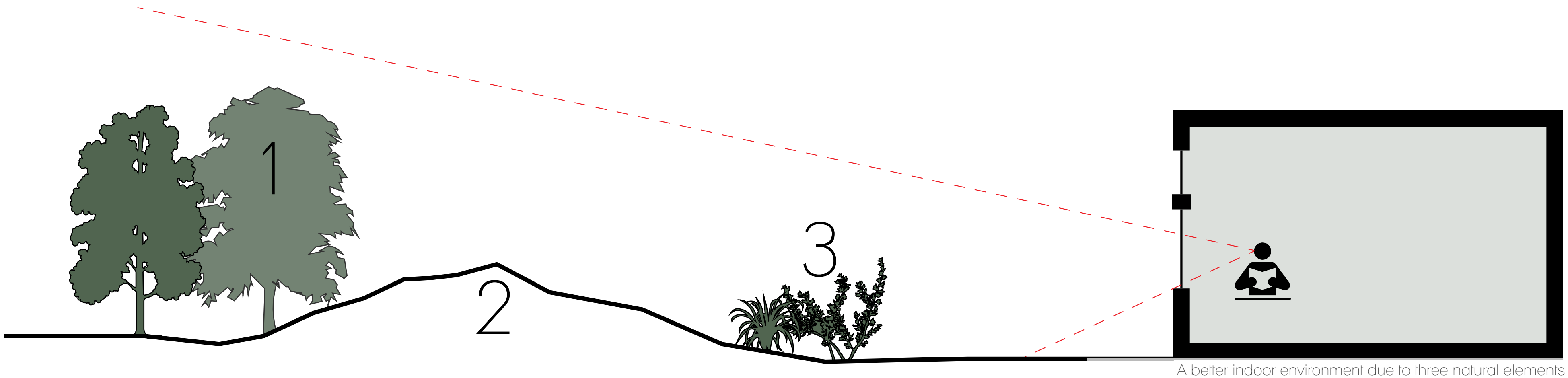
SOCIAL SUSTAINABILITY

When sustainability often is measured in firm numbers and diagrams it is as well important to design with the more soft values in a social and human approach. As most psychically needs and pleasure are measured social needs need to be described more as principles to be followed.

One of human basic needs is the need for safety. If safety and security are not present, it's hard to feel comfortable. To design spaces people like to occupy and stay is important. Proper illumination of paths, roads and hallways and clearly divided areas create the feeling of safety and prevent the chances of assaults. If accidents happen it is comforting to know that help is within reach this as well gives a feeling of safety [Green building Council Denmark, 2012].
Visual well-being is also rated as a social aspect to fulfill human comfort. Building integrated art and art on site contribute to the feeling of visual wellbeing [Green building Council Denmark, 2012].

To obtain social sustainability for a school the functions in the school need to be adaptive and flexible to accommodate different needs. The flexibility needs to work in different ways e.g. flexibility during the day when different people with different intensions use the space, and the flexibility to completely change the function for a room e.g. from a classroom to an open office space. A school sports hall might as well be used for concerts, card game club or other functions that demands different setup in furnishing or spaces. This way of using buildings outside normal work hours and possibly integrate public facilities utilize buildings in a much better and more sustainable way [Green building Council Denmark, 2012].

With departure in the principles stated in DGNB, safe areas with easy access and clearly legibly will be worked out and the use of the school outside normal school hours will be embedded in the layout of the building.



A better indoor environment due to three natural elements
Ill. 44

THE EFFECT OF A GREEN VIEW

Studies have shown, when implementing just two or three elements of nature (it can be some few trees, a bit of landscape, and sight of vegetation), there will be fewer ailments, higher satisfaction with the view [Kaplan, 1993], higher job satisfaction, and higher odds of delivering a high work performance in general [Lottrup, 2012]. It as well shows, that as long as these natural elements are represented in the view, buildings and park lots can also be implemented without causing a negative effect [Kaplan, 1993]. However, the positive effects are most prominent if the elements of vegetation appear as "wild nature". Meaning that a flat and mowed lawn will not have the same qualities as a small hill or wild vegetation [Lottrup, 2012].

It is important to mention, that the studies are based on office environments, and might not be directly used for school environments. However, there are good reasons to believe the results should be almost similar due to the similarities of the two working environments.

Cool colors	Blue	+ loyalty, trust, intelligence, security − coldness, fear, masculinity	Green	+ money, growth, freshness, healing − envy, jealousy, guilt	Purple	+ royalty, ambition, luxury, spiritual − mystery, moodiness
Warm colors	Red	+ love, passion, heat, strength − anger, danger, warning	Yellow	+ sun, creativity, intellect, happy − irresponsible, unstable	Orange	+ courage, success, friendly − ignorance, sluggishness
Neutral colors	Gray	+ security, solid, reliability − gloomy, sad, conservative	White	+ purity, fresh, easy, clean, innocence − winter, cold, distant	Black	+ protection, dramatic, classy, formality − death, evil, mystery

Colors impact on emotions
Ill. 45

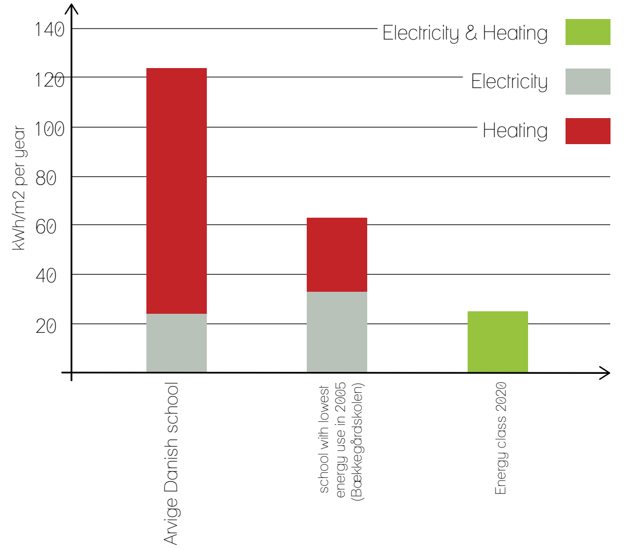
COLOR'S IMPACT ON PERFORMANCE

Research has shown a clear impact on the performance on offices workers when colors differ on the walls. This research is based on offices work, but as school work is performance based as well some key elements is extracted and will be implemented in the design of the school.

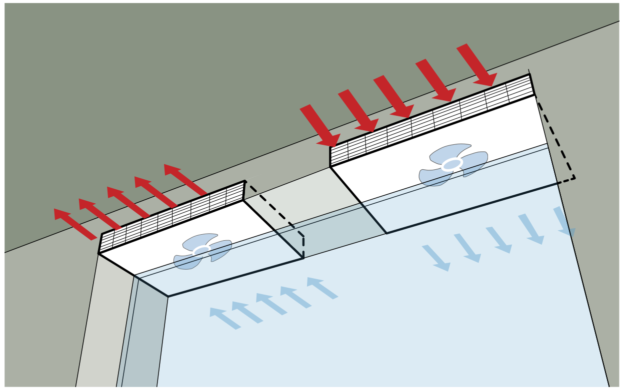
Performance of tests and writing where analyzed in three similar offices with only the color on the walls in difference. One office with white, one with blue and green and one with red color on the walls.
Persons were divided into high and low screener individuals. High screeners are people who learn and work better in environment with external stimuli in comparison to low screeners who work better in environment with little external stimuli [Kwallek, Soon and Lewis, 2007].
The research shows that the performance varied for high and low screeners when they work in rooms with different colors. High screeners performed better in the white and the red office and low screeners better in the blue and green office.
As red activate the brain to increase human receptiveness to external stimuli the high screeners performed better here. The blue and green office had the opposite effect with blue invoking a calming effect, which helps people to concentrate on the task at hand and green with contractive properties, meant that low screeners performed better here [Kwallek, Soon and Lewis, 2007].

However colors also have other pros and cons (see ill. 45) depending on high or low screeners. Blue makes rooms feel more private and calming and green soothing the feelings.
In general blue and green colors, like most colors in nature, help people focus in learning environment and improve efficiency [Kwallek, Soon and Lewis, 2007].

Depending on function and purpose of functions the corresponding colors which improve e.g. psychical activity outdoor and in exercise will benefit from having red color. Classrooms and relax areas will benefit from green and blue colors to improve concentration and perception.



Energy use for Danish schools in 2007
Ill. 46



Principle for InVentilate's mechanical ventilation with heat recovery
Ill. 47

InVentilate placed over window, seen from inside
Ill. 48

InVentilate placed under window, seen from outside
Ill. 49

ENERGY STRATEGY

Due to future prospects of the building, it is decided that the building have to fulfill the energy demands for building class 2020. Resulting in a total energy use of no more than 25kWh/m2 per year, including electricity for lighting (however, a subsidies will be given when e.g. high ventilation or lighting is needed, the subsidies will be dimensioned after SBI 213) [BR 7.2.4.3]. The approach of this project is not only to meet the energy frame but also ensure a good indoor environment for learning. To fulfill this ambition, the energy strategy is divided in thee focus points: ventilation with low energy use, avoid overheating but still allow a high daylight factor, and economic amount of insulation.

VENTILATION WITH LOW ENERGY USE

Based on previous studies, mentioned on page 35, it has been decided to use an air change on 10 l/s per student. Meaning that most of the operating costs will be spent on ventilation. Therefore, it is important to use an effective ventilation strategy. Our aim for the summer season is to use as much natural ventilation as a good indoor environment can allow, but in periods mechanical ventilation might be needed due to issues with draft and wind speed. Doing the winter season InVentilate mechanical ventilation system with a heat recovery of 86 percent, and an energy use of 271-300J/m3 will be used the entire time. InVentilate, will in this case will be boxes of 107 cm wide x 8,2 cm high that have to be placed directly in an exterior wall and can deliver 40 l/s per unit (see ill. 47 and appendix 4). This solution does not uses any pipes meaning thickness of deck can be decreased with approximately 50 cm. InVentilate is a sustainable mechanical ventilation due to few materials for production, low cost of installation and low operational energy use. However the openings will normally be visible both inside and outside the building, so to avoid an unwanted and disturbing expression InVentilate have to be a part of the design process.

To ensure the right amount of natural ventilation doing the summer season, a CO_2 and temperature sensor will automatically control units with openable windows. To avoid problems with burglary and peo-

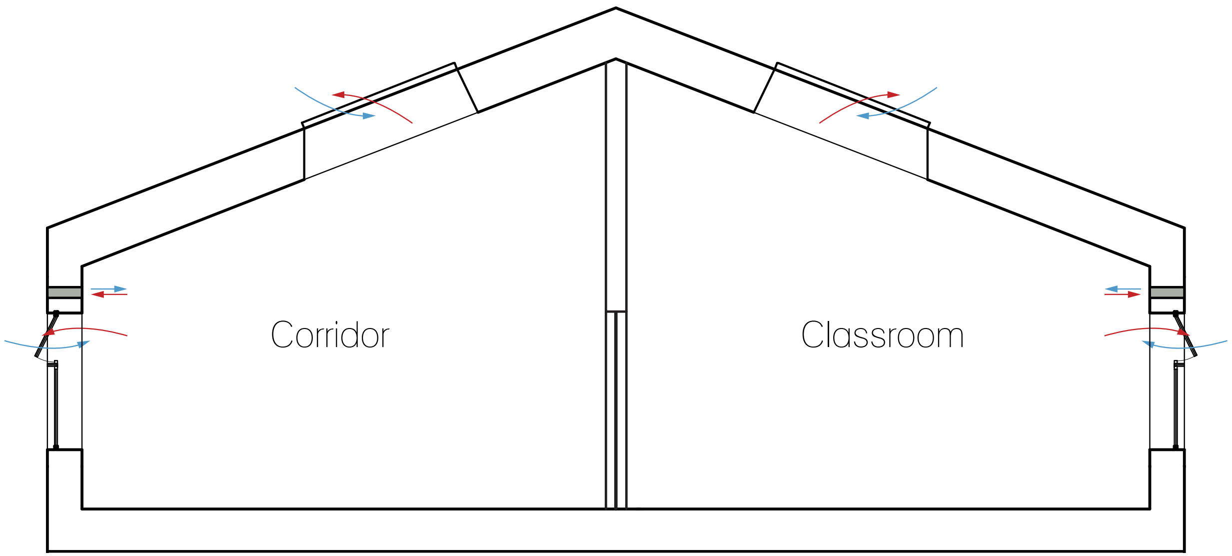
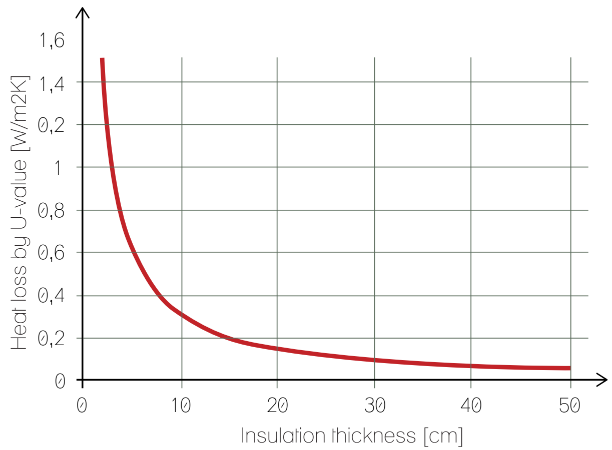


Diagram of ventilation principles
Ill. 50



Efficiency of mineral wool
Ill. 51

ple falling out of the windows, these units will be slim and highly placed (see ill. 50). A placement just under the ceiling will also minimize problems with draft because the wind speed will be reduced before it drops into the climate zone. It will also be preferred to have a manually controlled window in each room, so the users have the opportunity to influence the indoor climate. By having this user control the user satisfaction will increase as well.

ECONOMIC AMOUNT OF INSULATION

The efficiency of insulation is exponential, meaning that adding more insulation according to lower the heating demands is only beneficial to a certain point (see ill. 51). The optimal amount of insulation will differ according to the buildings use and shape, and will therefore be optimized when the shape of the building is decided, by using Be10 simulations.

SUN SHADING THAT ALLOWS A HIGH DAYLIGHT FACTOR

Due to high internal gains and the irritating effects of glare, direct sunlight should be avoided in the classrooms. However, a high amount of daylight is still preferred because it improves the working environment and can reduce the use of electric lighting. Unfortunately shading devises will lower the daylight factor, therefore as a strategy it is chosen that all classrooms should be facing north

It requires attention and skills to design the glass areas facing east, west and south. The goal is to get interesting views form the inside and good indoor daylight conditions but doing it with a limited amount of glass so overheating is avoided. Here BSim and Be10 will be used as assisting tools.

SOLAR CELLS FOR OWN USE

Due to Danish regulations, public buildings are not allowed to sell electricity to a NET system [(Ingeniøren, 2013)]. Seen from an economic perspective it is very unbeneficial and unsustainable to build a public zero energy building, or to use large amount of solar cells. However, it can still be beneficial to have a smaller amount of solar cells because the school always have some electricity spending, due to mechanical ventilation and digital teaching.

SUBCONCLUSION

With rising global demands for social and environmental sustainability, new technologies and strategies need to be integrated in the earliest parts of the design phase in order to fulfill future demands for low heat loss, total energy use (25kWh/m2 per year) and indoor environment by fulfilling DS1752's category A for atmospheric comfort and category B for temperature.

The use of hybrid ventilation will affect both the technical devices and visual expression of the school. DGNB's guidelines of how to ensure safe and comfortable areas through clear partitioning of functions and well-lit occupation areas will be used.

Daylight and acoustics are key elements in a proper functioning classroom. A daylight factor of at least 3 percent in workspaces is set as a criteria, which contributes to a good view of the outdoor scenery as well. Acoustic materials on the floors, walls and ceilings will bring down reverberation time by covering at least 10 % of the walls with acoustic panels.

Research into how colors like blue and green can increase performance-based tasks like teaching sessions and tests in classrooms will be applied and red applied to physical activity areas.

V

ROOM DISPOSITION

ROOM PROGRAM
FUNCTION DIAGRAM
VISION

ROOM DISPOSITION

The functions, their sizes and quantity are based on the original room program for Skolen i Sydhavnen from 2007, which is a program for a two lined school with 500-600 students and 80 teachers. Factors such as light, air flow rate and CO2 level are based on the preceding chapter. With focus on creating the best environment in classrooms, while other functions primarily are following category B and the building regulation.

Looking through window
Ill. 52

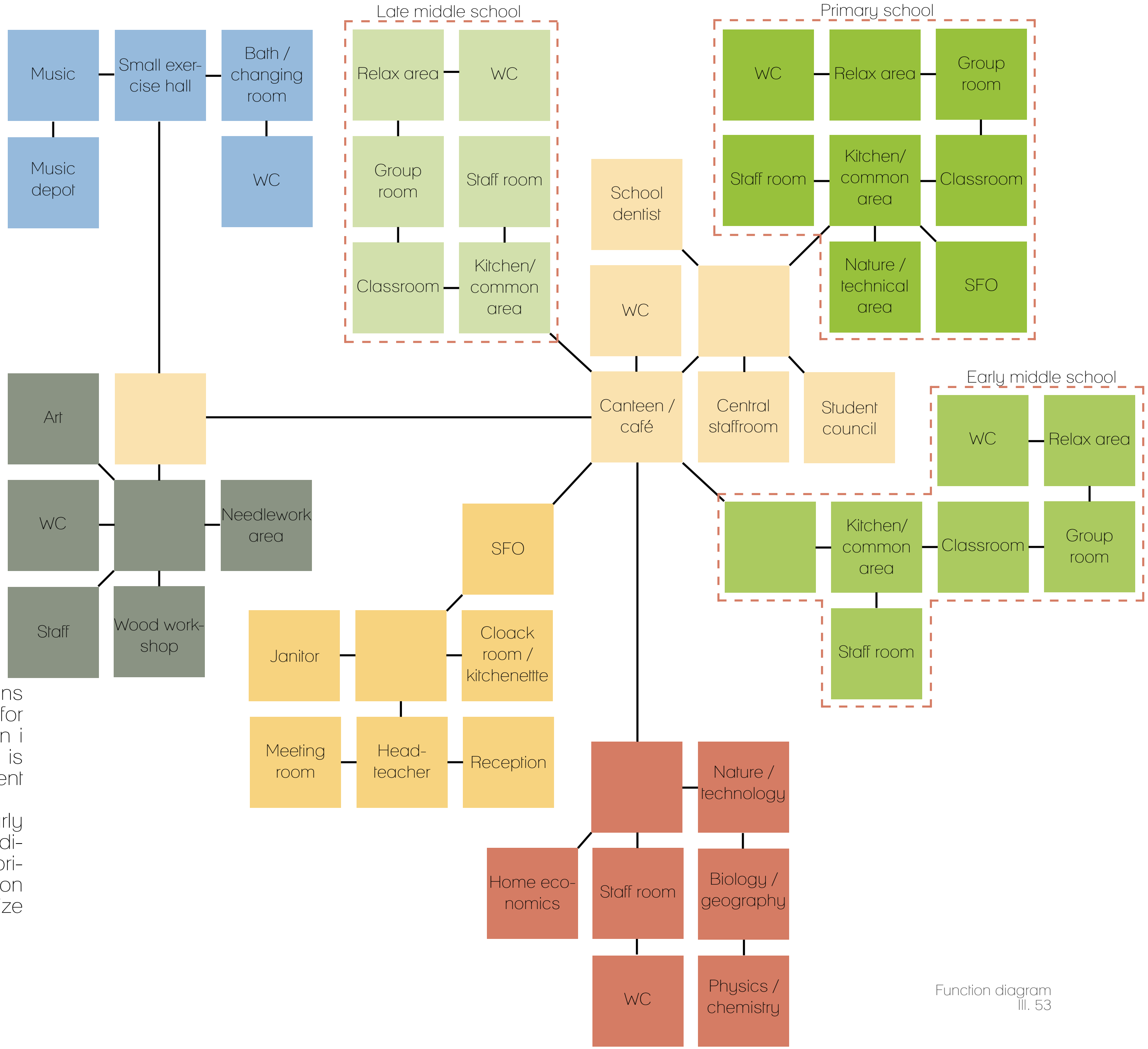
	Function	Area	No.	Area sum	Operating temperature		CO2 Niveau	Air flow rate		Daylight factor	Light level	Optimal orientation	Desire of sunlight
		m2		m2	winter	summer	ppm	l/s pr. m2	l/s pr. person	%	Lux		
PRIMARY SCHOOL													
1.1	Classroom	60	8	480	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
1.2	Group room	20	4	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
1.3	Kitchen / Common room	40	2	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
1.4	Nature / Technical area	80	1	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	N/A
1.5	Decentralized staff room	30	1	30	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
1.6	Relax area wich locker & wc	30	9	270	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	Desired
1.7	Depots (for materials)	15	8	120	-	-	-	-	-	-	-	-	Not desired
1.8	Receiving room for SFO	20	1	20	20 - 25*	23 - 26*	-	-	-	-	-	-	Desired
				1140									
EARLY MIDDLE SCHOOL													
2.1	Classroom	60	6	360	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
2.2	Group room	20	4	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
2.3	Kitchen / Common room	80	1	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
2.4	Decentralized staff room	30	1	30	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
2.5	Relax area wich locker & wc	30	6	180	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	Desired
2.6	Depots (for materials)	15	6	90	-	-	-	-	-	-	-	-	Not desired
				820									
LATE MIDDLE SCHOOL													
3.1	Classroom	60	3	180	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
3.2	Group room	20	4	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
3.3	Kitchen / Common room	80	1	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
3.4	Decentralized staff room	30	1	30	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
3.5	Relax area wich locker & wc	30	6	180	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	Desired
3.6	Depots (for materials)	15	6	90	-	-	-	-	-	-	-	-	Not desired
				640									
SCIENCE FACILITIES													
4.1	Biology / Geography area	80	1	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
4.2	Physics / Chemistry area	80	1	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	Not desired
4.3	Nature and technology	80	1	80	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
4.4	Home economics	80	1	80	20 - 24*	23 - 26*	900¨	(20 l/s)¨	10**	3″	300	N	N/A
4.5	Decentralized staff room	30	1	30	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
4.6	Depots (for materials)	20	6	120	-	-	-	-	-	-	-	-	Not desired
4.7	WC	20	1	20	-	-	-	(10 l/s)¨	-	-	-	-	N/A
				490									

	Function	Area	No.	Area sum	Operating temperature		CO2 Niveau	Air flow rate		Daylight factor	Light level	Optimal orientation	Desire of sunlight
		m2		m2	winter	summer	ppm	l/s pr. m2	l/s pr. person	%	Lux		
DESIGN													
5.1	Art (dry / wet area)	80	2	160	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
5.2	Wood workshop	40	1	40	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	N/A
5.3	Needlework area	40	1	40	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	N/A
5.4	Decentralized staff room	30	1	30	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
5.5	Depots	15	4	60	-	-	-	-	-	-	-	-	Not desired
5.6	WC	20	1	20	20 - 24*	23 - 26*	900¨	(10 l/s)¨	-	3″	300	-	N/A
				350									
MUSIC & EXERCISE													
6.1	Music	80	2	160	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	-	N/A
6.2	Depots (music)	10	2	20	20 - 24*	23 - 26*	-	-	-	-	-	-	Not desired
6.3	Small exercise hall	150	1	150	17 - 24*	23 - 26*	900¨	-	10**	-	300	-	N/A
6.4	Bath / changing room	20	2	40	20 - 24*	23 - 26*	-	(15 l/s)¨	-	-	-	-	N/A
6.5	Depotes (exercise hall)	15	1	15	-	-	-	-	-	-	-	-	N/A
6.6	WC	20	1	20	20 - 24*	23 - 26*	-	(10 l/s)¨	-	-	-	-	N/A
				405									
ADMINISTRATION													
7.1	Headteacher	20	1	20	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	N	N/A
7.2	Reception with 4 secretaries	50	1	50	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	N	Not desired
7.3	Janitor	10	1	10	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
7.4	Meeting room	20	2	40	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	N	Not desired
7.5	Cloakroom / kitchenette / wc	30	1	30	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	-	N/A
7.6	SFO (youth center) Chef	20	1	20	20 - 24*	23 - 26*	900¨	0,7*	7¨	3″	300	N	N/A
				170									
8.1	Central staffroom	60	1	60	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
8.2	Student council	20	1	20	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
8.3	School dentist	200	1	200	20 - 24*	23 - 26*	900¨	0,7*	10**	3″	300	N	N/A
8.4	Canteen / café	180	1	180	20 - 24*	23 - 26*	900¨	0,7*	10**	-	300	S,E,W	Desired
8.5	WC	20	2	40	20 - 24*	23 - 26*	-	(10 l/s)¨	-	-	-	-	N/A
8.6	Depots (for materials)	20	6	120	-	-	-	-	-	-	-	-	Not desired
8.7	WC	20	1	20	20 - 24*	23 - 26*	-	(10 l/s)¨	-	-	-	-	N/A
8.8	school library	200	1	20	20 - 24*	23 - 26*	900¨	0,7*	10**	-	-	-	N/A
		840											
Gross area sum:				4855									

*Category B **Category A ¨BR20 ″DGNB

FUNCTION DIAGRAM

- Other functions
- Primary school
- Early middle school
- Late middle school
- Music & exercise
- Design
- Administration
- Science facilities



This function diagram describes how functions need to be located to fulfill practical requirements for the school's disposition. With departure in Skolen i Sydhavnen's room program a functional layout is worked out, where the canteen is the central element with sub sections around it.
The three primary school phases, primary-, early middle and late middle school is connected with direct access to the canteen as a focal point. Each primary phase does as well center around a common area where pupils from different ages can socialize or find relax- and group rooms for contemplation.

Function diagram
Ill. 53

VISION

To create The School of Tomorrow for Aalborg municipality through research of the new Skolereform and pedagogical aspects behind kids' ability to learn, which will help students improve their academic level by way of architecture that supports social well-being and environmental sustainability.

VI

PRESENTATION

MASTER PLAN
CONCEPT
PLANS
FLOW
PRIMARY SCHOOL
EARLY MIDDLE SCHOOL
LATE MIDDLE SCHOOL
HEART ROOM
SCIENCE
DESIGN
SECTIONS
FACADES
MATERIALS
INDOOR CLIMATE & CONSTRUCTION

PRESENTATION

This chapter will present the final design proposals for a new school in Gigantiumkvateret, Aalborg. Through visualizations, concept diagrams, plans, sections, facades and principal drawings the functionality, spatial qualities and flow is presented.
Starting with the overall master plan and concept then followed by immersing into the branches and specific areas of the building the proposal will be presented.

Three girls
Ill. 54

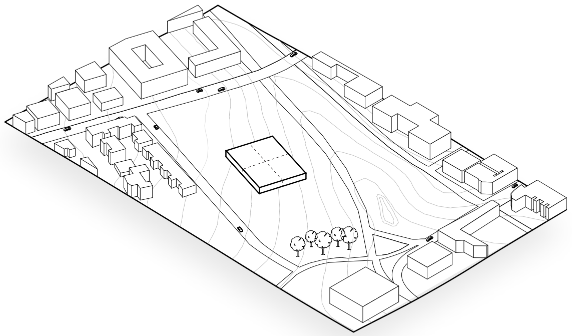

Entrance
Ill. 55

MASTER PLAN

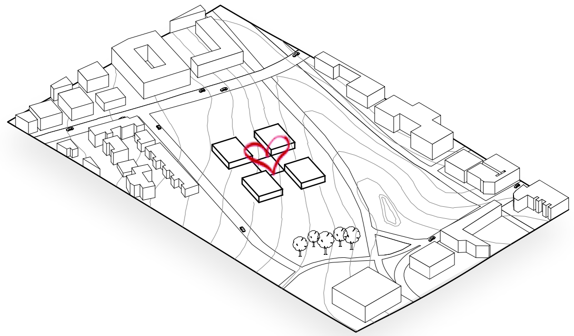
The School of Tomorrow illustrates a proposal of a public school in the city area Gigantiumkvarteret in Aalborg. Skolereformen with focus on psychical activity for the pupils and diverse learning techniques for each student is reflected in the building.

Master plan
Ill. 56

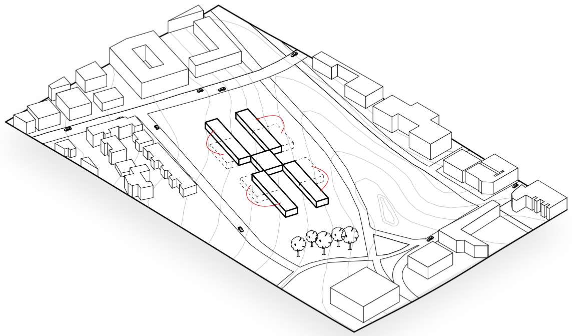
CONCEPT



Total building area placed on site



Creating heart room

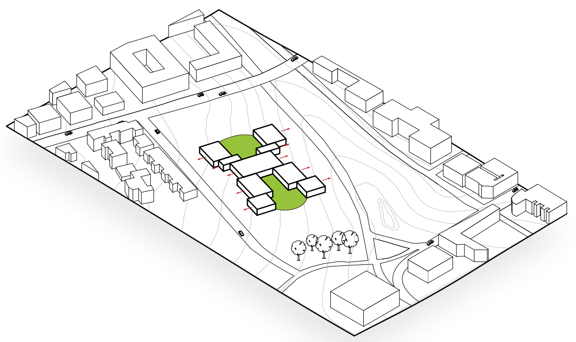


North orientation

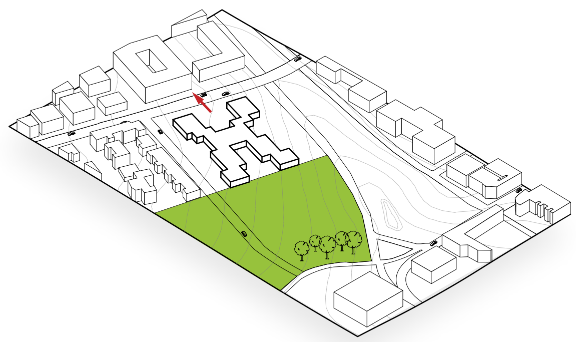
The school's total square meters of 5.000 m2 is placed on the big 25.000 m2 site leaving a lot of the area open for outdoor recreational space. To respect the context in Gigantiumkvarteret the building follows the other building line directions in the area.

The heart room will contain the café, multi hall and library and be the natural room for gatherings in the school for pupils and larger events. The other functions are divided around the heart room.

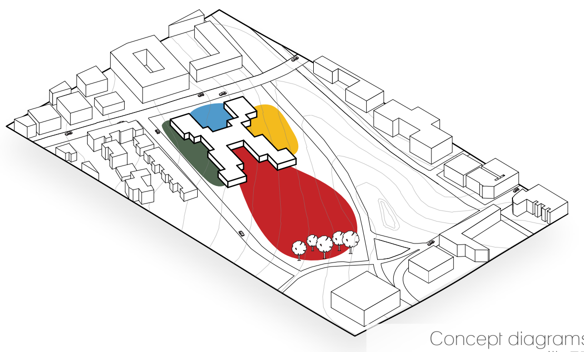
Due to optimize the amount of classrooms with an optimal orientation, with little direct sun to avoid glare and overheating, a bigger north orientated facade is created. South orientated facade for relax and group areas is as well created. Slimmer volumes where sunlight is able to illuminate the functions inside but still compact to reduce building envelope contributing to lower heath loss is made.



Opening courtyards



Align with context



Concept diagrams
Ill. 57

Dividing outdoor areas

By opening the narrow spaces, between the branches, new green playgrounds shielded from three sides is made. The different displacements of the blocks create a diverse exterior look and dynamic hallways with opportunity for niches and relax areas inside the school.

The school is moved west to underline the new Gigantiumkvateret building lines and continue the recreational space in the plan. The school will shield from Einsteins Boulevard and make a large schoolyard towards east.

From the displacement of the volumes new embraced rooms are created, suitable for the different levels of ages in the school to occupy in break hours. Thomas Manns Vej will serve as entry point and drop-off place due to its slower pace

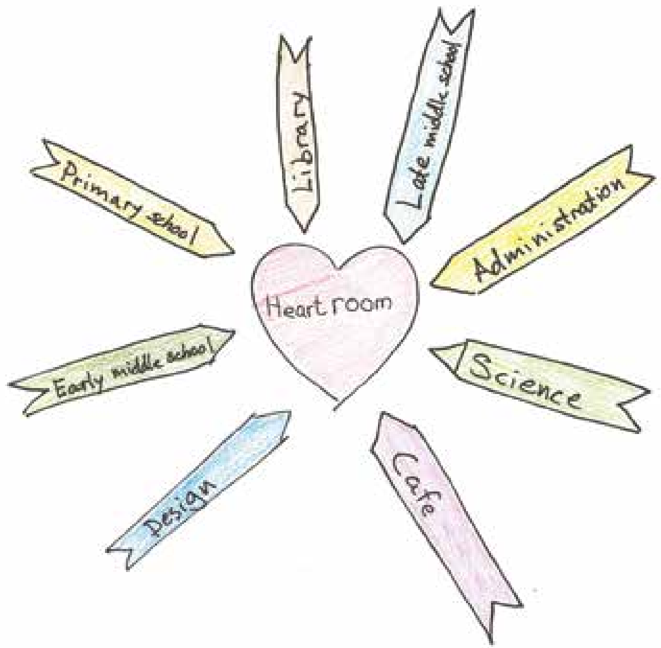


Diagram for functions connected to central heart room
Ill. 58

PLANS

The plan is divided into branches with primary school located in the north east part of the school, early middle school and design in the south east part, late middle school in the north west part and science in the south west part. As departure in the common heart room with the café, library and multi hall as main areas of gathering other functions has been attached to this room (see ill. 58). From each branch there visually connection to the hearth room is established. Besides classrooms, each branch features quiet group rooms, relaxation niches, a small kitchen and access to outside.
When entering the main entrance one will be directly in the center of the building with an open library and multi hall in front and science and design exhibitions to both sides. As the space branches out to four areas it is easy to get an overview of the building from this point. The multi hall and café will be the natural center of life and invite people to take part whether one wishes to observe or participate in activities.

Most public functions are located in close contact to the entrance and give easy access to these when rented out for e.g. local cooking courses or music rehearsals.

The students will have great effect on the expression of corresponding branch as exhibitions are located in the beginning of every area and show off students work at the school.

Throughout the school the classrooms are located towards the north leaving space towards south for recreational purpose, group rooms, relax areas and offices.

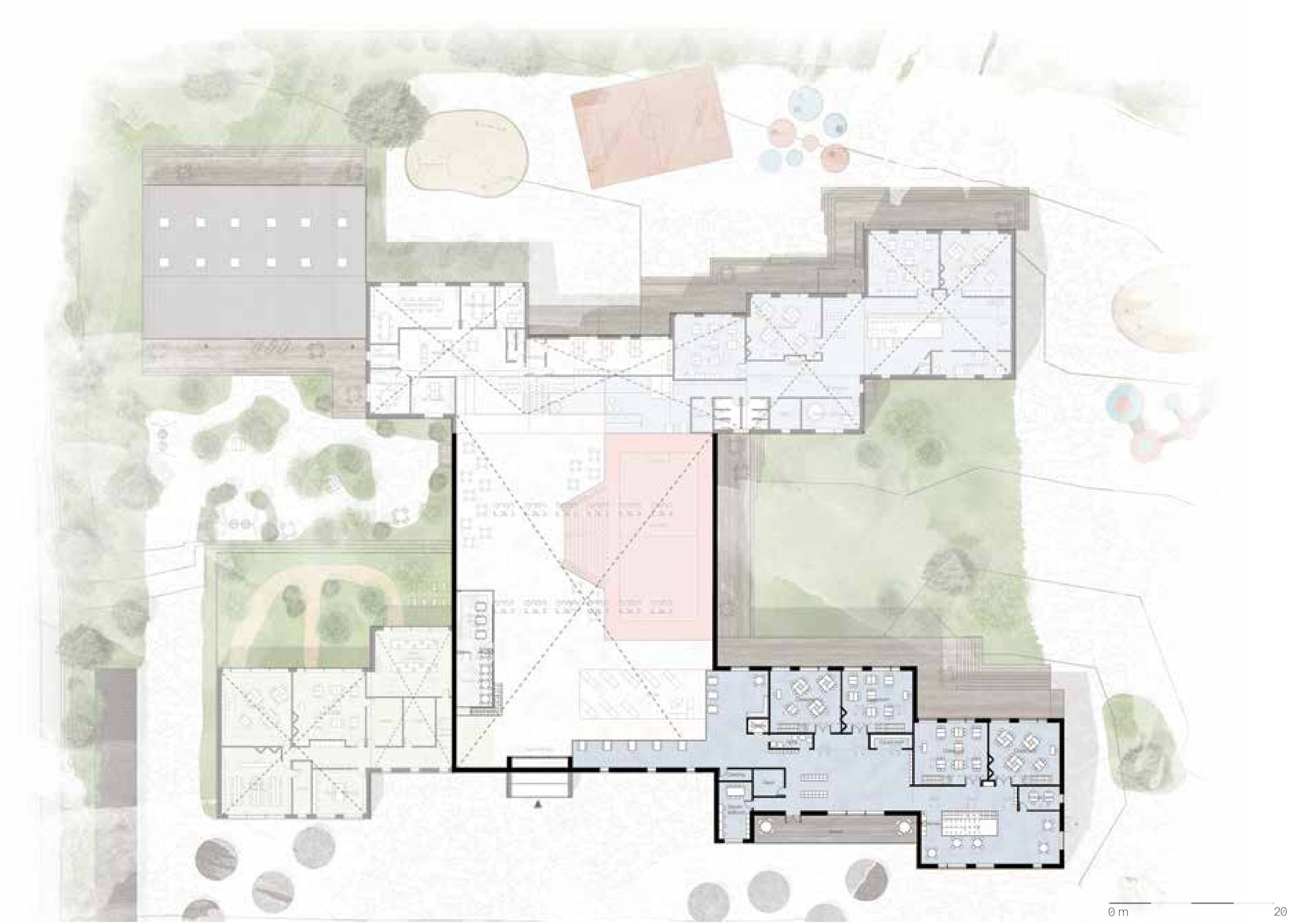
Each branch has assigned a floor color to create playfulness and identity. The colors are a chosen to support the atmosphere and functionality in corresponding branch.

Ramps and elevators are installed around the school to secure good access.
Fire emergency routes and exits has been secured throughout the building (see appendix 7).

Ground floor
Ill. 59

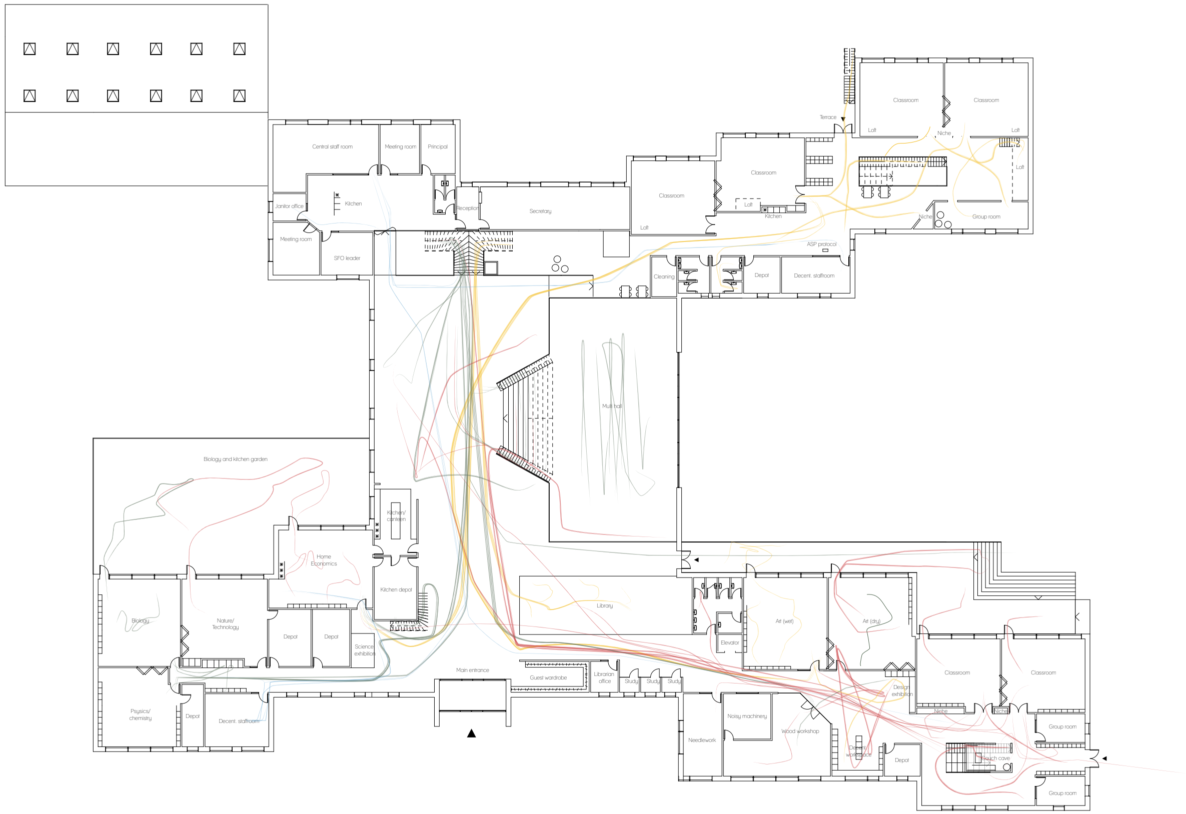
0 m 20 m

-1 floor
Ill. 60



0 m 20 m

1st floor
Ill. 61

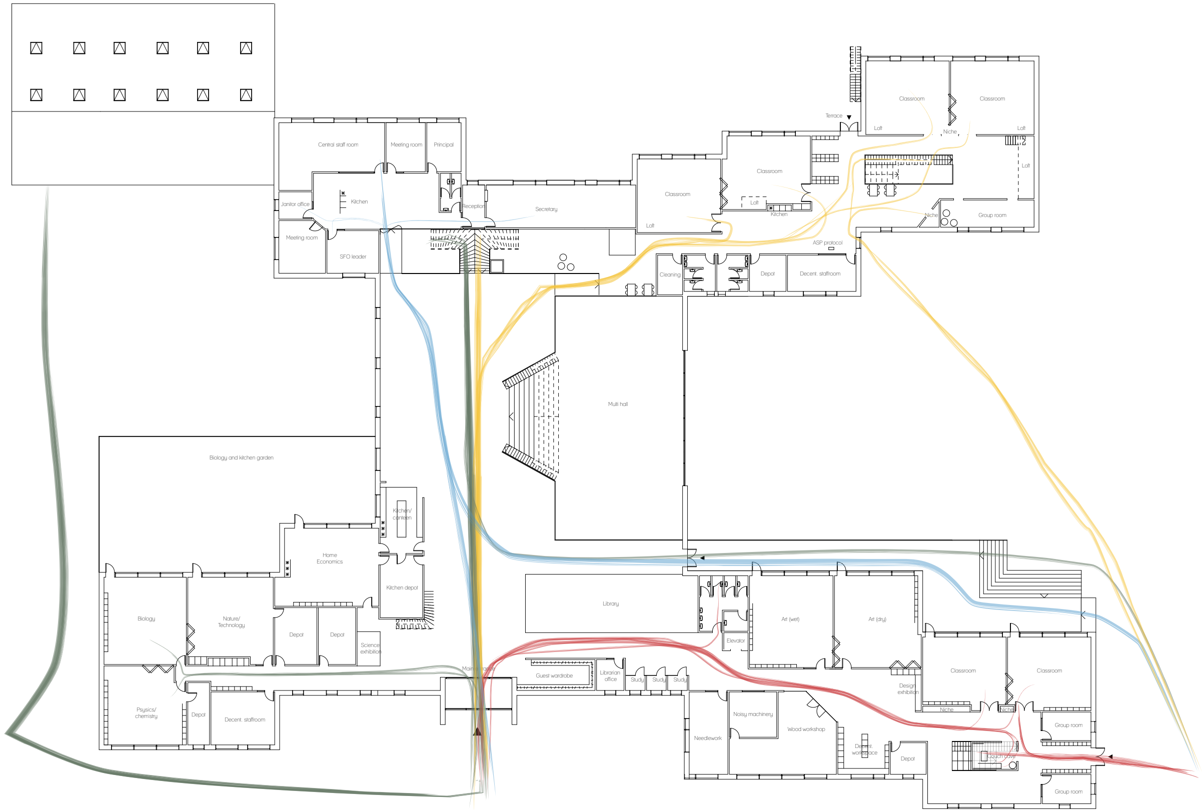


Flow during school day

FLOW

To insure life in the heart room, mixed use and a visible contact across class levels, all age of students will be passing through the heart room doing daytime. The multi hall, café, science and design facilities will ensure flows across the building.
As part of Skolereformen it is essential to combine traditional teaching methods with physical exercise but the opportunities for exercises is often limited in a full furnished classroom. This issue is solved in the plan layout where all classrooms have direct access to an open floor area on the corridors as well as easy access to outdoor areas.

- Primary school students
- Early middle school students
- Late middle school students
- Teachers

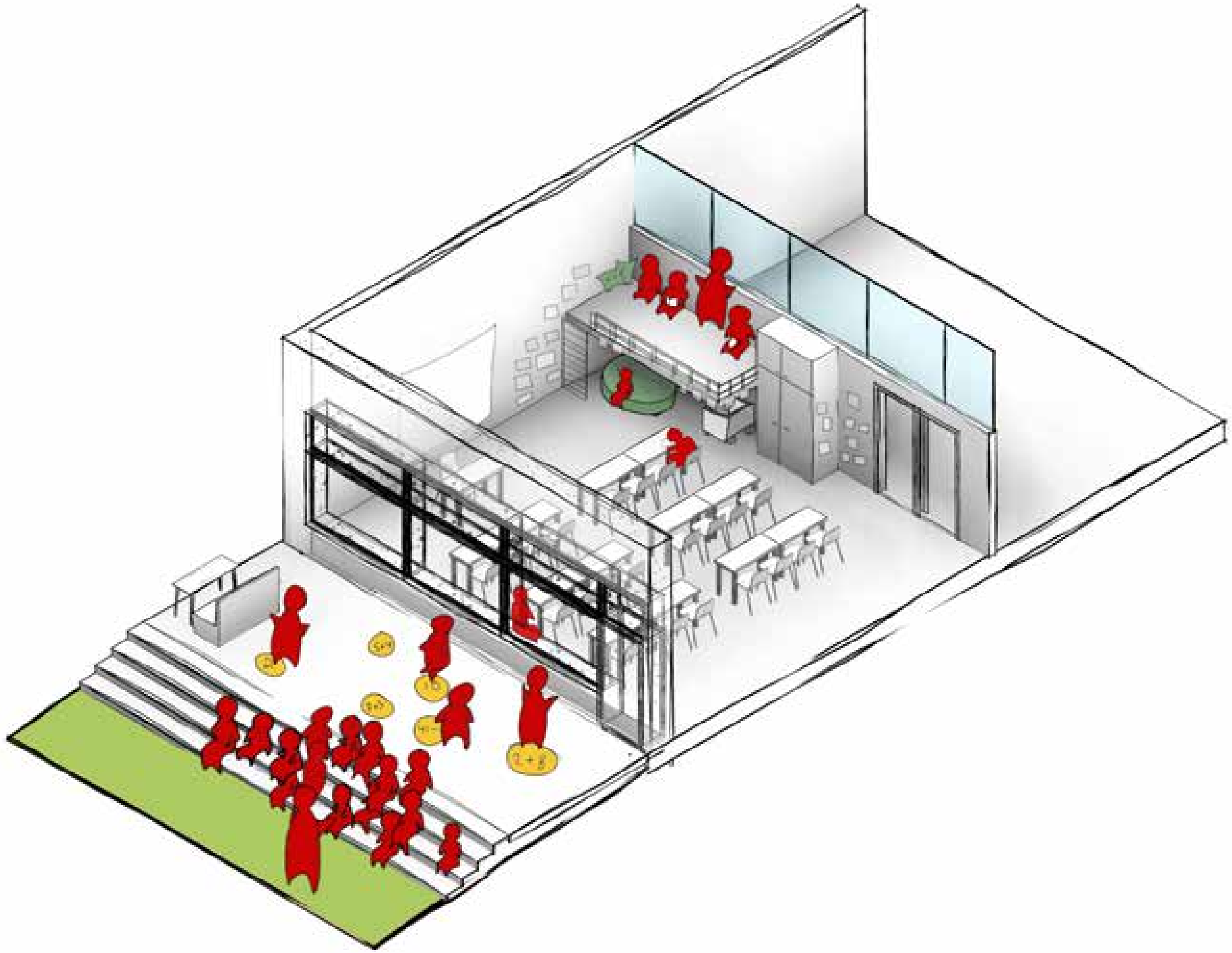


Flow at arrival
Ill. 63

When arriving in the morning, it is most obvious for the pupils to use the main entrance and from there be led out in the individual branches. However, it is also possible to enter directly into the individual branches from the outdoor areas, which might be preferred for late middle school students that have arrived to the school by bike.

PRIMARY SCHOOL

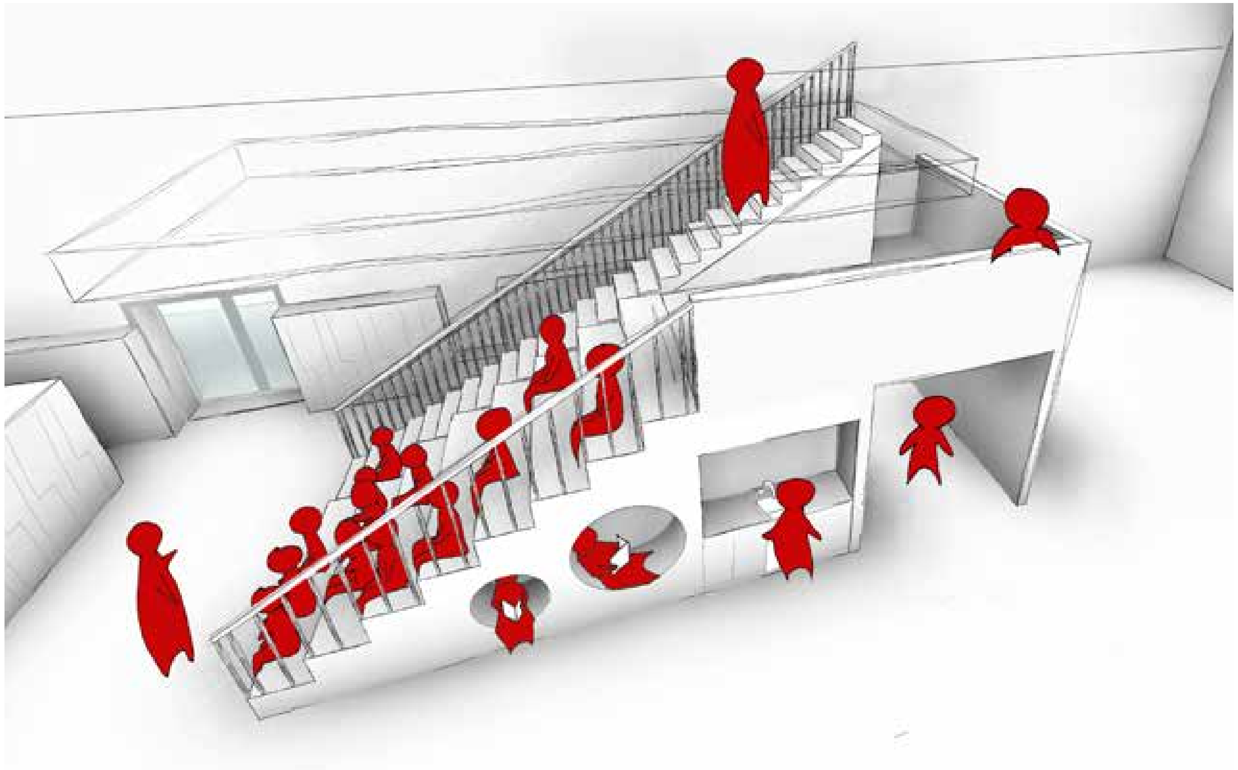
The primary school branch includes pupils from preschool to 3th grade resulting in 8 classes divided on two floors. In primary school the pupils need direct contact to the teachers, meaning they do not work as much individually outside the classrooms as in the case of the older students. However, they still have open floor areas outside classrooms so it is easy to move out of the classroom and use the floor area for various kind of teaching that often involves physical exercises. An outdoor terrace is placed just outside the classroom, here it is possible to make outdoor teaching and exercises (see ill. 64). This unit does not have group rooms attached to each classroom but instead features more relax areas and loft spaces inside the classroom. Niches incorporated into stairs and walls making diverse and playful hall ways for the pupils to occupy. They thrive better with other kids of their own age and therefore mostly centered on the same primary school branch.



Primary school classroom principle
Ill. 64

Primary school -1 floor plan
Ill. 65

The stair connecting the two floors ensures visual contact across the floors. It can also be used for gatherings and teaching for up to 50 pupils at a time. The stair also creates areas with various spatial qualities; there is a lifted area where it is possible to see the ground floor from above, and under the stair a cozy cave zone is implemented (see ill. 66).
In the afternoon the primary school is transformed to an ASP, here the open floor areas can easily be transformed to a playing area.

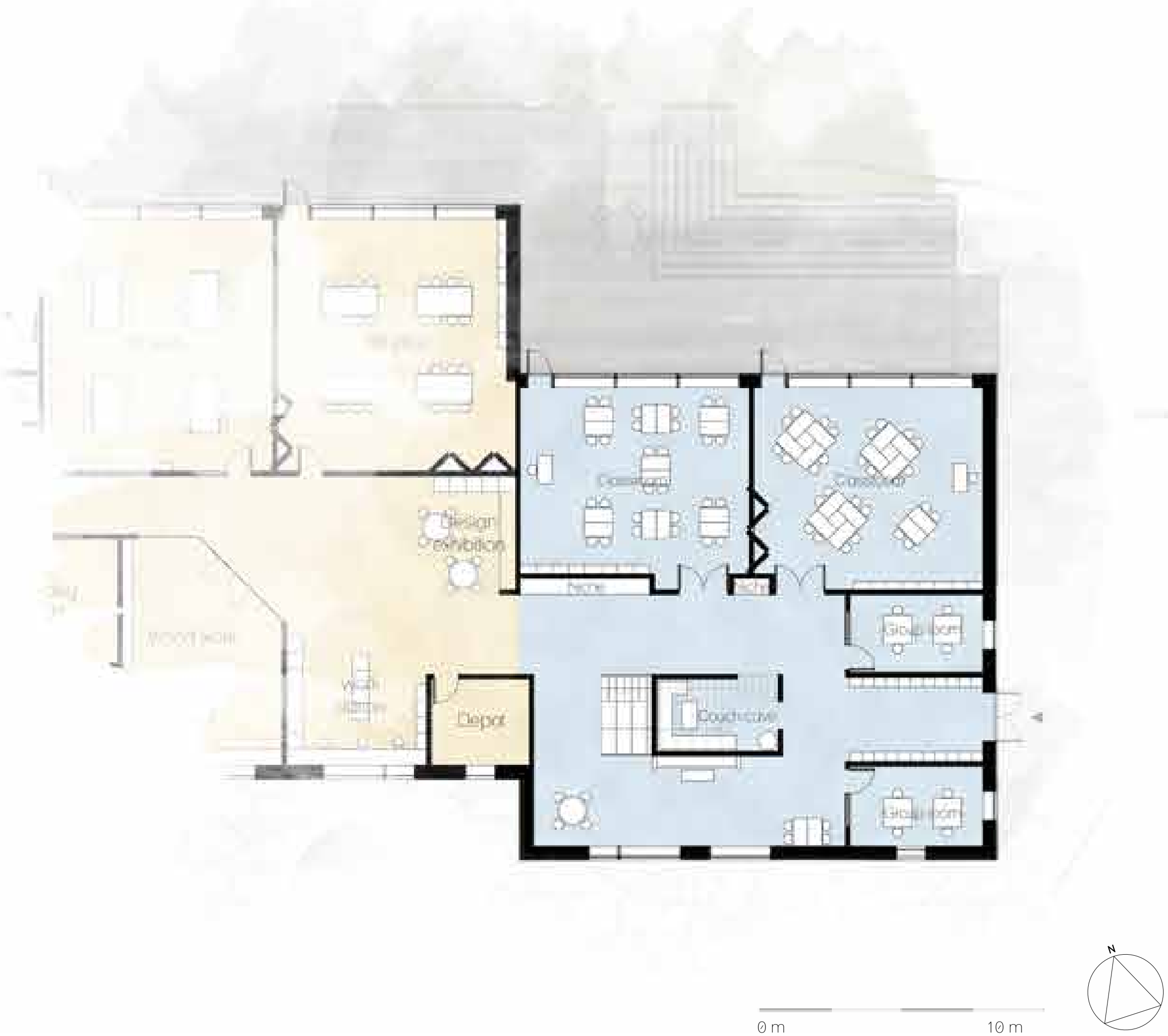


Primary school stair principle
Ill. 66

Primary school ground floor plan
Ill. 67

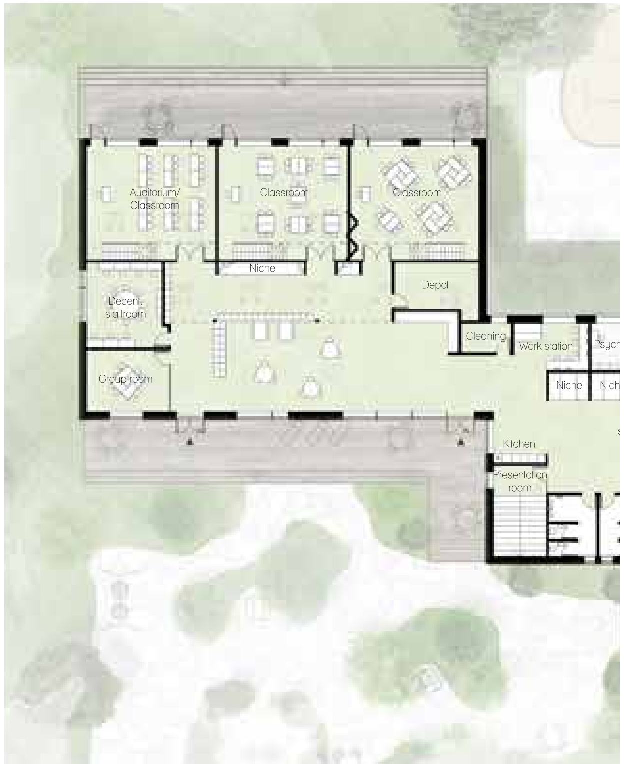
EARLY MIDDLE SCHOOL

The early middle school contains pupils from 4th to 6th grade resulting in 6 classrooms, two on the ground floor and four on the 1st floor. Here the students are offered a diverse learning environment, with niches and group rooms of different shapes and sizes. The middle age pupils likes to explore and curiosity drive them further away from the early middle school branch. They have direct access to the big school yard with plenty of opportunities to explore. Classrooms features group rooms and the branch has a large platform with view to the heart room that connects them to the community of the rest of the school.



Early middle school ground floor plan
Ill. 68

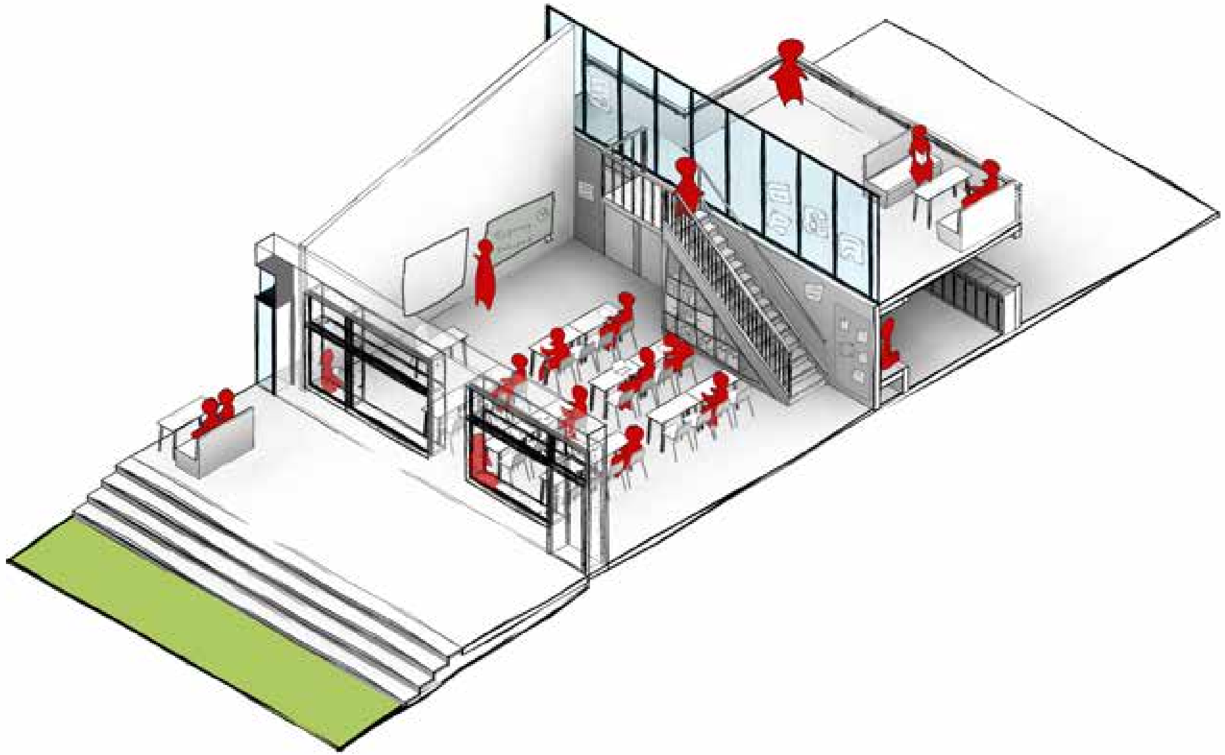
Early middle school 1. floor plan
Ill. 69



Late middle school -1. floor plan
Ill. 70

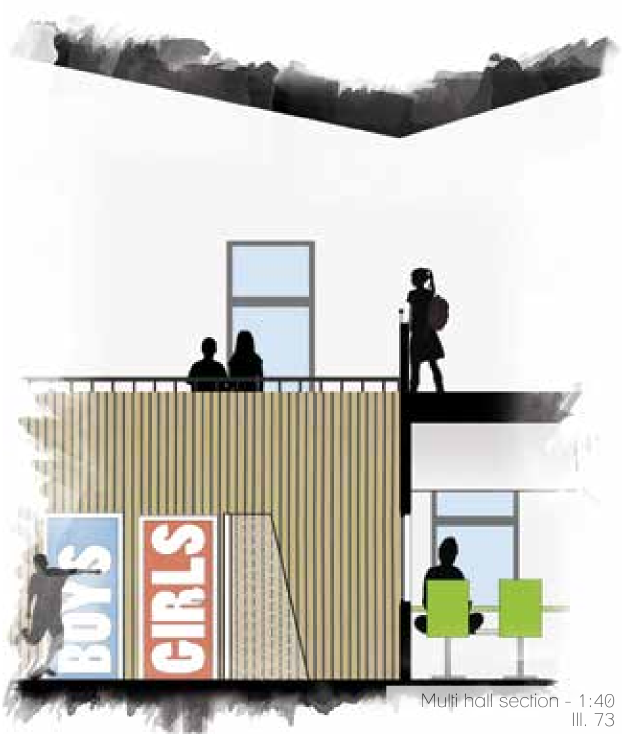
LATE MIDDLE SCHOOL

In the late middle school the students, 7th to 9th grade, are more social based and requires more spaces for social meeting. The unit is furnished with big group rooms, a big stair for lectures and reviews and large outdoor sitting area. The unit is more shielded from the rest of the school, but they occupy design and science areas as well. They have one classroom per every second class as they use science and design rooms more than the other age groups. From the classrooms there are direct access to a lifted group room with spacious qualities, an outdoor terraces as well as smaller sitting niches in the window frames (see ill. 71)

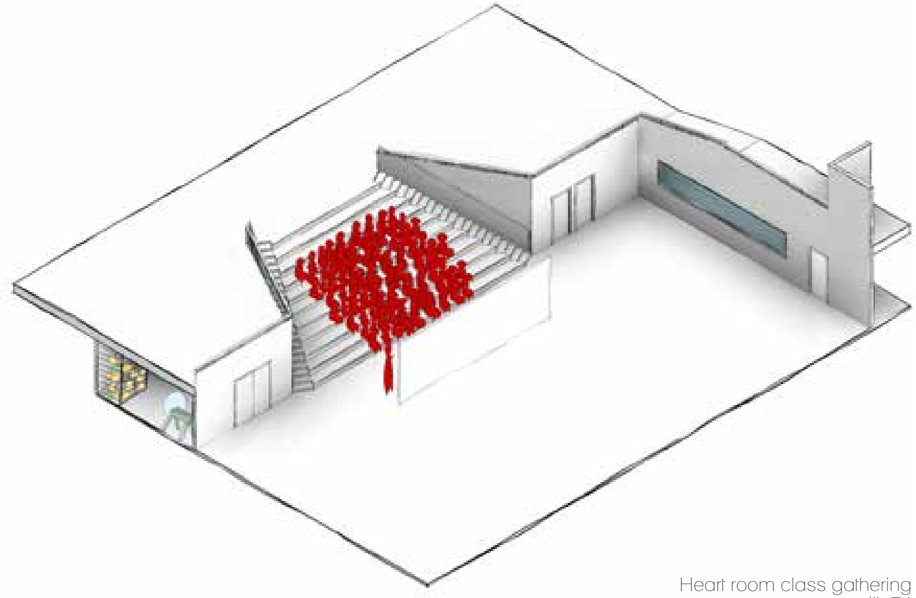


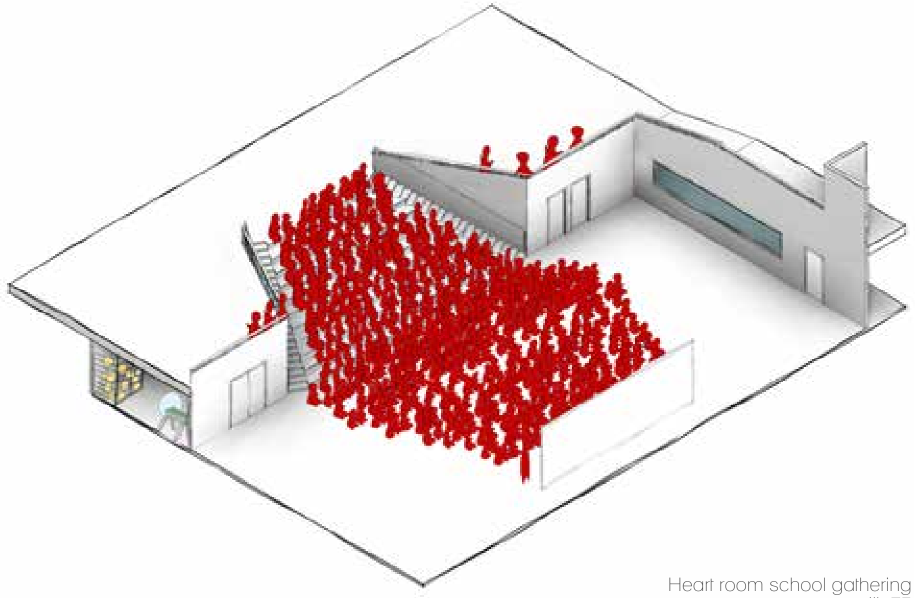
Classroom principle
Ill. 71

Late middle school
Ill. 72



Multi hall section - 1:40
Ill. 73


Heart room class gathering
Ill. 74


Heart room school gathering
Ill. 75

HEART ROOM

The heart room features the functions the whole school can gather around. The café, the big stair and the multi hall will attract people to either physical exercise, joining for social lunch or school meetings on the stair. It will as well be the main flow artery and from here pupils, teacher and citizens will have an overview of the building. The heart room also has a character of monumentality giving the children some kind of pride for being a student in this school. The stair and hall can be used for different types of gathering, where 2-5 classes easily can be gathered on the stair for a common lecture. For special events where all 600 students will be gathered the hall's floor area will be included as a siting area (see ill. 74,75). Throughout the day the stair will also be used as a social gathering area. From here, it is ideal to look at the other kids who are playing in the hall or looking across the hall, through the big window area and out on the kids playing in the school yard.

Heart room
Ill. 76

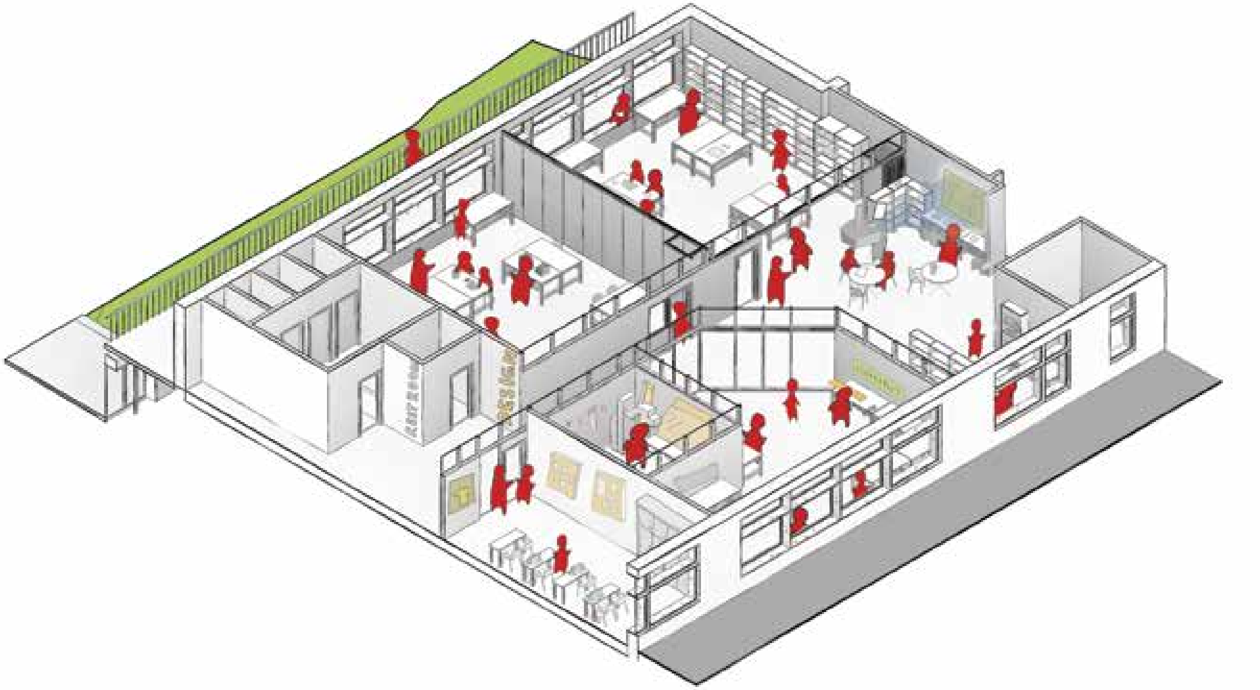
Science branch plan - Ground floor
Ill. 77


Home economics
Ill. 78

SCIENCE

As the school will have a science profile the science functions is located towards the main entrance. In this way exhibitions will be visible from the street and experimentations done in subject rooms visible as well. The hallway is furnished with science related objects. It will not feature niches or group rooms as here the teaching is going on inside the subject rooms. Exhibitions at the entry point of the science area will be just inside the main entrance. All rooms can be joined as one if wanted by turning the folding walls aside.

Design branch plan - Ground floor
Ill. 79



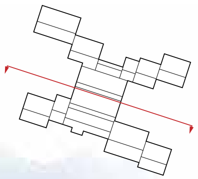
Design area principle
Ill. 80

DESIGN

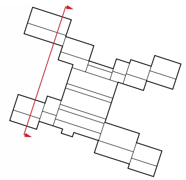
The design branch includes two art rooms, needle work and a wood workshop. These rooms can both be used for separate teaching and as a combined workshop environment where folding walls making it an option to merge the two art rooms. A common area across the different workshops is created by a central placed expedition that includes movable workshop stations, here the pupils can socialize and work interdisciplinary with the workshops different tools and materials.

The design branch is a visual and audible stimulating area to walk through due to glass doors and glass walls that creates visual contact to the workshops. The exhibition area is also expressive with shelfs, a projector wall and open working stations.

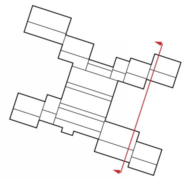
SECTIONS



Section AA - 1:500
Ill. 85



Section BB - 1:500
Ill. 86



Section CC - 1:500
Ill. 87

FACADES

North elevation - 1:500
Ill. 81

South elevation - 1:500
Ill. 82

East elevation - 1:500
Ill. 83

West elevation - 1:500
Ill. 84

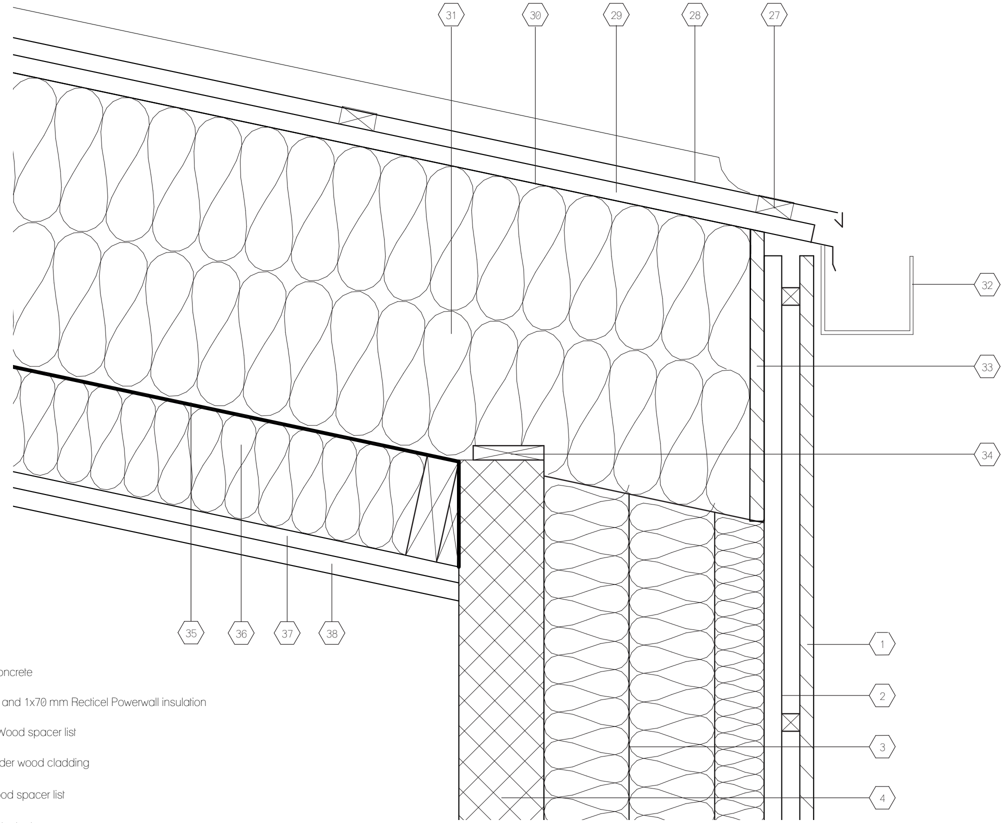
MATERIALS

Exterior

Larch is chosen as facade material due to its sustainable properties as biodegradable, organic and recycles potential and the sympathetic tangible surface. Larch has natural resistance to mold and can therefore be used with or without chemical treatment. The vertical cladding is a constructional protection against mold.

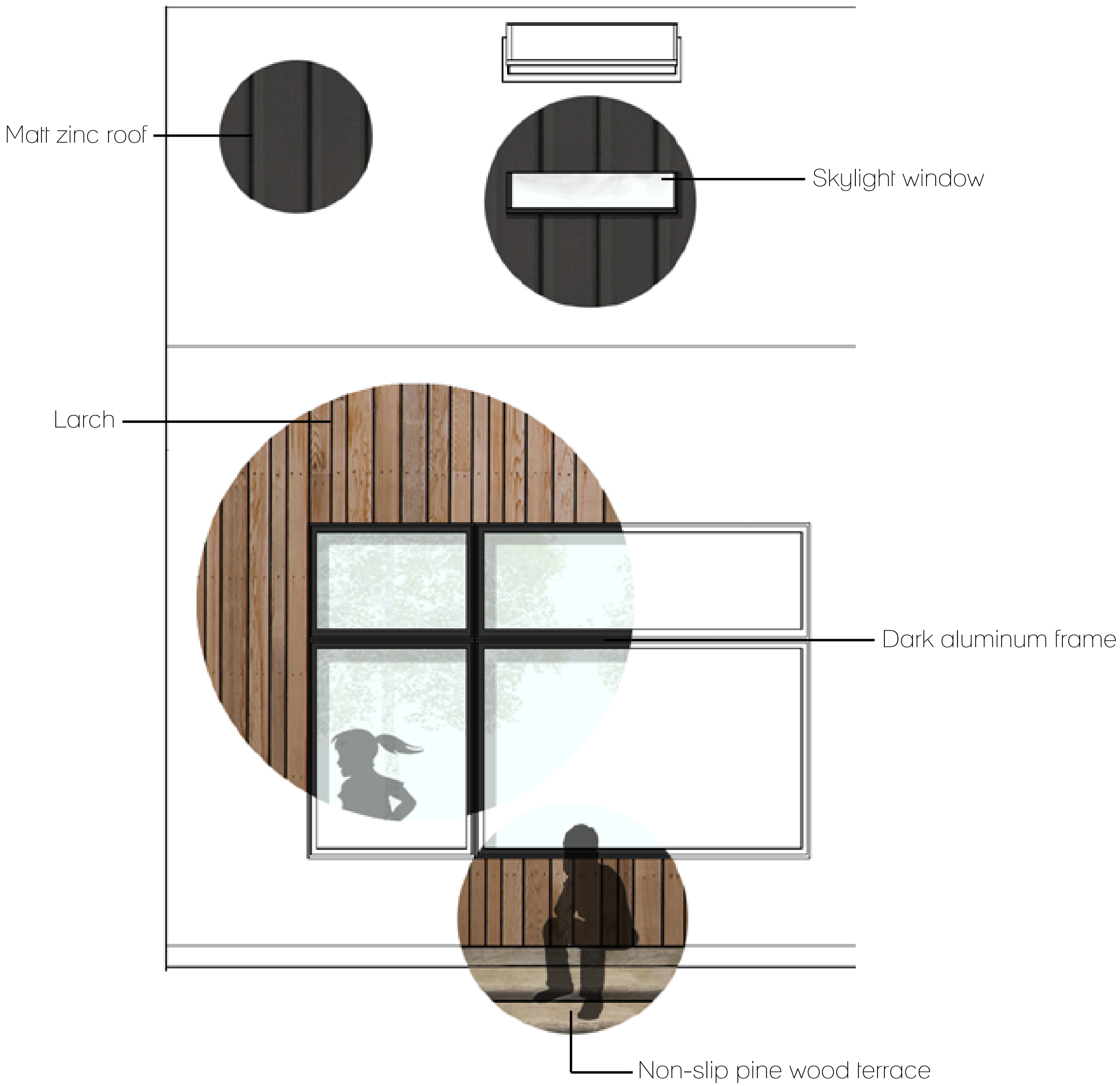
A matt dark zinc roof with standing seam will cover the pitched roofs underlying the vertical direction from the wooden facade and creating a contrast to it.
Zinc offers resistant to corrosion, rust and is more sustainable than most other metals because of its lower melting point and is almost maintenance free. A proper installed zinc roof will as well last for more than 100 years making it an economical great choice too [Rheinzink.dk, 2016].

The outdoor terraces will be made of pine wood to continue the soft facade and get a natural grey color over time. The wood will be treated so it is nonslip for the safety of the children.



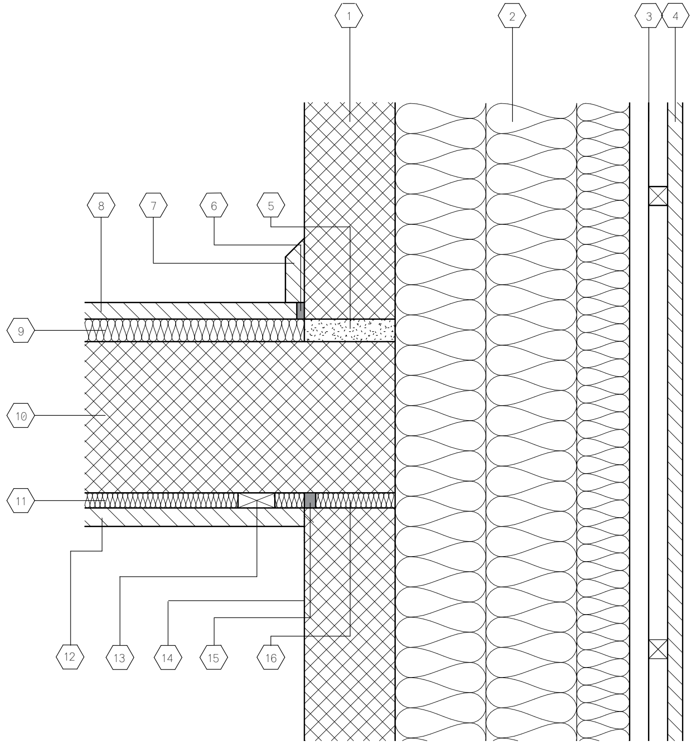
- 1 — 120 mm concrete
- 2 — 2x120 mm and 1x70 mm Recticel Powerwall insulation
- 3 — 2x25 mm Wood spacer list
- 4 — 20 mm Ceder wood cladding
- 27 — 25 mm Wood spacer list
- 28 — Zinc matt black plate
- 29 — 25 mm Wood spacer list
- 30 — Roof underlay
- 31 — 500 mm Rockwool Flexibatts
- 32 — 125x125 mm Zinc matt black
- 33 — 21 mm Plywood
- 34 — 20x100 mm Roof straps
- 35 — Vapor barrier
- 36 — 145 insulation / Formwork
- 37 — 22x95 mm Furring / 18 mm insulation
- 38 — 25 mm Troldtekt

Roof detail - 1:10
Ill. 88



Facade materials
Ill. 89

1. 120 mm concrete
2. 2x120 mm and 1x70 mm Recticel Powerwall insulation
3. 2x25 mm Wood spacer list
4. 20 mm Ceder wood cladding
5. 30 mm Grouting
6. Joint
7. Wood wallbase
8. Epoxy floor
9. Rockwool floorplate
10. 200 mm concrete floor deck
11. 20 mm insulation
12. 25 mm Troldtekt Akustik Plus
13. 45x20 mm Structural timber
14. Paint
15. Joint
16. 20 mm insulation



Floor slab detail - 1:10
Ill. 90

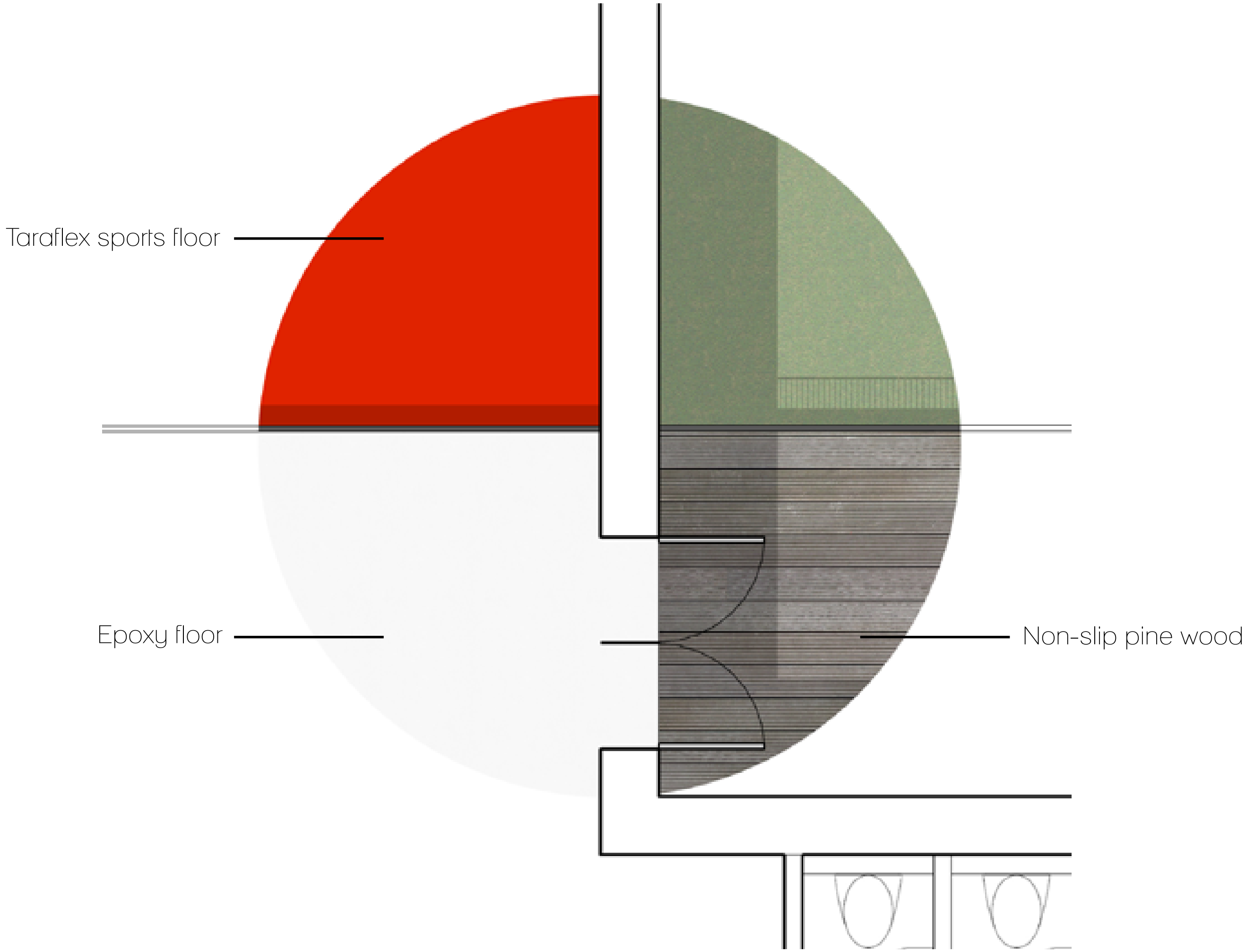
Interior

When it comes to schools durability and low maintenance materials is essential.
Therefore floors made of epoxy which is extremely durable, low maintenance and easy to clean and can be made in any color is desired.
To separate relax areas from transition areas relax areas will have synthetic carpet material (Bolon) or different coloring on walls or floor.

The multi hall floor is done in Taraflex which is sound absorbing soft sports flooring that can be made in any color as desired in this school.

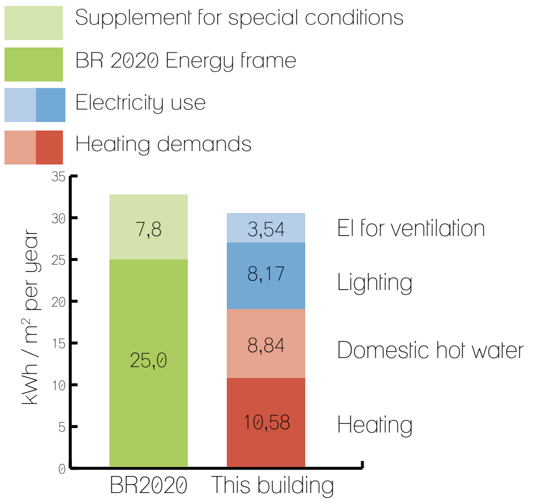
In the multi hall wooden walls with gap between each lamella provide esthetically coherence with the exterior cladding and contribute to a good indoor acoustic environment.

The school is built as a heavy construction with high thermal capacity, with concrete walls, floor slabs and roof. If a light construction was used it was not possible to fulfill energy frame for 2020 as the energy use will be on 35,1 instead of 30,6 kW/h/m^2 per year, with current settings.

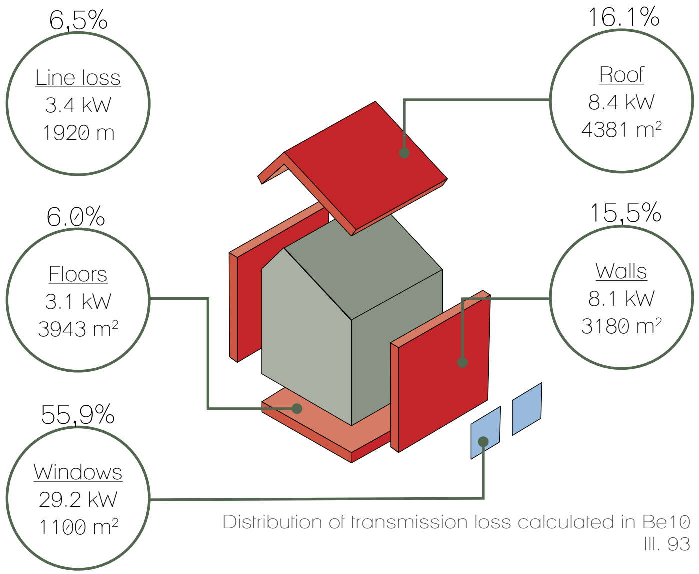


Floor materials
Ill. 91

Be10 results



Energy frame and distribution of energy use calculated in Be10
Ill. 92



Distribution of transmission loss calculated in Be10
Ill. 93

Parameters

Roof U-value 0,06 W/m²K	Internal heat supply from people 4 W/m2	Internal heat supply from equipment 6 W/m2
Wall U-value 0,08 W/m²K	Solar cells Peak power: 0,14 kW/m2 RS : 75%	Air change 2 - 5,68 l/s m²
Floor U-value 0,08 W/m²K	Line loss 0,03 W/mK	Heat recovery 85,5 %
Windows U-value 0,8 & 1 W/m²K	Windows g-value 0,34 & 0,5 %	Ventilation SEL value 0,271 J/m³

Above 26°C Max. 100 hours

Above 27°C Max. 25 hours

Max. 900 ppm CO_2

ENERGY USE

The building is aiming for fulfilling a good indoor climate, especially in the classrooms where both visual and atmospheric comfort is set after very high standards. Is it also an ambition that the building fulfills the 2020 energy demands, this is achieved when adding an energy supplement for a special high air change calculated after SBI 213 to 7,8 kWh/m2 per year. Meaning the total energy frame is extended from 25 to 32,8 kWh/m² year.

As seen in the graphics above (see ill. 92) the school fulfills the energy requirements with the use of 30,6 kWh/m2/year (without photovoltaics) with no overheating (appendix 3).

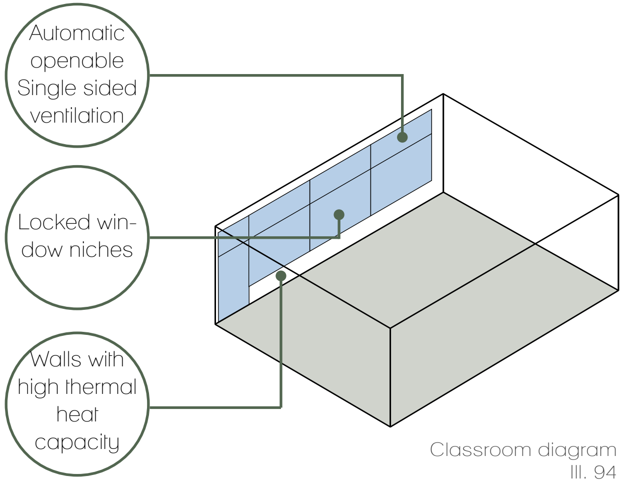
PHOTOVOLTAICS

The building will not be connected to a net where it is possible to sell excess energy, meaning it is impossible to reach a zero energy building, unless batteries are used for storage energy. Batteries is considered a too expensive solution. Instead it is possible for the school to use PV's only for supply its own electrical use (11,71 kWh/m2 per year). This solution will according to Be10 calculations bring the total energy use down to 19 kWh/m2 per year when placing 322 m2 of standard PV's on the south-orientated rooftops. In reality it is not possible to provide the total use of electricity without using batteries because there will be days without sun.

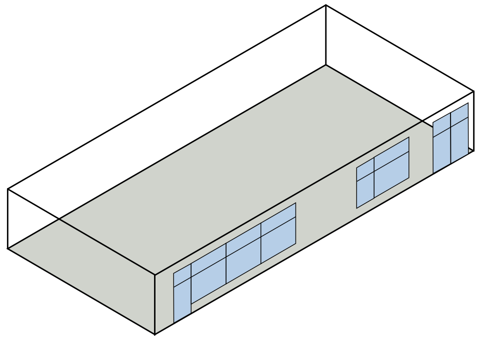
Bsim results Classroom		
Above 26°C/year	Above 27°C/year	Max CO_2 level
36 hours	12 hours	636 ppm

Bsim results Relax area		
Above 26°C/year	Above 27°C/year	Max CO_2 level
36 hours	7 hours	687 ppm

Parameters		
People load	Equipment load	Radiator heating
28	2500 Watts*	6 kW
Mechanical ventilation supply	Heat recovery	Set temperature mechanical ventilation
0.322 m³/s	86 %	19°C
Max. natural ventilation rate	Set temperature natural ventilation	Infiltration air change
5/h	21°C	0.1/h
Classroom window area	Relax window area	*90 w per laptop x 28 students
20.4 m²	39.1 m²	



Classroom diagram
Ill. 94



Hallway diagram
Ill. 95

Above 26°C Max. 100 hours

Above 27°C Max. 25 hours

Max. 900 ppm CO_2

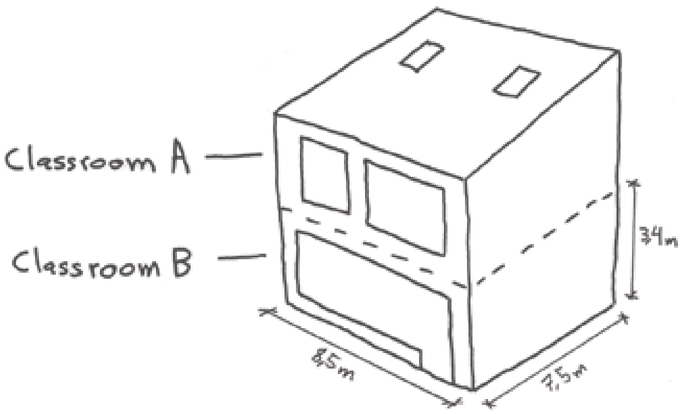
INDOOR CLIMATE

To analyze the indoor climate the critical areas in the building was selected and calculated on. A classroom in the eastern part of the school with big glazed facade and adjacent rooms on both sides was selected. The high internal heat gains demand a high ventilation rate to fulfill requirements from BR20 and category A (DS 1752) according to maintain comfortable air quality and temperature. A south faced hallway area with big windows and high people load is as well analyzed.

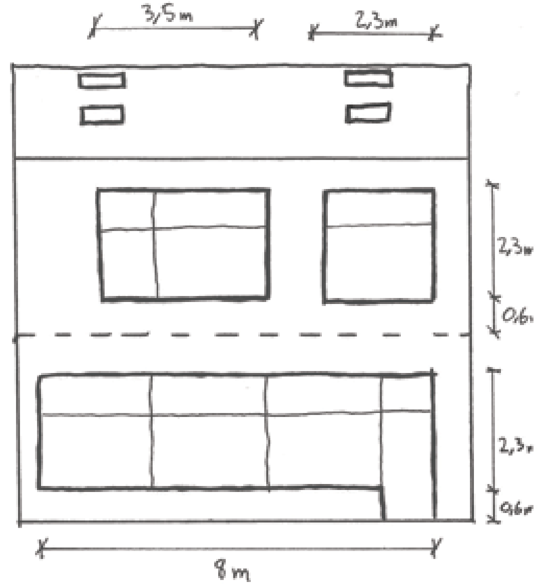
It is calculated that pupils are present in classrooms from 8-11 then one hour break from 11-12 and then again in classroom from 12-16.

In the hallway the daily schedule is set that only 14 of the students are present in the hallway area besides from 11-12 where 28 are present.
Summer holidays are from week 25-32 therefore overheating hours in this period is subtracted.
From April to September the natural ventilation system will be activated with automatic controlled openable windows which will cool down the building during hot summer months.

It is calculated in Bsim that the classroom and hallway, with these setups, fulfill requirements for both temperature and atmospheric comfort.



3d diagram of classrooms with windows
Ill. 96



Measurement of windows for classrooms
Ill. 97

SHAPE OF WINDOWS FOR CLASSROOMS

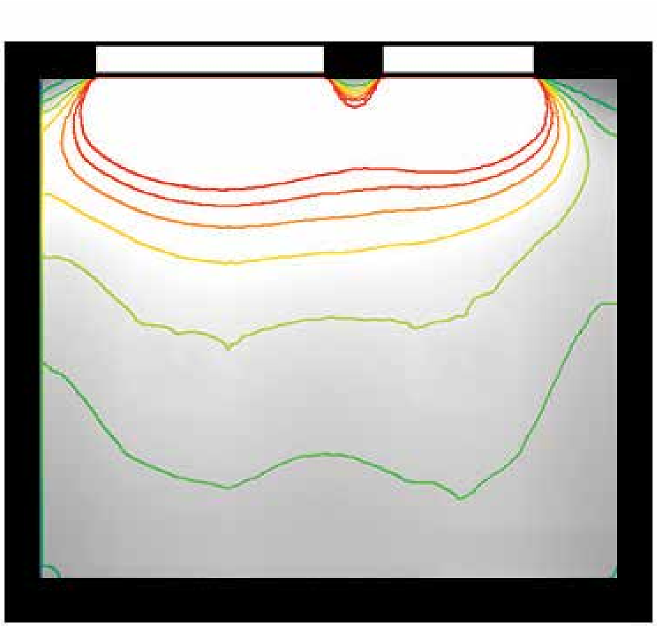
Natural light is important to create a good working and learning environment, by increasing the amount of natural light the student's performance and well-being will be improved and electricity spend on artificial lighting will be decreased.

External shading devices have a negative influence on the daylight factor, so to avoid the need of external shading all classrooms are facing north. As mentioned in the program, a daylight factor of minimum 3% is required in working areas. Studies made with Velux Daylight Visualizer show that it are very difficult to fulfill these criteria in areas that a placed most far away from the façade. Resulting that almost the entire northern facades have to be made of glass, however the glass area can be reduced if roof light is implemented, more details of these earlier studies can be found in the design process (page 98). Due to heat loss and acoustic reasons, it is preferred to use roof light so the glazing area can be reduced (see ill. 96, classroom A) but some classrooms are placed under 1st floor and do not have the option of using skylight. Here a bigger glazed facade have been created, including a glass door, which also insures easy access to the outdoor areas (classroom B).
All windows inside the classrooms are made with sill depth of 45cm and sill height of 60cm above floor. Making it possible to use the windows as working stations.

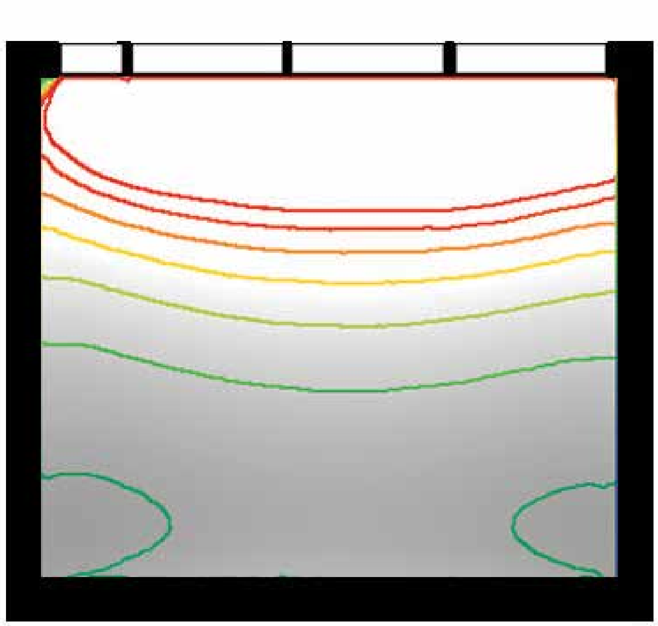
Because the window frames are used as sitting areas it is by safety reason not possible to open the main windows, but the smaller upper windows will be used in an automatically venting system that insures a good indoor climate in the summer season.

Daylight Factor

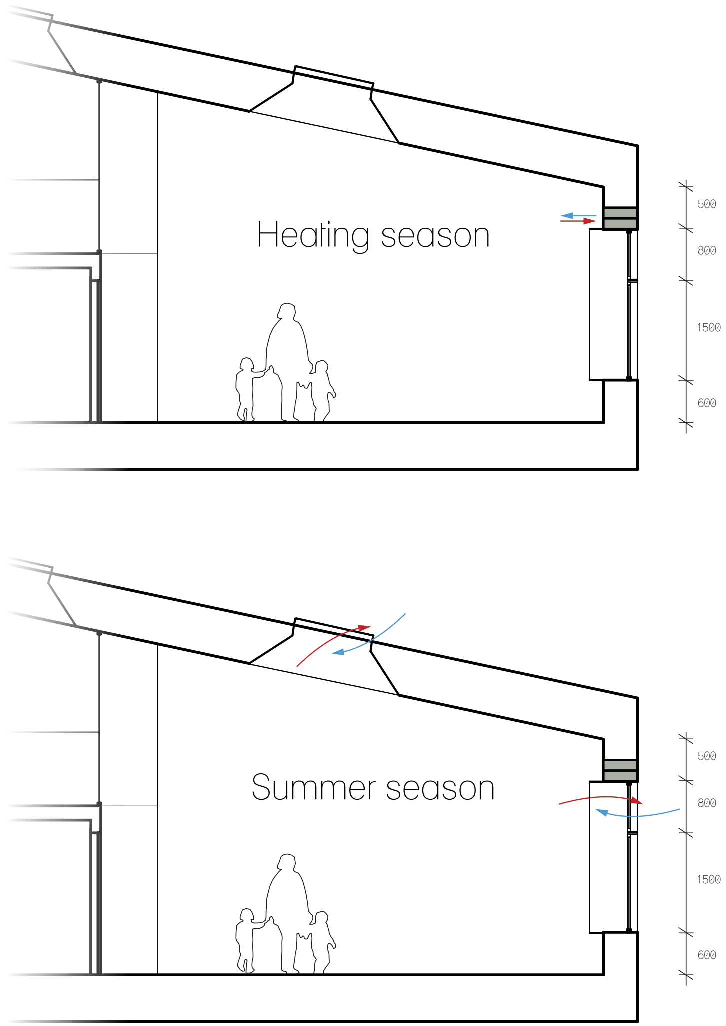
8%
7%
6%
5%
4%
3%
2%



Daylight factor for classroom A
Ill. 98



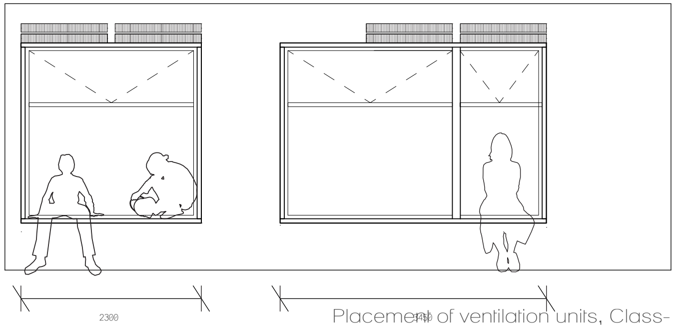
Daylight factor for classroom B
Ill. 99



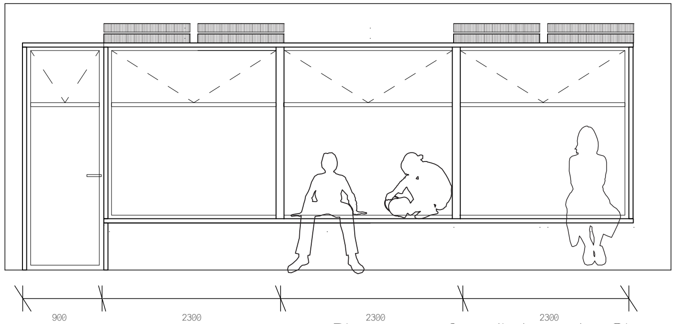
Ventilation principles
Ill.: 100

VENTILATION PRINCIPLES

In summer season, the classrooms are ventilated by highly placed sensory windows that automatically can control the air change according to temperature and CO_2 concentrations. In the heating season, decentralized ventilation units with heat recovery from InVentilate are used (see ill. 100). The reasons for using this system are of InVentilate's high efficiently with a very low electrical use, further info can be found in (appendix 4).
InVentilate are almost implemented for the entire school, only the heart room will be using another strategy, here a mechanical stack ventilation strategy will be used because the deep volume makes natural ventilation and InVentilate ineffective. The stack ventilation will blow in along the floor and rise around people, due to thermal buoyancy, and extracted in the ceiling.



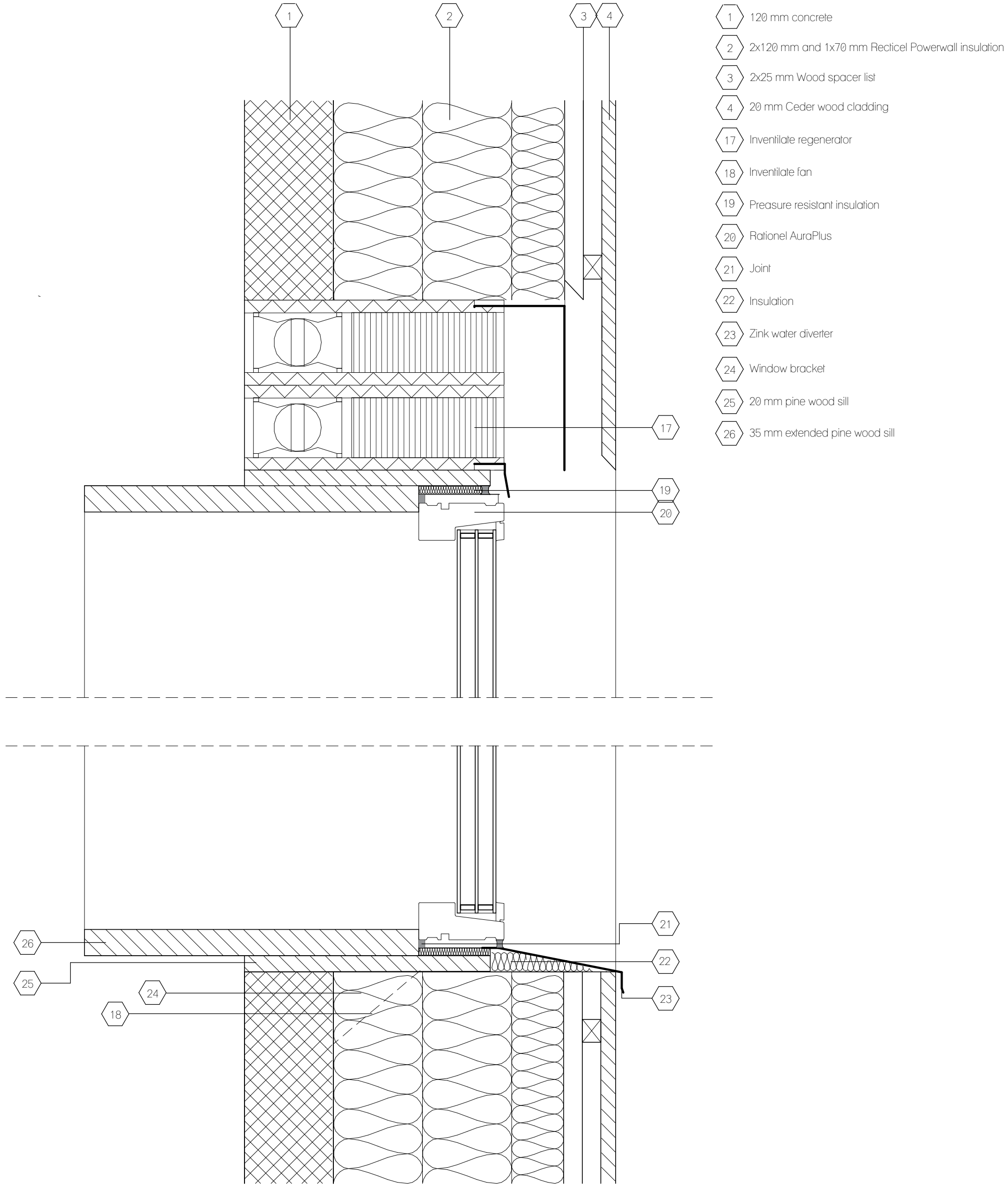
Placement of ventilation units, Classroom A
Ill. 101



Placement of ventilation units, Classroom B
Ill. 102

WINDOW CONSTRUCTION DETAIL

The ventilation system InVentilate is, from the outside, integrated into the window ribbon where the wooden cladding will cover for the air intake is at the top (see ill. 103). Inside InVentilate will be visible as grills over the windows.
However the window sill is extended to 45 cm, in the classrooms, to allow pupils to occupy this place as seating and working area. The room underneath the sill can be used to store bag packs and other objects as well.

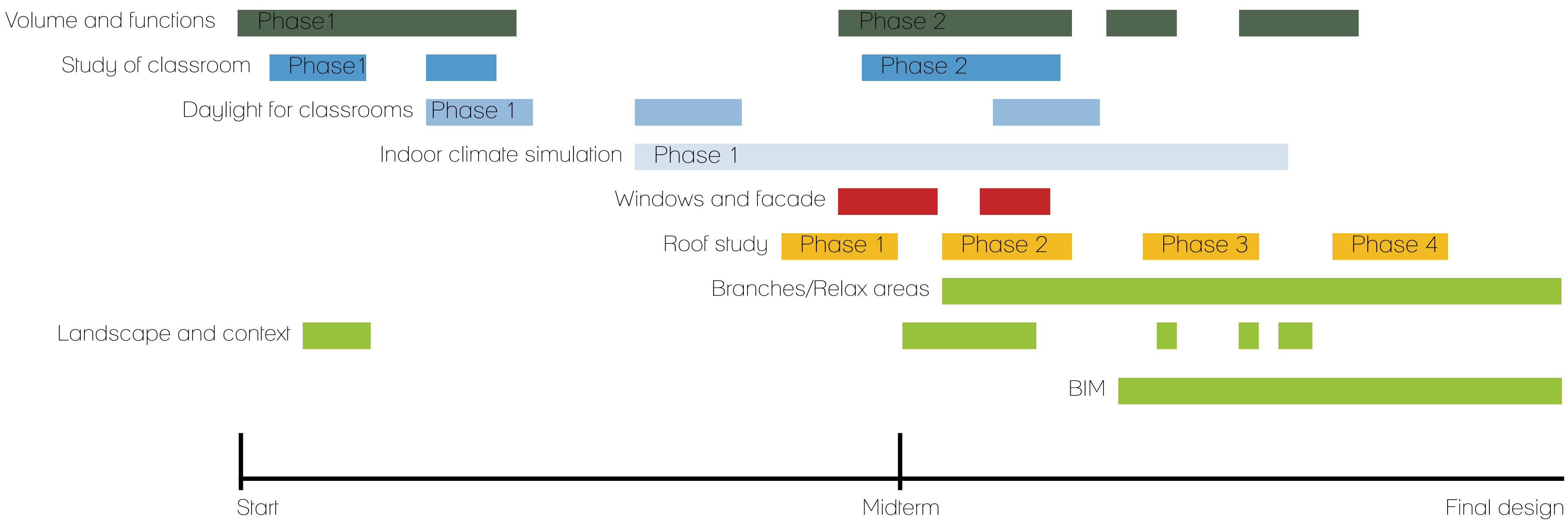


Window detail - 1:10
Ill. 103

VII

DESIGN PROCESS

CLASSROOM
CORRIDOR, RELAX AND GROUP AREAS
VOLUME AND FUNCTIONS
FACADES
ROOF



Time schedule
Ill. 104

DESIGN PROCESS

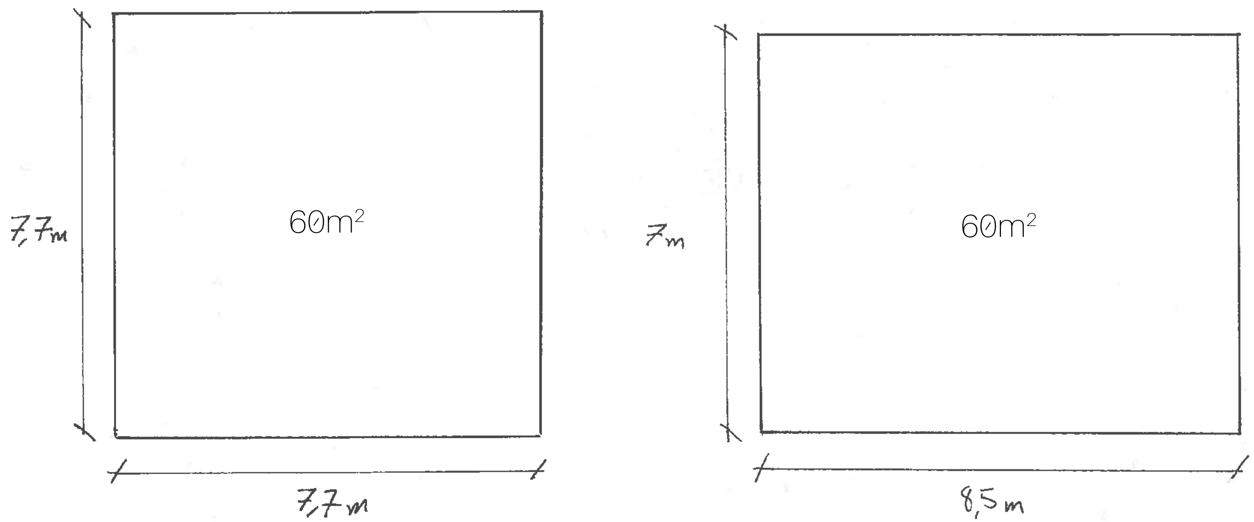
Throughout this project the starting focus have been to work from the inside and out, meaning that plan and functional aspects have been the foundation for the outer shape of the building. Technical considerations such as daylight and indoor climate have also been implemented very early in the design process. As an integrated process' different technical and aesthetic aspects have influenced, informed and changed each other. Meaning nothing has finished at once but all aspects have been improved when other aspects have influenced the design. A time schedule of the project is shown above.

CLASSROOM DESIGN CRITERIA:

To begin with a list of design criteria was made for classrooms, as classroom has been the part the school has been designed around in terms of technical demands, functional requests and ideas for at school of tomorrow (see ill. 105).

- Relax or/and group areas in classroom
- Have a square layout for easy changing in furnishing
- Minimum 3 % daylight factor
- Avoid glare
- Good view to the outside
- Good air quality that fulfills ventilation demands for category A
- Comfortable temperature around 21°C for optimal task performance
- Utilization of colors to enhance concentration skills
- Opportunity to merge classrooms into bigger rooms in teaching regards
- Opportunity to open classrooms towards the corridor
- Easy access to outdoor
- Good acoustic environment
- Robust choice of materials
- At least two walls for teaching possibilities

Classroom design criteria
Ill. 105



Classroom dimensions
Ill. 106

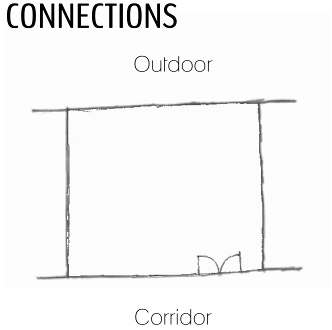
CLASSROOMS PHASE 1

According to the room program all classrooms should be 60 m2. Due to flexibility for different types of teaching with different needs for furnishing it is preferred to use a square shape in plan. However, daylight studies showed that it was very difficult to deliver the required daylight factor of 3% in the deep volumes, so the shape was changed to 8,5m wide and 7m deep for daylight to penetrate to the deepest end of the classroom (see ill. 106).

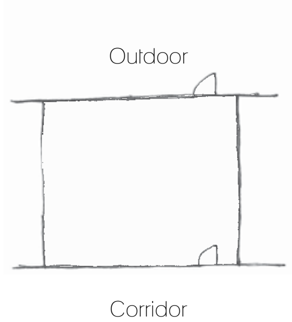
CLASSROOMS PHASE 2

To shape a classroom of tomorrow it is ideal that the classroom can contain different working zones with focus on group work, individual work, traditional teaching, and offers both comfortable learning and a relaxing atmospheres in the working zones. It is also important how the classroom opens to the surroundings. A catalog of benefits and disadvantages for different solutions can be seen on the next page.

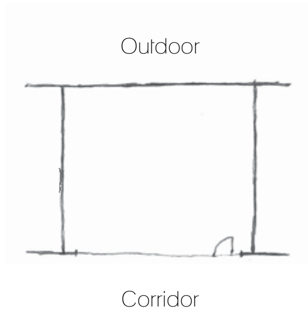
CONNECTIONS



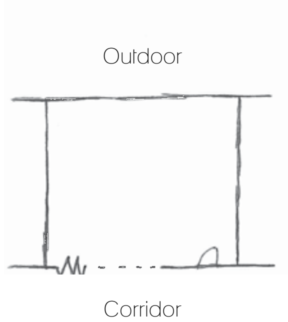
Double door
- ➕ Good opportunities to extend the classroom.
- ➕ Can shield off noise and disturbing views from corridor



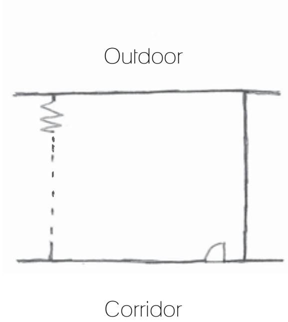
Outdoor connection
- ➕ Possible to move teaching outdoor.
- ➕ Create space for group- and individual work in summer time.



Glass wall
- ➕ Visual connection to work area on corridor.
- ➖ Distraction in view.
- ➖ Can lead to acoustic problems.
- ➖ Limits usable wall area that can be used for e.g. exhibition area both inside the class and in the corridor.

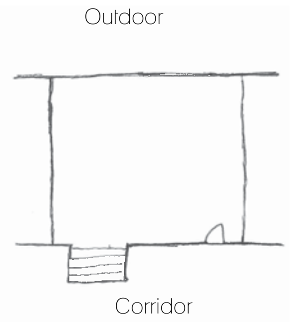


Folding wall
- ➕ Very good opportunities for extending the classroom.
- ➕ Can shield off noise and disturbing views from corridor
- ➖ Limits usable wall area that can be used for e.g. exhibition area both inside the class and in the corridor.

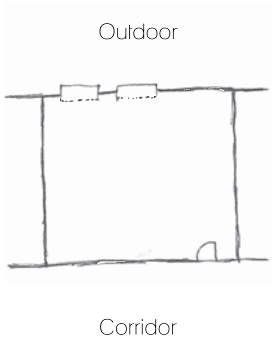


Folding wall (to classroom)
- ➕ Very good opportunities for extend the classroom.
- ➖ Can lead to acoustic problems.
- ➖ Limits the "exhibition area" inside the classroom.

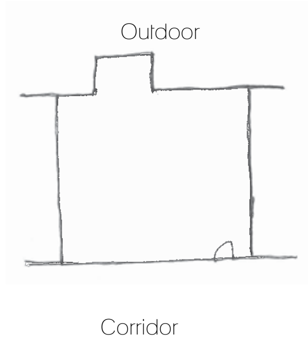
WORK ZONES



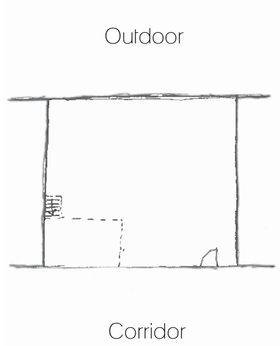
Stairs to occupy
- ➕ Possible to work individually and in small groups.
- ➕ Alternative place for gathering



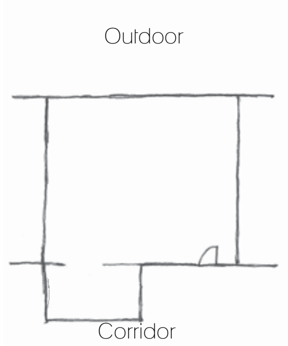
Window niches
- ➕ Possible to work individually and in small groups.
- ➕ Do not use extra space



Niche in facade
- ➕ Possible to work individually and in small groups.
- ➖ Less daylight in the classroom

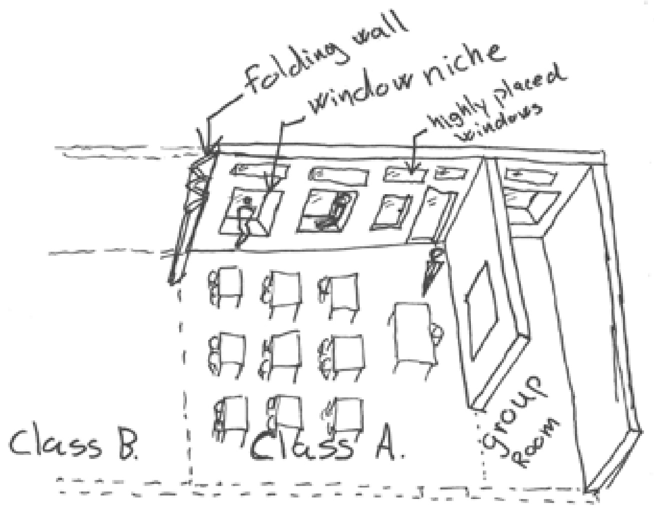


Loft area
- ➕ Possible to work individually and in small groups.
- ➕ Adds more space

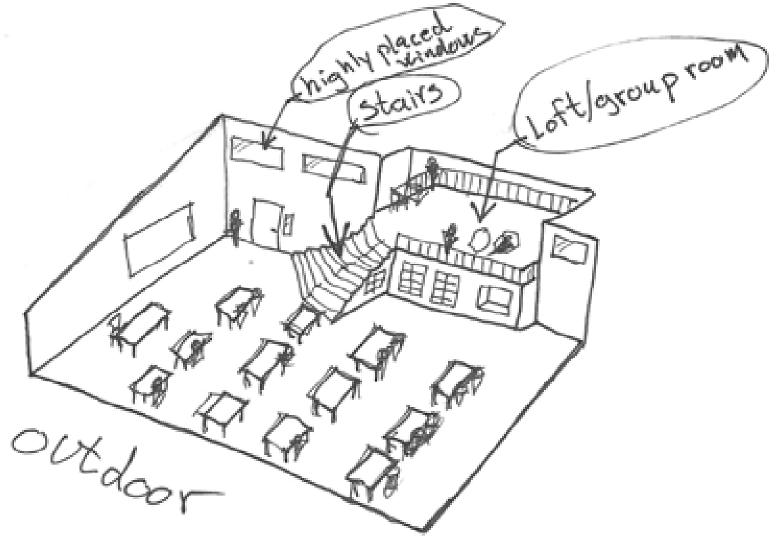


Niche in interior wall
- ➕ Possible to work individually and in small groups.
- ➖ Takes space from corridor

Classroom catalogue
Ill. 107

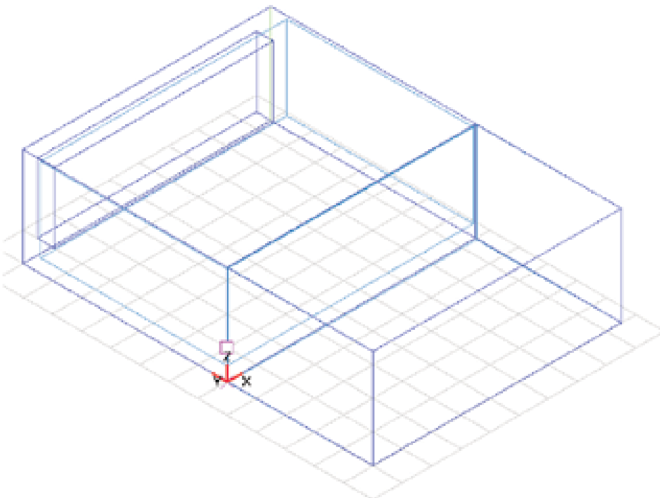


Classroom drawing
Ill. 109



Classroom drawing
Ill. 110

After the catalog was made, the next step was to design a classroom that included as many of the advantages without including the disadvantages. It was decided to implementing smaller niches in the windows where 1-3 persons can sit and work in a more relaxed position. It was also seen as a good opportunity to move the larger group rooms up under the ceiling to save square meters and offer different atmospheres and working environments.



Calculation Info:

Co2 = 450 ppm
People Loade = 26 students
Glass area = 14,2 m2
Ventilation = 0,574 m2/s
Equipment = 8 PC's
Venting = max 5/hours

Criteria Info:

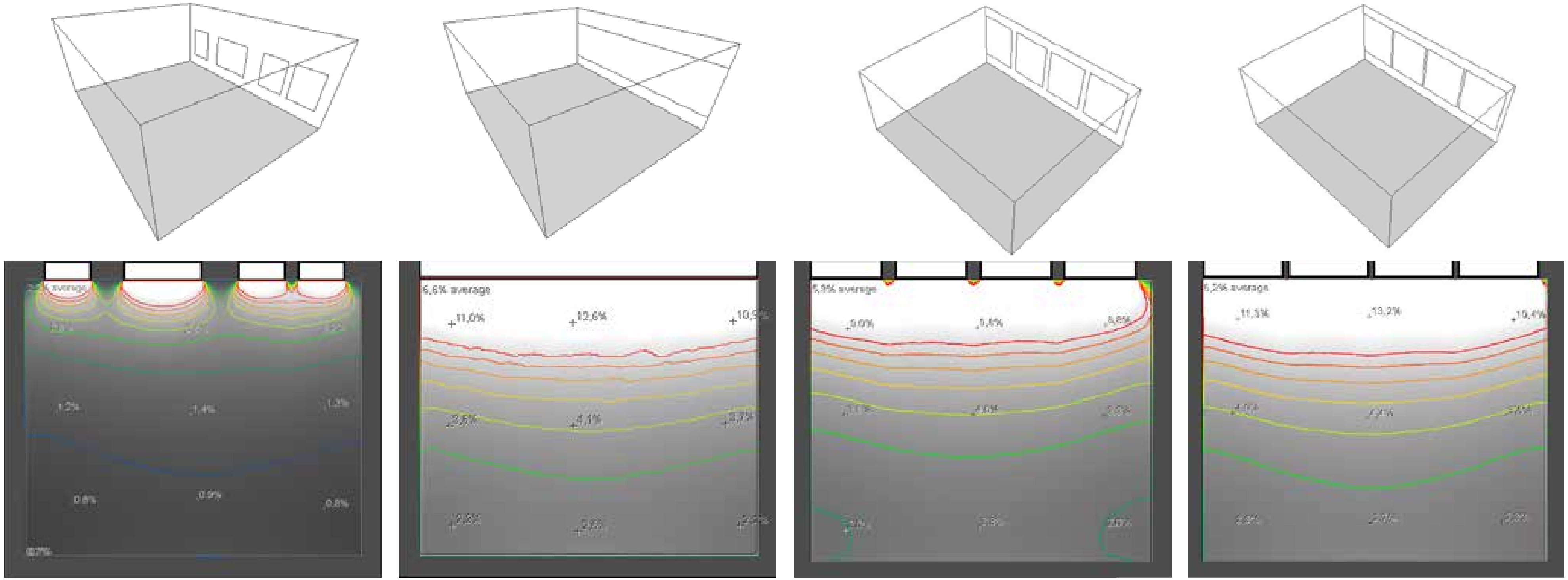
Max permitted Hours >26 : 100
Max permitted Hours >27 : 25

orientation	Hours >26	Hours >27
0°	60	23
45°	133	51
90°	309	163
180°	1043	585
-90°	434	207
-45°	147	72

Bsim calculation - Overheating hours depending on orientation
Ill. 108

INDOOR CLIMATE SIMULATION

To get a better understanding of how big influence the orientation of a classroom has on the indoor climate an early simulation was made in BSim. The results here can only be seen as guidelines, because the values will change when other parameters such as venting and glazing area is changed. But it still gives a clear indication that a north orientated classroom is the optimal solution according to indoor climate, and that it can be difficult to obtain a good indoor climate without using shading devices if the facade is not north orientated.

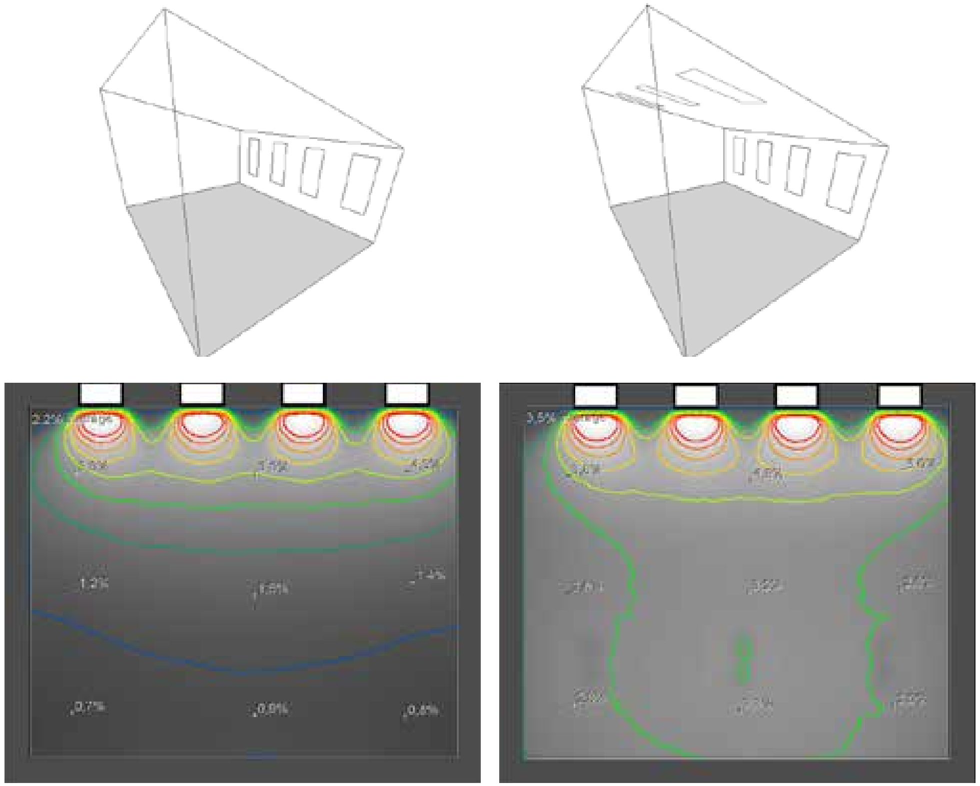


Velux daylight simulations - Ground floor without sky light
Ill. 111

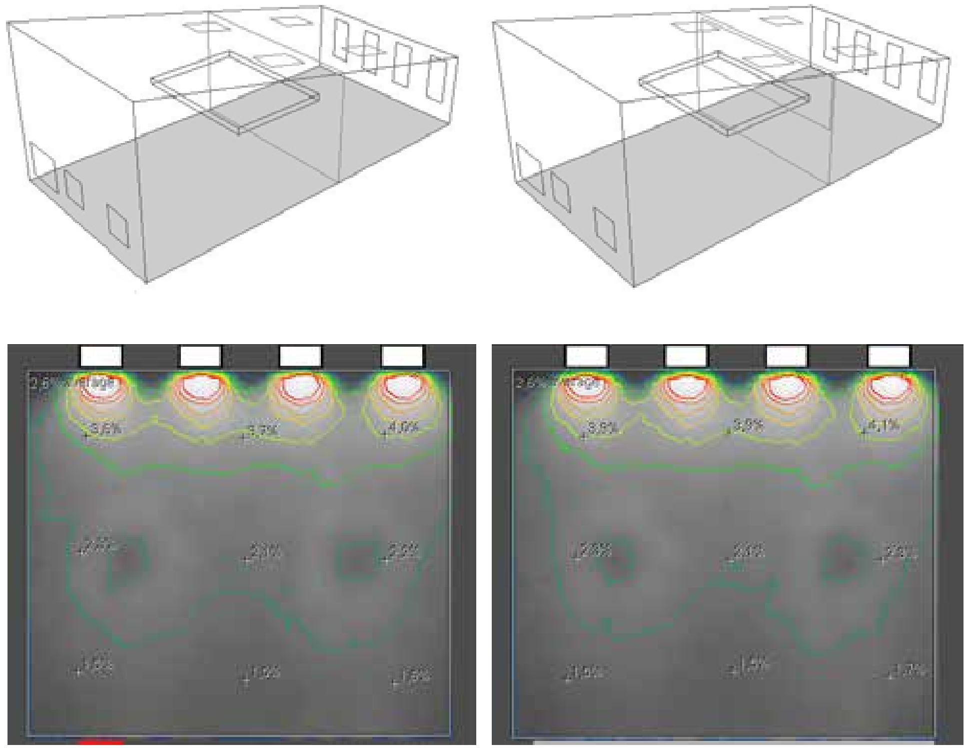
DAYLIGHT - GROUND FLOOR

Early daylight studies made in Velux Daylight Visualizer showed that it was difficult to reach a daylight factor on 3% in the whole classroom. However, if almost the entire facade was covered with windows it is possible to achieve a daylight factor of 3% for 75% of the classroom, and 100% of the room will archive a daylight factor above 2%.

It was determined that the windows will be used as niches. Resulting, that the windows is designed to be placed 60 cm above ground for comfortable sitting height. To divide the window area into smaller niches structural supporting columns will be placed with a two meter distance. A study showed that by decreasing the thickness of the columns from 30cm to 10cm the daylight factor was increased beneficially (see ill. 111).



Velux daylight simulations - 1st floor with & without sky light
Ill. 112



Velux daylight simulations - 1st floor with & without corridor window
Ill. 113

DAYLIGHT - FIRST FLOOR

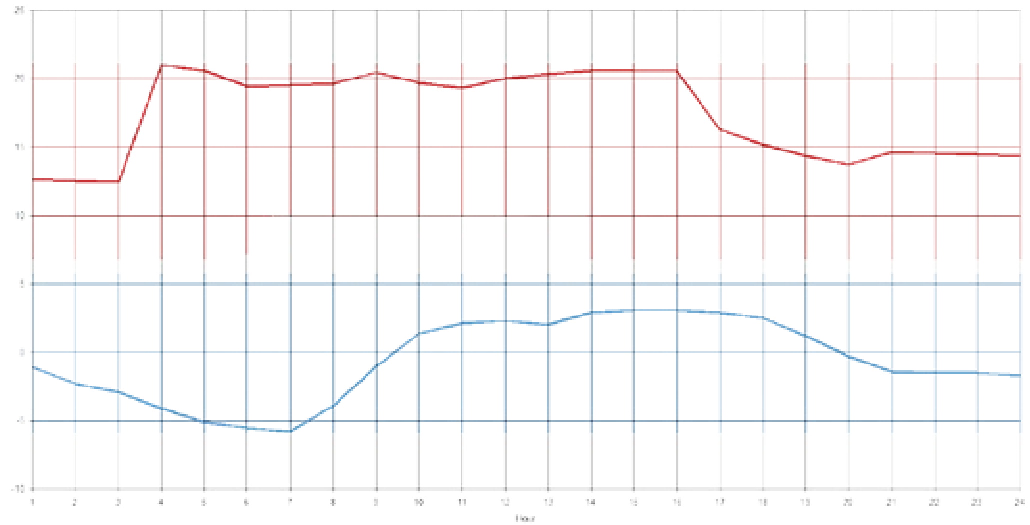
Simulations showed that if a minimum of two skylight windows were implemented the amount of daylight was significantly increased and it was possible to achieve a daylight factor of 3% deep into the room even without implementing a huge glassing area in the façade. The quality of light is also better because the room is enlightened from more than one direction which lowers the contrast of light in the room (see ill. 112).

DAYLIGHT - INTERNAL WINDOWS

Later it was decided to create window openings in the partition walls that separate the classroom from the corridor. Due to acoustic and functional reasons, the windows are placed 2,5 meter above the floor and from here continues to the ceiling. The main intention with windows inside was to create more quality to the indoor light by illuminate the room from two directions and thereby decrease the contrast in light. It was also expected that the windows would increase the daylight factor so the window area in the façade could be decreased, and by this reduce transmission loss.
However simulations showed that the windows inside did not influence the daylight factor because the amount of daylight already was higher in the classroom than in the corridor (see ill. 113). Even though it was not measurable the windows were added because of the idea that it gives a higher quality of light with less contrast.

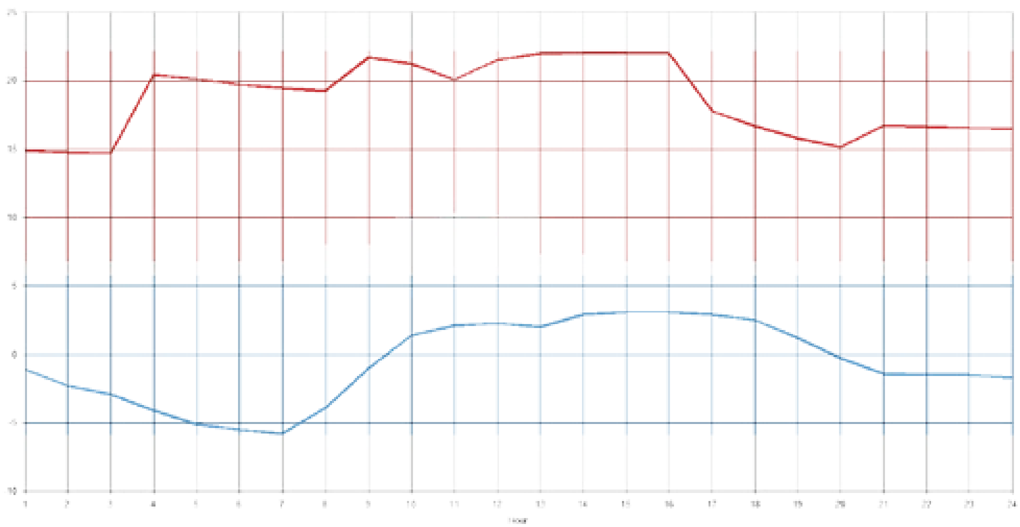
Inside temperature
Outside temperature

21 march



Wooden exterior wall
Ill. 114

21 march

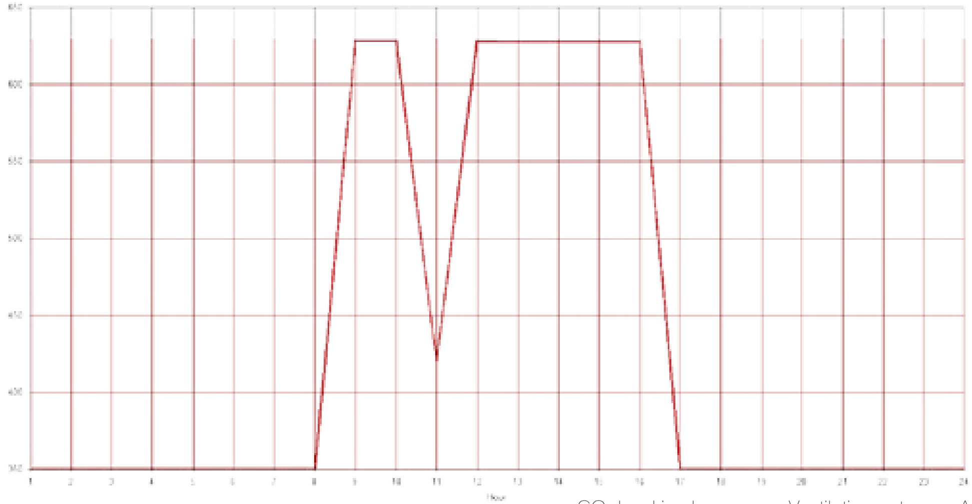


Concrete exterior wall
Ill. 115

DAY SIMULATION

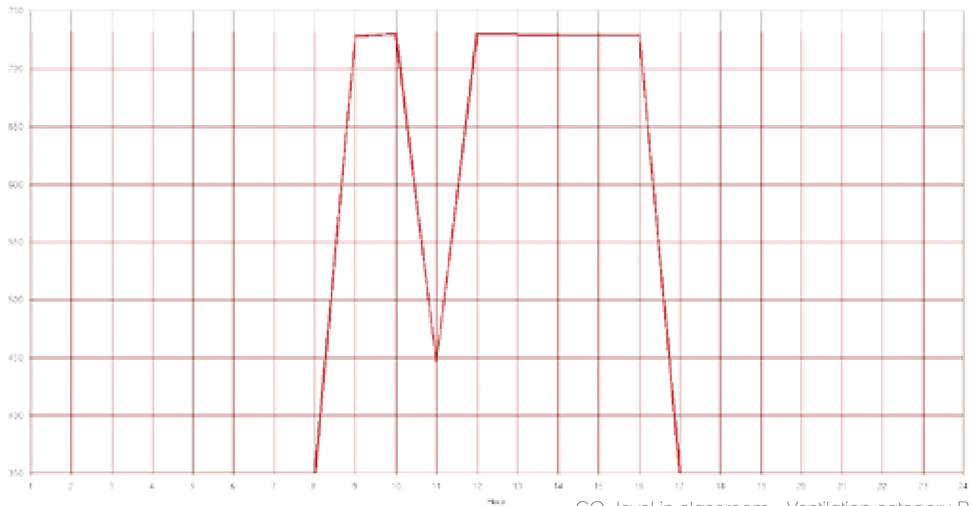
Day simulations has been made to compare the indoor temperature fluctuation when external wall construction is either concrete or wood (see ill. 114,115). The daily temperature fluctuations during a normal day in march is mostly the same, but wood performs a bit better as the temperature is closest to 21oC during school hours. But as the wood performs better in temperature the robustness demands to the materials in a primary school is much better for concrete. BSim calculations also tells that with wooden exterior walls the school has a higher heating demand due to less thermal accumulation, 467 kWh/year more for wood. Therefore it is chosen to make the school with concrete exterior walls.
As seen in ill.:116,117 the current settings fulfill BR20 requirements for CO_2 level, but as we strive to fulfill DS 1752 category A and previously shown analysis show that pupils perform better at category A it is chosen to have this high ventilation rate.

21 march

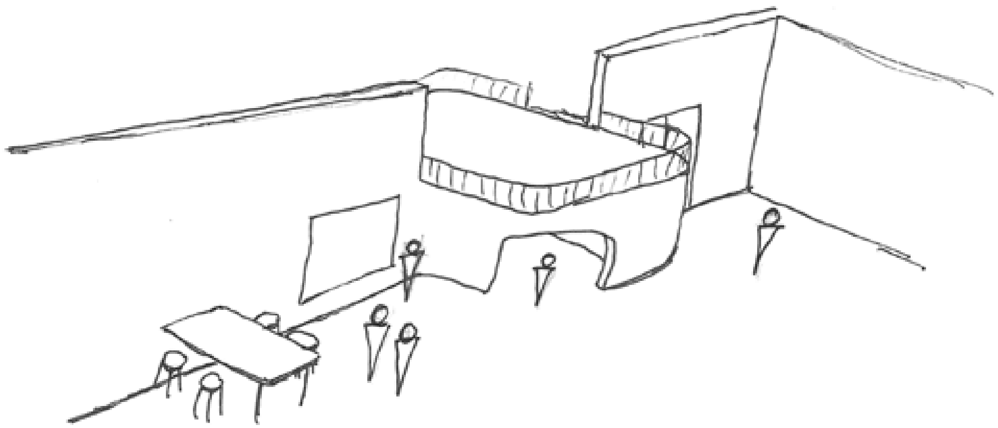


CO_2 level in classroom - Ventilation category A
Ill. 116

21 march



CO_2 level in classroom - Ventilation category B
Ill.117

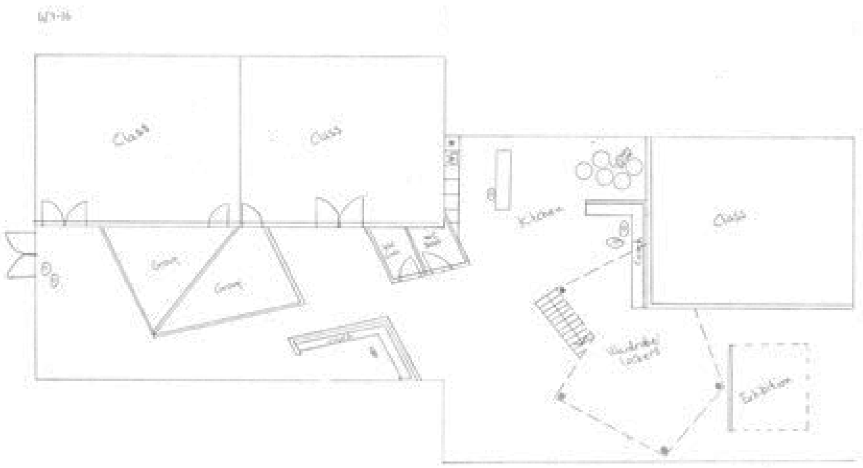


Group room extending from classroom over corridor
Ill. 118

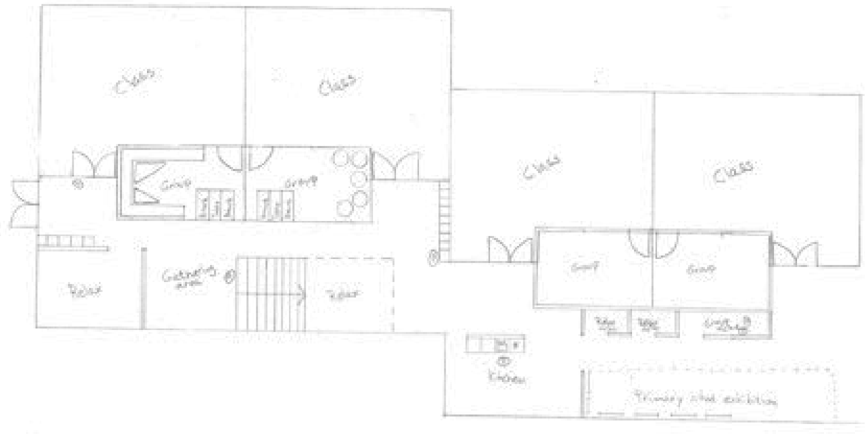
CORRIDOR, RELAX AND GROUP AREAS

As the new way of teaching Skolereformen encourage to integrate group rooms, relax areas and kitchens into the pupils area. The typical hall ways used for transit has been investigated to include these areas within. Group rooms and relax areas of different sizes and shapes was investigated in plans, perspective and section drawings. The displacement of the volumes gives a dynamic flow and kitchens and niches can occupy the voids that occur thereby.

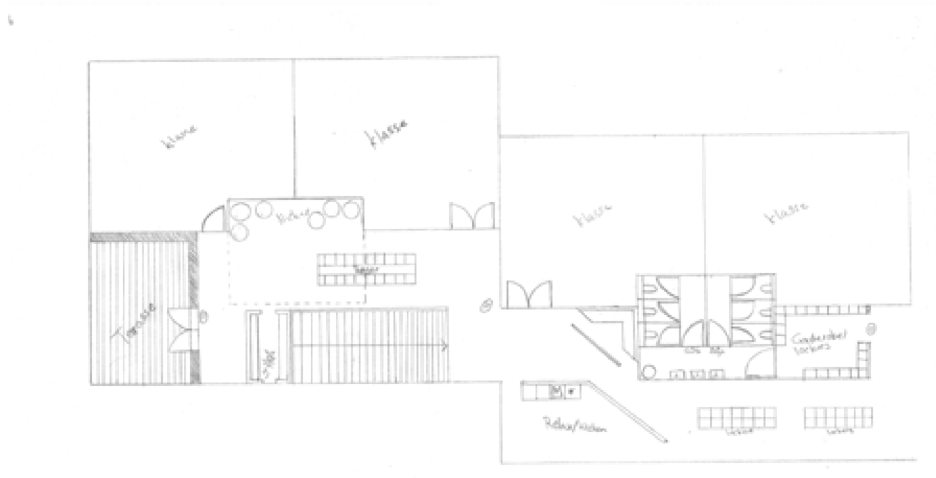
- Create identity for each branch
- Own kitchen attached to every branch
- Easy access to outdoor
- Easy access to heart room
- Furnish with group rooms and relax areas
- Open spaces for classrooms to extend into
- Exhibition of student's work
- Good accessibility no matter physical handicap
- Places for contemplation and places for play
- Use colors to enhance either concentration or physical activity
- Places to gather at least two classes
- ASP in primary school branch
- Good partitioning of hard and soft programmed areas
- Flexible areas and furniture for extended functionality
- Contact to subject rooms
- Decentralized staffroom for each branch



Corridor - angled hallway run late middle school
Ill. 119



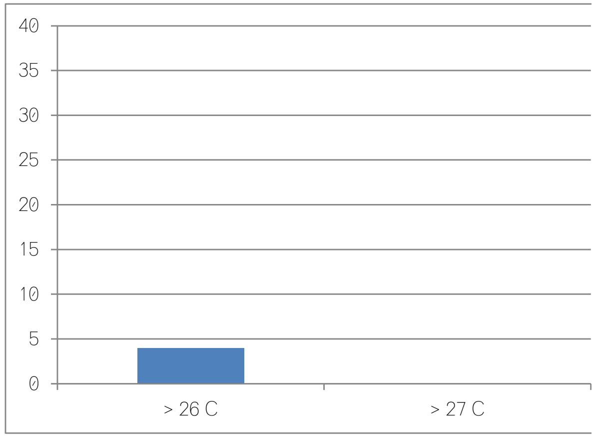
Corridor furnishing drawing - Primary school
Ill. 120



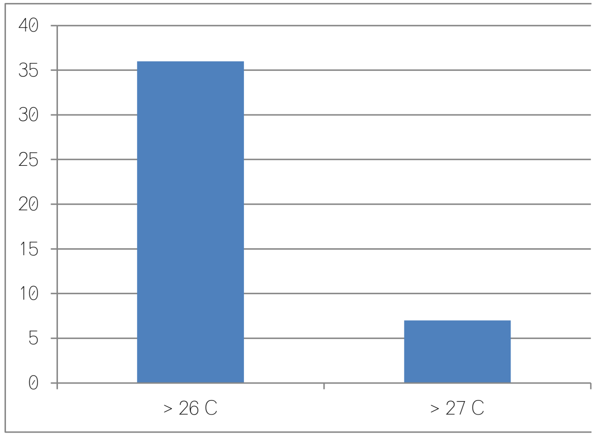
Corridor furnishing drawing - Primary school
Ill. 121

Angled hallways was tried (see ill. 119) but a more strict right angled hall way corresponding to the building volumes was preferred to make coherence. Niches meant to be able to contain 1-5 students and group rooms range from 4-10. This gives rooms for students to choose whether they want social interaction or more private contemplation time.

As primary school students don't have much use of group rooms and more use of playing and relax areas the big group rooms are left out. Big stairs from the ground to the first floor was instead tested. These big stairs are able to function as transit area as well as furniture for single pupils, group activities or in teaching regards (see ill. 120, 121).



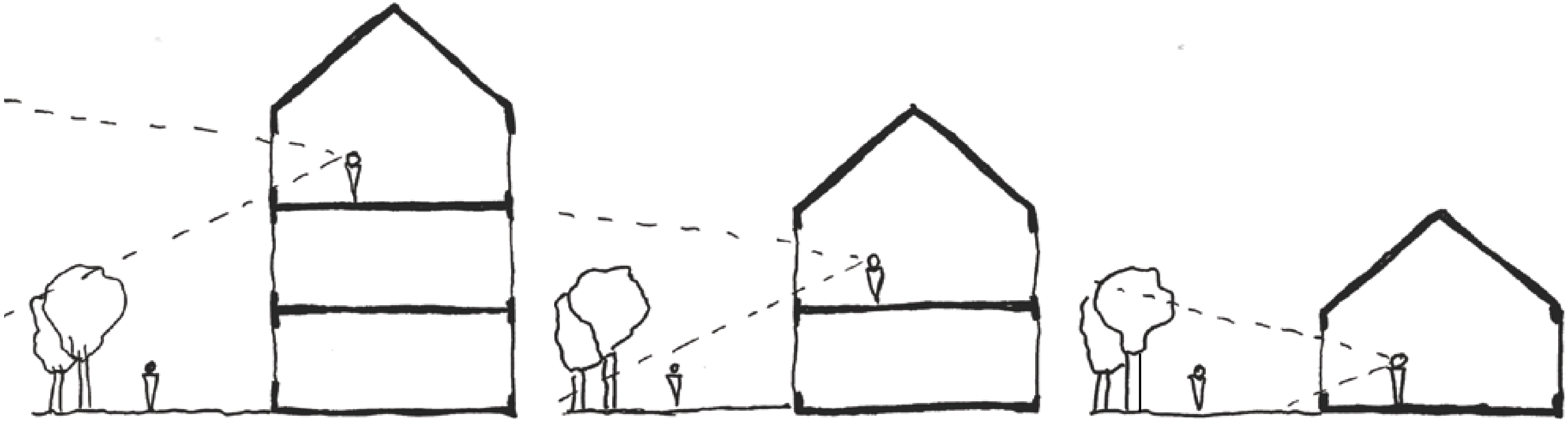
Overheating hours with shading
Ill. 122



Overheating hours without shading
Ill. 123

CORRIDOR OVERHEATING SIMULATION

Our initial concern about the corridors with big windows directly towards south was that overheating might occur. Therefore an overhang to shade from the high summer sun was applied in BSim. As the overheating hours was low with only 4 hours above 26°C (see ill. 122) we tried testing it without any shading devices. The result showed that the corridors was still able to fulfill regulations, and because of that, it was found as a better choice to leave out shading and have a clean architectural expression but a few more overheating hours and benefit from higher daylight factor (see ill. 123).



Principal view drawings
Ill. 124

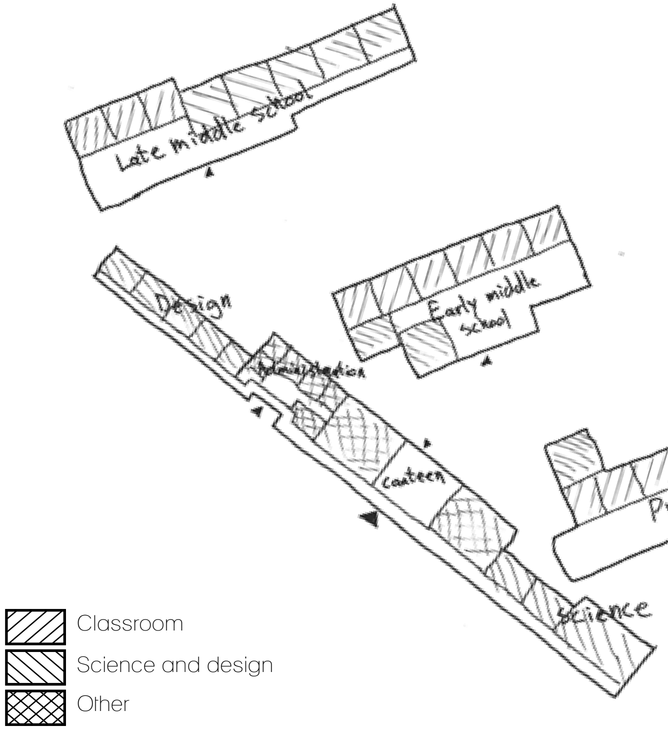
3 stories
- ➕ More outdoor space
- ➕ Less envelope
- ➕ Unobstructed view
- ➖ Bad visual contact between outdoor- and class area
- ➖ Expresses a less homely architecture
- ➖ Bad opportunities for outdoor teaching

2 stories
- ➕ Unobstructed view
- ➕ Relatively compact envelope
- ➕ Acceptable visual contact between outdoor- and class area
- ➕ Can expresses a homely atmosphere
- ➕ Acceptable opportunities for outdoor teaching

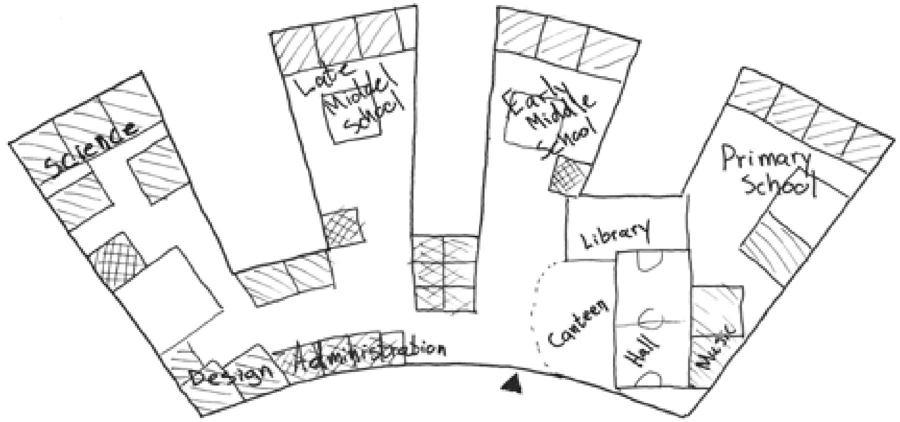
1 stories
- ➕ Good visual contact between outdoor- and class area
- ➕ Good opportunities for outdoor teaching
- ➕ Can expresses a homely atmosphere
- ➖ Obstructed view
- ➖ Large amount of envelope

VOLUME AND FUNCTIONS - PHASE 1

Before starting on shaping the volumes, a discussion was made of how many floors would be preferable according to create a modern school that can fulfill the parameters discovered in the program.
Here it was decided that 1-2 floors would be preferable, because both the physical and visual contacts to the outdoor area is limited if the school gets higher. This low scale will as well contribute to a more recognizable exterior with elements of security, tactile materials and kindness relation between building and pupil that can correspond to suburb neighborhoods.



Finger principal layout - single-storey
Ill. 125

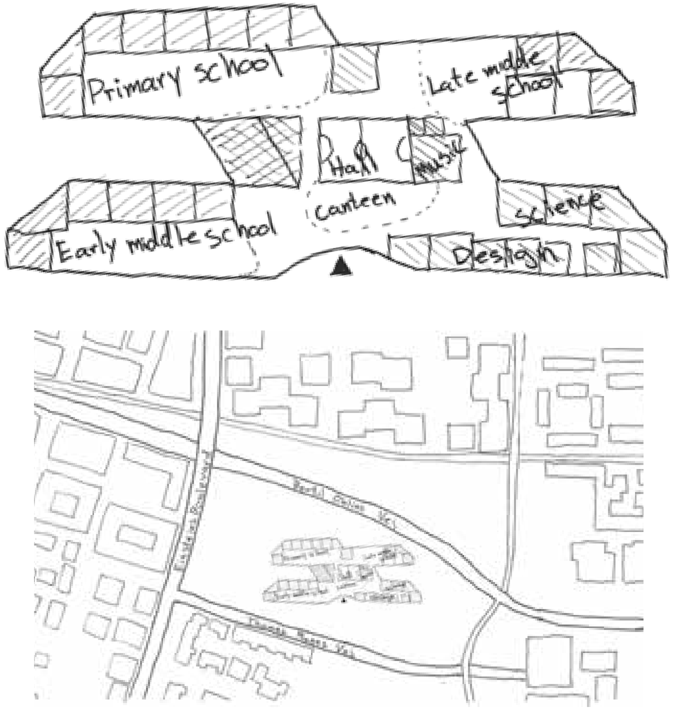


Finger principal layout - single-storey
Ill. 126

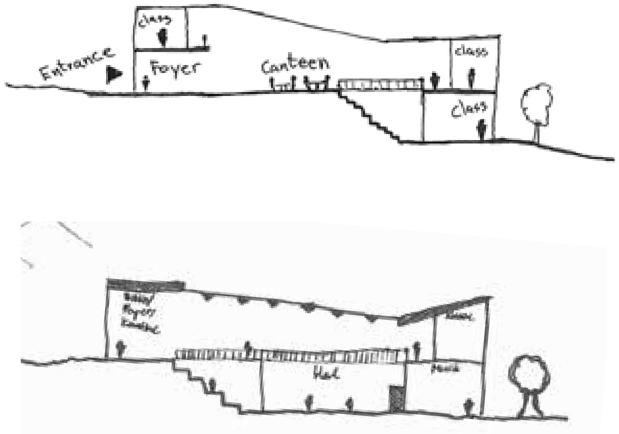
With focus on north orientated classrooms and creating individual branches for; primary school, early middle school, late middle school, design, science and administration and furthermore creating a central common room as a heart space for all the branches the first drawings was made.
Combining this main idea with a single story building was problematic because it would include long corridors and a big footprint. These plans did not utilize the site well as no defined outdoor spaces was made and conflicted with the master plan layout building grid (see appendix 1).

Finger principal layout - in context
Ill. 127

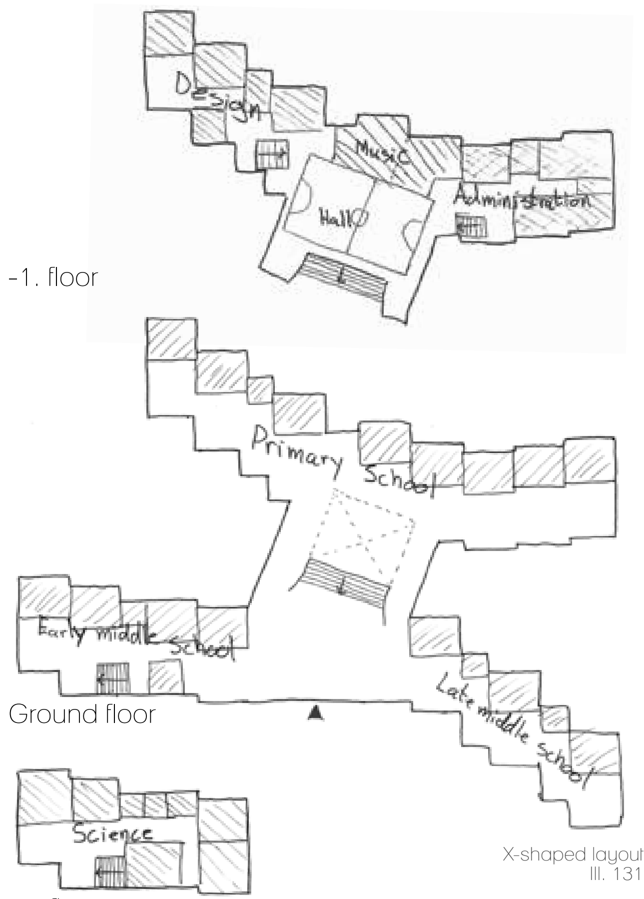
Finger principal layout - in context
Ill. 128



H-shaped layout
Ill. 129



Sections through heart room



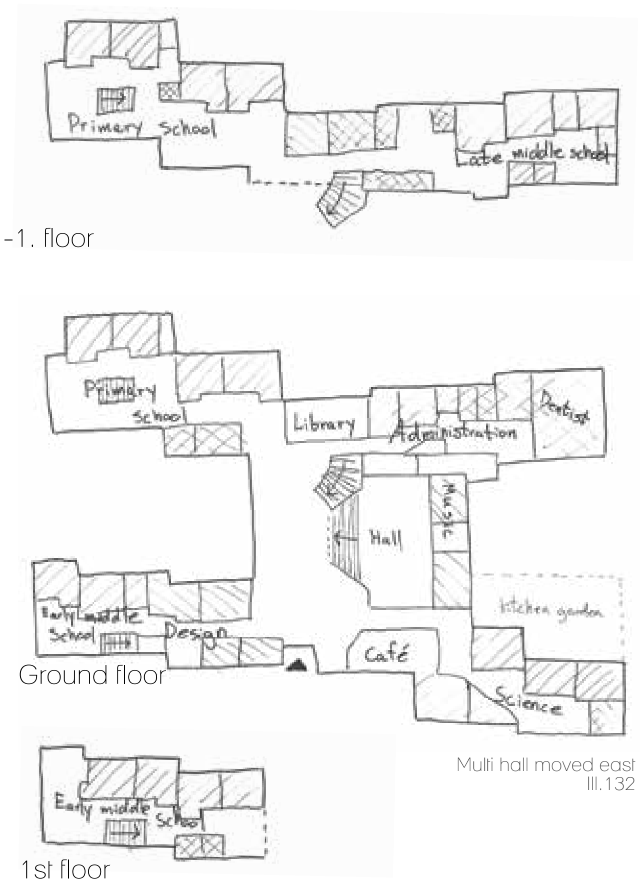
X-shaped layout
Ill. 131

THE H-SHAPE - PHASE 2

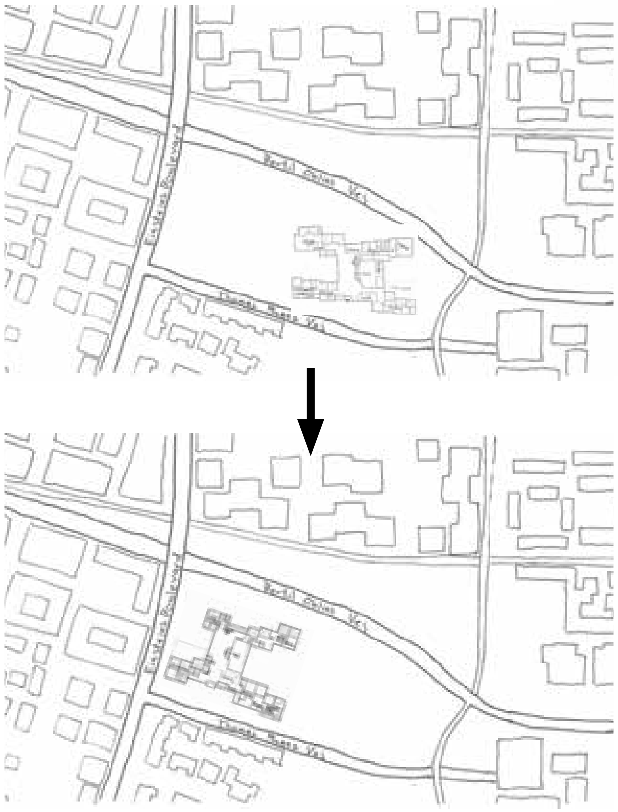
The concept (see ill. 58 page 58) of having all branches attached to a central heart space but at the same time have all the classrooms and offices orientated towards north, the H-shape seemed to be the optimal solution. With its limited space for corridors and a more compact volume demands for avoiding waste space and energy demands it met some of the criteria for the building volume. However, the outdoor space was still undefined on the site (see ill. 129).

Another design challenge was how to implement the multi hall as an active and social part of the heart room. By using the sites natural level differences (see ill. 130) to lower the hall one story, the heart space was now split into two open rooms with an interesting visual contact from the upper café area down to the hall. This also made a hierarchy between the café and entrance and clearly expressed its functions as transition area and social anchor point. The multi hall was shielded with only the big stair to access it. Activities going on in the hall was now undisturbed by people passing by in and out of the school and to other activities.

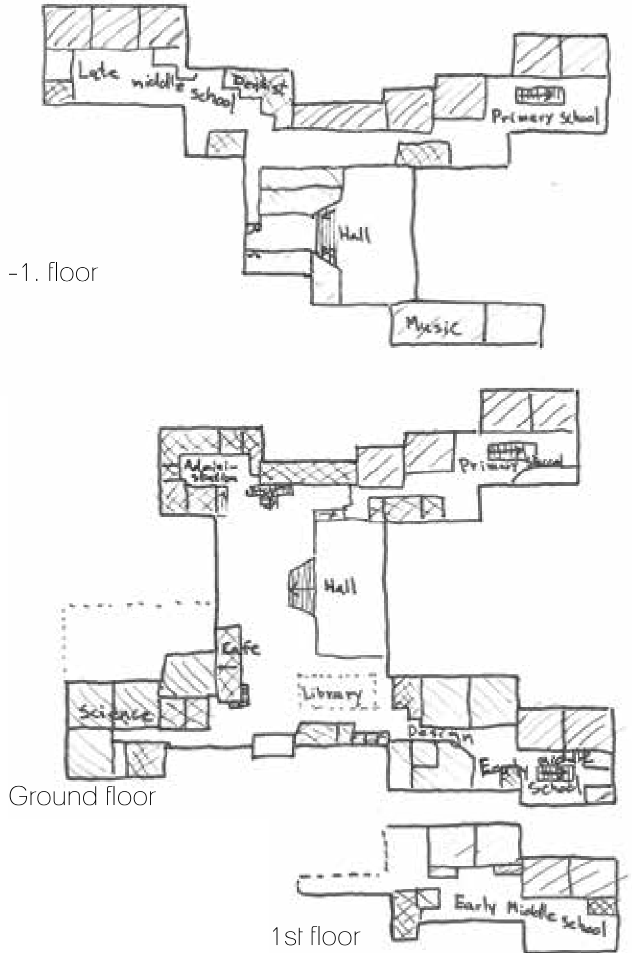
To create better outdoor areas and views out to larger areas with scenery the H-shape was opened up to a X-shape, but the facades was still facing north/south due the desire of north orientated classrooms (see ill. 131).



Multi hall moved east
Ill.132



Building moved to follow master plan grid



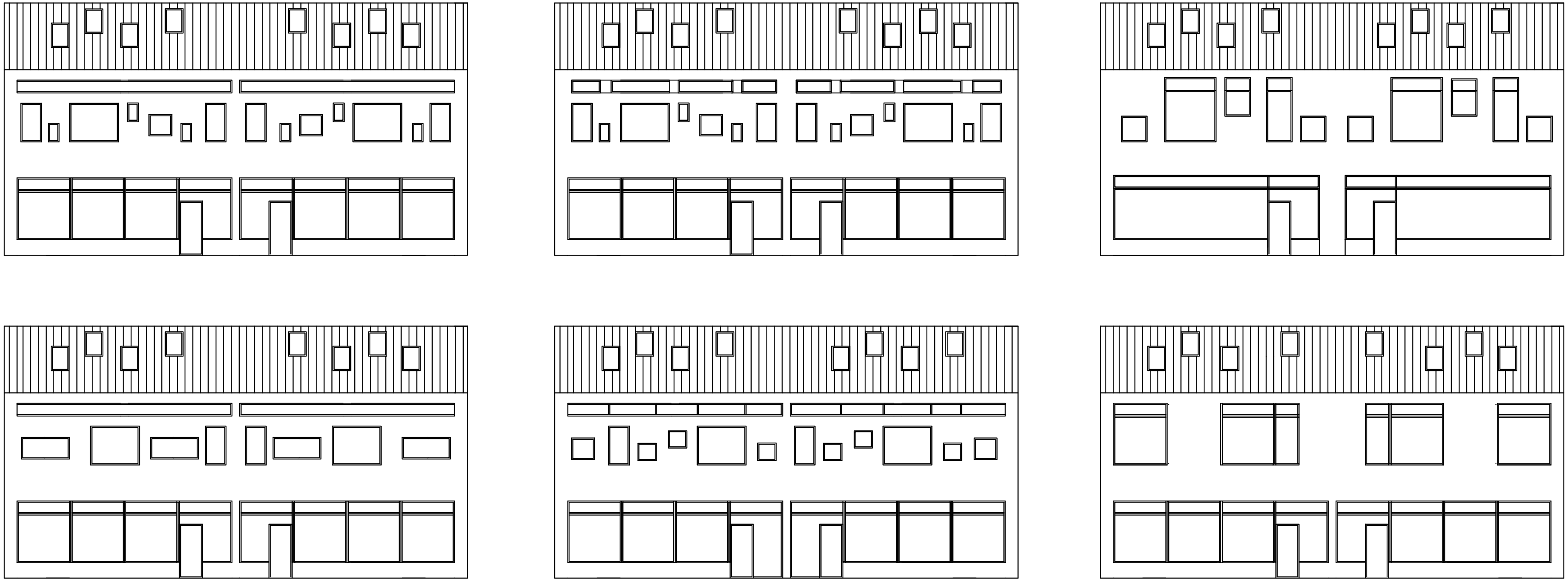
Heart space connected to outdoor
Ill. 134

By rotating and moving the multi hall to the east a better defined and centralized heart space was been created to the west of the multi hall.
The science area and home economics got their own kitchen garden, the late middle school got south orientated outdoor terrace. The administration was moved to the upper floor to insure proper office conditions, undisturbed by distracting views to playing kids and the noise, as kids easily create noise at 85 dB and the recommendation tells to keep it between 45-50 dB in offices [miljøstyrelsen, 2015].
A sound proof glass wall between administration and the heart room inside was made to shield from noise from the multi hall and general transition as well. The glass also secures visual contact to the administration and create a cohesion teachers and students in between (see ill.132).

The whole building have been moved from the east end to the west end of the site (see ill. 133). To ensure the same relations to outdoor areas and their connections from the nearby indoor functions, the whole building except the heart space have been mirrored.

The dentist and administration was moved to a more central location, so it is easy to find for strangers, meaning that no functions are placed above the late middle school, which give better opportunity for ensuring good daylight conditions by using skylight windows in the classrooms.

To create a more spacious view and atmosphere in the heart space, and to create a better connection between the heart room to the big school yard, the music room was moved and make space for a curtain wall between the multi hall and the outdoor area (see ill. 134).



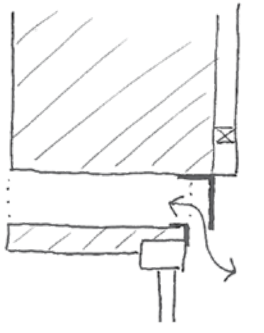
Facade window experimen-
tations

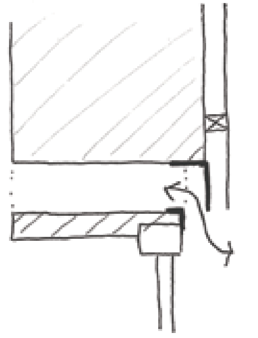
FACADES

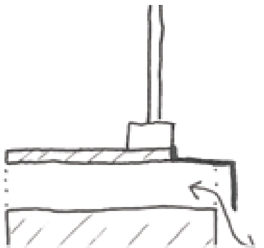
Because the classroom is the function that has the most difficult requirements to fulfill (daylight factor, views, creating niches) the placement and shape of windows take its starting point in the classrooms. To ensure a uniform expression the lines and shape of the windows will be used for almost the entire building.

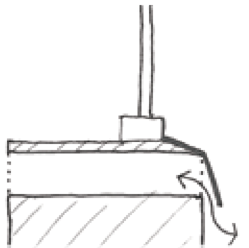
As earlier mentioned the daylight studies informed that classrooms placed on ground floor without roof windows would need a huge glazed area in the facade. Classrooms placed on 1st floor with skylight windows can achieve the daylight requirements with a much lower facade window area.

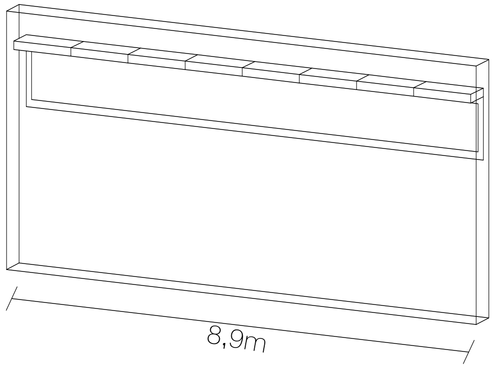
To create a playfulness to the facade different windows rhythms was tested. However, the expression between the ground floor and the 1st floor was too big. The intention of insuring pleasant views to scenery from inside the classroom was limited in some areas because of small or highly placed windows limited the view. Another design parameter was how to include highly placed windows for venting without disturbing the external expression.
The solution was a more simple expression that ensures consistency and simplicity from the outside, with big and low placed windows that create good views from the inside (see bottom right proposal ill. 135).


Window top - InVentilate wood facade
Ill. 136

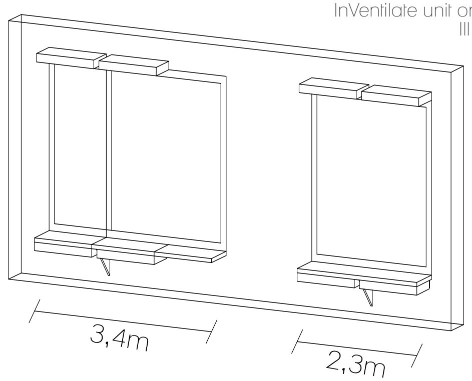

Window top - Wood facade covers InVentilate
Ill. 137


Window sill - Right angle outer sill
Ill. 138

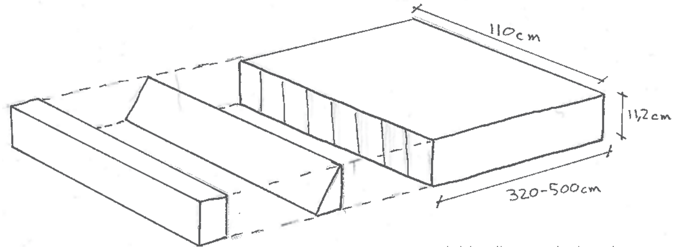

Window sill - Angled outer sill
Ill. 139



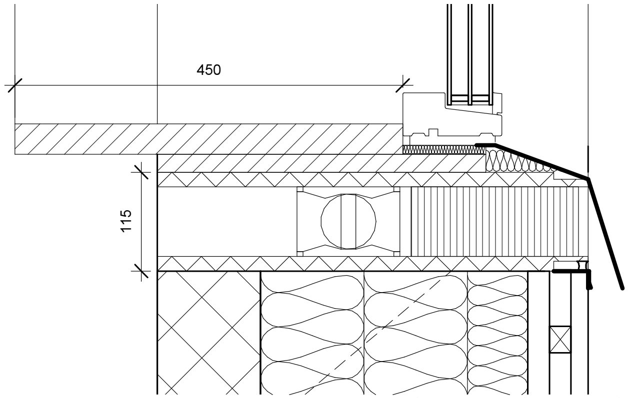
InVentilate unit on line
Ill. 140



InVentilate unit above and below
Ill. 141



InVentilate unit drawing
Ill. 142



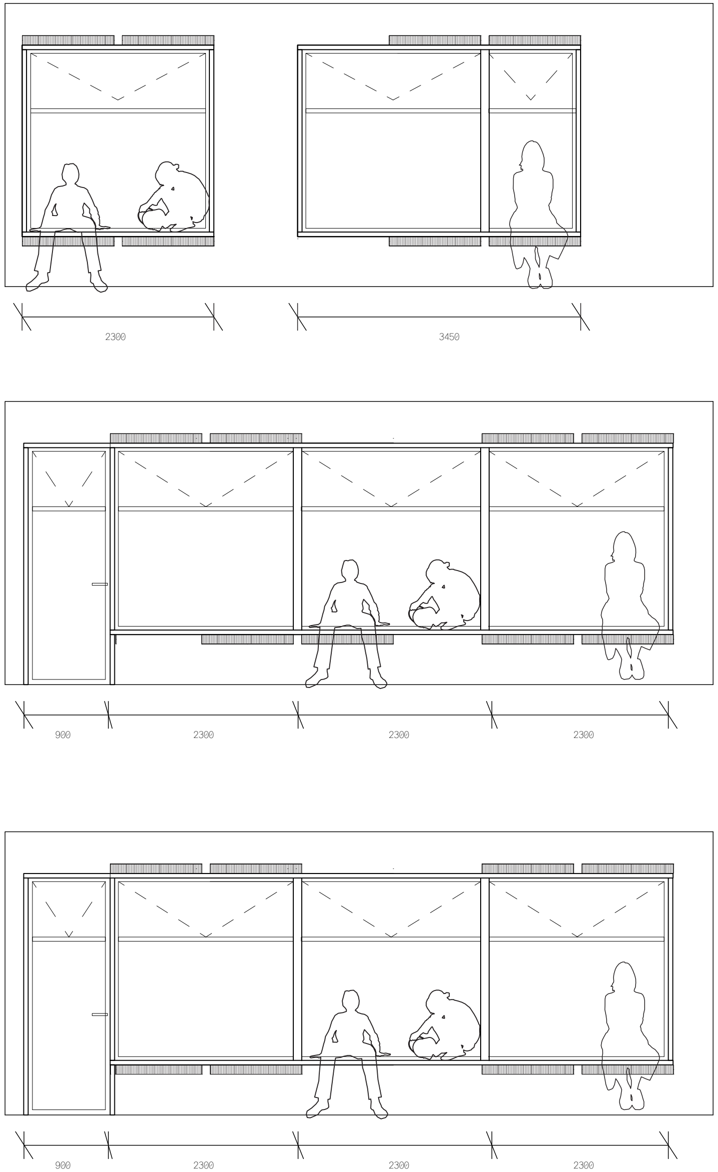
InVentilate under window detail
Ill. 143

Another challenge that has been implemented in the developing of the facade expression was how to incorporate the decentralized ventilation units. Due to aesthetic and structural reasons, it was decided that the ventilation units should be placed above or under the windows. Aesthetically to place the unit in extension of the window sill it would create a more homogeneous look to the outer facade that we wanted. Technically if the units were places separately away from the windows the load bearing concrete wall might suffer from these gaps. By placing the ventilation units close to the windows, it would from the outside visually be possible to make units integrated into of the window frame, or make them nearly seamless with the facade cladding (see ill. 137,138).

Calculations showed (see appendix 5) that 8 decentralized ventilation units of a length of 110 cm (InVentilate V8 units) would be needed for each classroom. The first idea was to place all above a highly placed ribbon window (see ill. 140). The ribbon windows seemed to be inappropriate according to aesthetic expression and structural reasons. However to make space for all 8 units the length of the facade had to be extended from to 9,0m.

The solution was to place the ventilation units both above and under the windows (see ill. 141), by giving the windows a length of 2,3 m it was possible to place two units next to each other and also place a window construction bracket between them so the window frame can be supported.

As question and concern about draft in thermal comfort regard, the unit under the window did not fulfill the regulations for draft that has to be lower than 0,15 m/s in occupation areas [BR15 6.3.1.1 stk. 3] and our case it was 1,87 m/s. Due to this regulation two layers of InVentilate units was installed over the windows instead. As we think the visual expression from inside is not as good and integrated, however this was necessary (see ill. 146).



Considerations about InVentilate seen from classroom
Ill. 144

Visualization of one unit over and one under the window
Ill. 145

Visualization of two units over the window
Ill. 146


Building 3d print - Angled pitched roof
Ill. 147


Building 3d print - pitched roof
Ill. 148

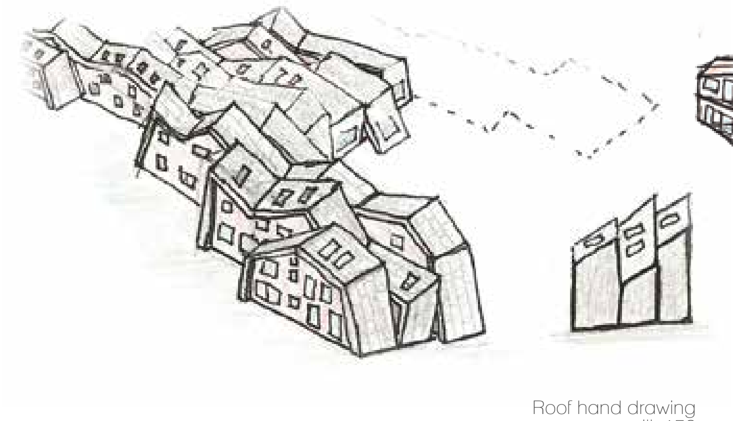

Roof hand drawing
Ill. 149


Roof hand drawing
Ill. 150

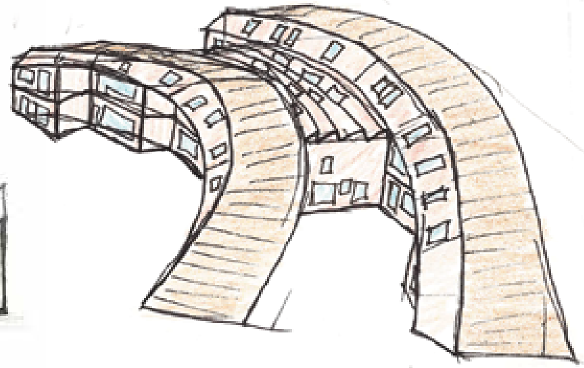
ROOF - PHASE 1

The first ideas for the roof was based on creating a playful and iconic pitched roof that also could bring the building down in scale (see ill. 147). As technical parameters the roof had to include smaller south orientated roof areas that possibly could be used for photovoltaics and north orientated skylight which earlier studies showed were preferred for the classrooms. However, the studies showed this type of roof could not fulfill those criteria as the roof surface would be facing east-west. It also made some strange spatialities inside the rooms with irregular ceiling angles. With the same intentions, a more strictly roof structure was also tried, here the shape turned out to have a too industrial expression (see ill. 148-150).

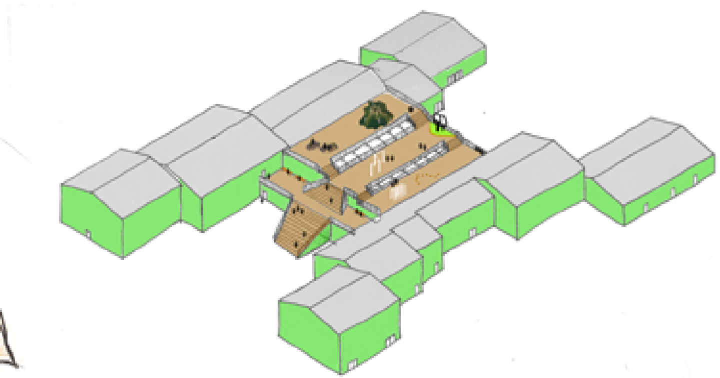

Roof hand drawing
Ill. 151



Roof hand drawing
Ill. 152



Roof hand drawing
Ill. 153



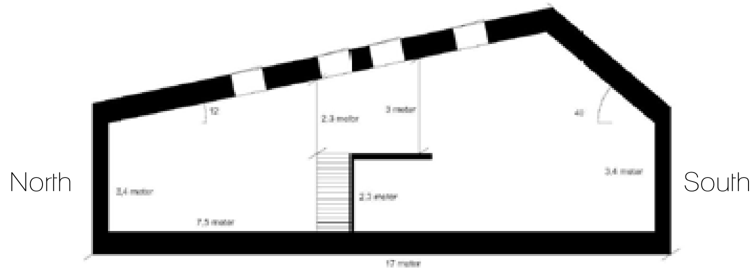
Roof hand drawing
Ill. 154

Roof hand drawing
Ill. 155

ROOF - PHASE 2

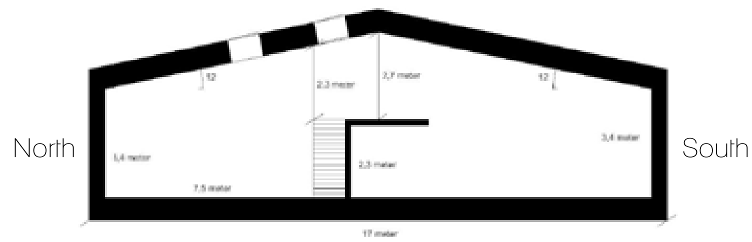
As a next step, it was tried to shape a roof that would make the building seem like one or two units with focus on avoiding an industrial expression. However the roof had another architectural expression than the building itself, that was conflicting with each other, the square shape against the organic geometric form (see ill. 153, 155)

It was also tried to implement the roof as a roof terraces, as part of the school yard, but the idea was dismissed because the outdoor area already is bigger than for an average Danish suburban school and therefore no greater need for more outdoor area (see ill. 154).



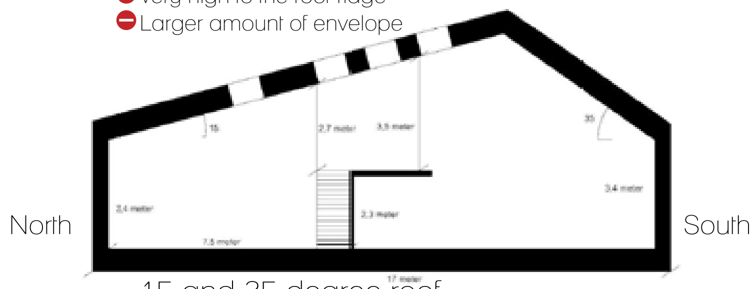
12 and 40 degree roof

- Fulfill requirements for ceiling height over stairs
- Little direct sun into sky light windows
- Very Good angle for photovoltaics
- Very high to the roof ridge
- Larger amount of envelope



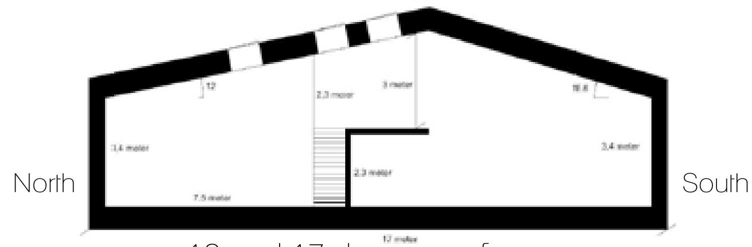
12 and 12 degree roof

- Fulfill requirements for ceiling height over stairs
- Not good angle for photovoltaics
- More direct sun into sky light windows



15 and 35 degree roof

- Fulfill requirements for ceiling height over stairs
- Little direct sun into sky light windows
- Good angle for photovoltaics
- High to the roof ridge
- Larger amount of envelope



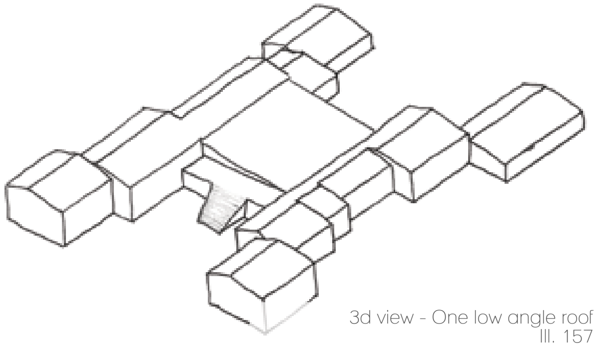
12 and 17 degree roof

- Fulfill requirements for ceiling height over stairs
- Good ceiling height in loft area
- Okay angle for photovoltaics
- Some direct sun into sky light windows

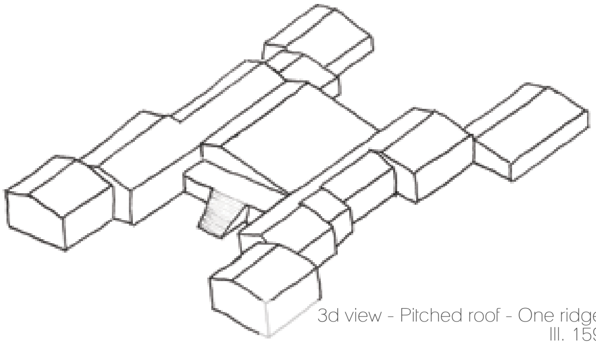
Roof heigh experiments
Ill. 156

ROOF - PHASE 3

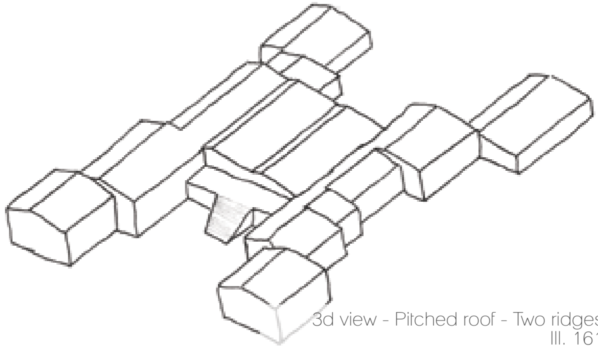
To give a clear and functional expression it was decided to work inside out, and let the functions and wanted atmosphere of the inside shape the external roof. At this time it was decided that there should be space for group rooms elevated over the corridors. The angel of the roof was a synthesis of creating a group room area with a more cozy atmosphere but still fulfilling the regulations saying roof height over staircases must not get below 2,3 m. It was also a wish to bring light from windows on the north facing roof part into the group rooms and relax areas (see ill. 156).



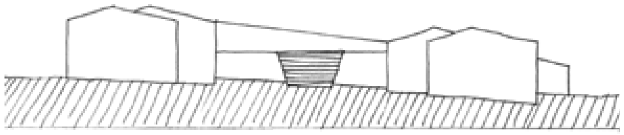
3d view - One low angle roof
Ill. 157



3d view - Pitched roof - One ridge
Ill. 159

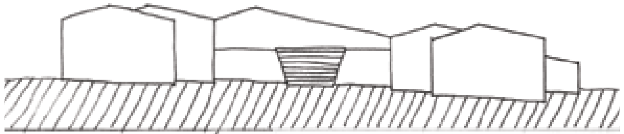


3d view - Pitched roof - Two ridges
Ill. 161



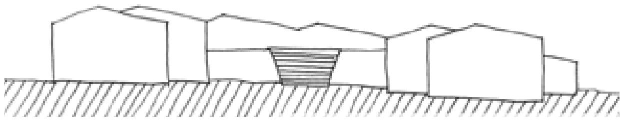
East facade - One low angle roof
Ill. 158

- No south orientated roof for photovoltaics
- Not the same expression as surrounding rooftops
- Too small slope to create north orientated roof light



East facade - Pitched roof - One ridge
Ill. 160

- Large south orientated area for photovoltaics
- No profound meaning of why the roof is highest above the library



East facade - Pitched roof - Two ridges
Ill. 162

- Mimes the other rooftops and create consistency
- Large south orientated area for photovoltaics

HEART ROOM ROOF

The final part was to shape the roof over the multi hall and heart space, the intention was to insure an overall coherence from the outside but also create aesthetic and spacious qualities and coherence when standing inside the heart space. By using the same angle and directions (beside ill. 157) as the surrounding roofs different designs was tested (see illustrations above).

Roof heigh experiments - 3d view
Ill. 163

VIII

EPILOGUE

CONCLUSION
REFLECTION
LITERATURE LIST
ILLUSTRATION LIST

EPILOGUE

In this chapter the final conclusion and reflection is presented. Literature and illustration list is also present in this chapter.

Girl
Ill. 164

CONCLUSION

New learning methods and a new Skolereform has resulted in changes of the physical needs of a primary school where physical activity, group work, digital media, individual feedback and individual contemplation has come into focus. At the same time in this project the ambitions was as well to integrate social sustainability, low energy use and a good indoor environment. It is a challenging task to accommodate all these aspects and at the same time meet the requirements of all the school functions in an slating terrain. To fulfill all aspects the integrated design process has been used throughout the project.

With departure in forming a social and central heart room with a café, library and a multi hall, the remaining functions propagate out from the space into four branches. These four branches divide the outdoor area into four, one smaller relaxing area where the late middle school students have the opportunity to socialize, a play area for the primary school and ASP with activities suited for them, entrance area from Thomas Manns Vej and a large school yard that features physical activities for everyone. The displacements of the building volume creates the outdoor areas but as well niches and cozy nooks inside the building, which make social gathering places and a diverse interesting passages through the branches.

The H-shape of the building ensures that most of the teaching rooms are facing north, which create better indoor climate, good daylight conditions and as well good visual contact to the outside due to the large glazed facade area. This orientation counteracts also problems with glare and overheating hours. The relatively compact building form, with deep volumes in one and two stories, contributes to a more stable indoor climate and reduces transmission loss to outside.

In this new school the wish to create good and diversified learning environment has been a focus area and the school offers new spatiality beyond traditional teaching methods like, group rooms for discussion and creative work, niches for individual reflection, gathering places for presentations and lectures and indoor and outdoor areas close to classrooms so the teacher easily can include physical activity in the teaching.

With the departure in working with social sustainability, from DGNB's certification system, of what social sustainability contains, there is made a school that insures good indoor climate in terms of temperature, atmospheric comfort and visual comfort. The classrooms fulfills recommendations for DS/EN 1752 category A, that though research, as described in the program, shows that a better indoor climate enhances students capability to learning in a positive way compared to regular schools that only just meet the requirements stated by the building regulations.

The surrounding city has been included as an active part in the planning of the school where the citizens can use the science, design, multi hall and kitchen area after normal school hours. Due to logistic, social and energy concerns these functions is located close to the main entrance, which makes it possible to shut down the rest of the school during night.

It has been a challenge to meet the high ambitions to create a good indoor climate that has resulted in rooms with high air change rate and big window areas which is conflicting with the low energy frame for BR2020. It is though succeeded by using mechanical ventilation with low energy consumption, orientate windows and adjust the glass transmittance, integrate natural ventilation and thermal heat accumulation. With these initiatives and a special subsidy the building fulfills the energy requirements for BR2020.

REFLECTION

To design a new public primary school with focus on the needs of tomorrow has turned out to be a bigger challenge then expected. A lot of demands for functions combined with spacious and functional thoughts of how a school of tomorrow can be designed that do satisfy new teaching technologies had to be solved.

This proposal for a school of tomorrow offers a variation of classrooms, group rooms and niches that provides the framework for social relations, accommodate students different work tasks and the individual's needs.
There is established good condition for the use of digital media in teaching regards e.g. by securing that glare does not occur in classrooms and niches. If the school should be erected in real life the design and configuration of the building will be dependent on the school's educational approach, therefore it is a shame that no specific principal and teacher group was afflicted this project to target their wishes. This was unfortunately not the case because Aalborg Municipality is not that far in the plans of the school yet. Instead the project takes its departure in the new Skolereform and digital learning as the Municipality refers to in their school vision.

Though it can be questioned how much a new school should follow the Skolereform as part of it have been criticized and a lot wonder that some parts might change e.g. long school days and study contemplation quite soon. On the other hand this project gives some suggestions on how the spacial and functional aspects are able to solve lots of the future concerns about indoor climate and functionality and can make the framework to enhance students learning outcomes.

School yards are an important part of the pupils' daily life and wellbeing. This proposal has therefore focused on creating outdoor area to accommodate all needs where students can interact and meet but as well areas specified for e.g. primary school and ASP where the younger kids can feel "at home" and safe. The elderly students also have an area where they can withdraw from the younger kids and socialize without disturbance from playing kids. Outdoor areas are drawn on conceptual level and further development of these can be relevant to suit areas better for specific needs.

The school's basic design takes its departure in indoor climatic considerations about how to avoid overheating hours in classrooms and other subject rooms where a high internal heat gain is already present. This is partly solved by turning rooms towards north and partly by having a high air change. These principles have shown through Bsim calculations to be true and it has led to later climatic calculations have not had bigger impacts on the building design. However, it has been necessary to install skylight windows to obtain good daylight in classrooms and windows with low transmittance to avoid overheating. This might have been solved by a steeper roof angel.

By focusing on indoor climate and functionality, structural concerns have been limited in the design process, which might have led to some critical construction issues, especially in the heart room where columns or huge beams unfortunately might be necessary. If the project should be further projected these structural issues should be solved in coherency with the architectural expression.

The building context has little influence in the design of the school. This will be a relevant factor to relate to, like materials and size, but with the limited knowledge of how the area will look when built, and future context, the main focus area has been the overall building lines in the master plan, the close position to Gigantium and Aalborg University that can integrate the neighborhood into the education.

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IX

APPENDIX

APPENDIX

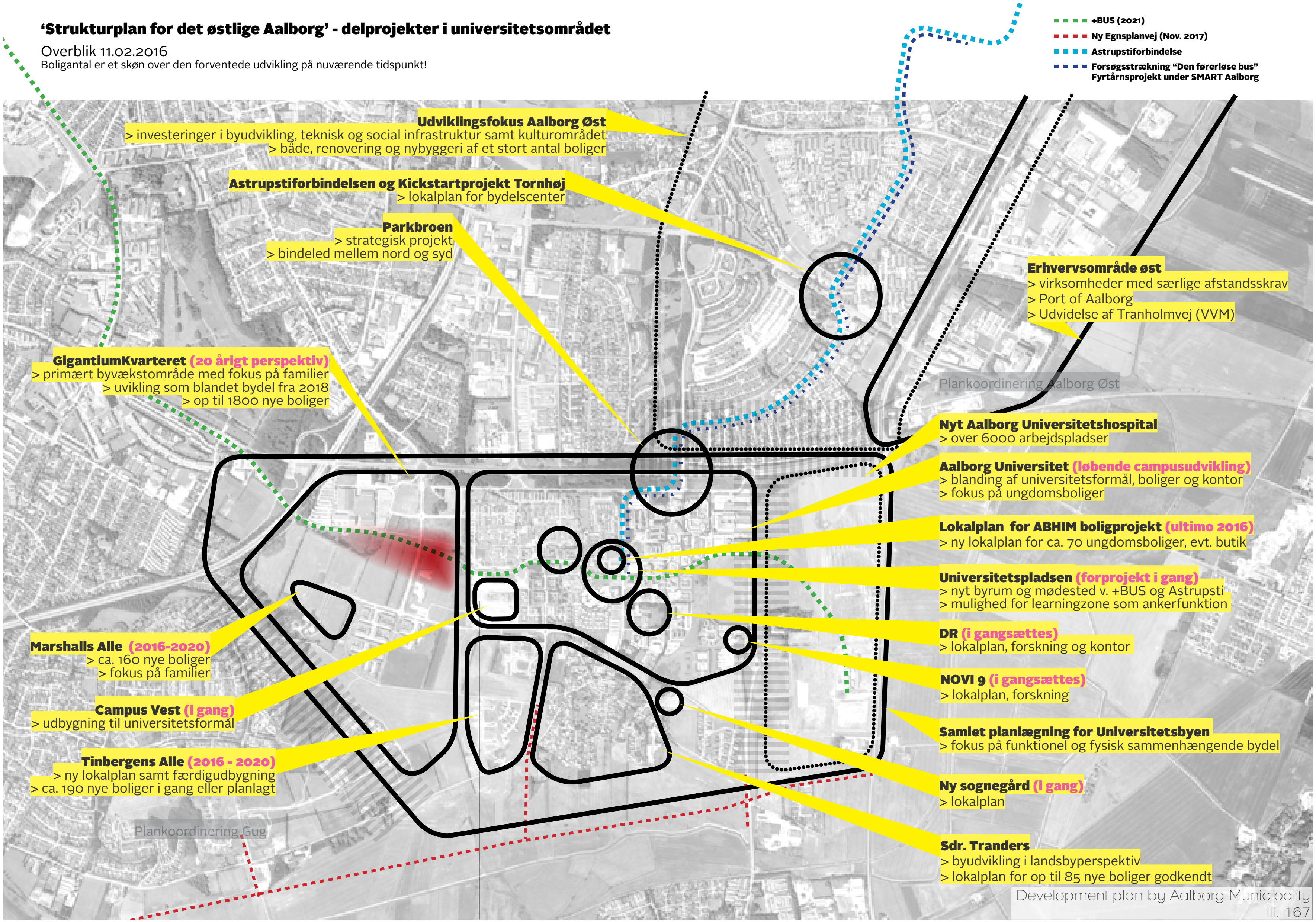
In the appendix material referred to previously can be found, as comprehensive drawings, text and diagrams. Be10 calculations and InVentilate from the final building is present in this chapter.

Girl with question
Ill. 165

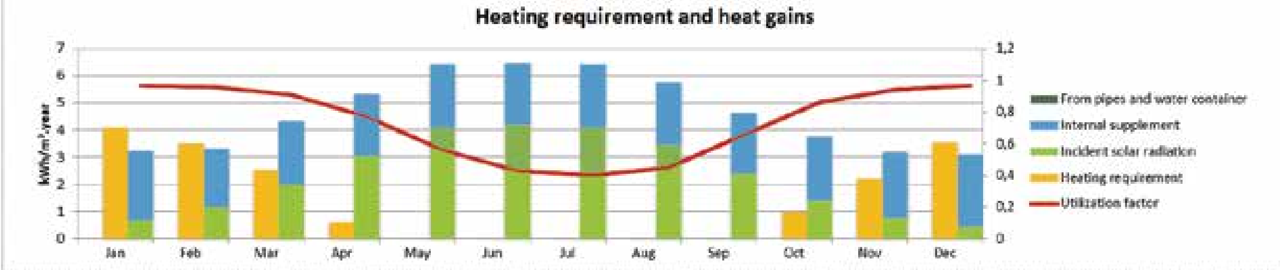
Master plan by Vandkunsten
Ill. 166

'Strukturplan for det østlige Aalborg' - delprojekter i universitetsområdet

Overblik 11.02.2016
Boligantal er et skøn over den forventede udvikling på nuværende tidspunkt!

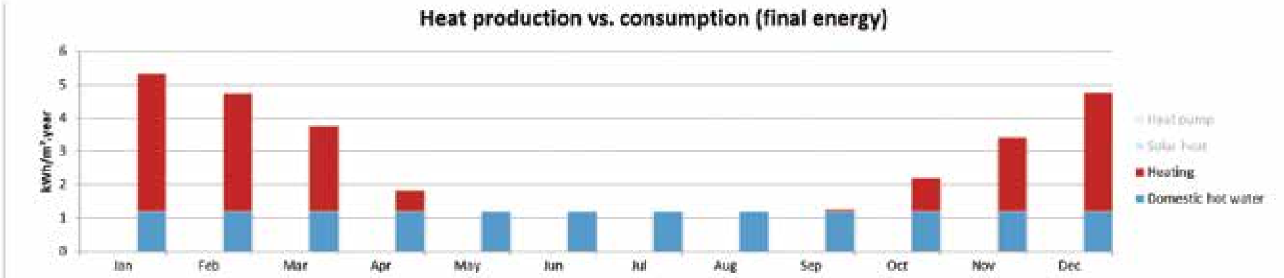


Development plan by Aalborg Municipality
Ill. 167



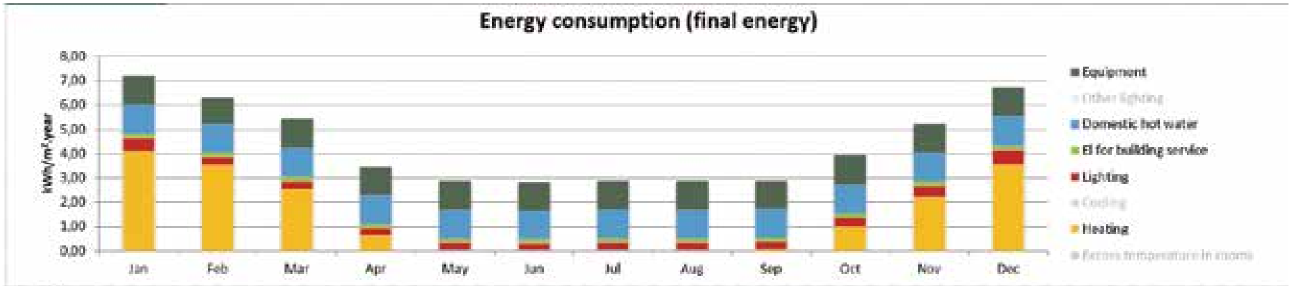
kWh/m² year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating requirement	4,11	3,52	2,55	0,62	0,01	0,01	0,01	0,01	0,06	0,99	2,20	3,54	17,63
Incident solar radiation	0,68	1,15	1,97	3,05	4,07	4,21	4,09	3,44	2,38	1,38	0,75	0,46	27,62
Internal supplement	2,54	2,16	2,31	2,23	2,31	2,23	2,31	2,31	2,23	2,37	2,42	2,61	28,04
From pipes and water cc	0,06	0,05	0,06	0,05	0,06	0,05	0,06	0,06	0,05	0,06	0,05	0,06	0,67
Utilization factor	0,97	0,96	0,91	0,77	0,56	0,43	0,40	0,45	0,66	0,86	0,94	0,97	0,74

Heat requirements and heat gains
Ill. 168



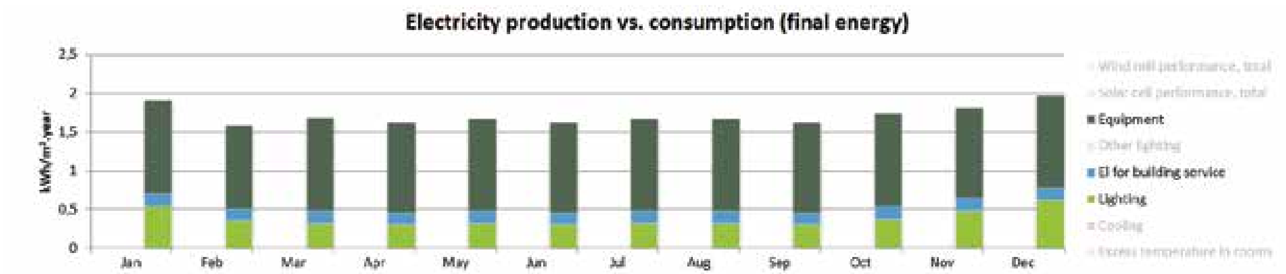
kWh/m² year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Domestic hot water	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	13,9
Heating	4,11	3,52	2,55	0,62	0,01	0,01	0,01	0,01	0,06	0,99	2,20	3,54	17,63
Solar heat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Heat production vs consumption
Ill. 169



kWh/m² year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Excess temperature in ro	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heating	4,11	3,52	2,55	0,62	0,01	0,01	0,01	0,01	0,06	0,99	2,20	3,54	17,63
Cooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lighting	0,54	0,36	0,32	0,30	0,31	0,30	0,31	0,31	0,30	0,38	0,49	0,62	4,54
El for building service	0,17	0,15	0,17	0,16	0,17	0,16	0,17	0,17	0,16	0,17	0,16	0,17	1,97
Domestic hot water	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	1,20	13,9
Other lighting	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Energy consumption
Ill. 170



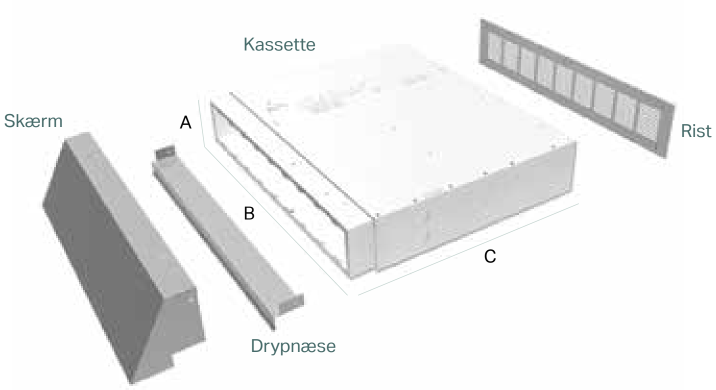
kWh/m² year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Excess temperature in rc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lighting	0,54	0,36	0,32	0,30	0,31	0,30	0,31	0,31	0,30	0,38	0,49	0,62	4,54
El for building service	0,17	0,15	0,17	0,16	0,17	0,16	0,17	0,17	0,16	0,17	0,16	0,17	1,97
Other lighting	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Equipment	1,20	1,08	1,20	1,16	1,20	1,16	1,20	1,20	1,16	1,20	1,16	1,20	14,10
Solar cell performance, t	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wind mill performance,	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Electricity production vs consumption
Ill. 171

APPENDIX IV

Tekniske data for MicroVent 2-8, 2/2, 3/3

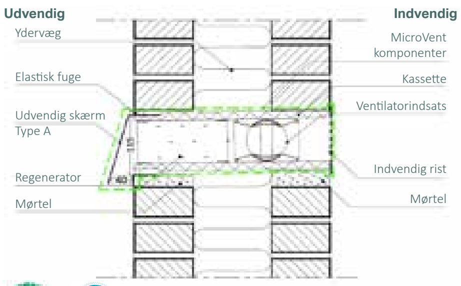
Indbygningsdele



Måltabel

Dimensioner	Kassette			Udsparing	
mm	A	B	C	H	L
MV 2	112	350	320-500	115	357
MV 3	112	475	320-500	115	482
MV 4	112	600	320-500	115	607
MV 5	112	725	320-500	115	732
MV 6	112	850	320-500	115	857
MV 7	112	975	320-500	115	982
MV 8	112	1100	320-500	115	1107
MV 2/2	112	850	320-500	115	857
MV 3/3	112	1100	320-500	115	1107

Montage i ydervæg



3. udgave 2014

InVentilate
SUSTAINABLE VENTILATION

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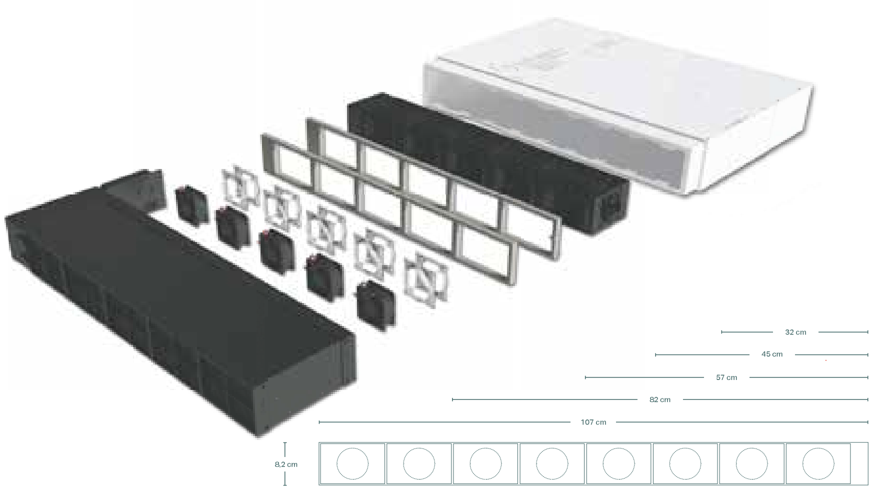
Produktinformation

MicroVent 2-8

InVentilate
SUSTAINABLE VENTILATION

Inventilate magasine page
Ill. 172



MicroVent 2-8

Anvendelse
MicroVent er en effektiv og yderst energibesparende løsning til at sikre et godt indeklima i kontorer, institutioner, skoler og boliger. Med en SEL-værdi på bare 300 J/m³ giver MicroVent en besparelse på el til transporteret luft på op til 85 % sammenlignet med central ventilation.

Funktion
MicroVent består af minimum to mikroventilationsenheder. Enhederne koordinerer og fordeler ind- og udblæsningsarbejdet mellem sig, så luftskiftet enten holdes på et konstant prædefineret niveau eller justeres efter behov. Antallet af enheder dimensioneres i forhold til behovet for luftskifte. Systemet er på den måde yderst fleksibelt, og der er derfor ikke en øvre grænse for den luftmængde, som systemet kan præstere.

Ventilatorer
MicroVent fås med henholdsvis 2, 3, 4, 5, 6, 7 og 8 ventilatorer. Ventilatorerne i MicroVent er monteret i en cylinder. Cylinderen vender ventilatorerne og genererer herigennem et flow gennem enheden, som får enhederne til at ændre funktion fra indblæsning til udblæsning.

Regenerator
I MicroVent anvendes en regenerator til varmegenvinding. Regeneratoren er en plaststruktur, der virker ved, at flowet af kold og varm luft skiftevis blæses gennem regeneratoren. Princippet er en særlig god løsning ved temperaturer under 0 grader celsius. Modsat en traditionel krydsveksler eller modstrømsveksler har regeneratoren ikke problemer med isdannelse i veksleren og af samme årsag er der ikke behov for forvarmning. Derfor er regeneratoren en meget enkel og energibesparende løsning.

Samtidig har løsningen den fordel, at frikøling let og nemt kan praktiseres ved at stoppe flow-reverseringen, når indetemperaturen er for høj, og udetemperaturen er lavere end indetemperaturen.

Styring
MicroVent er udstyret med et LON-interface, så systemet kan kobles til BMS-systemer. Her er det muligt at styre hver enkelt enhed individuelt. Ved hjælp af en Smartserver kan MicroVent også styres via internettet. I denne kan der også laves HTML-interfaces, så MicroVent kan betjenes via computer eller smartphone. InVentilate har også styringsmoduler til behovsstyring og intelligent systemopbygning af MicroVent. Kontakt InVentilate for nærmere specifikationer.

Simpel og fleksibel indbygning

MicroVents rørløse design giver hidtil ukendte indbygningsmuligheder i både eksisterende og nye bygninger, eftersom enhederne monteres direkte i bygningens ydervægge.

I ældre bygninger, hvor andre systemer kommer til kort pga. pladskrav, kan MicroVent nemt monteres med markant lavere omkostninger. Skal vinduerne i forvejen skiftes ud i forbindelse med renovering, anbefales det at montere enhederne over eller under vinduet. På den måde bliver anlægsbesparelserne endnu større.

Skal vinduerne ikke skiftes, og er der udelukkende tale om at installere ventilation, kan enhederne indbygges som særskilte udsparinger i ydermuren til en pris, som stadig ligger langt under den på rørførte systemer.

Egenskaber pr. sæt

Varmegenvinding:	85 %	
SEL-værdi:	300 J/m³	
Luftskifte pr. sæt:		
MV 4	20 l/s	72 m³/h
MV 6	30 l/s	108 m³/h
MV 8	40 l/s	144 m³/h

Om mikroventilation

Mikroventilation kan defineres som lokal decentral ventilation. I stedet for at skifte luften gennem et omfattende rørsystem af ventilationskanaler, skiftes luften direkte gennem bygningens klimaskærme. Dette sker ved hjælp af minimum to enheder, som arbejder sammen om at skifte luften. Dermed erstattes den brugte luft i lokalerne med den friske luft, som typisk findes udenfor hvert lokale i bygningen.

På www. inventilate.com kan du læse mere om, hvilke forudsætninger der skal være til stede i en bygning for, at mikroventilation performer som ønsket.

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SUSTAINABLE VENTILATION

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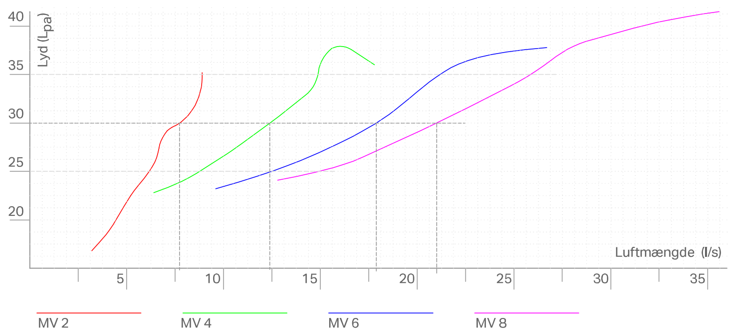
Tekniske data for MicroVent 2, 4, 6 og 8

Beregnet lydniveau i 1 meters afstand fra MicroVent enhed for MV 2, 4, 6 og 8



Luftmængder for MicroVent

Luftmængde	Per sæt af 2 enheder			Per enhed		
l/s	Min.	Nom.	Max.	Min.	Nom.	Max.
MV 2	6,4	10,4	17,8	3,2	5,2	8,9
MV 2/2	-	-	-	6,4	10,4	17,8
MV 3/3	-	-	-	9,6	15,6	26,7
MV 4	12,8	20,8	35,6	6,4	10,4	17,8
MV 6	19,2	31,2	53,4	9,6	15,6	26,7
MV 8	25,6	41,6	71,2	12,8	20,8	35,6

Varmegenvinding for MicroVent 2, 4, 6 og 8

Varmegenvinding	Max.	Nom.	Min.
	%	%	%
MV 2-8	92	86	78

Elforbrug for MicroVent 2, 4, 6 og 8

Energiforbrug	W/per enhed	SEL-værdi*
MV 2	1,58	300
MV 4	2,84	284
MV 6	4,17	278
MV 8	5,43	271

Elforbrug er beregnet ved nominelt flow. * SEL = Specifikt Elforbrug ved transport af Luft (J/m³)

Kastelængder

MV 2	2,4 m
MV 5	4,1 m

Ved en temperaturdiferens på max. 2 grader og enheder placeret max. 200 mm under loft.

Data.:

Lydniveauer er udmålt og beregnet af DELTA.

Flow og varmegenvinding er udmålt og beregnet af Teknologisk Institut.

Elforbrug er beregnet af InVentilate.

Samarbejdspartnere :

TEKNOLOGISK INSTITUT

InVentilate
SUSTAINABLE VENTILATION

APPENDIX V

$$28 * 10\frac{l}{s} = 280\frac{l}{s}$$

$$64m^2 * 0{,}7\frac{l}{s} = 44{,}8\frac{l}{s}$$

$$280\frac{l}{s} + 16{,}8\frac{l}{s} = 324{,}8\frac{l}{s}$$

$$\frac{324{,}8\frac{l}{s}}{40\frac{l}{s}} = 8{,}12\ ventilation\ units$$

Ventilation calculation
Ill.: ???

Need			
	l/s pr m2	0,7	fullfil category B
	l/s pr pers.	10	fullfil category A
load and room dimensions			
	classroom m2	64	
	room height	3,4	
	m3	217,6	
	nr of pers.	28	
calculating ventilation needs			
	l/s for room	44,8	
	l/s for pers.	280	
	l/s total	324,8	
	m3/s	0,3248	
	l/s pr m2	5,075	
	times per hour	5,37353	
nr of inventilate for one classroom			
(l/s total) / (40 l/s) =		8,12	units

Ventilation calculation
Ill. 174

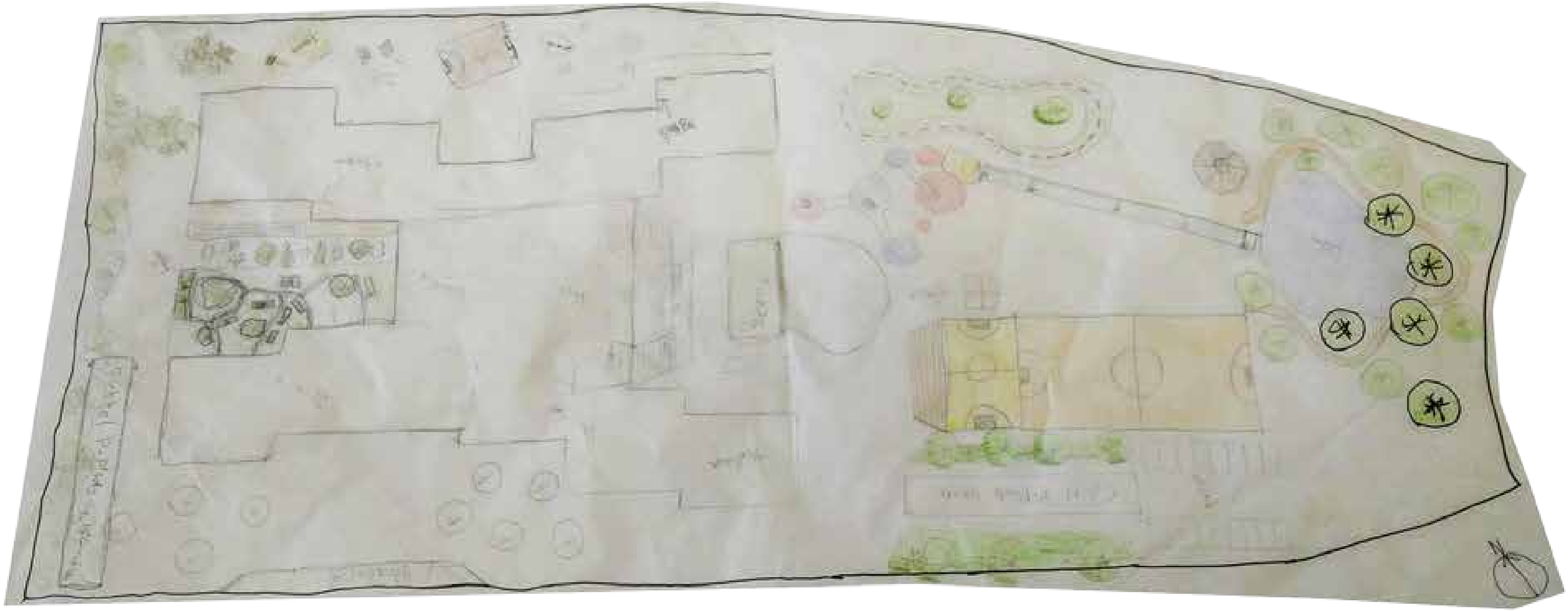
CALCULATION OF MECHANICAL VENTILATION

Based on research presented in the program, it is documented that an air change of 10 l/s per person will improve the performance of the students. However, there are no evidence that the students' performance is improved further by also improving the air change per square meter (room pollution) and the room is already considered to be low polluted. Therefore it is chosen to use a combined air change of 10 l/s per person (category A), and 0,7 l/s m2 (category B).

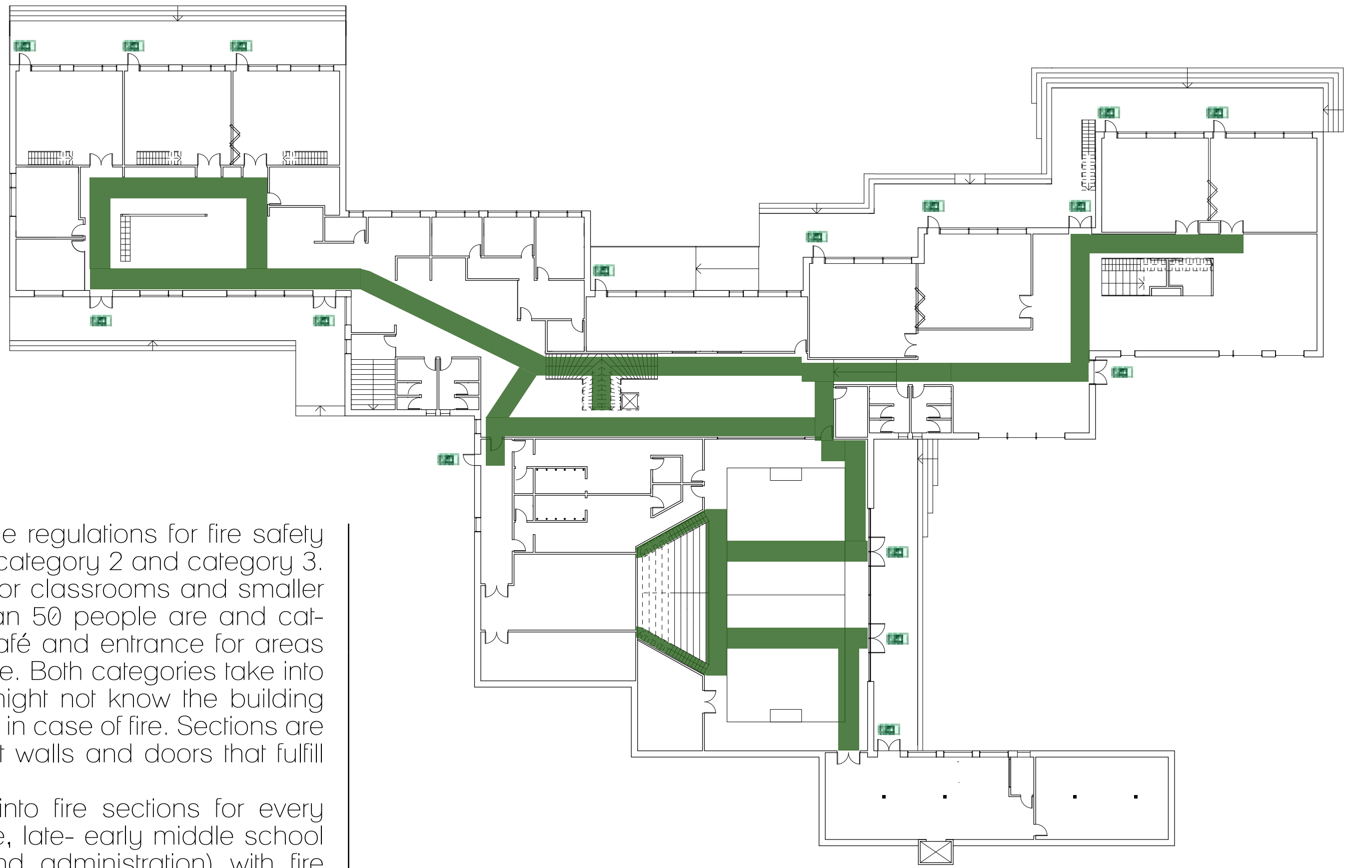
To find out how many mechanical ventilation units (VM8 units from InVentilate) one classroom needs to fulfill these criteria, the following calculations have been made. one MV8 unit can deliver 40 l/s

The results shows that 8,12 units are needed for a classroom with 28 students. This is rounded down to 8 units, as an alternative it should be rounded up to 10 units because there should be an equal amount of units in one room, this alternative is considered too expensive.

APPENDIX VI



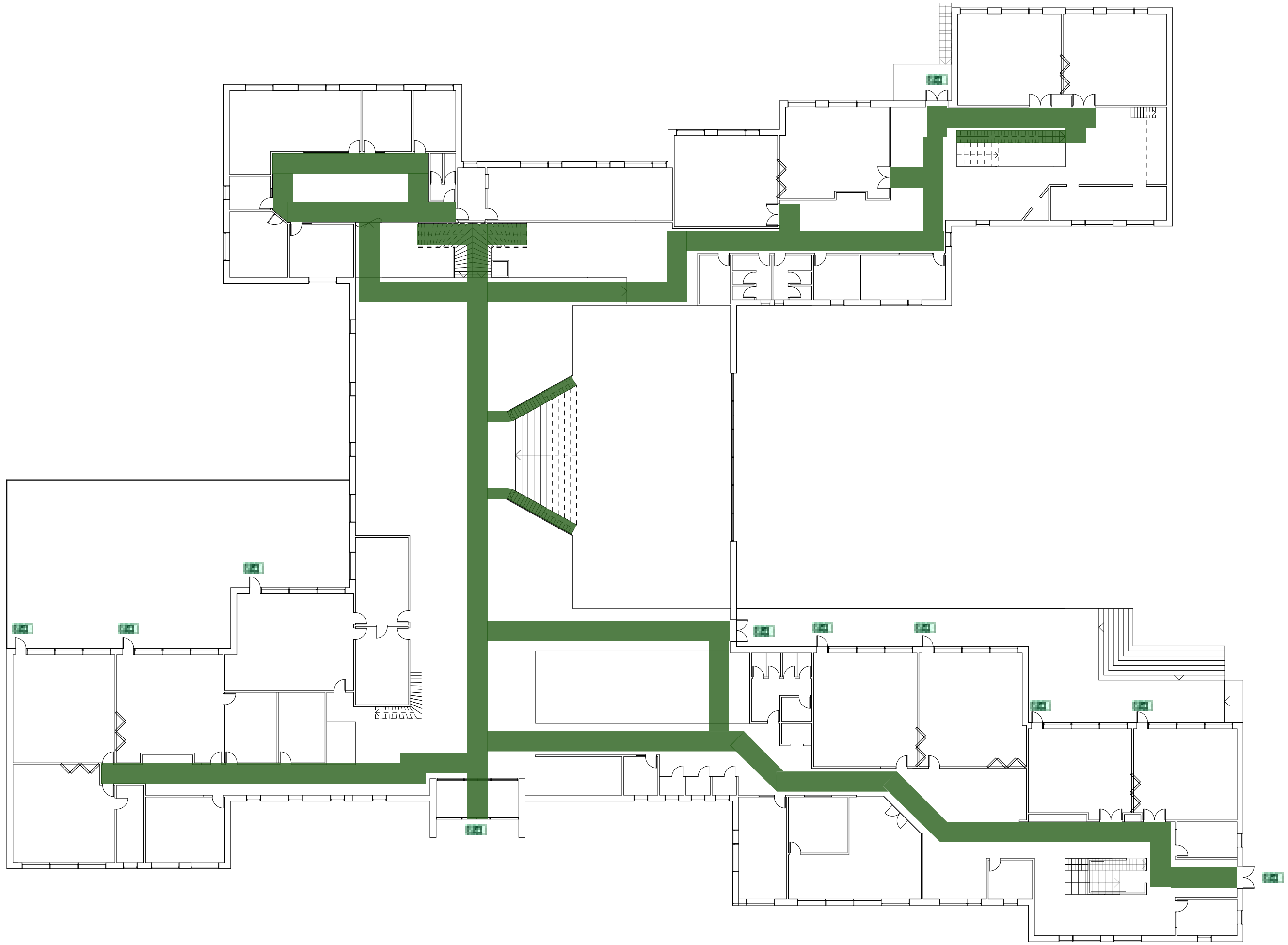
Early hand drawing of outdoor areas
Ill. 175



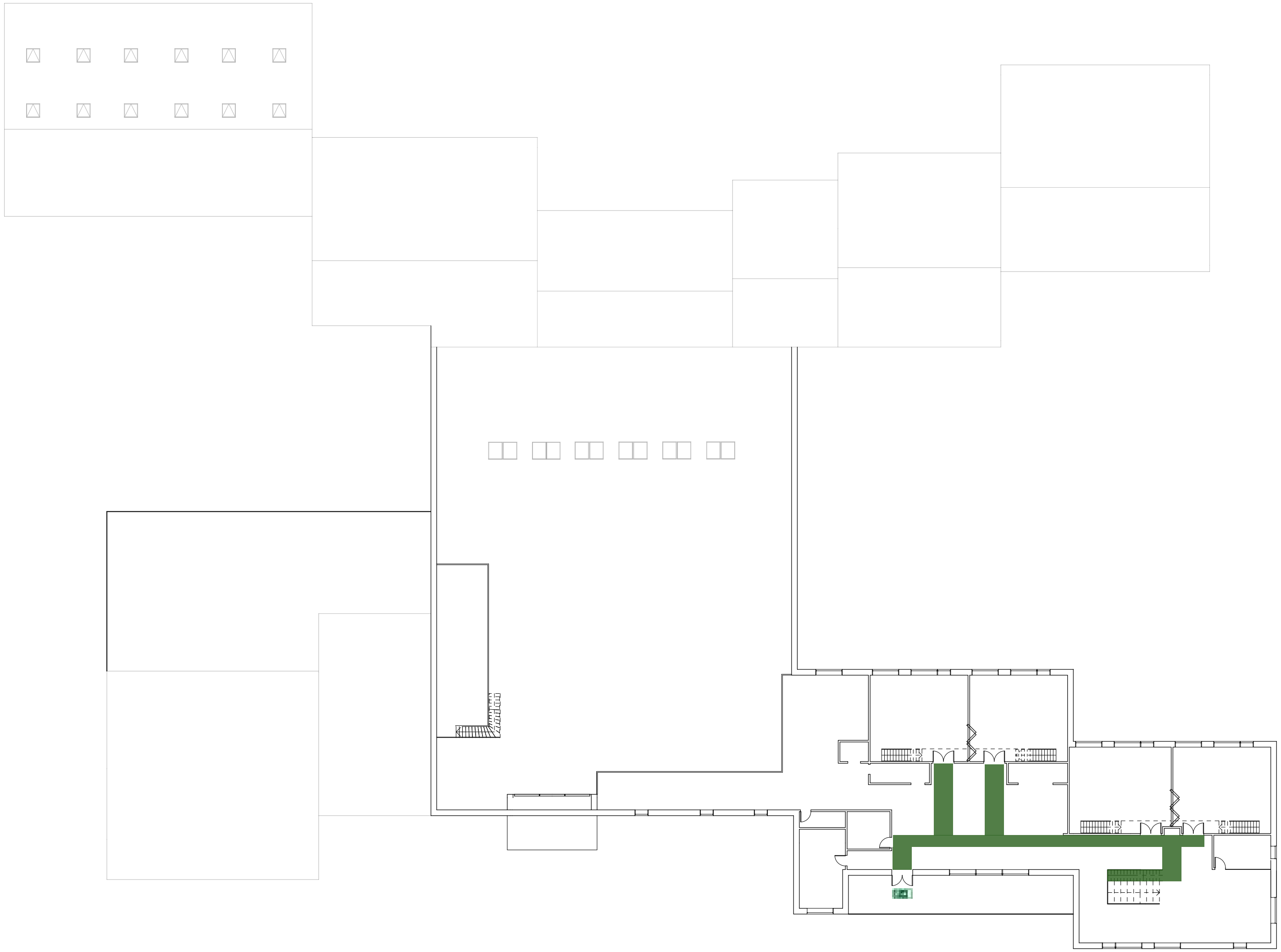
FIRE

This chapter contains the regulations for fire safety as stated in SBi 230 for category 2 and category 3. Category 2 is followed for classrooms and smaller functions where less than 50 people are and category 3 for multi hall, café and entrance for areas with more than 50 people. Both categories take into account that the user might not know the building but is still able to escape in case of fire. Sections are divided with fire resistant walls and doors that fulfill REI 60 A2-s1, d0.
The school is divided into fire sections for every branch (design, science, late- early middle school and primary school and administration) with fire gates that automatically close off between the heart space and the current function. Each fire section has minimum 2 escape exits to terrain within 50 meters. Sprinkler system is installed throughout the school. Smoke ventilation in category 3 areas is applied to automatically open over doors and windows in case of fire.

Fire plan - -1 floor
Ill. 176

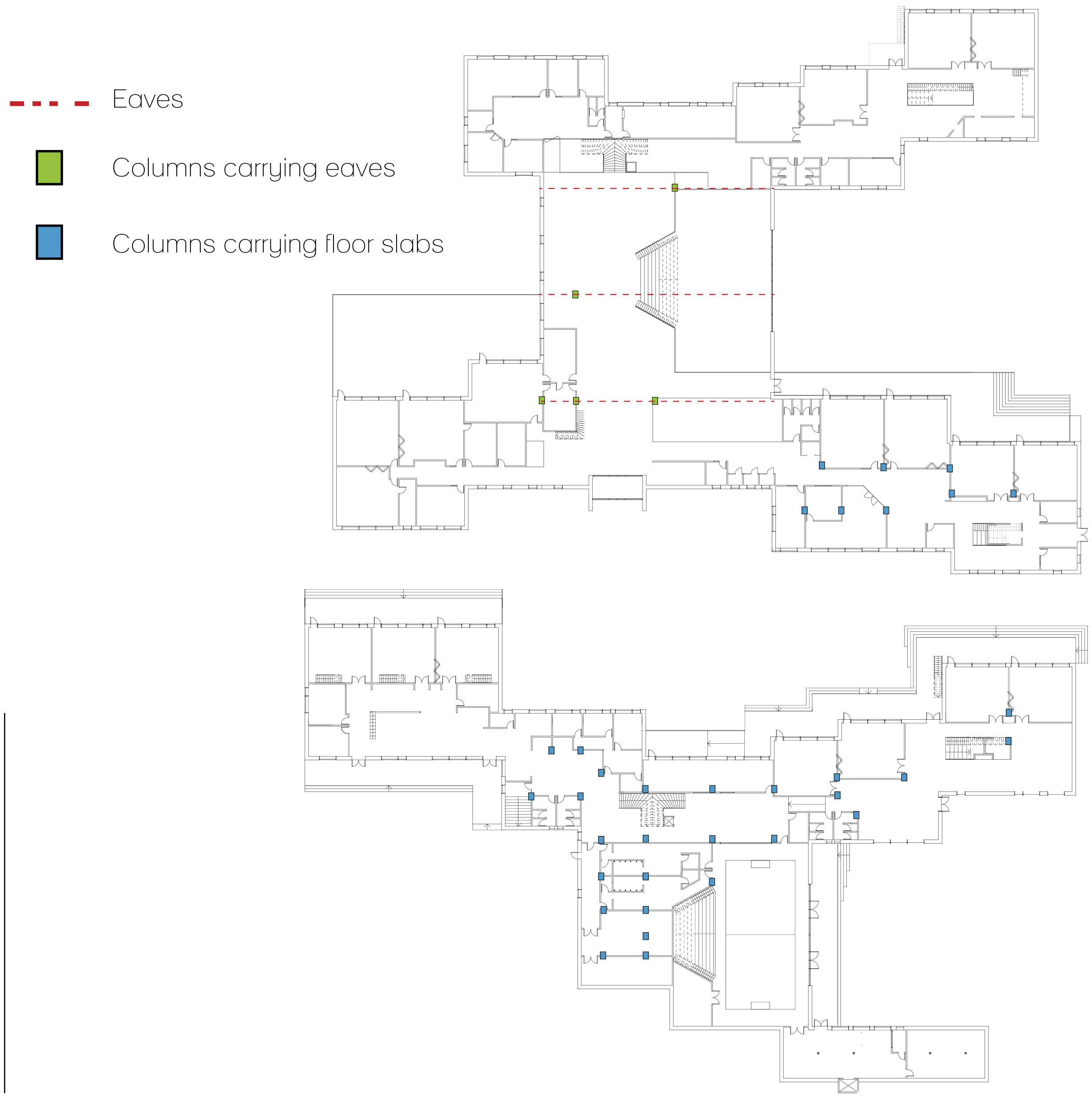


Fire plan - Ground floor
Ill. 177



Fire plan - 1 floor
Ill.178

APPENDIX VIII



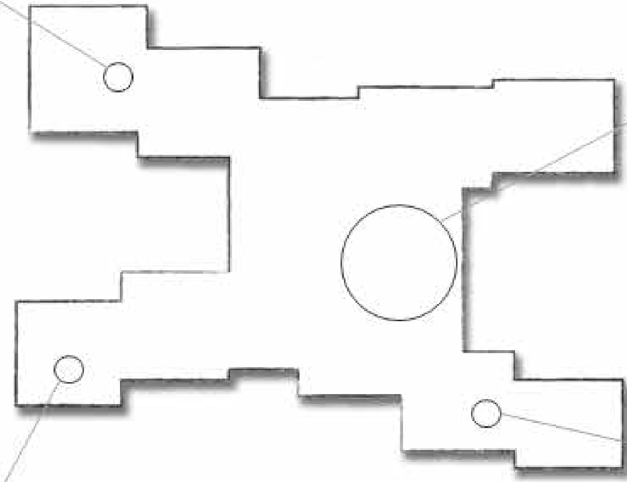
STRUCTURAL PRINCIPLE

These diagrams shows considerations about how columns will carry floor slabs and eaves. The rectangles shall only be seen as placements guidance and not as correct dimensions. The columns are placed mostly hidden inside partition walls. All partition walls are made as light weight construction that easily can be demolished if redeployment of rooms is wished. External wall is as well load bearing where the roof will support on.

Principle of columns
Ill. 179

APPENDIX IX

Niches
Ill.: ???



Stairs down to sports hall
Ill.: ???

Big stair
Ill.: ???

Kids playing with water
Ill. 180

APPENDIX X

Trampoline in school yard
Ill. 181

Plant boxes
Ill. 182

Birkerød school schedule
Ill.187

House zinc roof and wood facade
Ill.183

Cembrit facade - Vibeengskolen inspired
Ill.184

SOSU Skejby
Ill.185

9.årgang	Mandag	Tirsdag	Onsdag	Torsdag	Fredag
8.15-9.00	SCIENCE	IDRÆT	ENGELSK	TYSK	KULTUR
9.00-10.00 (BEV)	SCIENCE	IDRÆT	ENGELSK	TYSK	KULTUR
10.00-10.45)	SCIENCE	IDRÆT	ENGELSK	TYSK	KULTUR
10.45-11.30	SCIENCE	IDRÆT	ML-ML FRANSK	TYSK	KULTUR
11.30-12.15	SPISE	SPISE	SPISE	SPISE	SPISE
12.15-13.00	SCIENCE	DANSK	ML-ML FRANSK	DANSK	MATEMATIK
13.00-13.45	SCIENCE	DANSK	VALGFAG FRANSK	DANSK	MATEMATIK
13.45-14.30	MATEMATIK	DANSK	VALGFAG FRANSK	DANSK	MATEMATIK
14.30-15.15	MATEMATIK			T-CAFE	MEEMENTOR
15.15-16.00				T-CAFE	T-CAFE

Birkerød school schedule
Ill.186

NOTES

NOTES