PLACES FOR LEARNING

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PROLOGUE

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IDA BERTELSEN

ABSTRACT

The project report is a result of a design process creating a Danish public school, using the integrated design process as method, where both the architectural and technical aspects are in focus from the start of the process. The problem statement investigated is:

How can a Danish public school be designed with a holistic sustainable approach, and focus on creating pleasant class rooms and working areas developed based on pedagogy?

The buildings design is based on design criteria, a room program and a function diagram made on the ground of a variation of analyzes and research in the beginning of the process.

The theme for the project is sustainable architecture, where the approach to making the building, choosing materials and reaching an energy class 2020 energy frame are in focus. Passive- and active initiatives will be used to reach the energy frame 2020.

The different user segments have been analyzed through different case studies and their needs and opinions are a part of the designing process.

READER'S GUIDE

The project report contains six chapters: Prologue, Framework, Analysis, Presentation, Design Process, Epilogue, which can be followed in the bottom of each page. Throughout the report different part conclusions are made to sum up the current chapter. In the end, a conclusion and reflection sum up the whole project. To achieve a better understanding of the design process this is mediated after the final design proposal.

Illustrations are numbered with the current page number followed by a numerical order. For example (Ill. 16.2), where 16 is the current page number and 2 is the adjacent illustration number on the current page. An overview can be found in the back of the report.

If north isn't specified on an illustration it will be rotated upwards, otherwise a northern arrow will be present.

Referencing in the report is done with the Harvard method. An overview can be found in the back of the report.

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CONTENT

INTRODUCTION

The project thesis is designing a Danish elementary school in Skærbæk, Denmark. A competition is underway, and the project is based on the competition material, however only as inspiration. The challenges in the project will be solved using knowledge from both architectural and engineering aspects with the use of the integrated design process. Several iterations will help find the most optimal solution for the specific situations.

The main theme for the project is sustainability. Considerations, interviews, and case studies, based on visits, conducted prior to the semester, will be used to understand the different user segments and their needs and wants for a new school building.

The site analyzes including the micro climate will be used in the design process to shape the building in the most optimal way. It will help form both the inside of the building and the urban areas.

The energy class 2020 will be reached by using passive and active initiatives to reduce the energy consumptions. It will support the sustainable aspects and help create a holistic design. Thermal- and atmospheric indoor climate will be in focus to reach the requirements for comfort class B or C.

MOTIVATION

The public school is one of the most important pieces of architecture in Denmark, perhaps the world. It is a building everyone experience, grow up in and evolves in. The beginning of shaping humans starts in the elementary school where we learn values and form our personality.

The school development in the new century with new technology changes, the didactic method and the whole way we learn and teach. We go from the more front facing blackboard teaching method to a more open- and individual learning/teaching method where walls importance decreases.

The new Danish School Reform dictates that every child needs to have a minimum of 45 min. activity every day. This means that the old school building needs an upgrade where architecture invites for movement (Undervisningsministeriet, 2017).

The location in Skærbæk, Southern Jutland is based on a competition brief of a new school with 0^{th} - 9^{th} grade of around 6000 m^2. The competition program will be used as inspiration for the project and not as demands. The competition adapts to the new school reform and lay the base for making a school in an environment where nature can be an integrated part of the building and where the city doesn't set the limit.

INITIATING PROBLEM STATEMENT

How can a Danish public school be designed with a holistic sustainable approach, with focus on creating pleasant class rooms and working areas developed based on pedagogy?

METHODOLOGY

THE INTEGRATED DESIGN PROCESS

It is a design method that focus on integrating knowledge from engineering and architecture. They focus on solving a problem statement by interacting with each other. Aesthetic and sustainable solutions are not ensured but the method gives tools to work controlled with the many different parameters. It enables holistic sustainable architecture through an iterative process. Following are the different phases described.

The problem formulation is the problem statement research in the project. In this phase the motivation and themes are mediated.

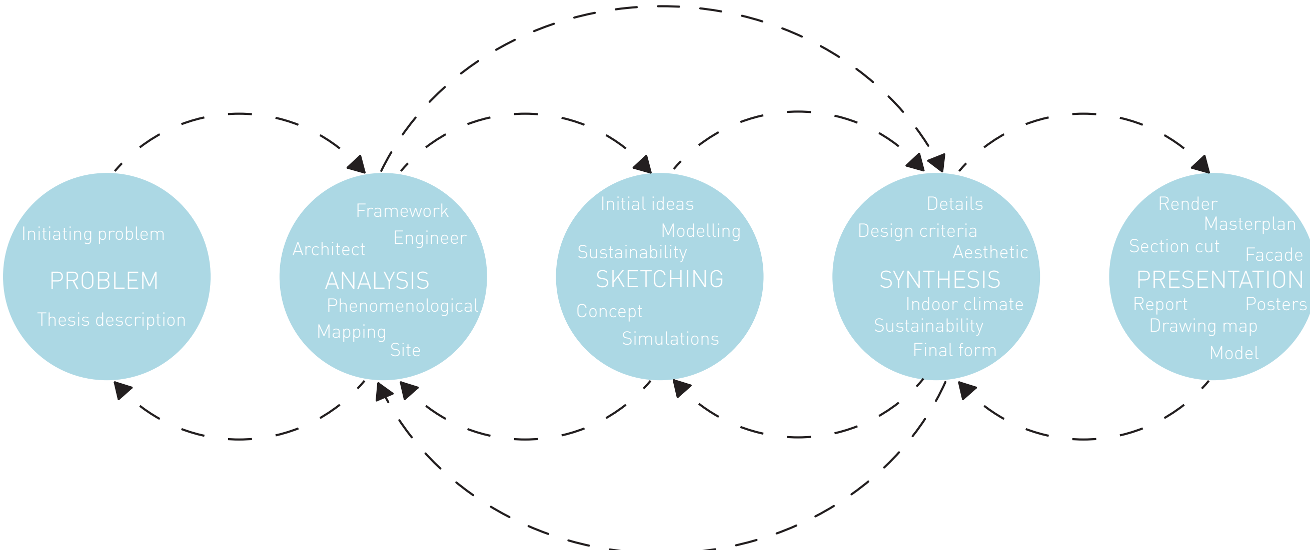
The analysis phase is all the research and analyzes done before the sketching can begin. It consists of both the framework - where the project topics are investigated, including sustainability, The Danish Public School and Tectonics - and the analysis chapter - where phenomenological- and mapping analyzes is used to understand the site, through Kevin Lynch's Image of the city, Norberg-Schulz' Genius Loci, Gordon Cullen's Serial Vision and analyzes of the micro climate. A conclusion is mediated in a function diagram, room program and design criteria.

To understand the relation between theory and practice several case studies has been made of different Danish Schools, where the focus is on sustainability, technology, spaces and rooms.

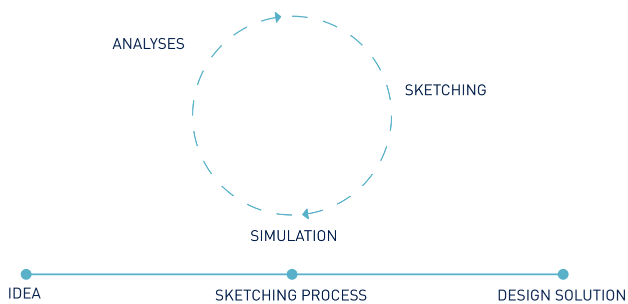
The sketching phase is where all knowledge is combined to provide a base for the design, so every demand is respected. Different tools are used to generate ideas and investigate solutions like sketching, modeling, both physical and 3D models, simulations, using Flow Design, for wind studies, and LCA-byg, for assessing materials, among others.

The synthesis phase is the detailing phase were the building finds its final form. Every demand and criteria from the analysis phase are met. All parameters considered in the previous phase merge together and form an aesthetically, technical and functional design. Different tools are used throughout the process like sketch-up, Adobe, Be18, BSim, physical modeling, among others.

The presentation phase is the presentation of the project, the report, posters, models and drawing folder. It is presented in a way so every quality, design criteria and targets are clear. It is mediated through plans, section cuts, facades and spatial visualizations (Knudstrup, 2005).



Ill. 9.1: The Integrated Design Process



Ill. 9.2: Loops During Sketching Phase

Ill. 10.1: Vadehavet

FRAMEWORK

FRAMEWORK

The following explores the themes of the master thesis. Sustainability is analyzed through both the general sustainable aspects including economical-, environmental-, and social aspect but also when looking directly at school design. The way architecture affects learning, tectonics and the new school reform are themes which will also be touched throughout the project.

HISTORY OF THE DANISH PUBLIC SCHOOL

Through time a lot of different school buildings have been made in Denmark. Today three different school typologies dominate, however the schools are around 50+ years old and they have been modified or extended. This means that the three typologies rarely are seen in their original form. The buildings are often based on the didactic method used at the time and objectives. The buildings can therefore be seen as physical manifestations of different times view on didactic and pedagogy.

In the ending of the 19th century there was a difference between the schools in the country and in the city. Most people went to a school in the country however because of urbanization the growth was in the city. Together with the teacher qualifications level, improvements were made.

In 1720-1880 the school was called the village school. It was a one storeys building placed in the center of a village.

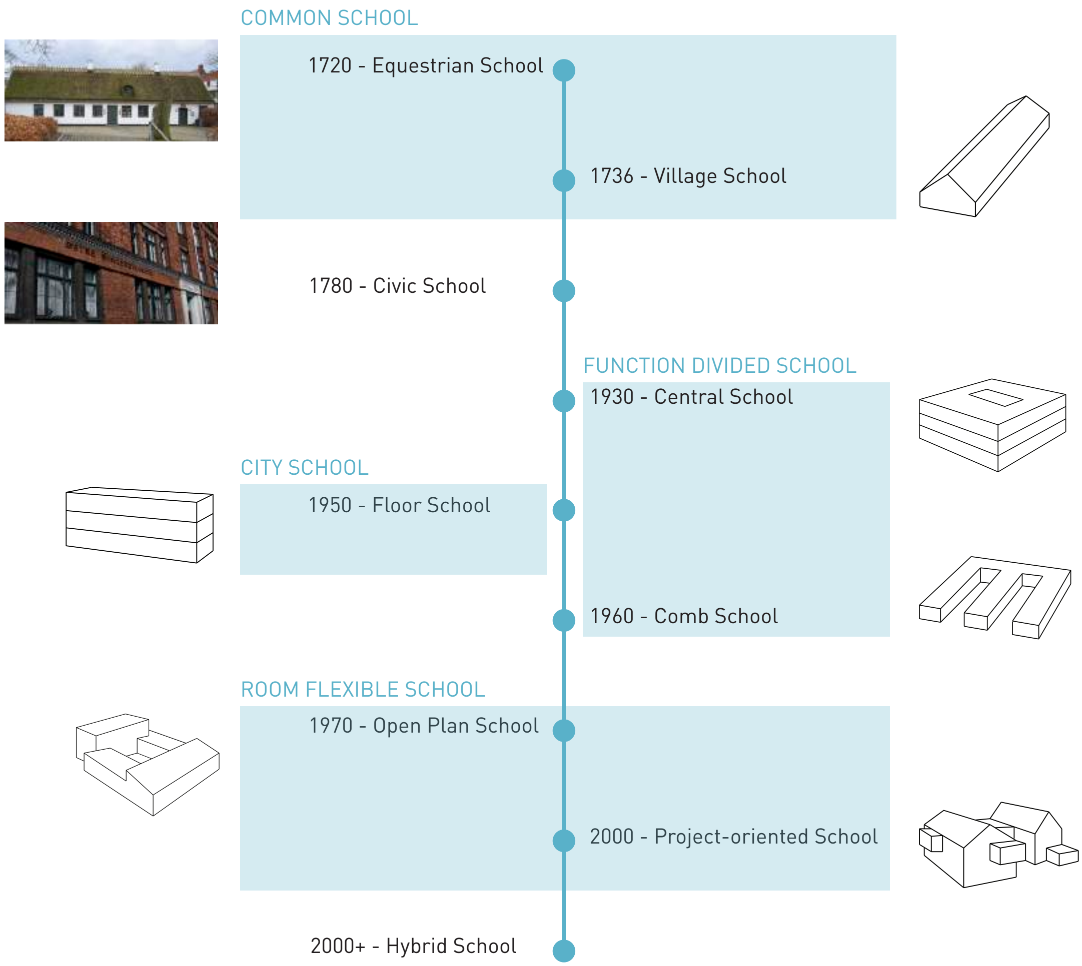
Around the end of the 19th century and the beginning of the 20th century new demands for age divided classes posed new requirements for the school building. 'Floor School' (Etageskolen) is a result of this and it was built in the city. It had 3-4 storeys and the class rooms are around 50 m^2.

In 1930-1945 there was the central school. It was of 2-3 storeys and had an atrium in the center of the building. The class rooms have large windows and the materials used is often concrete or bricks.

With the growth in the city there was a need for bigger schools. New subjects were added to the curriculum like History and Geography. These larger schools were called 'Function divided schools' and were made with a uniform template. It is a one storeys building and the whole design is made based on the different functions. The materials used is often a rear wall of concrete and front wall of brick.

Through the 1960s and 1970s the didactic method was based on 'learn to learn'. It was about problem solving, critical thinking and communication, to create flexible, stable citizens. This resulted in an experimental school typology. There was a need for high flexibility in the rooms and it is called 'Room flexible schools'.

It is split into two ages one with an 'open plan school' in 1970-1980 which is of 1-2 storeys. The other one is the 'project-oriented school' from 1990-2013. Here both the teacher and the students are in focus. The shape varies, and the school design is often different from one another. It is of 1-3 storeys and is characterized by high rooms and large windows and outdoor

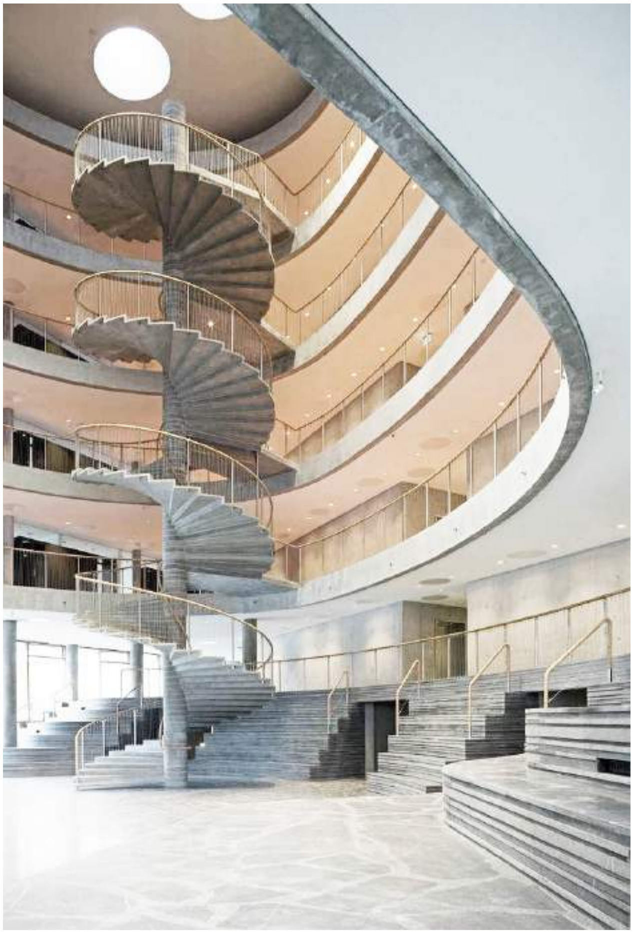


Ill. 13.1: History of Schools

areas.

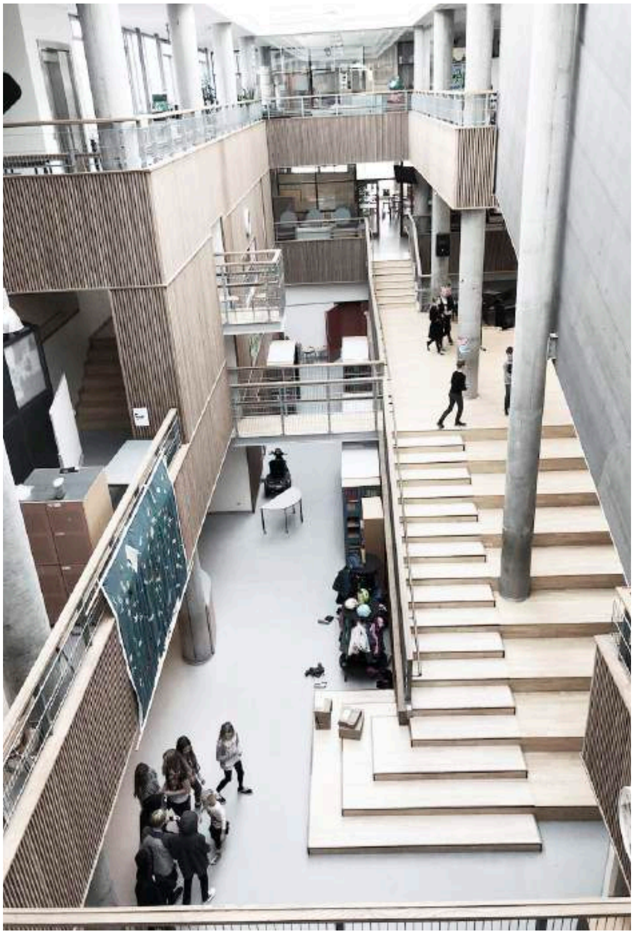
Today the schools are going through a change again because of the new school reform. The rooms need to be more flexible and mobile because they shall accommodate three different functions. It needs to accommodate the teaching, supportive teaching and teacher preparation. The new demands make requirements for the architecture and we see new schools and renovations everywhere. The tendency is to create buildings that utilize the already existing buildings and achieve a higher form of flexibility and spatial interactions that not only accommodate the desires for today but also for the future.

The school today is called the open school or hybrid school and is based on an interaction between the school and the local community and how to implement reality to a theory-based world (Modelprogram, 2014 & Jørgensen, 2017 & Realdania, 2016).



Ill. 14.1: Kilen Copenhagen Buisness School, Lundgaard & Tranberg - Open School

Ill. 15.1: Ørestads College, 3xn - Open School



Ill. 15.2: Hellerup School, Arkitema - Open School

ELEMENTARY SCHOOL

The Danish elementary school is the public primary school and it is mandatory for all children. Its purpose is to prepare children for their future. The Education Ministry has made different initiatives to enhance the students' skills and well-being, but at the same time reducing the importance of social background. The following section describes some of these initiatives, which the architecture could have an impact on.

LEARNING ENVIRONMENT

A part of making a strong academically school is more IT and electronics in the classes, which creates variation and differentiation from the traditional way of teaching. It increases the students' motivation and creates more time for other activities.

Help with homework is a part of the normal school day and a place for this should be implemented when designing the school. The students and qualified teachers should be present for this.

Every day all students need to have physical activities for at least 45 minutes. It needs to enhance the learning and every form of physical activity needs to have an educational aim. It could happen in different ways. For example motion sequences during classes.

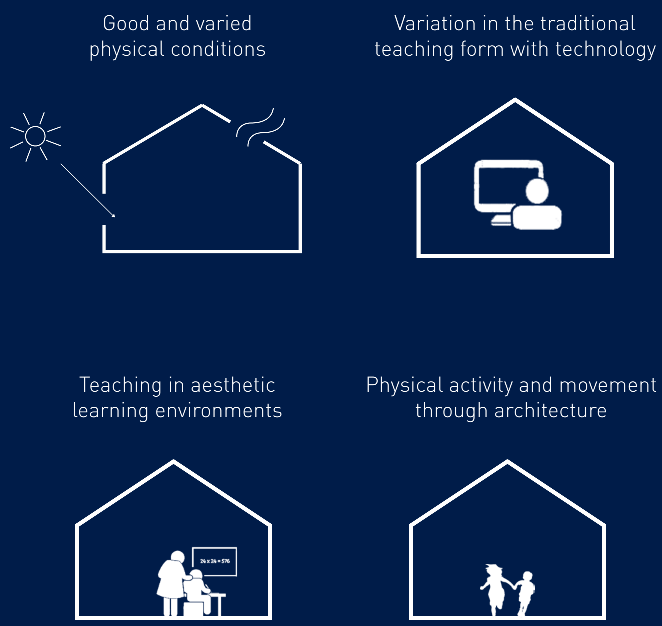
The school needs to be an open school, which involves part of the local community. It could be collaboration with local business', sport clubs, local museum, charity, etc. This should give the students more knowledge of community and associations.

The didactic focus on common learning goals, which gives the students a clear picture of their learning process. The learning plans describe the goals, not the steps towards it. This means that the teacher can reflect on the methods they use based on each student. (Undervisningsministeriet, 2017)

The competition program states four core values including location in nature, focus on professional development, movement in- and outside and use of varied working forms. The placement next to 'Vadehavet' need to be expressed in the school design and through a sustainable approach (Ill. 21.2). Focus need to be on the professional development of the students and this need to be mediated through interior design and in the professional work. Movement both in- and outside is a natural part of the everyday and the architecture needs to inspire this. Different working forms and method will be used both from theoretical and practical angles, and the architecture needs to inspire the students to use different working forms and method themselves (Competition program, 2017).

"The students must become as capable as they can and thrive"

- Education Ministry



Ill. 21.1: Learning Environment

Ill. 21.2: Kensington international Kindergarten, Plan Architect - Integrating nature

ARCHITECTURE AND LEARNING

The school building is where the youth spend most time, next after their homes. It is here they learn how to be around other humans. The school building as we know it is going through a transformation with a new way of learning. This is based on new goals, methods and transfer of knowledge. We are going from the classic front facing blackboards to an open workspace. The tablet or computer makes the working place mobile and the fixed workplace is no longer needed.

The digitalization has a directly effect on the architecture of education. Almost any location can be converted into a learning place. It requires a reorganization of the spaces we use. We don't need the fixed seating, and the intermediate areas are now being integrated in the daily school life.

The typology of the school is influenced by the current architectural epochs. During the industrial revolution, they build monumental school houses, the landscape was emphasized during the Modern and today we are starting to make digital learning factories. The schools are rated on the level of teaching. This means that a building with architectural spaces of high quality that creates successful learning spaces is in demand.

The focus for the architectural space has changed during the years. Handicap accessibility and safety have become a priority together with social- and cultural background. These factors have had an effect on how we teach and the common areas we implement in the architecture. (Meuser, 2014)

TEACHING ROOMS AS LEARNING LANDSCAPE

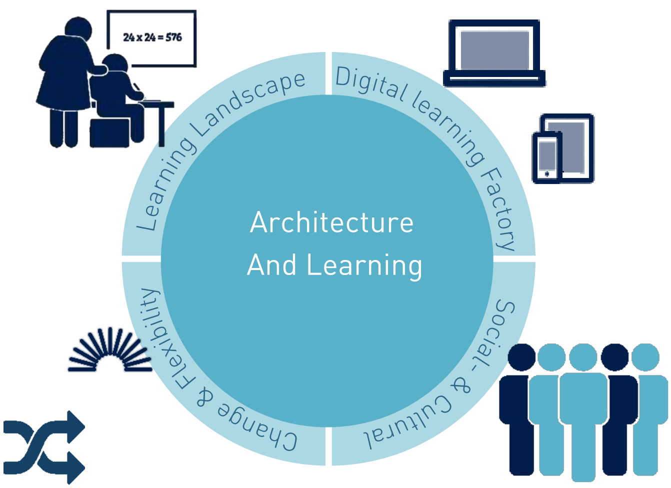
The architecture has an effect on us: the building, the interior, the furnishing and the urban areas. Because of the many different school reforms, the architecture for the school building need to be flexible, adaptable, multi-usable and so much more. The users are important when designing a school. The building must fit together with the pedagogy to enhance learning and it must break the norm of one room equals one function.

The classroom should be a place where both the teacher and the student feel at home. Together with this daylight, ventilation and acoustics is important when designing a classroom. It need to be flexible for teaching the whole class, teamwork and individual work. These rearrangements need to be quick and easy. The static seating position needs to be eliminated and different seating and movement possibilities, while learning, needs to be possible.

Physical activity needs to be a daily part of the school life. Movement activates the blood circulation and thereby more oxygen reach the brain and the concen-

''We give shape to our buildings, and they, in return, shape us''

- Winston Churchill (Meuser, p. 34)



Ill. 17.1: Architecture and Learning

Ill. 17.2: Nøvling school, KAAI - a digital learning factory

tration is increased. This need to be solved not only in the choice of furniture but also in the plan drawings.

The teamwork areas are also important, and they need to enhance encounters between students of different ages but also between students and teachers. Lounge and retreat areas can be used both for recess but also for group work.

The backpack principle enables the possibility of moving around. A cohesion between the classroom and teamwork area should exist, done different ways. It can be two classrooms with an adjacent teamwork room (Ill. 19.1). This requires a pedagogical concept where the two classes have some sort of cohesion. It can be a cluster of classes joined with a central teamwork area (Ill. 19.2). These clusters can be according to age or specialty like math, chemistry, etc. Lastly, it can be a learning landscape (Ill. 19.3). Here everything is mixed. There are no fixed classrooms. It is made based on individualization and self-reliance, so it is possible for each student to decide which kind of learning area/atmosphere they prefer. It is here important to make niches and dedicated areas to different activities with the use of for example mobile walls or different elevations. Here it is important to consider the child's scale in the large building.

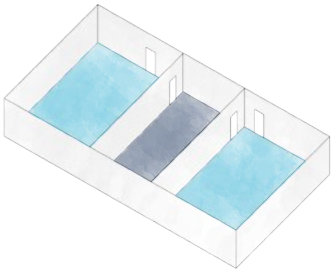
The team areas where the teachers meet can be made centralized or decentralized. Centralized is one big room where every teacher meets, discuss, communicate, etc. and decentralized is more rooms categorized according to specialization for example math or science.

The common areas which include auditoriums, sport facilities, etc., have a double purpose. A canteen can be an auditorium or access areas can be a meeting room. The clear line that divide areas becomes blurred. The separation of the school from the public becomes blurred. The canteen can be open to the public (Meuser, Müller, Schneider, 2014).

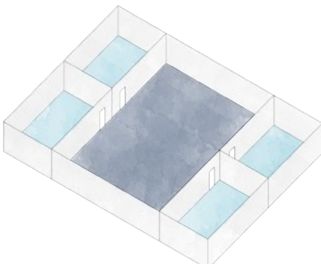
People are a part of their environment and the environment has an effect on how much we learn. Students develop through their time in school, through both their body, which needs health and safety, their mind, which need functional support and their spirit, which need aesthetic satisfaction and psychological comfort.

The outdoor areas need to be a part of the design process and be built as learning landscapes for Kinesthetic- and ecological learning. It could be gardens providing cafeteria food (Taylor, 2009).

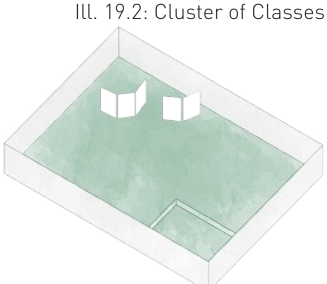
With this research, it is the goal to understand how the architecture can be directly used in the process of learning. How the architecture affects the learning and how the learning affects the architecture. This information will be used in the design process of the school building.



Ill. 19.1: Teamwork room



Ill. 19.2: Cluster of Classes



Ill. 19.3: Open Learning Space

Class room

Team work area

Open learning area

Ill. 19.4: Dymitr Malcew's Tree House Modules - Privacy in open places. Considering the scale of the child.

Ill. 19.5: Nøvling school, KAAI - Open learning areas.

SUSTAINABILITY

There are three key factors that describe sustainability: Economic-, Environmental-, and social sustainability. In architecture sustainability focus on the negative impact these three factors have on the earth with the materials, energy use, design, etc. Sustainable architecture is made to ensure that the action we take today doesn't have a negative impact on the future.

Economic sustainability is about making sure people have what they want without making compromises on life quality. It is the sustainability of the economic system. It is a satisfying production system which doesn't compromise on future needs. In architecture, it is using the given resources on materials in an efficient and responsible way.

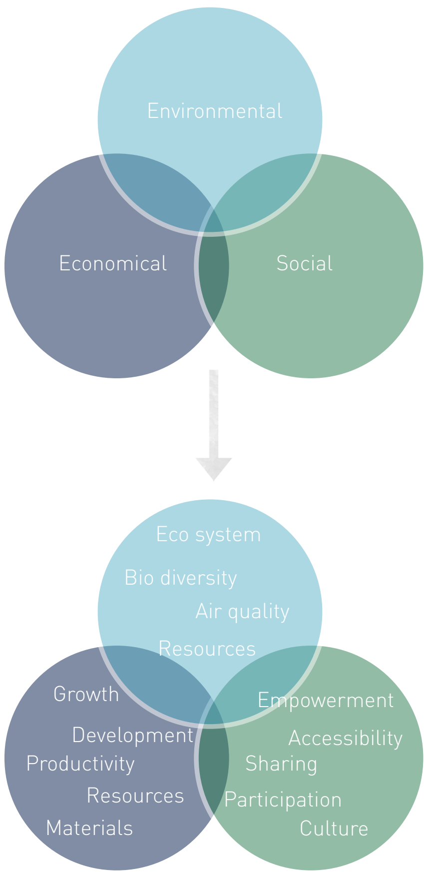
Environmental sustainability defines how to protect the earth and its ecosystem, the air quality, clean water, etc. It has a focus on the elements that have a negative impact on the environment. Use of resources must be kept within the regeneration rate and the production of resources must be controlled and with a sustainable approach.

Social sustainability is a lot of things. Most important is awareness of pollution or other harmful activities towards the people using the building. It is taking groups of people with different background and culture and making their living situation beneficial for one another. Also, it is about peoples living quality according to good temperature, moisture, air quality, etc. (Ill. 23.1) (Basiago, 1999 and Mason, 2018).

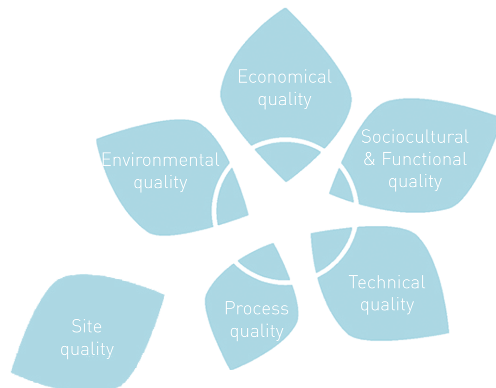
Another approach to sustainability is looking at DGNB certifications. It is a way to measure sustainability. The qualities measured in DGNB are environment, economy, Sociocultural and functional, technical and process. Within the different qualities are different criteria which needs to be respected. This could be air quality, accessibility, safety, transportation, life cycle assessment, etc. The different qualities are weighed equally of 22,5 % except for the process quality which is weighed 10% (Ill. 23.2).

Life cycle assessment or LCA is placed under environment because it focuses on the life cycle of the different materials used in the project from cradle-to-grave, and this have an impact on the environment. This means everything from the raw material to disposal of the used material (Ill. 23.3) (DGNB, 2014).

The project will have a sustainable approach. The three sustainable aspects will be considered in the design process, different aspects of the DGNB will be respected, however the project will not achieve any certifications. LCA will be used when choosing materials together with knowledge about maintenance and cleaning possibilities of the material.



Ill. 23.1: Sustainable approach



Ill. 23.2: DGNB Parameters

Ill. 23.3:Life Cycle

SUSTAINABLE SCHOOL DESIGN

This research is based on an article by Randall Fielding that explores six principles for making school design sustainable. The six principles will give an understanding of some of the complexity of designing a school that reduce the buildings negative effect on the earth and support the current centuries learning level. In the 21st century the schools no longer need to create people who becomes industrial workers. They need a more sustainable approach where it not only creates good graduates but also global citizens who can solve problems and have creative skills.

The first principle is *Networks*. It is about sharing resources with the community and the rest of the world. The boundaries within the school network should be blurred. The network being between cities, technology and knowledge within the society. Sustainability can then be achieved by utilizing the different facilities within the network like libraries, health care center, fitness center, etc. Mentor ships or internships can then be offered within the network.

The second principle is *Cycles and Waste*. In this case waste is referred to as waste of space. Hallways in schools is often only used for transition. By centering the class rooms around common areas the number of hallways or transition areas will decrease. The footprint can be smaller and the space become more human in scale.

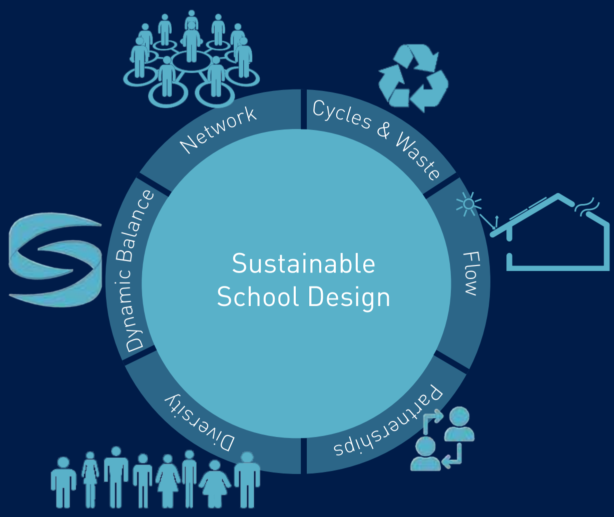
The third principle is *Flow*. This is about the passive initiatives one can make when designing a building. Peoples movement and activity can be used to passively heat the building. The use of natural daylight can reduce the energy used on light, but it also benefits the students with increased learning ability. Lastly, the placement of the building according to the sun and wind can be beneficial in more ways like daylight, heating and natural ventilation.

The fourth principle is *Partnerships*. A partnership with the local society where they not only coexist with the surroundings but they benefit from each other. A building where space, heat or light is never wasted. In a community where the existing facilities and the school's facilities are shared so no resources are wasted. This can be achieved by for example using existing sport facilities or sharing meeting rooms with the community after hours.

The fifth principle is *Diversity*. Stability is preserved by involving parents, different educators and the community. It can also be by having a variation of spaces. Different rooms that can be used in different ways will have a longer future. An adjustable system where the spaces is flexible gives a more sustainable school.

The sixth principle is *Dynamic Balance*. In the 21st century school the front facing blackboard teaching method is no longer enough. The students move around, work in teams, work individually, etc. and this happens all within one space. In addition to this, outdoor areas can be used for more than recess. It can be an outdoor learning space for different projects, science experiments, etc. This can balance the time student spend inside and outside.

A building not only need to be low on energy consumptions. The architecture need to shape the people (Fielding, 2012).



Ill. 25.1: Sustainable School Design Parameters

ZERO ENERGY BUILDING

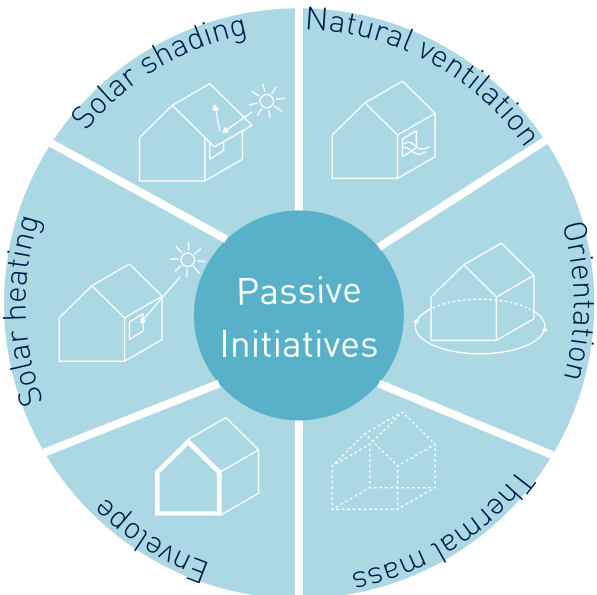
When looking at the building from a sustainable approach it is crucial to look at the buildings CO_2 emission. Buildings are responsible for around 40% of the CO_2 emission. There should be focus on making more energy efficient buildings to lower this number and the energy consumption, but also to replace fossil fuel with renewable energy (Nielsen, 2016). The goal in Denmark is to rely 100% on renewable energy by 2050 and a CO_2 emission reduction of 39% in 2030 (Sprotte-Hansen, 2017).

A Zero Energy Building (ZEB) is a way of designing buildings with focus on the problems listed above. The buildings in ZEB has a reduced energy demand, which is balanced by an equivalent energy generation and it is powered by renewable energy. There are four different ZEB definitions: Site ZEB, Source ZEB, Cost ZEB and Emission ZEB, the difference being on which unit of balance it is based on (Torcellini, Pless & Deru, 2006).

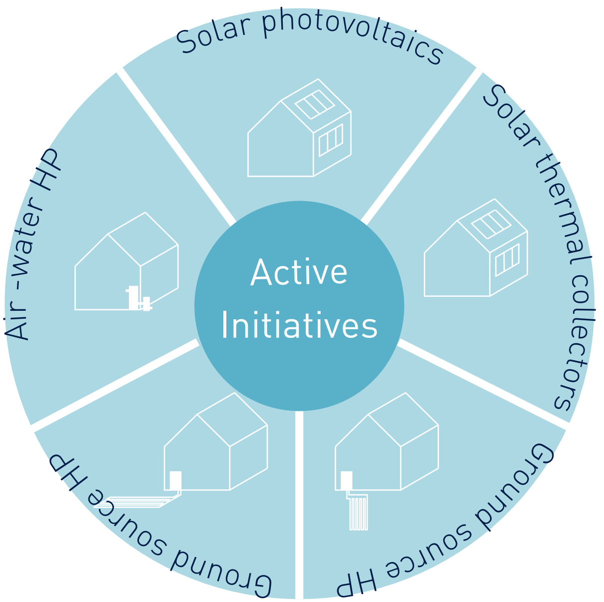
To reduce the energy consumption of a building different initiatives can be used. There are both passive- and active initiatives. The passive initiatives are those which can be implemented in the building design, it is the basic design elements of the building. It could be the placement of the building according to the sun or wind, to enhance passive heating/shading and natural ventilation or it could be making an efficient building envelope which will minimize the energy consumption for heating. These initiatives come in play from the beginning of the design process in the sketching phase.

To ensure low energy consumption active initiatives needs to be used. It is an addition to the building. It could be solar cells using the sun as a renewable energy or it could be a heat pump collecting energy from the earth or air and using this to heat the buildings water. The active initiatives should be integrated in the building design and not appear as an alien element. To achieve an integrated building design these initiatives, need to be a part of the beginning of the design process in the sketching phase (Bejder, Knudstrup, Jensen & Katic, 2014).

Throughout the design process different passive initiatives will be used to reduce the energy consumption. Solar cells will be used as active initiatives to reach the energy frame 2020. The building will not reach a ZEB standard, but use the initiatives to reduce energy.



Ill. 27.1: Passive initiatives



Ill. 27.2: Active initiatives - Heat pump (HP)

	DEFINITION	PROS	CONS
NET Zero Site	Energy produced equal to energy used, accounted for at site.	Low targets equals easy to reach goal.	Renewable energy supply options are limited on site.
NET Zero Source	Energy produced equal to energy used, accounted for at the source.	More comprehensive model, using primary energy.	Higher targets equals harder to reach.
NET Zero Cost	The cost utility pays owner for energy produced is equal to the cost the owner pays utility for energy.	Enhanced status with favorable change in feed-in tariffs.	More renewable energy installed because cost from utilities are lower than supply tariffs.
NET Zero Emission	Emission producing energy used is equal to emission-free renewable energy produced.	It can be achieved using on-site and off-site renewable energy.	The grid is often mixed by renewable and non-renewable energy.

Table 27.1: Net Zero Table

TECTONIC

In the project, tectonic is not a focus however it will be touched throughout the project on a basic level.

When talking about the correlation between tectonic and sustainability one of the more important issues is energy consumption, explained in the ZEB chapter on page 26. Energy demands are a focal point when talking building design.

Another challenge is the industrialization of constructions, the development of technology. The fine craftsmanship which was a big part of tectonic is disappearing and a reinterpretation of the concept need to respond to this.

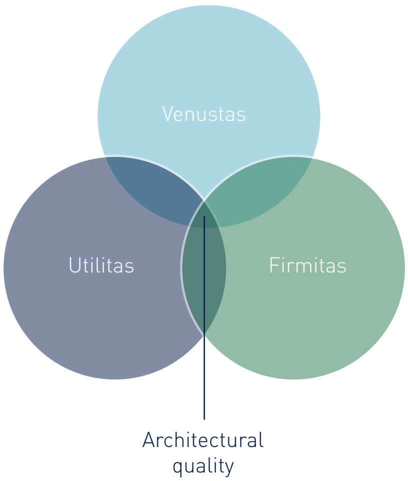
Vitruvius' theories about architectural qualities can be used to understand how tectonic and sustainability are related. He stated that architectural quality will occur in a building when it includes: *firmitas, utilitas and venustas*. Firmitas being durability, the construction and materials. Utilitas being utility, the function, the demands and needs of the user. Venustas being delight, the aesthetic.

Gottfried Semper defines tectonic as a result of conscious artistic work, material properties and design of construction. The function is not as relevant here.
When looking at both Vitruvius and Semper tectonic work need to have an artistic and creative idea (venustas) that is the overall principle for the construction (firmitas).

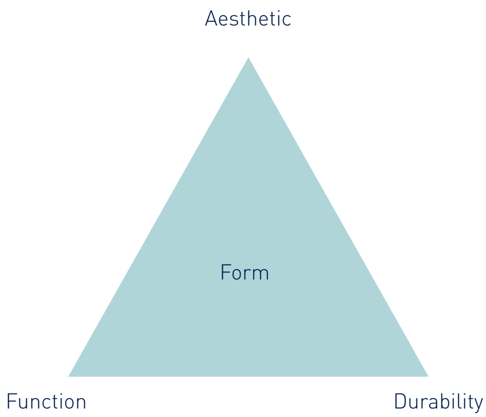
The before stated issue with CO_2 emission and energy consumption will be resolved directly in the choice of materials and the construction. This by looking at the materials and construction from a cradle-to-grave perspective. Tectonic is formed by transforming the materials potential and construction methods into architectural design solutions.

Architecture is not only materials but also ideas and values concerning the good life, which can be part of the function (utilitas). Social changes like growing individualism influences the process and the architecture need to be more diverse, flexible and adaptable (Bech-Danielsen, Beim, Christiansen, Bundgaard, Jensen, Madsen, Pedersen, 2012).

In the project, tectonic will be used in a sustainable connection. Firmitas, utilitas and venustas will be in focus when designing an environmentally friendly, functional building, and all three will be used when choosing materials and construction together with LCA. In the design process, it will be a key factor to reflect on to make a holistic project.



Ill. 29.1: Vitruvius' qualities



Ill. 29.2: Form triangle

Ill. 29.3: The Aarhus Architecture Lab, Vargo Nielsen Palle - a combination of tectonics, open spaces, learning and human requirements.

Ill. 30.1: Context Map

ANALYZES

The project site is analyzed through different analyzes looking at it through phenomenological analyzes but also through mapping of the site and micro climate. The project site is 42.000 m^2, including a barn/shed which will be removed, and the construction field is 10.000 m^2. The project needs to have a synergy between the leisure center towards north and the infrastructure (Competition program).

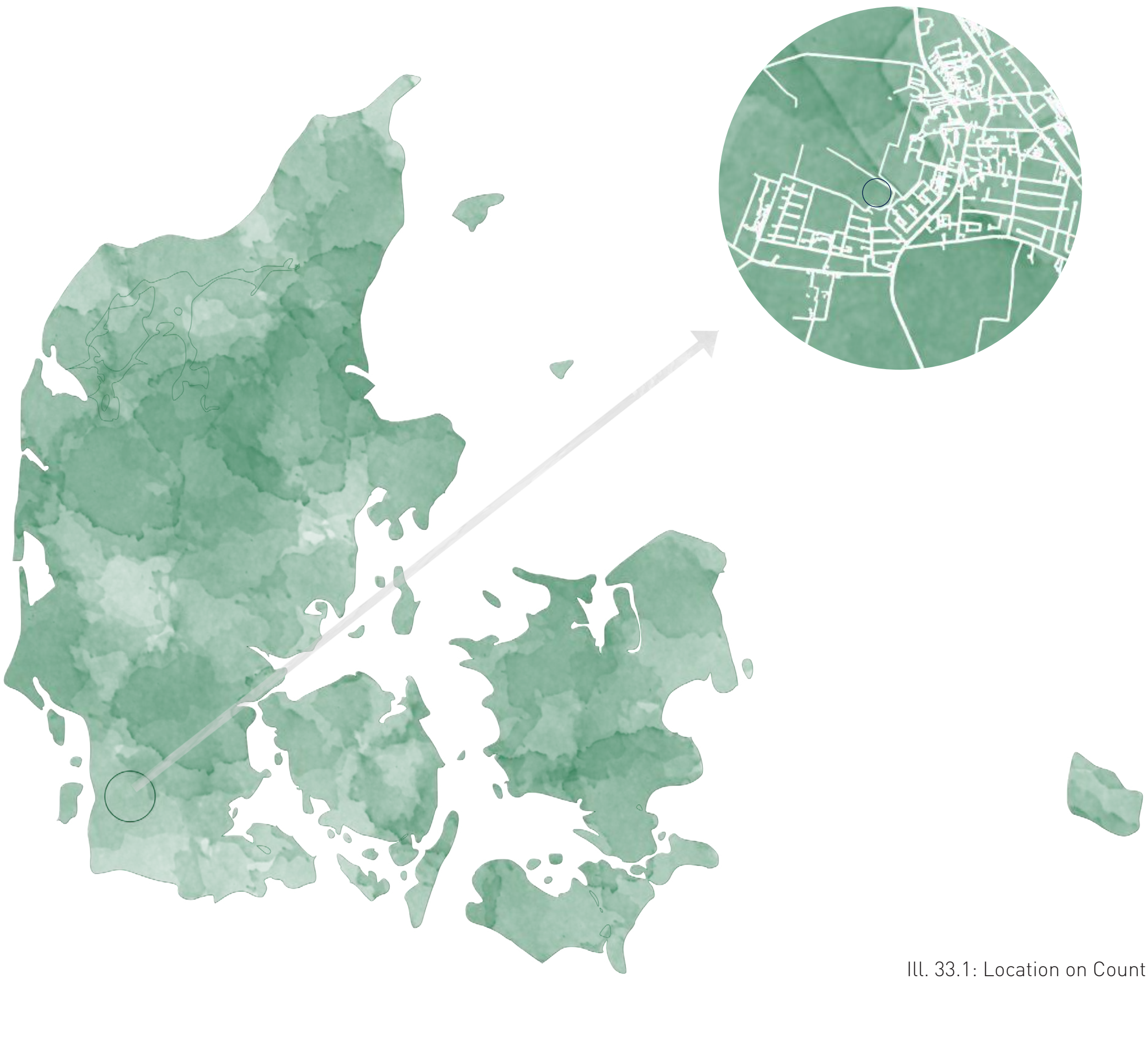
LOCATION

With the competition as a starting point the location chosen for the project is a field in Skærbæk, in Tønder municipality, in Denmark. Skærbæk is a small town in southern Jutland with 3.121 citizens.

The city is placed right beside The Mudflat (Vadehavet) National Park. This is the largest national park in Denmark and it extends from the Danish-German boarder to Blåvandshuk. It has an area of 1.459 km^2 and 300 km^2 of that is land. Its landscape is characterized by large fields.

Skærbæk city is a railway city located in a landscape with forest, fields and lowlands. Together these gives the area a distinctive landscape. In the area is also placed Bakkekammen by Gasse Høje, which relates to the history in the place and it has a far-reaching view.

The site is placed west in the city and is only one km from the city center and train station. The closets neighbors are Hjemsted Oldtidspark, Skærbæk leisure center, a residential development and fields in a flat landscape. The cadastral area is 42.000 m^2 and the building zone is around 6.000 m^2 (Competition program, 2017)



Ill. 33.1: Location on Country Map

BUILDINGS ON A MOUND

A mound is a fake island made in the middle of the marsh to keep the buildings from flooding. It is either a single, isolated farm building or a whole small village. In Denmark mound buildings can be found near the mudflat in Ballum marsh and Tønder marsh.

The architecture is typically a large farm building with 3-4 wings surrounding a courtyard. The buildings are characterized by thatch roofing and is surrounded by hedgerows. The brick buildings often vary from brown to light red. The bricks are often bigger than normal bricks and made with a cross-linking system and the socket is rarely visible. The function in the building is mirrored in the shape of the windows in the facade.

The materials used on the building depended on the local materials and there was often used only a few and they were simple. The walls are often not bearing walls, so the flood can push them away and the rest will still stand. The construction was often made of bearing columns which have a higher resistant to the flood than a bearing wall would have.

In the time when the mounds where build they were essential for living on the marsh. They protected from flooding. Later they build dikes to keep the water from the houses. The single standing mounds are a characteristic and gives the flat land value.

Some of the mound buildings are worth preserving because they are unique and rare to the Danish building customs, because of their special relation between building and landscape. Because of this relation the buildings most stand alone in the landscape and not be surrounded by other buildings or new vegetation. It is important to keep the transition between marsh and mound (SLKS, 2016).

In this project inspiration will be taken in the mound buildings when it comes to materials. An analysis of how sustainable the different materials are will help determine which will be used. Another factor which will help determine which materials are going to be used are how easy they are to clean, maintain and how durable they are.

Ill. 35.1: Mound building by Misthusum by Skærbæk

CONTEXT

KEVIN LYNCH

A mapping of the city is done with Kevin Lynch' method, 'The Image of the City'. By looking at the city from a structural view and find districts, edges, paths, nodes and landmarks which later can be used to define the design of the building.

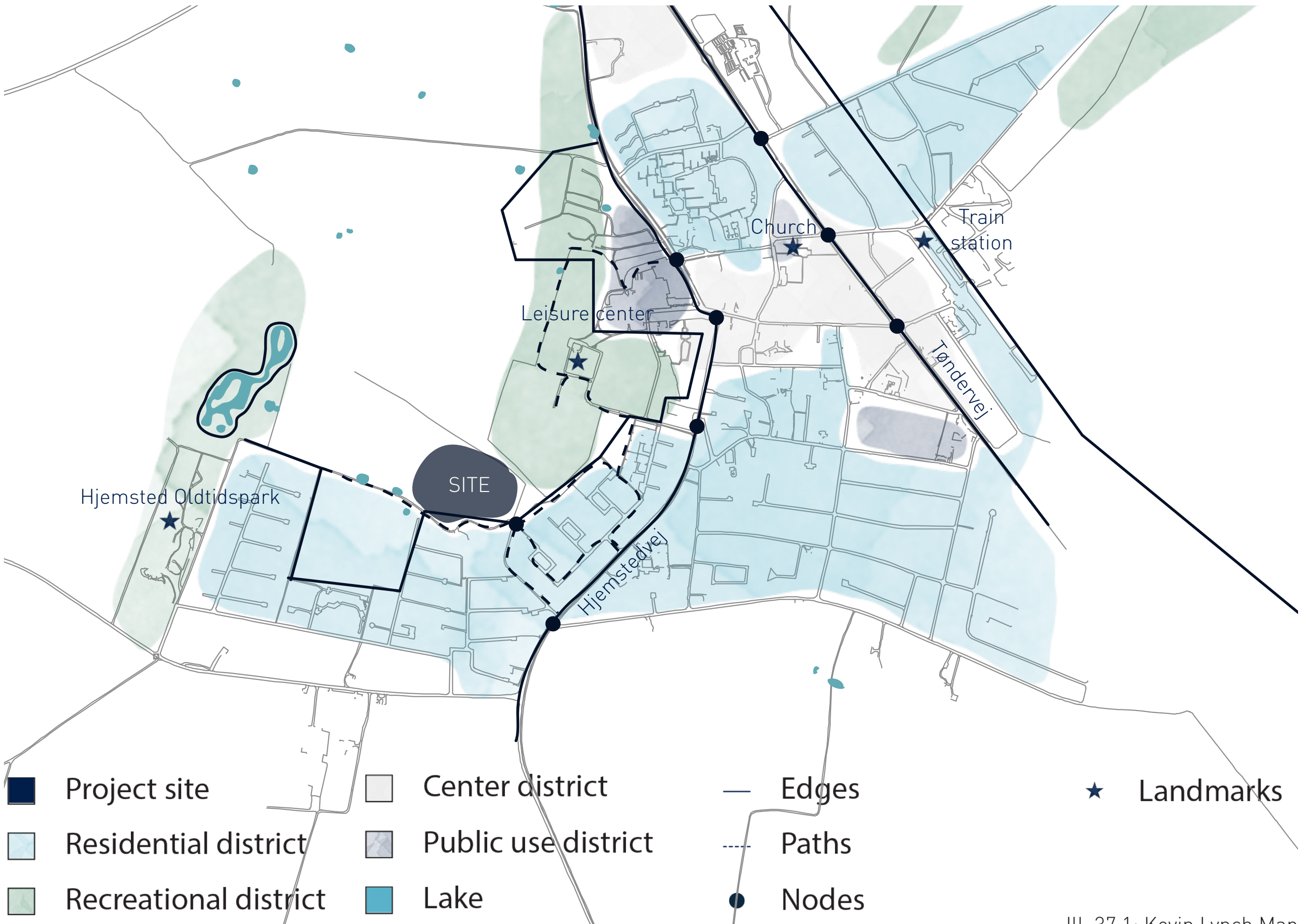
As Skærbæk is a small town there are only four districts. The residential district has the largest area and is the main part of the city. This is where the citizens live. The dwellings in the city are open low settlements, a typical suburban typology. The recreational districts are facilities around the leisure center and around the lake towards west, among others. This is large open areas with vegetation and fields. The center district is an area with shops, boutiques and restaurants. The public use district is areas with the church and cemetery, the local grocery store and the existing school.

The different edges define the boundaries people or traffic cannot cross. Here there are five primary edges. Some of the edges is based on traffic. One is the railway towards east, then there is highway 11, Tøndervej, which is the main road going through the big cities and there is a smaller highway going through the smaller cities, Hjemstedvej. There are also two other edges which is based on nature. One is the edge where the city ends, and the fields begin and the other is the lake towards west.

There are several nodes throughout the city. The main nodes looked at here is the ones closets to the project site. The two nodes on Hjemstedvej and the one right outside the project site. These nodes will help design the way into the project site and the placement and direction of the entrance.

The landmarks in the town are the station and the church near the city center. Then there is the leisure center, north from the project site and there is Hjemsted Oldtidspark west from the project site. Both the leisure center and Hjemsted Oldtidspark will be used in school functions. These should be connected to the project site (Lynch, 1960).

The different information found with this analysis will help create different design criteria, like the placement of the entrance, the paths to the two recreational areas and the traffic towards the school.



Ill. 37.1: Kevin Lynch Map

GENIUS LOCI

A visit to the project site gave a phenomenological understanding of the site. The Genius Loci is used to understand the room between the buildings and register the sense of a place through materiality, atmosphere, people, senses, etc. It is a walk through the city space experiencing the form, characteristics, scale, etc. (Norberg-Schulz, 1991).

On the dirt road Kagebøl where the road makes a crack is the meeting of the site from east. Here the city's characteristic shift from a city with red brick houses to an open field landscape. The traffic noise from the larger road, Hjemstedvej, is override by a chilly winter days harsh western wind and birds singing.

The smell of farm is acknowledged by the sight of three horses south of the site in front of the only house in eyesight not covered by trees and bushes. The horses and the fields belonging to the red farm house are defined by white fencing.

For now, the site is a field in fallow. However, the activity around the site is as expected. Despite of the soft, muddy path a lot of people use it for different morning activities. A man rides his bike, a woman walks with a stroller and an old lady walks with her dogs. With the city as a neighbor the place is dominated by nature and a feeling of peace and calm.

The lack of buildings makes the dominant color of the site green and brown. The dirt and the grass in different varieties only separated by rows off brown or green trees can be seen as far as the eye reaches towards north west. In the horizon towards north the city opens up with the yellow brick leisure center and yellow wooden house clusters.

In the west most side of the project site a small stream runs alongside the dirt path. It is only visible some places due to the heavy growth of wild grass covering it.

The site has endless potential with its open fields and no dominant materials. However, the feeling and identity of the place, with its nature, openness, freedom and fresh air should be kept when designing the new building.

Ill. 39.1: Site Pictures

SERIAL VISION

A serial vision is made to mediate the meeting of the site. The paths are determined in advance. It is based on phenomenological observations, where contrasting impressions occurs and changes along the way (Cullen, 1961).

The first route starts from Hjemstedvej and goes by the site. It explains the meeting with the site from south.

1. A larger road with minimum traffic. It is the outer corner of the city. One way is the open road with fields and the other is the city.
2. A dirt road with trees in front of the houses towards north and townhouses towards south, in red or yellow bricks with black roofs.
3. Around a corner a little farm house becomes visible. Standing at the edge with the city on one side and the open fields on the other.
4. The site is visible. It is a dirt field with pools of rain.
5. Two fenced fields. Two horses are eating hay, looking curiously around. A red house with a large shed is the only thing visible. Birds are landing on the fields and drinking the rain water. A man rides on his bike. The dirt road is long and goes around the fields. Towards south a residential neighborhood arises behind the trees.

The second route starts from the project site and goes up past the daycare towards the leisure center.

1. The choices are between two parallel roads, one dirt and one asphalt. The dirt road is muddy and wet and ends in a field filled with rainwater. The asphalt road is man made compared to the other. Between the trees on the asphalt road comes the silence.
2. The residential neighborhood becomes clearer towards east, red bricks and wooden sheds. The trees cover up the football fields in west.
3. A dirt road through the forest leads to the football fields. The ground is soft, wet and muddy. The view is directly towards the leisure center. A large building with a lot of parking. The green grass is a contrast to the asphalt. The view opens to the city.

The serial vision is used to get an understanding of how to approach the site. The analysis describes the contrast between the city and the open fields. This fact needs to be implemented in the design process. Together with the different demands for traffic this can both help design the entrance to the site but also help give the whole project a feeling that mirrors the sense of the place.

Ill. 41.1: Site Pictures

LOCAL-, MUNICIPALITI PLAN AND COMPETITION TERMS

MUNICIPALITY PLAN

Tønder municipality consists of five center cities and some local cities, Skærbæk is a center city. The center cities have different character like nature, history, etc. The quality of Skærbæk is that it is close to Rømø, which is an island in the mudflat. One of their focuses in development is sustainability and reducing the CO_2 emission.

A focus in Tønder municipality is the schools and learning. They priorities education and focus on coherence in the everyday. They work on making good and inspiring learning environments, that meets the children's individuality (Tønder municipality, 2018).

LOCAL PLAN

The areas purpose are dwellings and recreational area (Local plan, 2010) however this is revised, and the areas purpose will be public according to the competition program. The new local plan will be made together with the winning team.

COMPETITION PROGRAM

Rainwater needs to be a visible and aesthetic part of the architecture. A stream south of the site can be integrated. The municipality want the school to be a central part of the city with the placement of the building and its entrance, facing both towards the city and the leisure center. A path to the center is expected. Heavy traffic arrives at the school from south and light traffic from north. Four buses arrive at the school with 200 students every morning, which means 350 students arrive in another way, whereas 22% is in car. Around 50 staff members will also arrive by car. 120 cars will arrive every morning. An area for drop off is needed as well as 80 parking spots, 3 bus stops and 250 bicycle parking spots.

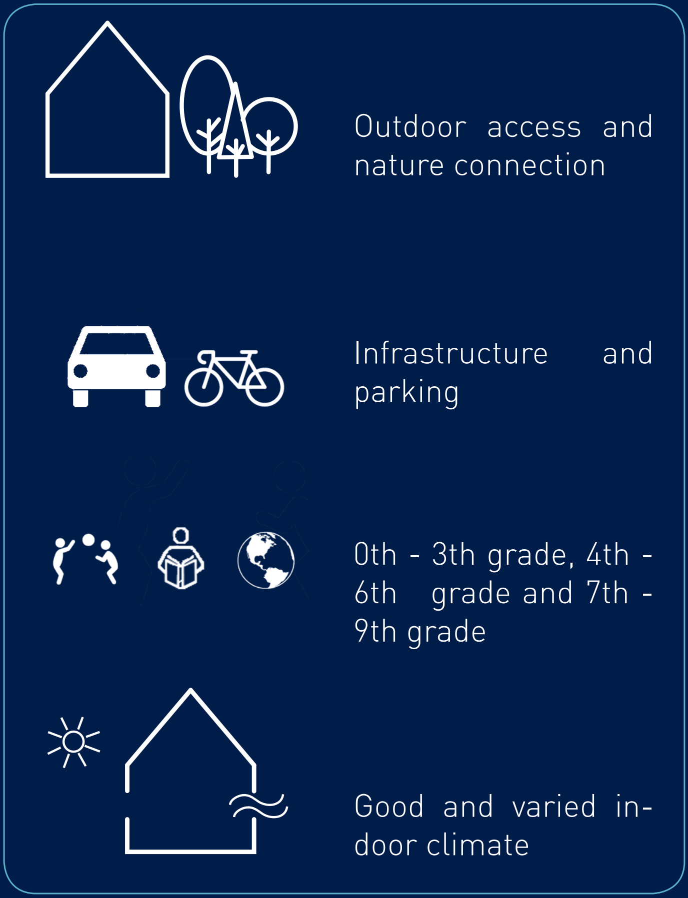
The idea with the leisure center (Appendix 3) is to utilize their sport facilities for physical education. This results in a small walk and the 0th - 3th grade should therefore be placed close to shorten the walk. The center can then use the school for sleepovers in connection with competitions.

Hjemsted Oldtispark can be used for history, science, art class, etc. The daycare will visit the school and the 0th - 3th grade should be designed after this. The general organization of the school needs to support different kinds of learning/teaching methods and outside teaching should be possible. Every square meter of the school should be used. Lastly, the school needs to be friendly towards disabled.

The architecture need to support the function and the subject groups there is in the new school reform. The design should be characterized by the surrounding nature and the mudflat. An observatory should make it possible to observe the weather, nature, animal life, etc. The nature should be close and maybe integrated in the architecture and the design should support education, activity and movement.

The school should be divided into three areas for students of different ages and with different focus. 0th - 3th grade with focus on learning through play, and the architecture should be safe and manageable, 4th - 6th grade should have open learning areas and 7th - 9th grade should have the outside world in focus and the architecture should be flexible. Everywhere there has to be spaces for both activity and peace.

There is a big focus on indoor climate and materials. Temperature, acoustics and light should be incorporated in the architecture. Materials need to be durable because of everyday use. The high level of movement need to be incorporated when working with the air quality. Mechanical ventilation should be the main source and both air and heat should be automatically controlled. Shading should be possible however the view shouldn't be compromised. Comfort class B or C needs to be respected (Competition program, 2017).



Ill. 43.1: Demands from Municipality and Competition Program

MICRO CLIMATE

The weather analyzes are made to support the decision of placement and to ensure great outdoor areas. Furthermore, it is made to place the windows to get the most optimal solution for natural ventilation and ensure good indoor daylight conditions in every room.

WIND

The wind analysis is based upon a wind station by Esbjerg airport. This was the closest to the project site and the location which was most similar to it. In the appendix (Appendix 1) wind roses from every month of the year can be found.

The primary wind direction is from west, north west or south west. Knowing the primary wind directions allows the design to integrate this when placing outdoor areas. Whilst different playgrounds and recreational areas can handle some wind, the more peaceful outdoor area for example the ones used for teaching or terraces should be shielded more from the wind.

Over the month of the year the wind direction changes. Going through the spring to summer months the primary wind direction shifts from west towards north west, while from the autumn to the winter month the primary direction shifts from west towards south west. People spend more time outside in the summer than in the winter and the primary direction which should be shielded from will be west and north west (Cappelen & Jørgensen, 1999).

TEMPERATURE AND PRECIPITATION

The information is based on a period from 2006-2015. The average temperature in Denmark in the summer period is 16,1°, in autumn it is 9,9°, in winter it is 1,7° and in spring it is 7,5°.

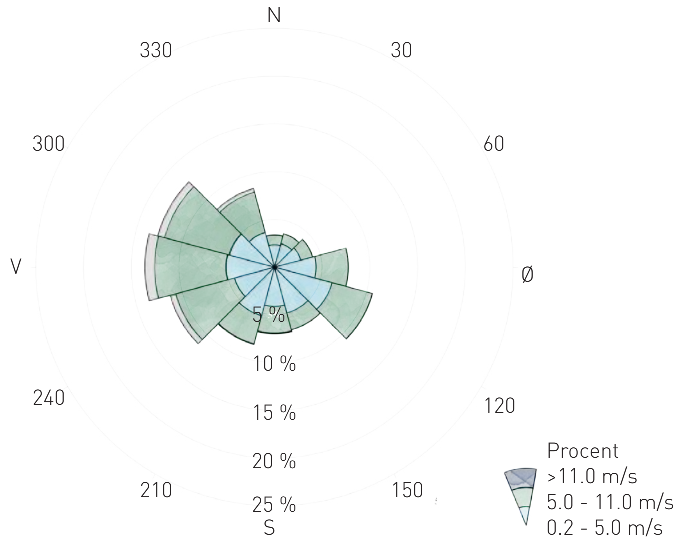
The average precipitation is in the summer period 236 mm, in the autumn period 234 mm in the winter period 186 mm and in the spring period 129 mm.

The average amount of sun hours in summer 669 sun hours, in autumn 305 sun hours, in winter 157 sun hours and in spring 593 (DMI,2018).

SUN

The latitude in Skærbæk is 55° and the longitude is 8°. The sun path diagram is made based on this information.

The diagram shows the sun path the 21st of June, the 21st of March and September and the 21st of December. In the summer period the sun's angle will be high, around 60°, during the autumn and spring the sun's angle will reach a maximum of around 35° and during the winter the sun's angle is very low with a maximum of 10°.



Ill. 45.1: Wind rose

	AVERAGE TEMPERATURE	AVERAGE PRECIPITATION	AVERAGE SUN HOURS
SUMMER	16,1⁰	236 mm	669 h
AUTUMN	9,9⁰	234 mm	305 h
WINTER	1,7⁰	186 mm	157 h
SPRING	7,5⁰	129 mm	593 h

Table 45.1: Temperature, Precipitation, Sun Hours

SHADOW

The project site is located in the outside of the city, which means there is no surrounding buildings that might cast shadow on the site. The only shadowing that will be relevant in this project will be the shadow the building make itself.

The few sun hours in the winter period should be utilized in a way so the urban areas are placed where the sun shines all year round.

NOISE

Due to the placement of the school no larger roads need to be shielded from because of noise. The roads leading to the project site are all small. The highway agency has made some limits which noise from roads needs to respect.

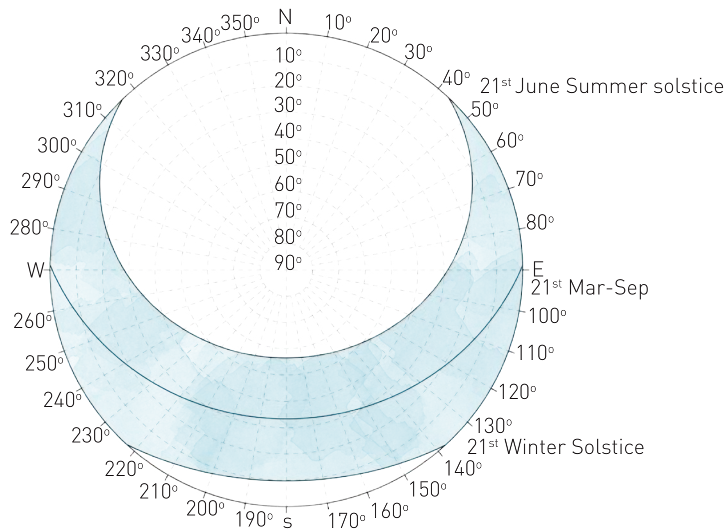
Around schools the limit is 58 dB, where under 10% will be bothered (Ill. 47.2). In the project, shielding from the noise the traffic that arrive at the school makes will be integrated. This could be done with noise reducing asphalt, which will reduce the noise by 2 dB. Noise barriers is the more obvious choice because they will reduce the noise up to 10 dB. A close forest could be a noise barrier, and the reduce is largest right behind the barrier (Vejdirektoratet, 2013)

CONCLUSION

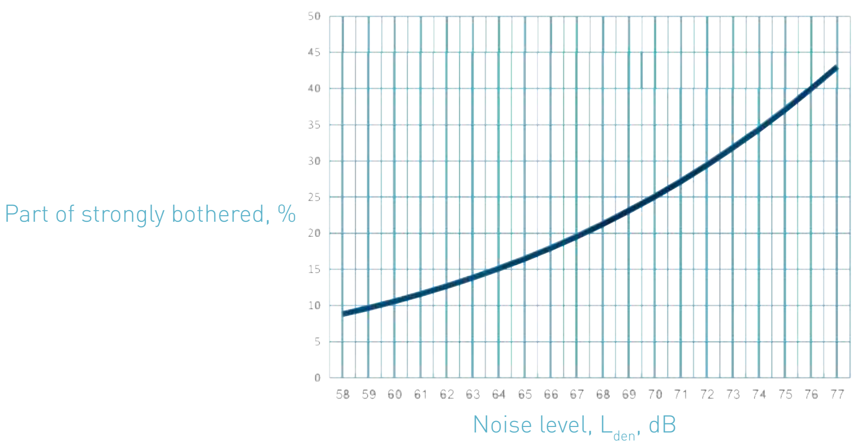
This information can be used when choosing the placement of the building. The building should be placed and oriented so there is a possibility to utilize natural ventilation, so a number of the building facades should face towards west or north west. Passive sun shading should be integrated in the design, especially from the low sun in the winter, and to ensure overheating is avoided. The building should be placed and oriented, so it utilizes the sun from south to enhance passive sun heat. It should also be oriented, so the urban areas have less shadow especially on the outdoor teaching areas.

The information can also be used when placing the solar panels. The solar panels will be an integrated part of the building, for example on the roof. With the sun path diagram the angle of the roof can be determined to face towards south for optimal results (Gaisma, 2018).

Denmark is not a country with hot weather and it often rains. This information can be used when looking at the outside areas. The outside and nature is a big part of this project, so different initiatives and design solutions should make it possible for the students/ teachers to be outside even when the weather doesn't invite to it.



Ill. 47.1: Sun Path Diagram



Ill. 47.2: Noise Pollution

USER SEGMENTS

When designing a school there are a lot of stakeholders that needs to be involved. One of these will be the user segments and others like associations, neighbors, etc. When making great design it is important to involve the others. In this analysis both of these is involved in different ways. The two user segments important for a school is the faculty and the students. This analysis has been made based on a visit to Videbæk-, Nøvling- and Sønderlands school and a discussion with the faculty, students and the head teachers.

Some of the factors was repeated. Everybody wanted a large hall, which could contain all the students, they needed more space everywhere, especially for storage and meeting rooms.

The different subject group teachers had different demands for these rooms. The Nature and Technology group wanted the three classes: Geography, Biology and Physics/Chemistry to be in one room with large depots that could contain everything the students wasn't allowed to use without a teacher present. They wanted room for both front facing teaching and workshop. With the culture group: Social studies, Christianity and History, there isn't that much a need for a subject room, however it could be fine with one large room that can be divided with flexible walls. The different groups should be associated with common areas, it should be easy to divide the room and both workshop and peace areas are needed.

The common rooms should be filled with different seating arrangement, so every student can decide what seating position they need to learn best. They should be fun, inviting and filled with activities that enable movement. The rooms need a large amount of daylight but also transparency into the building. In the part of the school with 0th - 3th grade the transparency should be focused in the top and bottom of the wall so the younger students doesn't get distracted.

Indoor climate is a very important factor when designing a school. A shoe free school will improve the indoor climate, make cleaning easier but also enable the possibility of using the floor as seating. Acoustics is also an important part of the indoor climate. The shape of the room, mobile shielding and the materials are all factors which can improve the acoustics. The materials used in the school should be maintenance friendly and steadfast. It needs to withstand large wear in many years every day.

Technology should be a part of the design of the school. Every school uses some kind of technology and it will only be more in the future.

The students focus on accessibility. They want a school which is easy to navigate, maybe using signs. They are happy with the different seating arrangement however they want more soft seating like couches. They think that lunch and other recess activities should be held together with the other classes and they wish for a canteen containing some of the classes divided by age.

As for the others, a workshop has been made for the competition with input from external users and local associations. The workshop was for different sports associations, the school board with student representative, the citizen council, the leisure center, Hjemsted Oldtidspark, etc. Together they have made different wishes for the new school. They want to use the school after hours and borrow some of the rooms with access to only the relevant rooms. Sometimes the hall at the leisure center is too big, so they wish for a smaller multi hall. The municipality demands then that it needs to contain other functions containing a storage close by for their equipment.

The urban areas should be designed so they are attractive for both user in school time and free time. They suggest: outdoor fitness, climbing wall and parkour equipment. Lastly, they suggest that the business community and the associations are integrated in the school day, for example using the swim trainer for swim classes (Competition program, 2017).

Ill. 49.1: User Segments Wishes

Ill. 50.1: Site Picture

CASE STUDIES

CASE STUDIES

Case studies have been made of three different schools all located in Jutland. The analyzes are made to achieve inspiration, understand the differences between the three schools and to build the base for making an optimal, sustainable school. In the case studies focus has been on area use, common areas, flexibility, sustainability and technology.

VIDEBÆK SCHOOL

Architect	ATRA Arkitekter A/S
Building owner	Videbæk Municipality
Area	5.300 m^2
Year finished	2005
Grades	0th - 9th
Students	464

Videbæk School is a traditional school as we see them in Denmark with a classroom to every grade based on the front facing method. The school is divided into five squares. One for each of the three groups the classes is sectioned in, one for the subject rooms like physics/ chemistry, home economics and music and one for the main library or PLC and administration (the heart of the school), placed in the center. Each of these squares has classrooms in the outer part and a common room in the middle. The squares make it possible to allow a lot of daylight into every room. Rooftop windows allows daylight into the common rooms.

The school is made with area optimization in focus, and hallways are made using a minimum of square meters. The squares with the common area fits together with the flexible learning method the school uses (ATRA Arkitekter, 2018).

In the common rooms and hallways different seating arrangement has been placed so the students can choose how they work best. Both the students and teacher are satisfied with this and only think they need more.

The school doesn't have any active initiatives however the materials at the school are dominated by red bricks and chosen based on duration and economy. The school are using WindowsMaster, which is automatically natural ventilation. This system is however not working for the school as intended according to the technical service leader, John Lindekilde (Appendix 2).

The school works with, the now traditional, technology such as smartboards and computer/tablets. As new technology they introduce a MakerSpace where they work with 3D printers, laser cutter, VR glasses, Robots, etc. as a part of the every day.

Ill. 53.1: Videbæk School, ATRA Arkitekter

NØVLING SCHOOL

Architect Kærsgaard & Andersen A/S
Building owner Aalborg Municipality
Area 2.300 m^2
Year finished 2017
Grades 0. - 6.
Students 179

Nøvling school has a new way of thinking the classroom. They have no closed rooms but they are defined by walls with large openings towards transition areas. The school is L shaped with 1st - 6th grade in the long wing and 0th, administration and subject rooms like chemistry in the short wing.

The school focus on utilizing every square meter and limiting hallways. In every transit area little niches have been made with a variation of seating. Some with couches with tables and some with bean bag chairs. The school is shoe free because of the focus on different seating. The students use the floor as seating (Appendix 2).

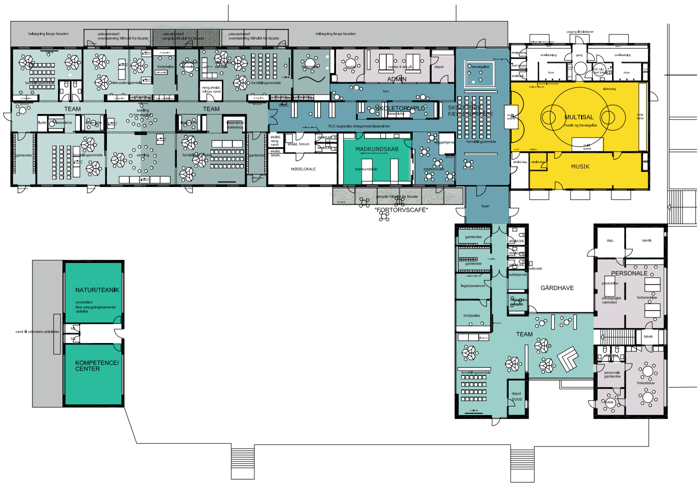
The large common area is the space between the two wings. Here the multi hall is placed with flexible ribs and scene arrangement. The changing room for both inside and outside gym is also placed here in between the multi hall and the outdoor football fields. This means that the sports associations using the football fields also can use the changing room without accessing the rest of the school.

In the common area the PLC is placed. The furniture in the room are flexible and movable. The tables are placed on rails, so the students can take their tabletop and move it around. The bookshelves have seating on top of them for the students to sit and read.

The food stall is placed in this common area. This means the students eat their lunch all over the school. They both take it back to their designated classroom area, but they also eat together with other grades in the common area (Morell, 2018).

The school does not have any active initiatives according to a sustainable approach. The new school was made as a renovation and the placement of the school was the same as the old school. The school is however optimized to the current standards for isolation and indoor climate.

The school uses tablets for reading every morning and computers. In the PLC they have an interactive floor they use for play and learning in the classes and in recess (Appendix 2).



Ill. 55.1: Nøvling School, KAAI

CASE STUDIES

SØNDERLANDS SCHOOL

Architect	Kjaer & Richter A/S
Building owner	Holstebro Municipality
Area	10.030 m^2
Year finished	2018
Grades	0. - 9.
Students	621

Sønderlands School is the largest of the three researched. The new school is an extension and renovation of the old school. They use the traditional method with front facing students in closed classrooms.

It is a school placed in the middle of a larger city which means the outdoor areas are minimum and the school utilize the roofs as recreational landscapes. A problem with the roofs and water leaks have made the school roofs inaccessible. However, when this is fixed the school will both use the roof for outdoor recreational areas and for access areas.

The school focus on utilizing every square meter, however the amount of hallways are remarkable larger than in the two other schools. The classrooms surround hallways, and these end up in common areas. The common areas are furnished with flexible walls and different seating options and a kitchen is dedicated to each of the grade groups.

In every classroom there are placed choir stairs, so the children can use them for seating and the windows are expanded with a small staircase up to the windowsill, so the children can sit in it.

In the project they worked with integration of solar cells as an active initiative. The outdoor areas are facing south and shielding from the western wind. The building shape shields from the largest road, Sønder Alle towards north.

The school uses smart boards and computers/tablets as a natural part of the everyday, however they do not have any new technology at the moment (Appendix 2).

Ill. 57.1: Sønderlands School, Kjaer & Richter

CASE STUDIES


Ill. 58.1: Site Picture

PART CONCLUSION

PART CONCLUSION

The following is the part conclusion for the program. It includes a conclusion of the different analyzes, design criteria, a vision, a more focused problem statement, a room program and a function diagram. These will make the base for the following design process.

PART CONCLUSION

This part conclusion will sum up the analysis phase. It will help create the design criteria and be a guideline for the design process.

An open learning area will make the base for the new classrooms. The school will be designed as a digital learning factory, where technology is in focus. The school need to be friendly for disabled, safe, flexible, adaptable, multi-usable, etc. The common area need to enhance encounters. The classroom and common areas need to be designed as a mix between the clusters and the open learning landscape. Physical activity and movement need to be an integrated part of the every day.

The school need to be sustainable to the extent that the three aspect is respected when looking at materials and ensuring peoples living quality. DGNB will be used as a guideline in the project. The LCA will be used when choosing materials, together with maintenance- and cleaning accessibility.

The different facilities already made should be utilized by the school for example the football fields and the leisure center, in return they can use the school's facilities. Every square meter should be utilized. The school should use passive initiatives to save energy. It should be an adjustable system with flexible rooms, so the students can move around.

The edge, Hjemstedvej, will be from where the primary traffic comes from and a connection with Kagebøl road and the parking lot should be established. Both the nodes and the edges will help define the entrance and the parking lot. The edge defined by the fields, where the feeling of crossing over to a more natural and peaceful place should be maintained. The landmarks Hjemsted Oldtidspark and the leisure center should have a direct connection to the school.

Through the two phenomenological analysis Genius Loci and Serial Vision the sites identity is found. A nature filled place with fresh air, smell of land, birds singing and the feeling of being on the edge of the city. All these aspects should be maintained when designing the school.

Through the competition program a lot of demands are found. However not all of these will be taken into account when designing the school. Some of them, which will be respected are: facing the entrance to make the school a part of the city, a path to the leisure center, traffic and parking demands, nature as character traits. The school will be divided into three parts: 0th - 3th grade, 4th - 6th grade and 7th - 9th grade, with different character traits. Focus will be on indoor climate and comfort class B or C will be respected.

The wind from west, north west and south west should be shielded however the most dominant wind comes from west where the land is flat, and nothing is shielding it, which means this is the primary concern. In spring and summer, the wind comes from north west, and because people are outside more this time of year this will be the secondary concern.

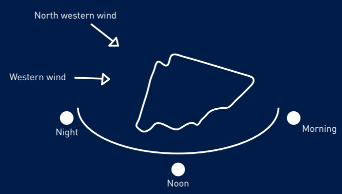
The angle of the sun will help design the passive and active initiatives. It will help integrate passive solar shading and solar cells. It will also help define the outdoor areas together with the primary wind directions.

Through the analysis of the user segments different demands have been highlighted. A multihall were every students and teachers can fit is very important. There should be space enough for meeting rooms and storage. The different subject groups should be designed in one large room with flexible dividing. Every subject group should be close to a common area. Different seating options should be integrated in both the common rooms and subject rooms. The rooms should be placed so every room have a lot of daylight and transparency. Indoor climate is important, and a shoe free school will enhance this. The materials and design solutions should be maintenance friendly and durable.

Technology should be integrated in the design. A larger area for lunch break is preferable. Some of the school should be accessible for the cities associations without they have access to the rest of the school, for example changing rooms and the urban areas should be designed so they can be used by the rest of the city.

The three schools analyzed are different according to the classroom. Videbæk- and Sønderlands school are more similar with the classic front facing blackboard rooms while Nøvling school is different with the open learning areas. In the design of the new school a mix of these two will be the base for the plan solution. There is both need for a quiet, closed space but also for more active open areas. All three schools focus on area optimization and utilizing the hallways, which also will be a focus in this project. The three schools all use some kind of passive initiatives when talking sustainable architecture. The solutions used in these schools will be used as inspiration for the project.

MAIN DESIGN CRITERIA



The micro climate shall be the base for placing the building and shaping the overall master plan

The user segment's together with the competition program's wishes and demands should set the guidelines for the plan layout

There need to be a synergy between the architecture and the nature

The architecture needs to enhance learning and physical activity

The accessibility towards the city, the leisure center and Hjemsted Oldtidspark shall help make the overall composition of the school and its openings

The school should be designed with a holistic sustainable approach seen in the materials, the passive- and active initiatives and the indoor climate

Ill. 62.1: Design Criteria

VISION

The vision for the master thesis is to design a Danish elementary school, where architecture enhances learning and movement. With the nature in focus the school should respect the context and keep its identity intact with a synergy between nature and architecture. The school should be designed for children and have optimal working spaces both for a variation of different students and faculty members. The building must fulfill the demands of energy frame 2020 and the processes most follow the integrated design process with a synergy between architectural- and technical aspects.

PROBLEM STATEMENT

How can a Danish public school be designed with a holistic sustainable approach, where the architecture enhances learning through an open school solution and with indoor climate as a main focus?

DESIGN CRITERIA

CLASSROOMS AND COMMON AREAS

The school designed as digital learning factory.
The subject groups placed in one large room.
Every classroom should be flexible and adaptable.
A variation of seating options shall be integrated.
Outdoor areas should be adjacent to the teaching areas and made possible for use all year long.
Transition areas/hallways shall be minimized.

SUSTAINABILITY AND INDOOR CLIMATE

The materials chosen according to economical- and environmental sustainability together with LCA and accessibility for maintenance and cleaning.
The building should comply energy frame 2020.
Active initiatives will be used to minimize energy use.
The DGNB will be used as a guideline, especially the social- and environmental qualities.
Mechanical ventilation as primary air source.
The class- and common rooms have natural daylight.
Comfort class B or C will be respected.
Nature should be a visible and aesthetic design element.
A tectonic approach used when choosing materials and constructions.

ACCESSIBILITY

Heavy traffic will arrive from south and defines the parking lot.
Light traffic will arrive from north and define the bicycle parking.
The main entrance to the school placed in connection to the city and leisure center.
Direct access established from leisure center and Hjemsted Oldtispark to the school.
The 0th - 3th grade closest to the leisure center and daycare, preventing a long walk.
Disabled friendly accessibility and safety as a focus.
The different functions should be organized so a natural flow is created.

MICRO CLIMATE

The identity of the place should be kept.
Noise from the p-lot shielded from east and south.
Wind from west and north west shielded on outdoor areas.
Placement of windows based on enhancing natural ventilation.
Placement of the building based on enhancing passive sun shading and decreasing overheating.
Placement of solar panels based on the suns path.
The building should be placed and shaped, so it does not cast shadow on the urban areas.

Ill: 65.1: Design Criteria Diagrams

ROOM PROGRAM

		Rooms	Area m^2	People	Daylight	View	Activity	Outdoor access	Air Change	Category
Gathering place	Hall	1	600	600	■	□	■■□	■	0,35 l/s/m^2	B
	Canteen	3	200	200	■	■	■□□	■	0,35 l/s/m^2	B
	PLC	1	200	600	■	□	■■□	□	0,35 l/s/m^2	B
0. - 3. grade	Class room	8	60	28	■	■	■□□	■	5 l/s/pers.	B
	Common area	1	200	224	■	□	■■□	□	0,35 l/s/m^2	B
	Wardrobe	4	10	-	□	□	■□□	□	0,35 l/s/m^2	C
	Toilet	1 pr. 10 pers.	24	14	□	□	■□□	□	15 l/s	B
	Depot	1	5	1	□	□	■□□	□	10 l/s	C
4. - 6. grade	Class room	6	60	28	■	■	■□□	■	5 l/s/pers.	B
	Common area	1	150	168	■	□	■■□	□	0,35 l/s/m^2	B
	Wardrobe	3	10	-	□	□	■□□	□	0,35 l/s/m^2	C
	Toilet	1 pr. 15 pers.	20	10	□	□	■□□	□	15 l/s	B
	Depot	1	5	1	□	□	■□□	□	10 l/s	C
7. - 9. grade	Class room	6	60	28	■	■	■□□	■	5 l/s/pers.	B
	Common area	1	150	168	■	□	■■□	□	0,35 l/s/m^2	B
	Wardrobe	3	10	-	□	□	■□□	□	0,35 l/s/m^2	C
	Toilet	1 pr. 15 pers.	20	10	□	□	■□□	□	15 l/s	B
	Depot	1	5	1	□	□	■□□	□	10 l/s	C

PART CONCLUSION

		Rooms	Area m^2	People	Daylight	View	Activity	Outdoor access	Air Change	Category
Craft and design	Class room	1	230	84	■	■	■■□	■	5 l/s/pers.	B
	Depot	1	40	1	■	□	■□□	□	10 l/s	C
	Ceramic oven	1	3	1	□	□	■■■	□	10 l/s	C
	Locked depot	1	20	1	□	□	■□□	□	10 l/s	C
Science	Class room	1	350	84	■	■	■■□	■	5 l/s/pers.	B
	Locked depot	1	20	1	□	□	■□□	□	10 l/s	C
Culture	Class room	1	180	84	■	■	■■□	□	5 l/s/pers.	B
	Depot	1	20	1	□	□	■□□	□	10 l/s	C
Home economics	Class room	1	180	28	■	■	■■■	□	20 l/s	B
	Viktualie	1	20	2	□	□	■□□	□	10 l/s	C
Music	Class room	1	100	28	■	■	■■■	□	5 l/s/pers.	B
	Depot	1	20	1	□	□	■□□	□	10 l/s	C
	Practice room	4	8-10	1-3	■	□	■■□	□	0,35 l/s/m^2	B
Subject area	Common area	1	>150	150	■	□	■■□	□	0,35 l/s/m^2	B
	Toilet	1	20	10	□	□	■□□	□	15 l/s	B

		Rooms	Area m^2	People	Daylight	View	Activity	Outdoor access	Air change	Category
Special	AKT	1	15	1-2	■	□	■□□	□	0,35 l/s/m^2	B
	Health care	1	20	1-2	■	□	■□□	□	0,35 l/s/m^2	B
	Psychologist	1	15	1-2	■	□	■□□	□	0,35 l/s/m^2	B
	Counselor	1	15	1-2	■	□	■□□	□	0,35 l/s/m^2	B
Administration	Office	3	20	1	■	■	■□□	□	0,35 l/s/m^2	B
	Open office	1	50	10-15	■	□	■□□	□	0,35 l/s/m^2	B
	Depot	1	20	3	□	□	■□□	□	10 l/s	C
Faculty	Staff room	1	50	50	■	■	■□□	■	0,35 l/s/m^2	B
	Quiet room	1	20	1	■	■	■□□	□	0,35 l/s/m^2	B
	Toilet	1-3	8	1-3	□	□	■□□	□	15 l/s	B
	Changing	1-3	10	1-3	□	□	■■□	□	15 l/s	B
	Wardrobe	1	15	-	□	□	■□□	□	0,35 l/s/m^2	C
	Kitchen area	1	10	5	■	□	■■□	□	20 l/s	B
	Meeting	4	25	8	■	■	■□□	□	0,35 l/s/m^2	B
	Preparation	5	70	10	■	■	■□□	□	0,35 l/s/m^2	B
Technical	Office	1	15	2	■	■	■■□	□	0,35 l/s/m^2	B
	Depot	1	200	1-2	□	□	■□□	□	10 l/s	C
	Technical	1-4	15	-	□	□	■□□	□	10 l/s	C
	Cleaning	4	10	1	□	□	■■□	□	10 l/s	C

		Rooms	Area m^2	People	Daylight	View	Activity	Outdoor access	Air change	Category
Sport	Changing	2	40	28	■	□	■■■	■	15 l/s	B
Sport	Teacher changing	1	8	1	□	□	■■■	□	15 l/s	B
Sport	Toilet	2	2	1	□	□	■□□	□	15 l/s	B
Sport	Depot	1	70	1	□	□	■□□	□	10 l/s	C
Sport	Multi hall	1	600	600	■	□	■■■	□	5 l/s/pers.	B
Outdoor	Observatory	1	60	28	■	■	■■□	■	-	-
Outdoor	Depot	1	30	-	□	□	■□□	■	-	-
Outdoor	Tiled area by class rooms	20	>10	29	■	■	■□□	■	-	-
Outdoor	Bicycle shed	1-4	-	250	■	□	■■□	■	-	-
	Total		6.996							

Table 69.1: Room Program

Every room which are needed in the new school are mentioned, however some of the rooms might have a double function and they might be a joint room in the final design. This could for example be the Hall and PLC or the classroom's common room and canteen.
The information used in this room program is based on the competition program, labor inspectorate (Arbejdstilsynet, 2018), an industry guidance (Klingenberg, 2014) and the building regulations (Bygningsreglement, 2018). The daylight factor for working stations are 2% (Kristensen, Traberg-Borup, Petersen, Johnsen, 2004)

	Category A	Category B	Category C
CO_2	800 PPM	1000 PPM	1500 PPM
Vent. pr. pers.	10 l/s	8 l/s	4,5 l/s
Temp. Winter 22°C	+/- 1,0	+/- 2.0	+/- 3.0
Temp. Summer 24,5°C	+/- 1.0	+/- 1.5	+/- 2.5

Table 69.2: Category and Demand

(DS 1752, DS/EN 15251)

FUNCTION DIAGRAM

There are four different colors in this diagram. The light blue consists of the classroom areas (home areas) and what are in connection with those. The dark blue consists of the faculty areas. The green consists of the subject groups and what are in connection with those and the gray consists of the central common area and technical rooms. Where the bobbles overlap there are a connection between the rooms. However, in the subject groups it is not decided which rooms should be in connection with each other.

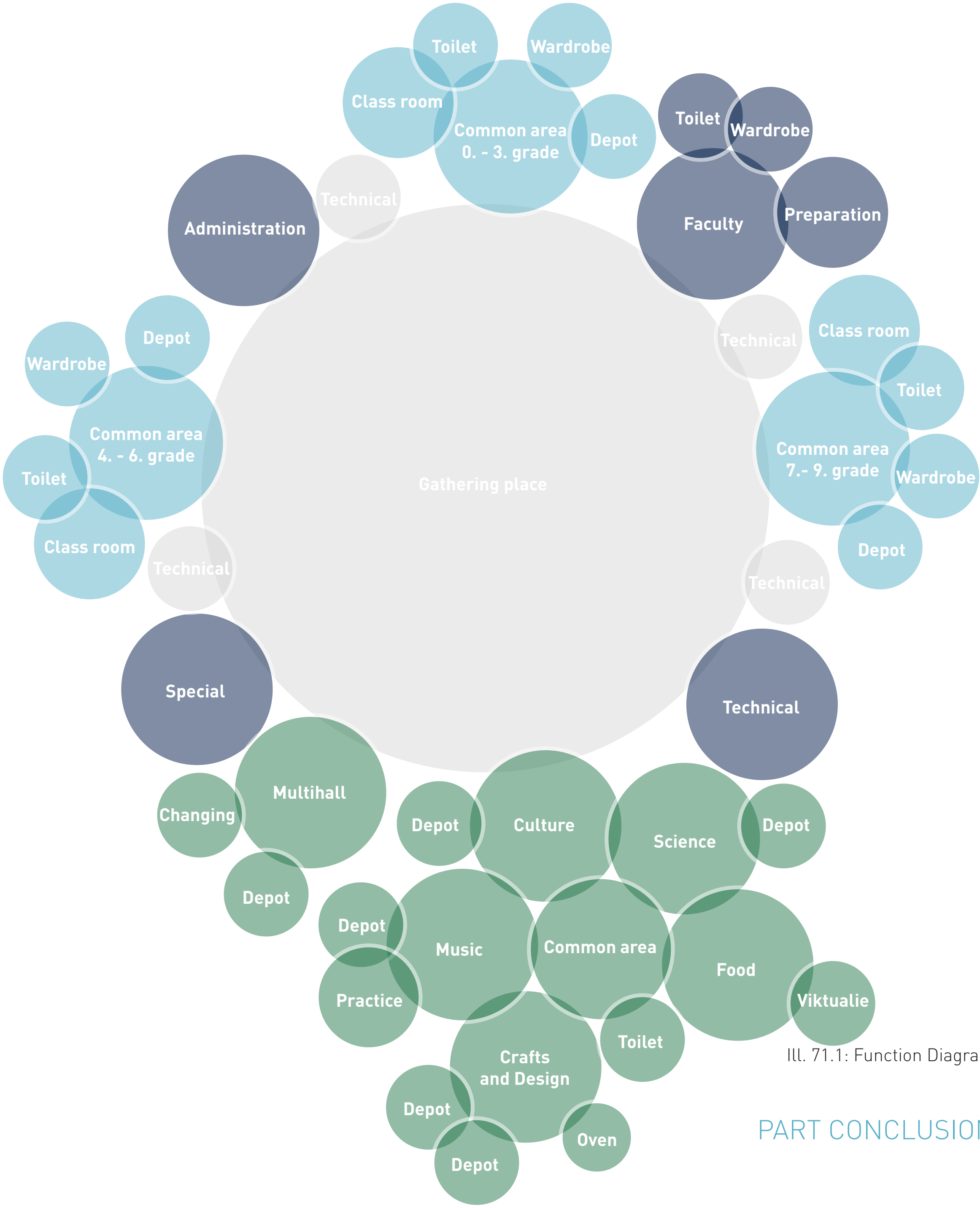
The school must accommodate 550 students and 50 faculty members. The school is divided into five different areas, that all have a connection to the central gathering place containing a hall, a scene, PLC and possibly a canteen. The five areas are: 0th - 3th grade, 4th - 6th grade, 7th - 9th grade, Faculty and Subject groups areas. Including in the subject groups are the sport facilities. The four small technical rooms placed around the central gathering place consist of ventilation, cleaning, etc.

Every home area has a common area, which the classrooms, toilet facilities and wardrobe centers around. The common areas are connected to the central gathering place.

The function diagram is made in connection with the room program and should be read together with it. In the room program clarification of what special and administration, among others, contains can be found.

The function diagram will function as a guideline for the further design process. It will be in focus both when designing the plan drawings, the overall concept, the overall shape and placement of the building.

Home area
Administration/management/faculty
Subject areas/sport facilities
Central gathering place



Ill. 71.1: Function Diagram

Ill. 72.1: Entrance to the Building

PRESENTATION

PLACEMENT ON SITE

The chosen site is a very large field with a lot of space. The placement of the school building has therefor gone through a process to find the most optimal location. The final placement was based on the shape of the building and the surroundings.

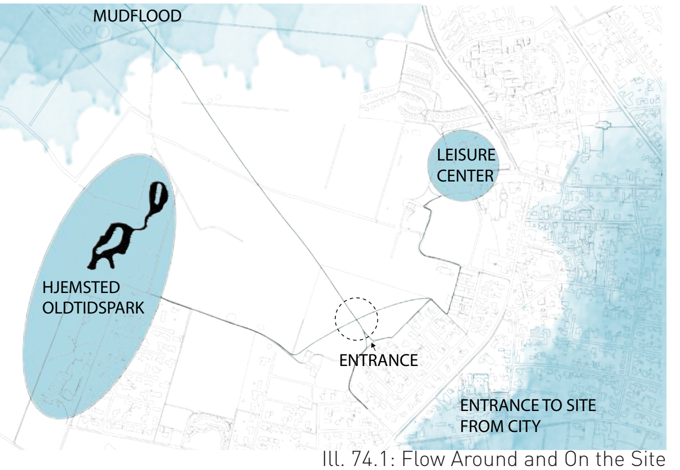
A flow diagram has been made to see the flow between Hjemsted Oldtidspark to the site, the leisure center to the site, the city to the site and the mudflood to the site. Where these four lines cross on the site is the placement for the building.

These four elements are the main surrounding elements, which the school needs a connection to. The entrance of the building should be in connection with the city and the leisure center. It is there for placed between the two access ways from the city.

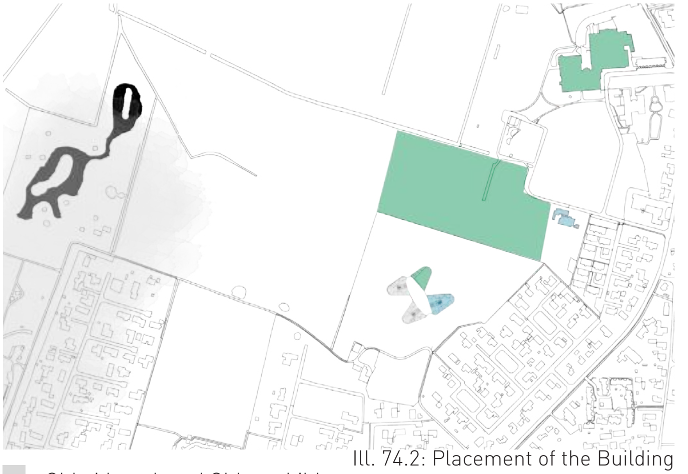
The multi hall and changing room are placed to the north to get an easy access from the leisure center and the football fields.

The youngest children are placed to the north east. By placing them here they both have the shortest way to the leisure center and there is a short distance to the daycare center.

The oldest children are placed to the south west and south east to give them the closest access to the park.



Ill. 74.1: Flow Around and On the Site



Ill. 74.2: Placement of the Building

- Oldstidspark and Oldest children
- Leisure center, Football fields and Multi hall
- Daycare center and Youngest children

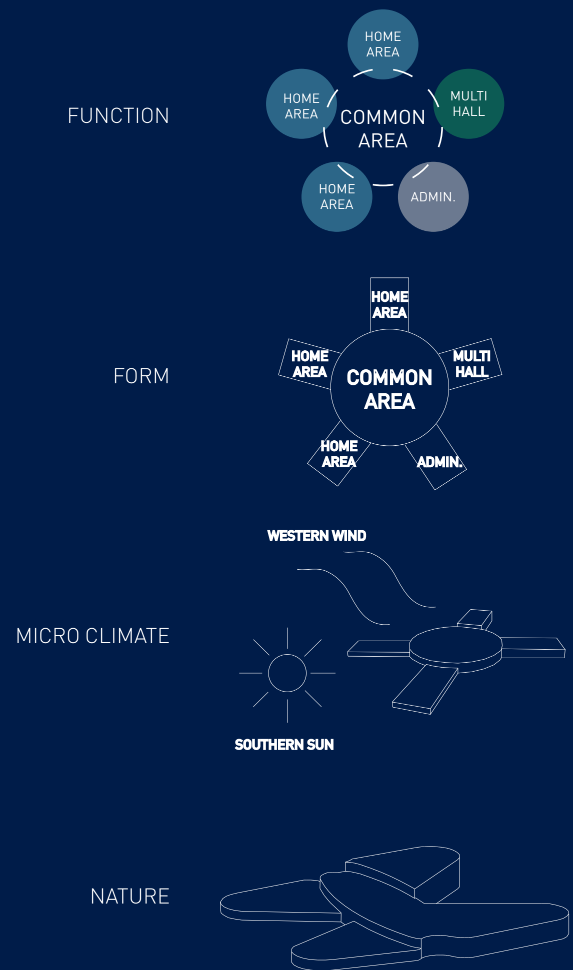
CONCEPT

The concept for the project is based on Louis Sullivan's statement ''Form follows function''. The function of the different areas in the school building has been determined and placed around a centering common area. The form of the building is then build from this.

From the beginning there were a large focus on minimizing the number of hallways. This has been done with this concept, where every function are connected to a common center, which then function as a distribution area.

The micro climate has changed the composition of the building and its heights. The building increases in heights towards north to open up for the facade towards south. The western wind is shielded from between the arches, where there will be possibilities for playgrounds.

The project has a large focus on the surrounding nature, which is then mirrored in the shape of the building using soft, organic shapes, that embraces the landscape. A way to respect the nature by blending in to it opposite of making a sharp edge building as a contrast to the soft and organic nature. Respecting the nature by blending into it instead of making a contrast the sense of place, found in the analysis phase on page 38-41, is kept.



Ill. 75.1: Concept Diagram

Ill. 76.1: Master plan

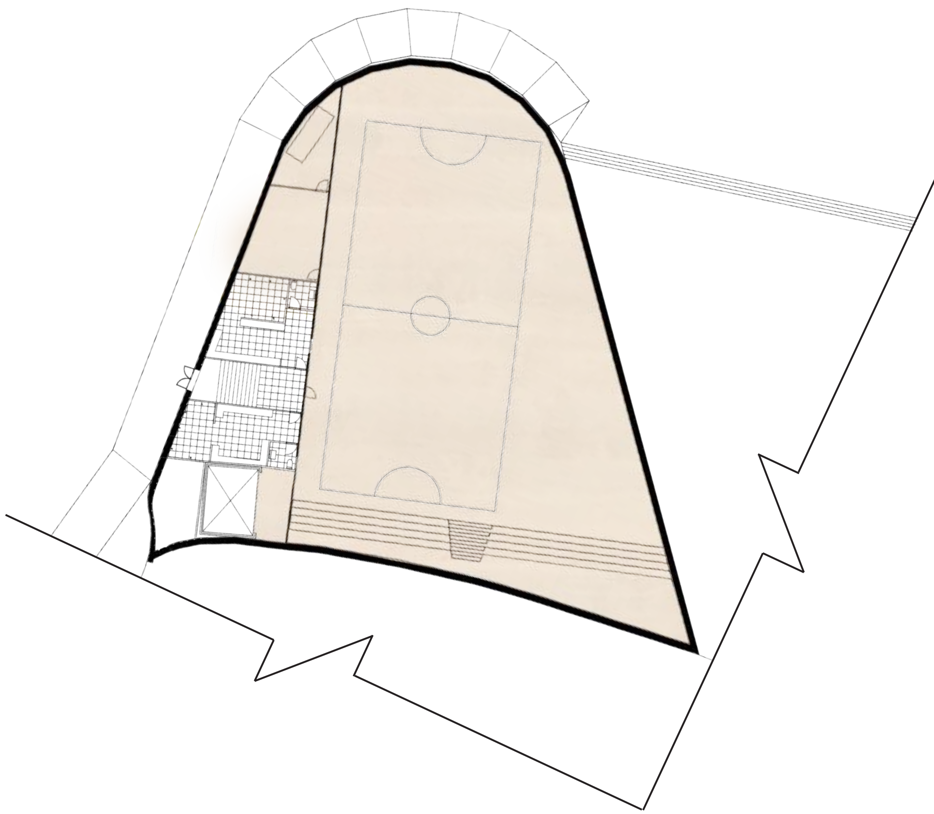
PRESENTATION

PRESENTATION

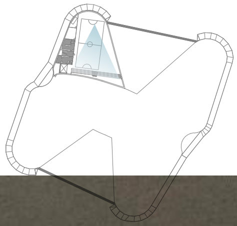
Ill. 78.1: Master plan

PRESENTATION

MULTI HALL



Ill. 80.1: -1.floor cutout 1:500



Ill. 81.1: Multihall

PRESENTATION

HOME AREA FOR 7th - 9th GRADE

INFORMATION

- Classrooms are 60+ m^2

- Each classroom is squared and the seating options a various. Three examples are shown here.

- The classrooms are L-shaped, which gives a possibility for placing a choir stair or other sort of seating.

- The classrooms are used for lectures and quiet places.

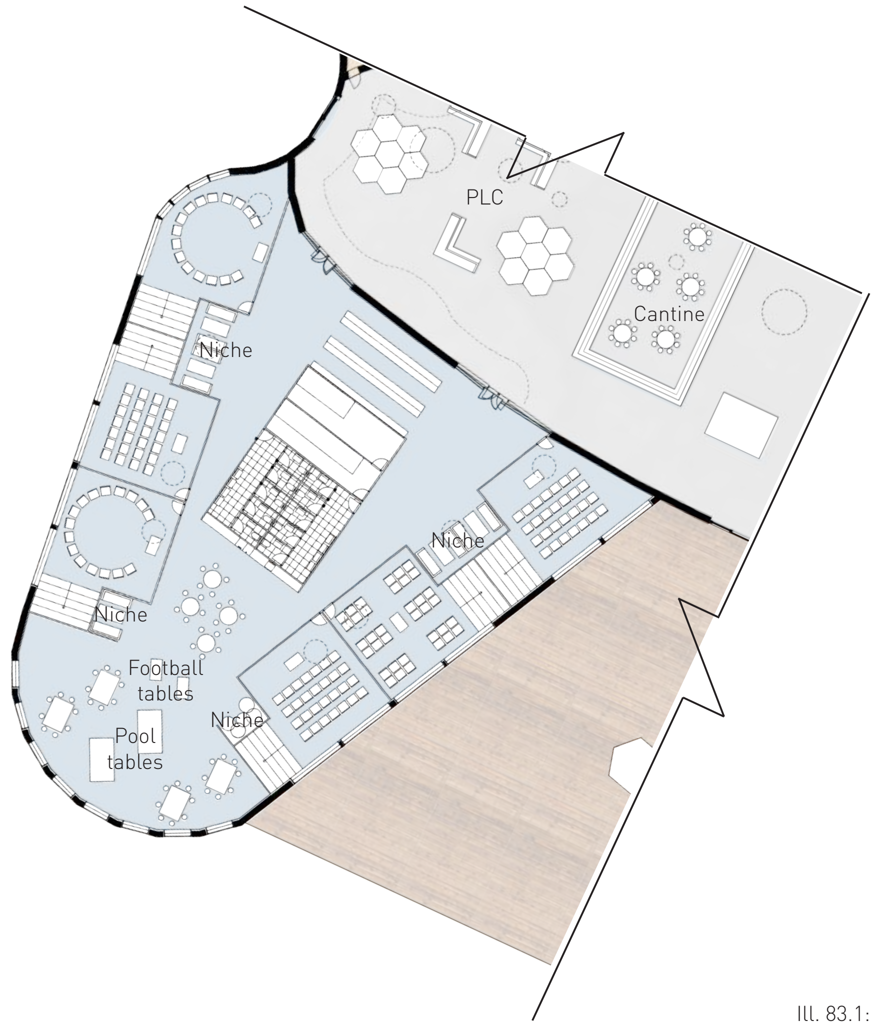
- Each home area has a large common room for workshop and more active work.

- Each home area has a core consisting of: wardrobe, service room, depot, toilets and kitchen.

- The core is placed in the middle of the room to utilize the dark areas.

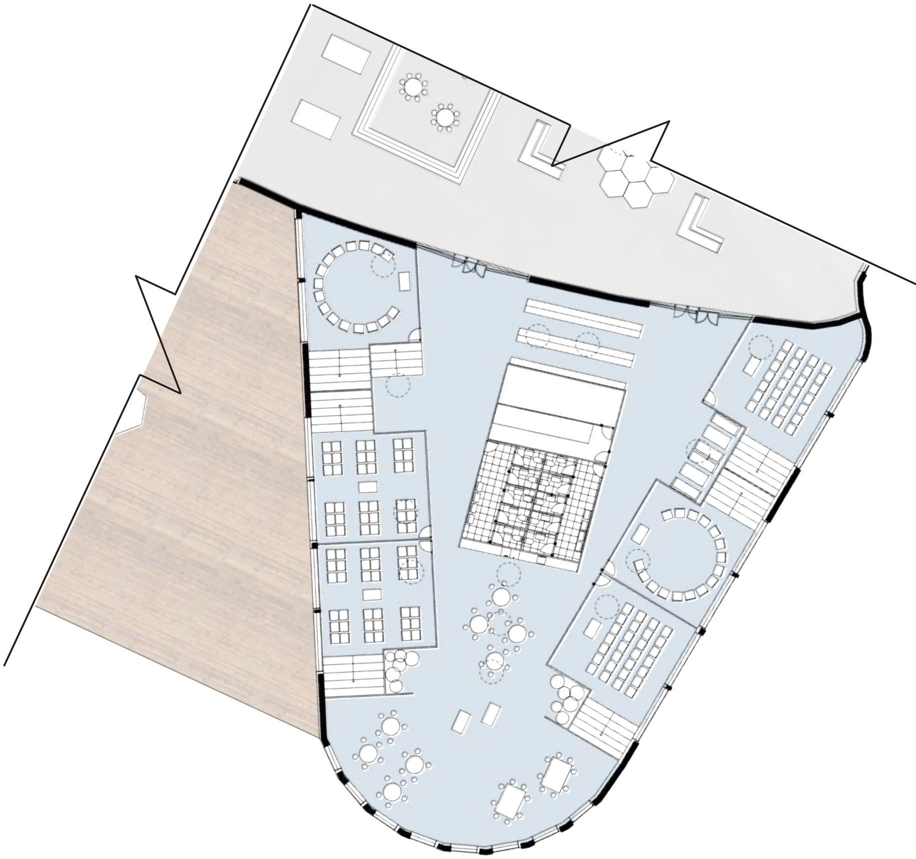
- Over the niches there is placed a skylight to achieve a cozy area with a little daylight.

- The niches are furnished with table-chair seating, bean-bag chairs or choir stairs.

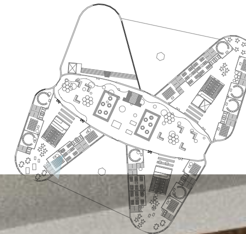


Ill. 83.1: 0. Floor Cut out 1:500

HOME AREA FOR 4th - 6th GRADE

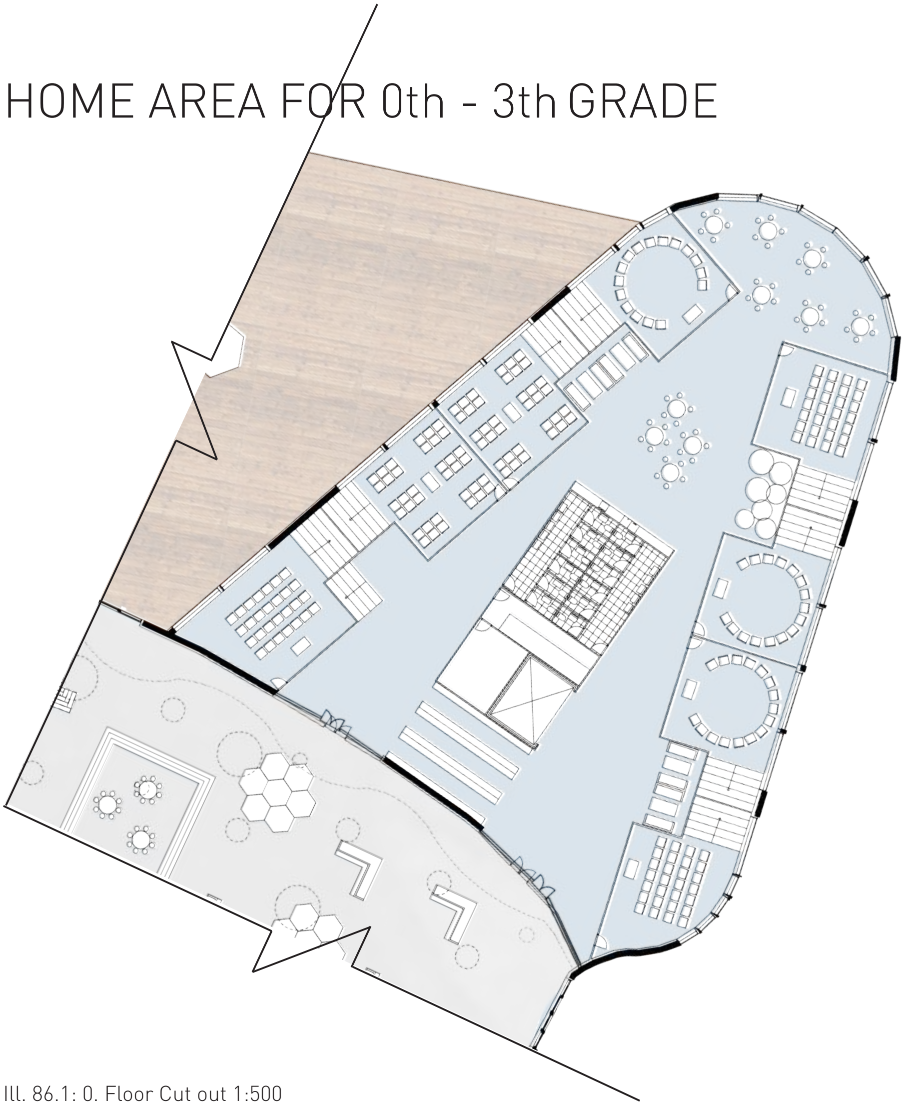


Ill. 84.1: 0. Floor Cut out 1:500

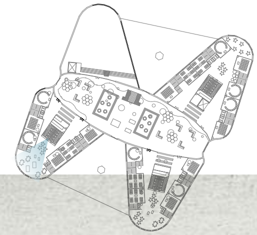


Ill. 85.1: Classroom

HOME AREA FOR 0th - 3th GRADE

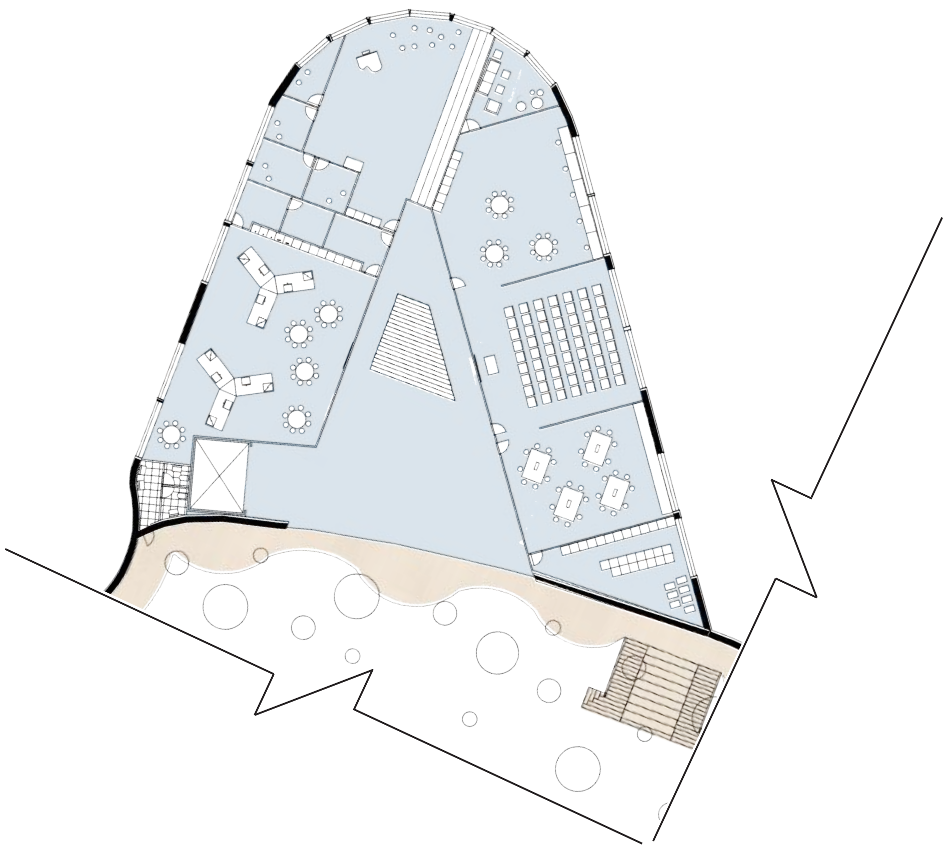


Ill. 86.1: 0. Floor Cut out 1:500



Ill. 87.1: Home Area Common Room

SUBJECT AREA

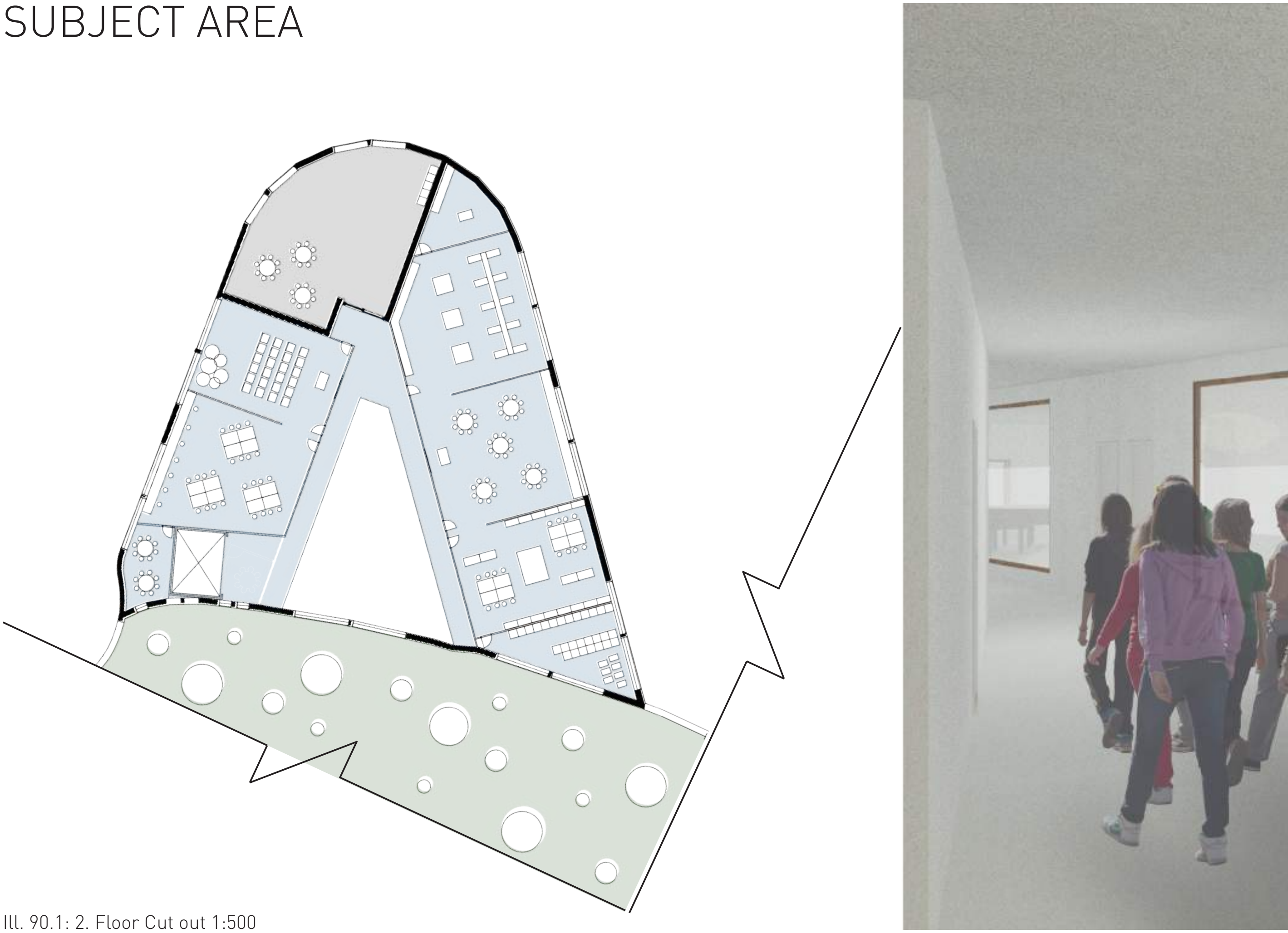


Ill. 88.1: 1. Floor Cut out 1:500

ADMINISTRATION

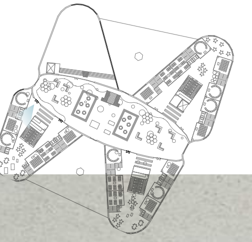
Ill. 89.1: 1. Floor Cut out 1:500

SUBJECT AREA

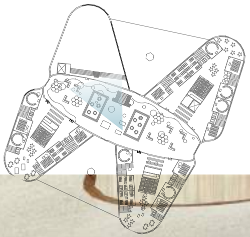


Ill. 90.1: 2. Floor Cut out 1:500

PRESENTATION



Ill. 91.1: Niche in Home Area

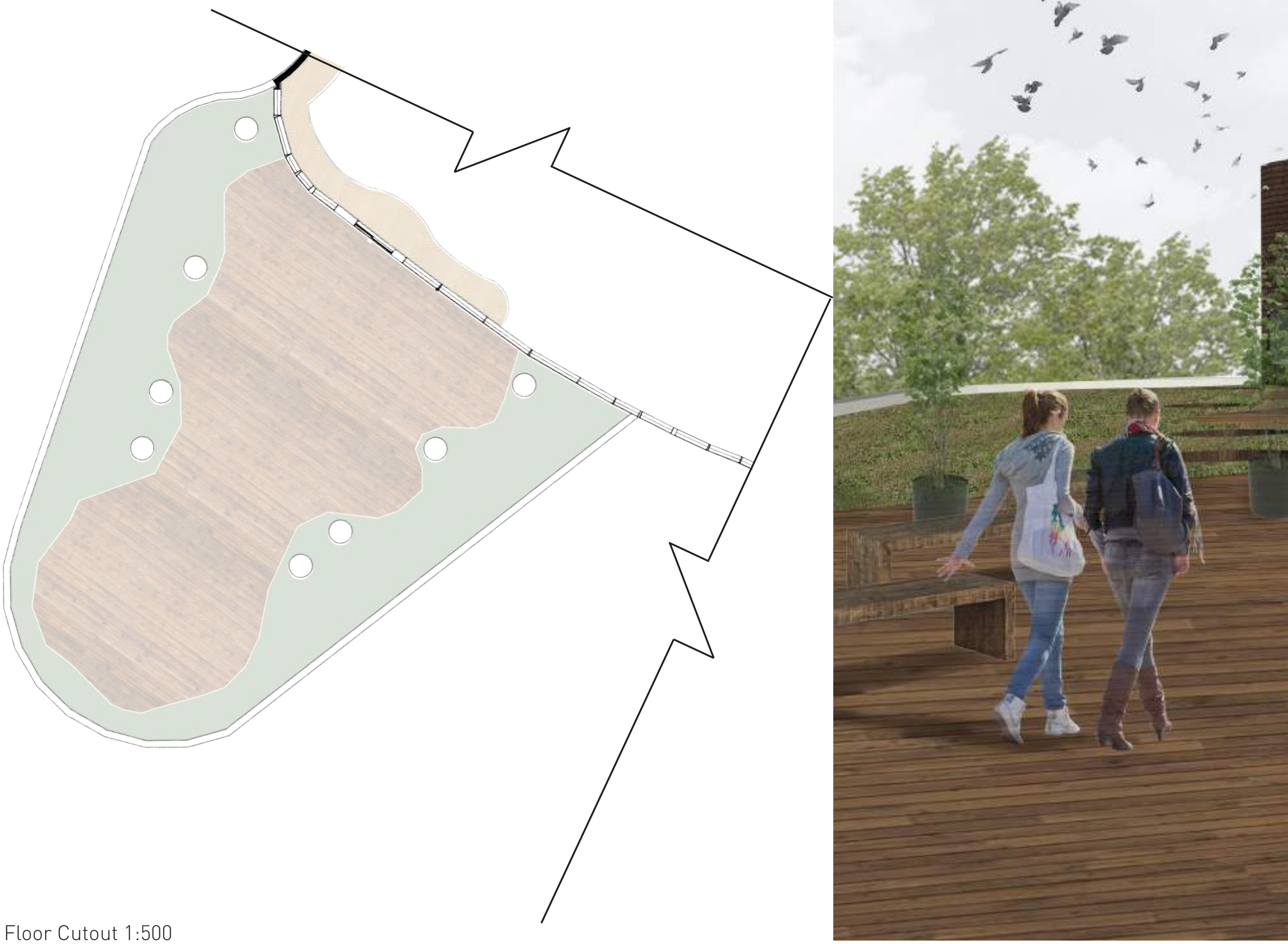


Ill. 92.1: Common Room

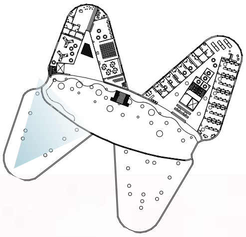
PRESENTATION

Ill. 93.1: Common Room PLC

ROOF TOP TERRACE



Ill. 94.1: 1. Floor Cutout 1:500



Ill. 95.1: Roof Top Terrace

PRESENTATION

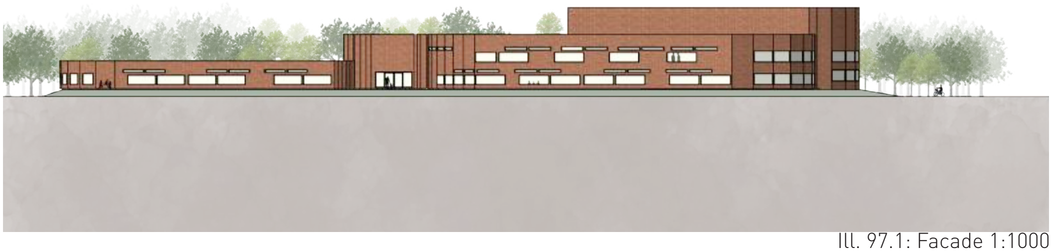
FACADE NORTH

Ill. 96.1: Facade 1:1000

FACADE SOUTH

Ill. 96.2: Facade 1:1000

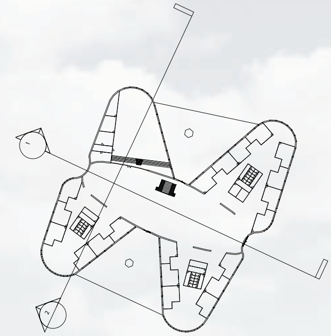
FACADE EAST

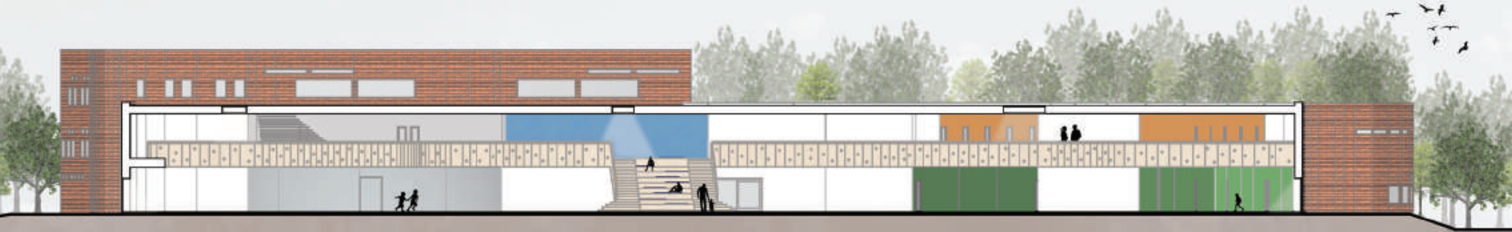


Ill. 97.1: Facade 1:1000

FACADE WEST

Ill. 97.2: Facade 1:1000





Ill. 98.1: Section 1 - 1:500

Ill. 98.2: Section 2 - 1:500

MATERIALS

The different materials used on the building is mediated here.

The cladding on the outer facade is bricks overlapping each other. They have a burned, red color.

The concrete is on the bearing walls on the inside. They stand raw in the room to give the rooms a variation of texture.

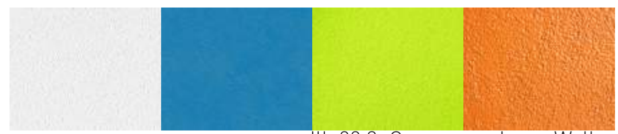
The rest of the inner walls is gypsum. They are for the most part colored white, however some places, for example in the niches in between the classrooms the walls will have a color depending on which wing it is.

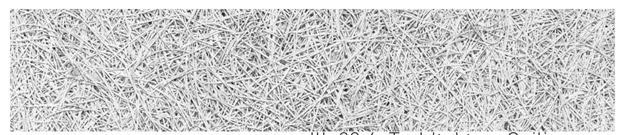
The ceilings are all covered in troldtekt. Troldtekt helps keep the reverberation time down and give the room good acoustic. Troldtekt is made of wood and cement. The mixture gives the plates a unique sound absorbing quality and the product is a nature product with sustainable qualities throughout its whole life cycle (Bygma, 2018).

As a sustainable approach the stairs and railing are made of pine, which is a local material. The color is white yellowish and gives a light, warm expression and feeling to the large room (Teknologisk institut, 2012). The brown treated pine is used to get a wood with a darker tone, which fit together with the light wood.


Ill. 99.1: Bricks on Facade

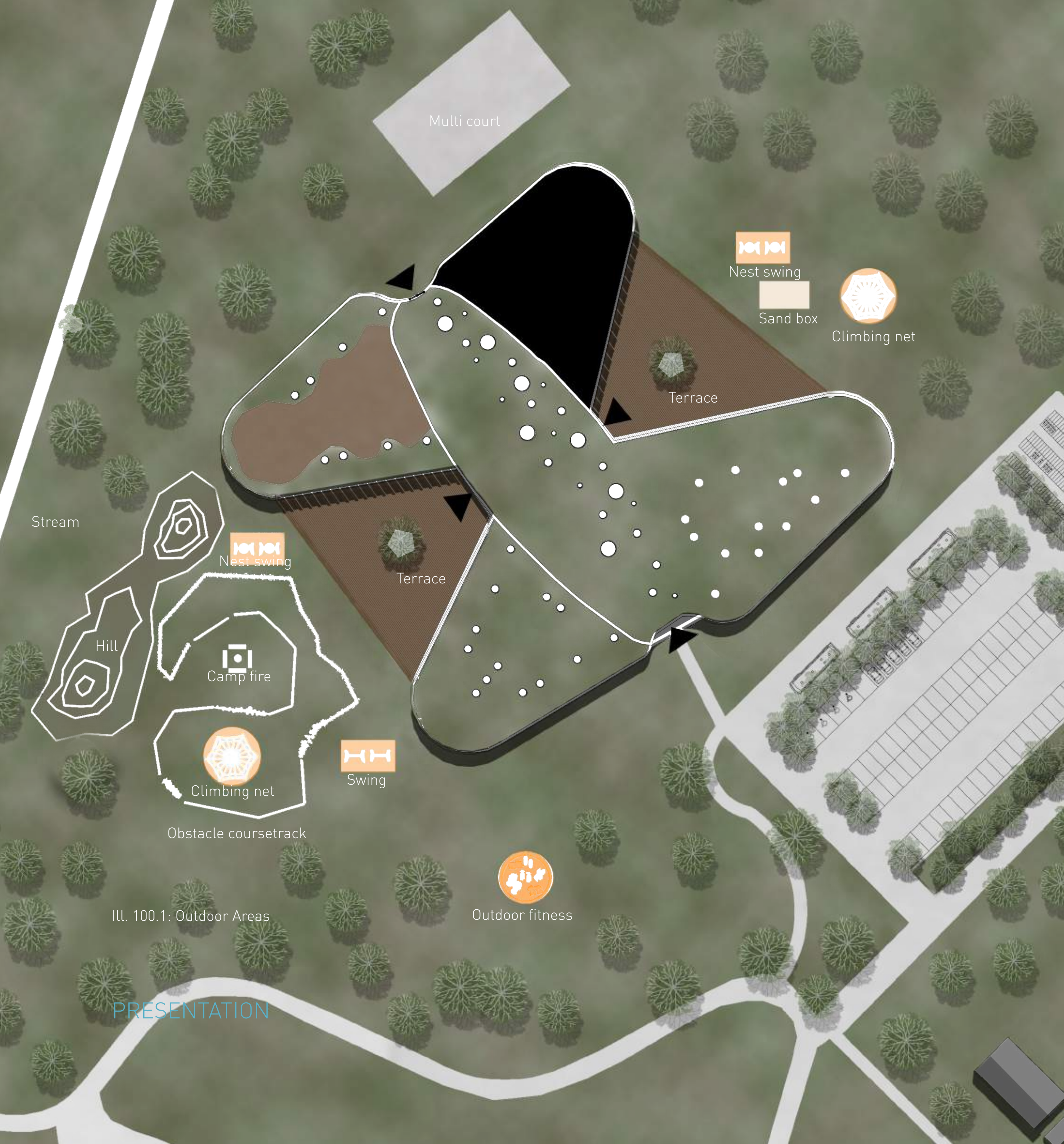

Ill. 99.2: Concrete on Inner Walls


Ill. 99.3: Gypsum on Inner Walls


Ill. 99.4: Troldtekt on Ceiling

Ill. 99.5: Pine on Staircase and Railing


Ill. 99.6: Brown Treated Pine on Windowsills and Terrace



Ill. 100.1: Outdoor Areas

OUTDOOR 1:1000

The outdoor area has not been in focus in the project. However, a proposal has been made.

The main playground has been placed south south-west of the building to utilize the sun all day. At the same time the parking lot has been placed north east of the building (see parking chapter on page 107).

On the north side a smaller playground is placed mostly for use by the youngest students. North west of the building a multi court is placed. The school will use the leisure centers football fields, however a smaller multi court closer to the school is placed for activity during recess, gym or the 45 min. each student need to be active during each day.

West for the playground two small hills has been placed for the children to play on. The position is based on the wind direction and they are meant to shield from the western wind.

There are placed trees south of the school. So, when arriving to the school the building will first become visible when close to the entrance. The trees are placed to distance the school from the roads and the rest of the city, without making the distance between the city and school greater.

In the south east densiphalt is the ground for an outdoor fitness area. This was a wish from the city, to use outside of school, but it can also be included in the school day for learning and activity.

A path on the playground made of an obstacle course consist of lines, monkey bars, stumps, etc. Around this obstacle course different activities are placed: nest swings, regular swings, climbing net, campfire, etc.

In between the two wings there are placed terraces. These are meant for outdoor learning, where the different classes can be moved outside. On this terrace there can be placed a solar cell or a wind turbine and the water tank with rain water can be placed here for the students to study. There could also be placed a vegetable garden where the students can grow different vegetables and herbs for home economics or lunch or to study during biology. The terraces are also meant for recess.

On top of the south west most wing there is placed a terrace. This is meant for the oldest children, to divide the children up during recess. The outside of the roof top is green roof and not meant for walking on. This means that the students can't go all the way out to the edge and a railing system will not be needed.

VENTILATION

AGGREGATE

In the building there are different zones with different loads and different time zones for when the ventilation is needed. Therefor there is a need for regulation. A VAV System is chosen for the building because of the different needs of air flow. The building can then be ventilated with the peak when in use and when not with a minimum.

Before every air supplier there is placed a throttle to manage the temperature in the rooms according to a temperature regulator. In between the temperature regulator and the throttle is a muffler to dampen the sound. There is placed a throttle in every room because they do not need the same amount of air on the same time.

In between every fire zone there is placed fire- and smoke damper in case of fire. So, the fire doesn't spread through the ventilation system. In front of each intake there is placed a damper, which can shut if the outside air is contaminated.

The system is regulated with serial regulation. This means that every component is regulated from the same regulator. For example, if the heating need decreases the heat recovery system will shut down before outdoor air supply increases.

An aggregate is chosen based on the calculated air supply, which is based on CO_2 and OLF. There is calculated an average air supply because the peak air supply is not needed all the time.

Zone	Average Air Supply m^3/h	Aggregate
South side	6.890	Nilan VPM 1000
North side	21.530	Nilan VPM 2200

Table 102.1: Aggregate

Two aggregates are placed one for each side of the common room.

The Nilan VPM 2200 has a peak of 32.000 m^3/h it has a heat recovery system of 94-98% and to accommodate the high air supply the SEL-value is placed on 1200 J/m^3 (Nilan VPM 2200, 2018).

The SEL Value is calculated with the formula:

$SEL = (\Delta P_{t,\,ind} + \Delta P_{t,ud}) / n_t$

Which is the pressure loss for inlet and extraction divided by the efficiency.

An overall strategy for the piping with two aggregates on the 0. Floor where the pipes go under the balcony between the two wings where it also serves the common room from the wall (Ill 103.2-103.4).

An example for the inlet component had been chosen from Lindab to be in the classroom. The needed air flow is 306 m³/h.

It is an inlet placed in the ceiling. Factors for the same inlet component has been analyzed and compared based on how many components are placed.

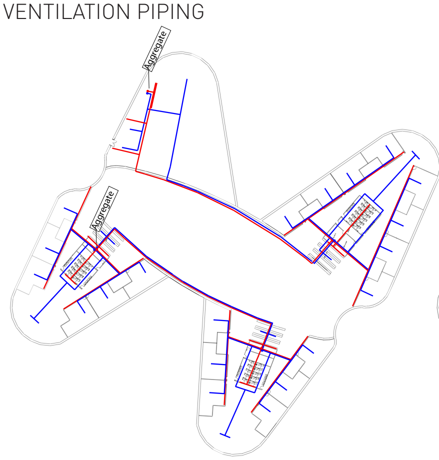
The second one (blue) is chosen because it has smaller pipes and the throw combined is enough for the size of the room. The factors compared to the first one is not that different compared to the extra number of pipes needed for 4 inlets.

	Amount	Air flow (m³/h)	Pipe Ø (mm)	Sound (dB)	Throw (m)
Inlet (LKPV)	4	93	160	30	1,3
Inlet (LKPV)	3	111	160	30	1,4
Inlet (LKPV)	2	165	200	30	1,8
Inlet (LKPV)	1	313	315	35	2,1

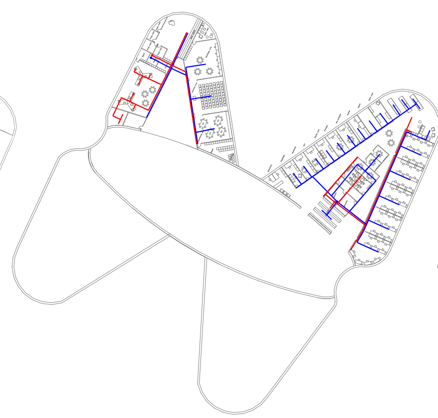
Table 103.1: Inlet component

Ill. 103.1: Inlet component

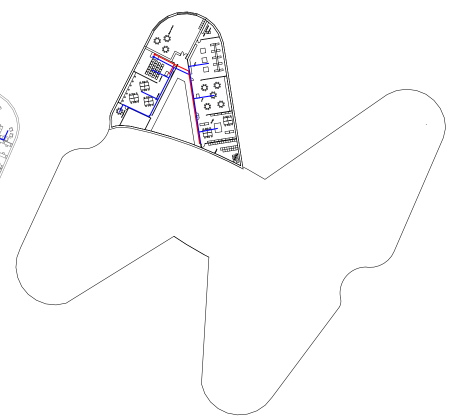
VENTILATION PIPING



Ill. 103.2: 0. Floor



Ill. 103.3: 1. Floor



Ill. 103.4: 2. Floor

ENERGY

A BE18 calculation has been made to see the primary energy use and to achieve the energy frame for 2020.

Different iterations have been made back and forth to find the perfect balance between the different factors to reach the goal.

A long process has been over the BE18 calculation and different factors has been in play throughout this process.

The natural ventilation and the solar shading has been adjusted to find a balance with no overheating and less as possible need for heating.

The air change from the mechanical ventilation has been made based on the average air change in each room. For example, the classroom will be in use from 8-16 and therefor the peak air change will be used here. For the rest of the hours a standard of $0{,}5h^{-1}$ has been used and an average of this is found (Ill. 104.1).

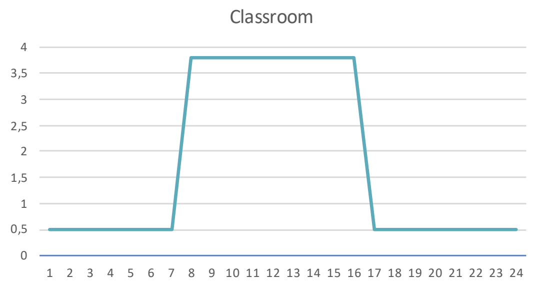
The SEL and heat recovery value has been found in the specifications of the chosen aggregate.

The solar cells have been calculated on page 186 and the u-values has been calculated in appendix 11.

The chosen windows are 2-layers energy windows with a g-value of 0,6 and a u-value of 0,8 W/m^2C.

CONCLUSION

The final result can be seen in the table 104.1, the blue column. The final inputs in the BE18 can be seen in appendix 13.



Ill. 104.1: Average Air Change

	Starting point	3 l/s m² natural ventilation	Solar shading 0,7	Solar cells
Energy frame 2020	57,5	46,5	45,9	23,0
Energy need: Heat	15,9	15,9	16,3	16,3
Energy need: power	20,1	20,1	20,1	10,1
Overheating	11,8	0,8	0,0	0,0

Table 104.1: BE18

INDOOR CLIMATE

A BSim calculation has been made on a classroom placed three different places with different orientation(Ill. 105.1).

Different iterations have been made to make the most optimal conditions for the indoor climate. The inputs have been based on different calculations and the inputs from BE18.

CONCLUSION

The results show that the classroom with rotation 3 is the warmest for the longest time, which makes sense when looking at the three orientations.

Another factor is solar shading. Every classroom needs solar shading with a factor of 0,1. This means external shading.

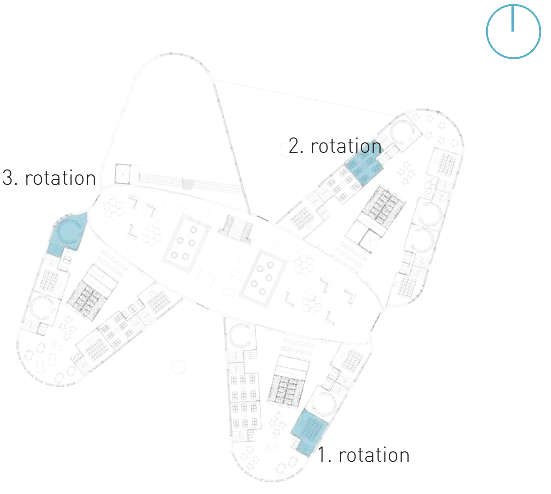
The window area for each classroom cannot exceed 14,5 m^2 and the window opening should be 80% of the window.

It is calculated that the windows need to ventilate with up to 5h^{-1}. A calculation has been made and shows it is possible (App. 14).

The ventilation will be controlled by the temperature because this needs the highest air change. (App. 12)

	1. Rotation	2. Rotation	3. Rotation
Venting	2 h^{-1}	4 h^{-1}	5 h^{-1}
Ventilation	0,3 m^3/s	0,3 m^3/s	0,3 m^3/s
Solar Shading	0,1	0,1	0,1
Window opening	0,8	0,8	0,8
U-value window	0,8 W/m^{2}C	0,8 W/m^{2}C	0,8 W/m^{2}C
Window area	14,5 m^2	14,5 m^2	14,5 m^2
Hours above 26°	57h	66h	65h
Hours above 27°	22h	25h	25h
Air change peak	12h^{-1}	11h^{-1}	12h^{-1}

Table 105.1: Rotation in BSim



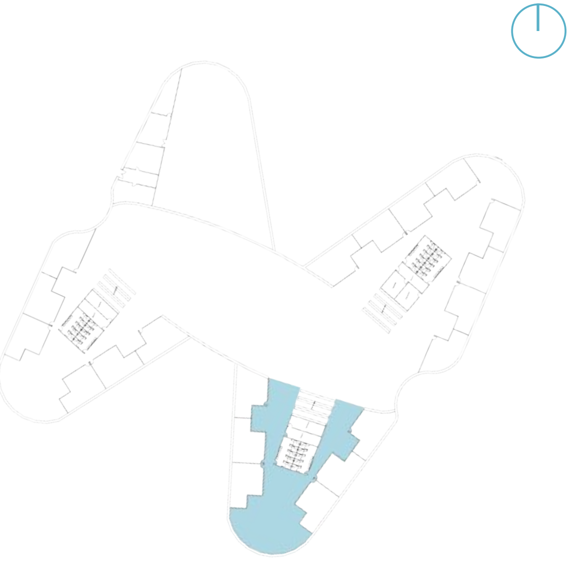
Ill. 105.1: The placement of the Different Rotations

HOME AREA

The common rooms in the home area is exposed to a lot of sun especially the ones towards south and south west. A 24-hour-average calculation has been made on the one by the 4th-6th grade.

If the ventilation air's temperature equals the outdoor air's			
24-hour average	ti =	30,8	°C
Max. Temperature	timax =	33,0	°C
If the ventilation air temperature constant is 18,5 °C			
24-hour average	ti =	29,0	°C
Max. Temperature	timax =	30,7	°C

Table 106.1: 24-Hour-Average Result



Ill. 106.1: Placement Simulated On.

CONCLUSION

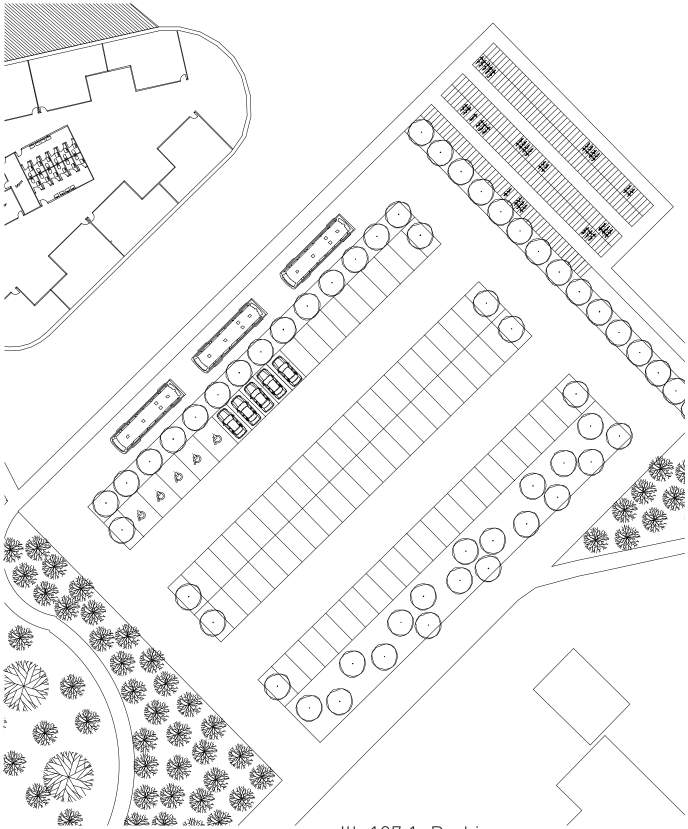
The calculation shows what was expected, that the room will be extremely warm. Because of this the window area has been decreased, however it will still be hot in the room.

PARKING

The parking for the project has been made based on the demands from the competition program (competition program, 2018). In there it is stated that there needs to be 250 bicycle parking spots, 80 car parking spots and 3 buses drop off spaces.

In the final design there is placed 250 bicycle p-spots (0,6m x 2m), 82 car p-spots (2,5m x 5m), whereas 5 is made larger for handicapped (3,5m x 5m) and 3 bus spots (6m x 12,5m).

The parking has been placed in two places, whereas one was chosen. The argument for chosen the one, was simply that it was placed on the northern part of the site instead of the southern part of the site. So that the sunniest places were reserved for playgrounds and recreational areas.



Ill. 107.1: Parking

FIRE REGULATIONS

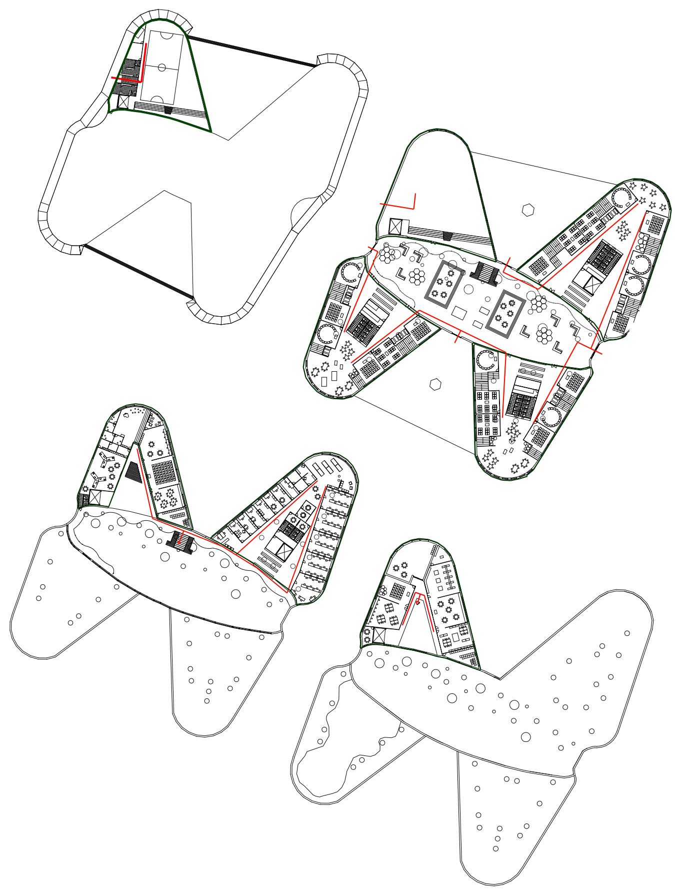
To ensure the fire safety in the building a strategy for the emergency exits has been made.

To ensure the highest level of safety each wing has been made in to a fire section (Green marking). This means there needs to be walls and a door from each home area to the common room. Each classroom will function as a fire cell.

Exits has been made in between each wing and the doors are double doors to ensure every user can exit the building.

There are no further than 25 m to an emergency exit route (the red line). The balcony on the first floor in the subject area is a design element, which is a result of this demand. To ensure the 25m maximum there was a need for a door in the room furthest away from the stairs. This problem was resolved by placing a balcony and a door from each section of the subject room.

Another exit route can be a window depending on the size of it and the height over terrain if the window is placed under 22 m over terrain or no higher than the fire fighters can reach it. In rooms with over 10 people there needs to be two exit routes. The large windows are 4m x 1,3m, which make them large enough as rescue openings (Bygningsreglement, 2018).



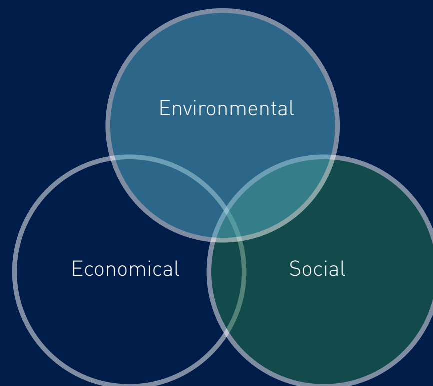
Ill. 108.1: Fire Plans

SUSTAINABILITY

The main focus in the project has been sustainability. The topic has been a part of every process through the project and it can be seen in different elements/factors of the final building design.
Solar cells as an active initiative has been used as a sustainable approach to the energy consumption (page 111). Rainwater has been collected from a roof to use for watering the vegetation around the school (page 112). Green roofs have been placed because of their positive impact on the environment and their ability to collect rainwater (page 110).

Passive initiatives have been used. The sun has been a design element when rotating the building and placing different rooms. For example, are the common room placed towards south and the classrooms are placed towards east and west. The outdoor areas with terraces between each wing has been placed strategically to make the building shield from the western wind and make room for a playground towards south. The height of the different building sections has been made do to the suns path, so the building shields as little as possible on itself and the observatory has been placed on the highest spot to achieve the best view.

A tight envelope has been made with a u-value fitting the wishes for 2020. The footprint of the building has been worked with and different elements in the building has been moved to the first and second floor to achieve a smaller footprint. Using the passive and active initiatives the energy frame 2020 has been reached in the program BE18 (page 104).



Ill. 109.1: Sustainability

The project has had focus on some of the categories in DGNB however, it cannot be certified. One of the categories which has been in focus is the social parameter. SOC 1.1 Thermal comfort and SOC 1.2 Indoor air quality has been achieved using 24-hour-average calculation sheet and BSim. SOC 1.4 visual comfort which has been achieved using Velux daylight visualizer. Another parameter is environment, where ENV 1.1 life cycle assessment has been looked at when chosen materials using the LCA-byg program and looking at the life time of the different materials. More parameters have been achieved using the integrated design process for example TEC 1.1 fire securing and safety, SOC 2.3 Conditions for cyclist, SOC 3.1 Architectural quality, etc.

GREEN ROOF

One sustainable approach has been green roofs. Some of the buildings roofs are green roofs. It is an extensive green roof from Icopal. The intensive green roof is for use and stay where the extensive green roof is not. It is Danish produced, with 7-9 different sedum species. It has built in drain and water reservoir and it is 95mm.

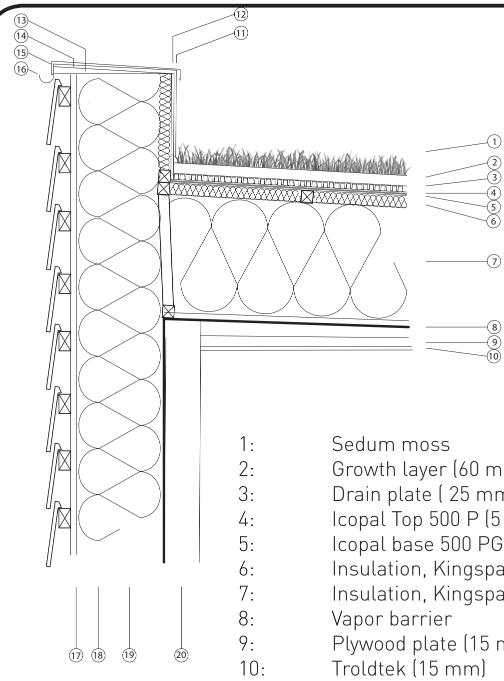
A green roof is placed because of its positive impact on the environment and its ability to obtain rainwater and help the sewer not overflow. The green roof is placed on top of the construction (Ill. 110.1) (Byggros, 2018).

	Extensive	Intensive
Precipitation	50 %	80%
Use	Only for plants	Stay, walks and terrace
Load	Small	High
Maintenance	Low	Regular maintenance and irrigation
Plants	Sedum moss, grass, dry tolerant herbs	Wide spectrum of: plants, bushes, trees, etc.

Table 110.1: Green Roofs

CONCLUSION

Do to the use of the green roof it will be an extensive green roof. It will not be necessary to use the roof for stay or terrace.



1: Sedum moss
2: Growth layer (60 mm)
3: Drain plate (25 mm)
4: Icopal Top 500 P (5 mm)
5: Icopal base 500 PG (5 mm)
6: Insulation, Kingspan (10 mm)
7: Insulation, Kingspan (45 mm)
8: Vapor barrier
9: Plywood plate (15 mm)
10: Troldtek (15 mm)
11: Roof felt
12: Waterproof plywood (15 mm)
13: Wedge shaped board plywood
14: Waterproof plywood
15: Zinc insulation
16: Gutter
17: Cover bricks (Petersen tegl C21)
18: Mounting construction (Plywood)
19: Insulation kingspan (220 mm)
20: Lightweight concrete (150 mm)

Ill. 110.1: Green Roof Detail

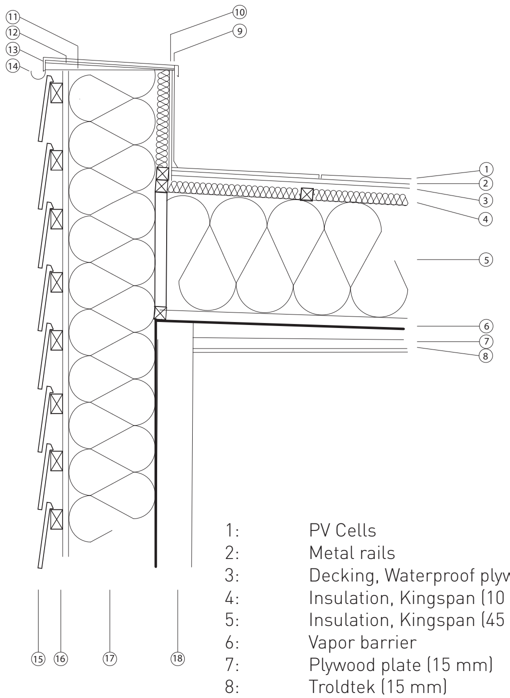
SOLAR CELLS

Another sustainable approach have been solar cells. The energy frame 2020 goal has been reached with the use of solar cells. Through the process of the project different iterations has been made to find out how to implement solar cells. Considerations of placing them on the roof, facade or the ground have been made and the decision of placing them on the roof has been because of the amount of space they demand and the unreachable placement the roof is compared to the others, with curious children around.

The peak power of solar cells is calculated to 0,17 kW/m^2 (App. 9). The decision for choosing the specific type has been made based on the different qualities of each kind (Bejder, Knudstrup, Jensen, 2014).

	Mono-crystalline	Polycrystalline	Thin film, various types
Area: 1 kW installed effect	5-7 m^2	6-9 m^2	8-16 m^2
Production/ year	140-190 kWh/m^2	120-150 kWh/m^2	50-110 kWh/m^2
Appearance	Black	Dark blue	Homogeneous black or brown
Embodied energy	4750 MJ/m^2	4050 MJ/m^2	1305 MJ/m^2
CO_2 emission	242 kg CO_2/m^2	208 kg CO_2/m^2	67 kg CO_2/m^2
Efficiency	12-15 %	10-13 %	5-9 %

Table 111.1: Solar Cells



1: PV Cells
2: Metal rails
3: Decking, Waterproof plywood (30 mm)
4: Insulation, Kingspan (10 mm)
5: Insulation, Kingspan (45 mm)
6: Vapor barrier
7: Plywood plate (15 mm)
8: Troldtek (15 mm)
9: Roof felt
10: Waterproof plywood (15 mm)
11: Wedge shaped board plywood
12: Waterproof plywood
13: Zinc insulation
14: Gutter
15: Cover bricks (Petersen tegl C21)
16: Mounting construction (Plywood)
17: Insulation kingspan (220 mm)
18: Lightweight concrete (150 mm)

Ill. 111.1: PV Cells Detail

RAIN WATER

Rainwater can be collected in a lot of different ways. As seen on the illustration 112.1 it can be collected through a green roof, through permeable pavement, a lawn and in a rainwater basin. In this project the water will be collected through a green roof.

As it is a public school it is not allowed to use rainwater for toilet flushes or washing clothes (Rainwater, 2018). However as a sustainable approach the rainwater is collected to water plants, the football field, etc. The system can also be used by the school as a learning tool.

The rainwater will be collected on the roof of the wing towards south east. The roof is 995 m^2. The average rainwater pr. year was found on DMI to 979,6mm (DMI, 2017).

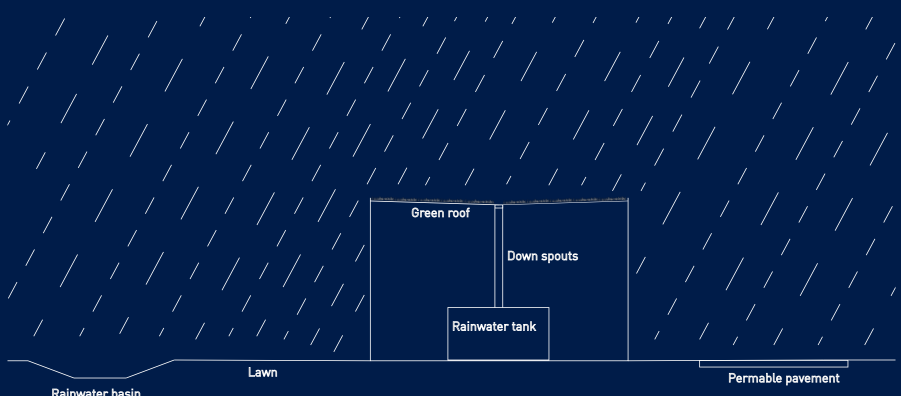
AMOUNT OF WATER AVAILABLE
979,6 l/m^2/year * 995 m^2 = 974.702 l/year.

SIZE OF TANK
It is decided that the tank needs to accommodate one week of rainwater.

974.702 l/year / 55weeks = 17.721 l

The tank will be connected to the stream so if it overflows the rainwater will continue in to the stream.

By collecting the rainwater in a tank and slowly putting it into the ground it will help the sewer system not to overflow.



Ill. 112.1: Rainwater

CONSTRUCTION

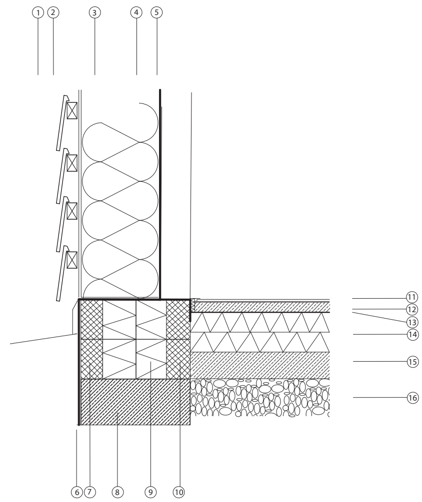
The construction of the building has not been in focus in the project however some thoughts have been made over the overall strategy for the construction. When designing the building and its facade the structure of these has been made.

The bearing elements are the external walls, which consist of a bearing concrete element. In each of the wings there is placed a core with toilet facilities, depot, service room and in one case an elevator. These will function as stabilizing cores.

The external walls, the foundation and the roof has been made in details. The u-value of each element has been calculated and can be found in appendix 11.

There are two different roofs, one with PV cells and one with green roof layer. The two details can be found on page 110 and 111.

In the report the details are not in scale, however each detail can be found in the supplied drawing folder in scale.



1: Cover bricks (Petersen tegl C21)
2: Mounting construction (Plywood)
3: Insulation kingspan (220 mm)
4: Vapor barrier
5: Lightweight concrete (150 mm)
6: Moisture barrier (Cardboard)
7: Leca term block
8: Concrete foundation
9: Polystyrene (270 mm)
10: Leca term block
11: Linoleum (or wooden flooring depending on the area)
12: Reinforced concrete (100 mm)
13: Radon barrier
14: Polystyrene (400 mm)
15: Concrete (200 mm)
16: Capillary layer

Ill. 113.1: Foundation Detail

SUN AND SHADOW

The sun and shadow analysis of the final building supports both the heights of the building elements and the placement of the outdoor areas.

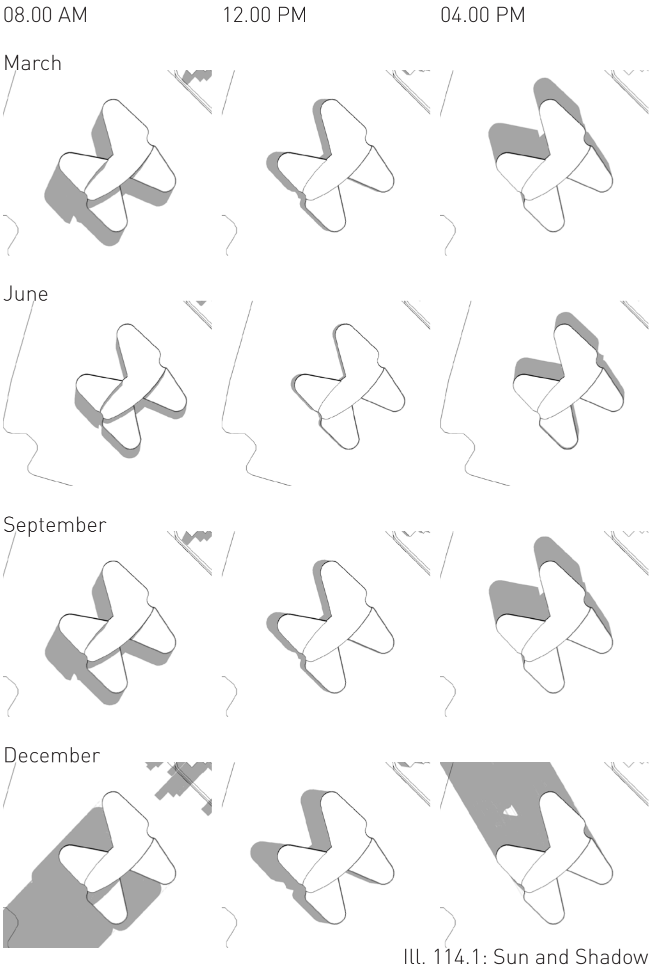
The entrance is placed towards the city and from where the main part of the users will arrive. This is towards east which means there will be sun on the entrance when the users arrive in the morning.

The parking is placed towards north east. This is where the most shadow will occur especially seen on the 4 pm pictures.

The main playground is placed towards south south-west. This is a place where there will never be any shadow.

In between the wings on each side there is placed a terrace for outdoor teaching and use. On the south side it will be relevant to place a solar cell and on the north side it could be relevant to place a wind turbine for the students to study and learn.

The rooftop terrace is placed on the south west wing. Here there will be sun all day.



Ill. 114.1: Sun and Shadow

WIND AND PRESSURE

WIND
The main wind direction is west. The rotation of the building makes sure that turbulence doesn't occur in the areas in between the two wings on each side of the building (Dashed circles), which is used for outdoor activities during the school day.

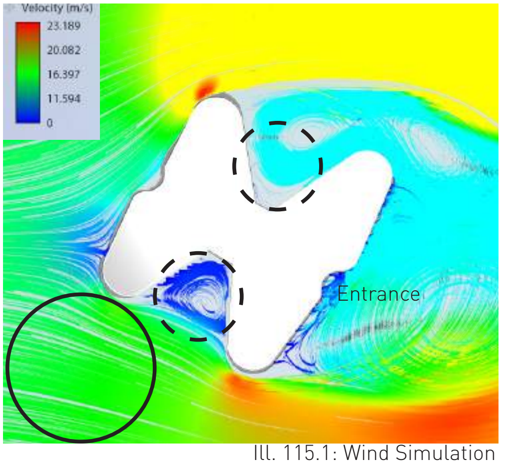
The areas with a red color has the highest velocity and are high because of how the wind hits the rounded corners on the building. These areas will not be used for playgrounds.

By the entrance there is a low velocity with very little turbulence.

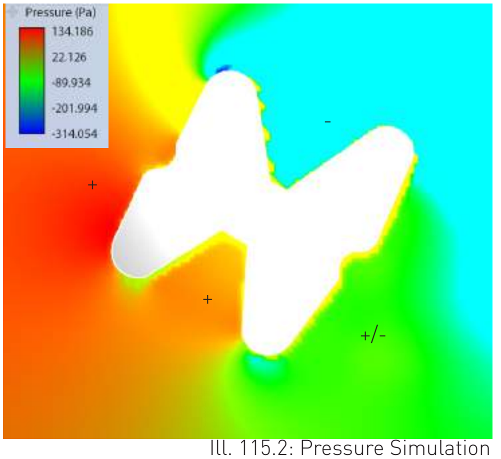
The main playground is placed where the circle (not dashed) is. Two small hills will be placed in front of the playground towards west to shield from some of the wind and to be used on the playground.

PRESSURE
In the common room there will be a possibility for cross ventilation if opening a door/window in west and in east with pressure as a driven force.

In the home areas there is used single sided ventilation, where temperature differences will be the driven force.



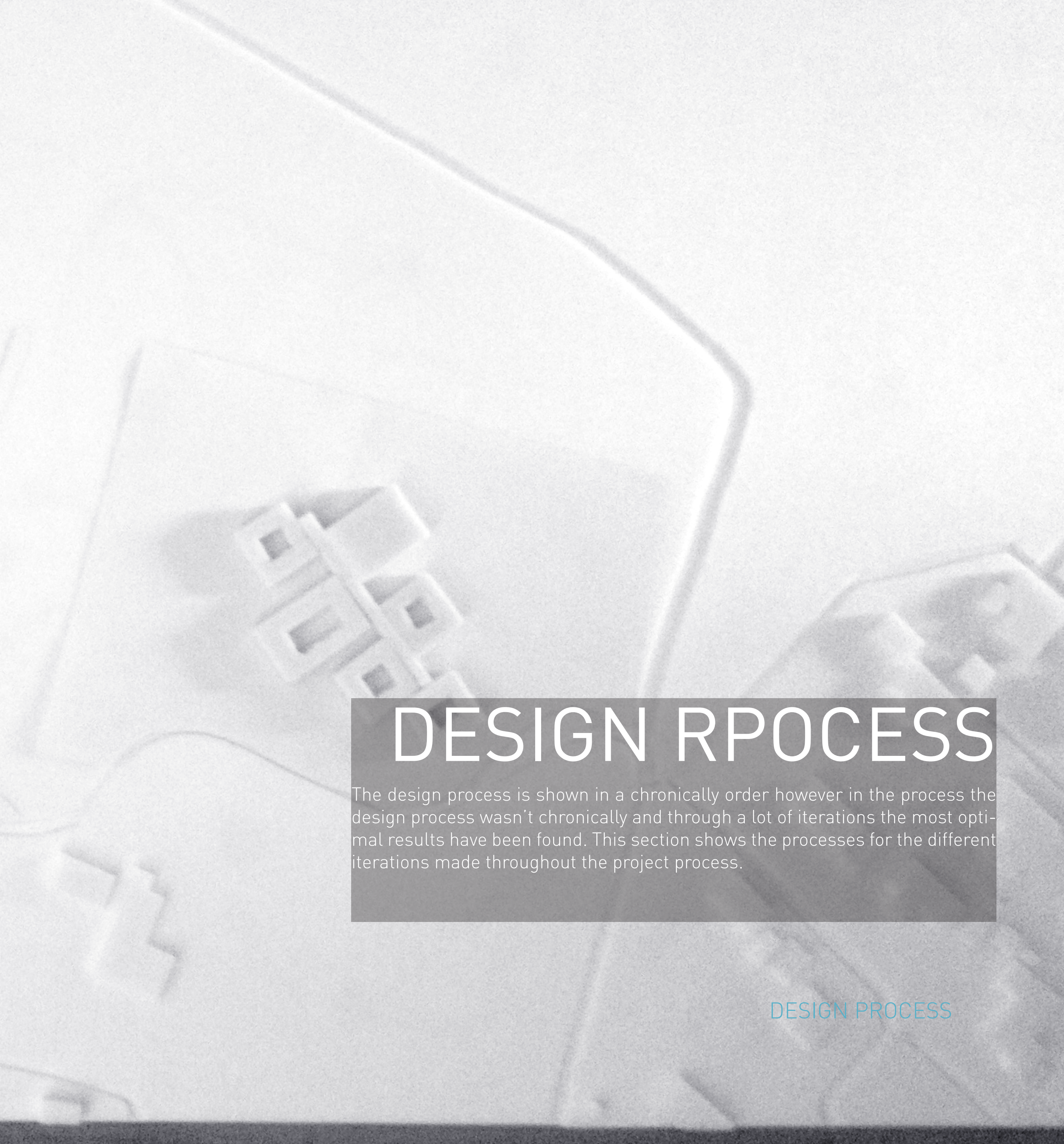
Ill. 115.1: Wind Simulation



Ill. 115.2: Pressure Simulation

Ill. 116.1: Design Process Picture

DESIGN PROCESS



DESIGN RPOCESS

The design process is shown in a chronically order however in the process the design process wasn´t chronically and through a lot of iterations the most optimal results have been found. This section shows the processes for the different iterations made throughout the project process.

COMPOSITION

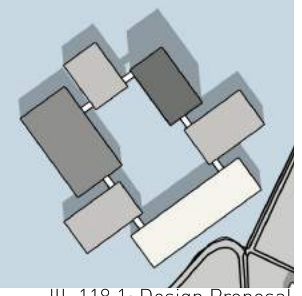
The beginning of the design process for the school building started out with a process of the composition. A free sketching face were everything was possible, and nothing was too much. The illustrations shown on this page was the first design proposals where sketch-up, hand drawings and 3D modeling in foam was used as tools (Expanded in appendix 3).

The focus became quickly minimizing hallways which for example eliminated the design on illustration 118.5 and 118.6.

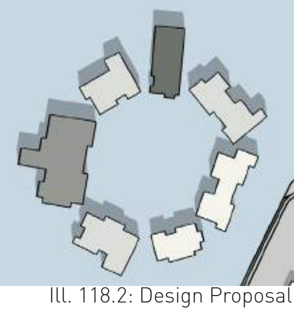
Illustration 118.4 became the overall shape, which was worked further with. The shape was build up from the different home areas, multi hall, administration and subject areas. These where then placed around a large common- and distribution area.

The shape needed to be more sympathetic which resulted in illustration 118.10. Afterwards the design was made less static by using more loose and organic shapes and the footprint was minimized by placing different functions on top of each other.

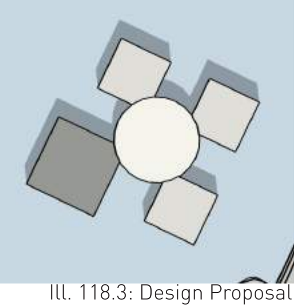
This resulted in a ''Butterfly'' shape with areas for each student group and a large common room to distribute from (Ill. 118.14).



Ill. 118.1: Design Proposal



Ill. 118.2: Design Proposal



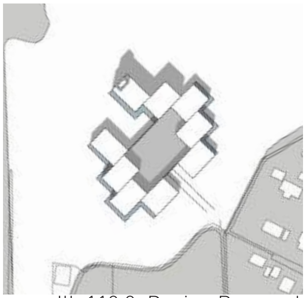
Ill. 118.3: Design Proposal

Ill. 118.4: Design Proposal

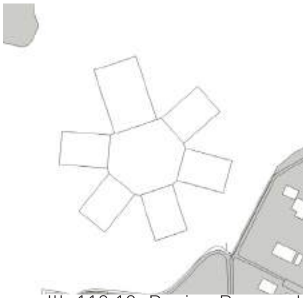
Ill. 118.5: Design Proposal

Ill. 118.6: Design Proposal

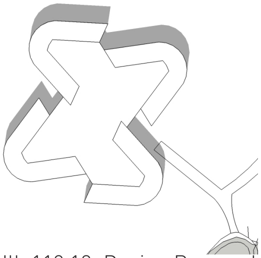

Ill. 118.7: Design Proposal

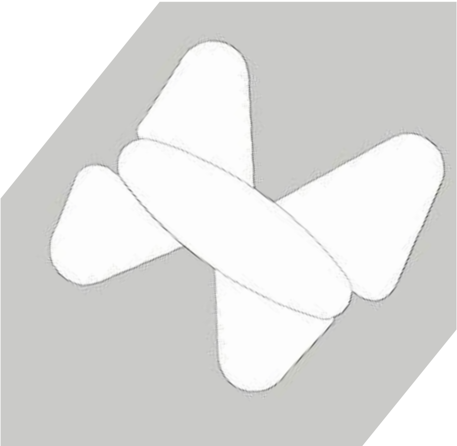

Ill. 118.8: Design Proposal

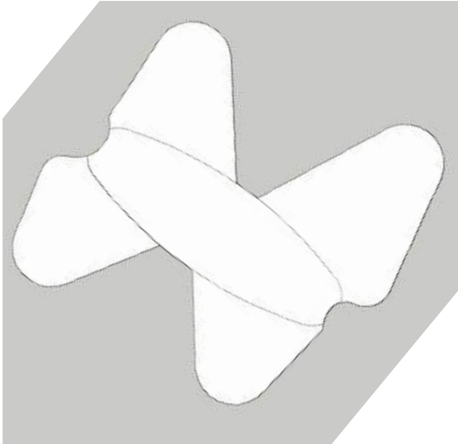

Ill. 118.9: Design Proposal


Ill. 118.10: Design Proposal


Ill. 118.11: Design Proposal


Ill. 118.12: Design Proposal


Ill. 118.13: Design Proposal


Ill. 118.14: Design Proposal

PLAN: CLASSROOM

To decide the form and function of the classroom three different solutions has been reviewed according to their functionality for the three home areas, their use of the space, their flexibility and mobility and how much they are visual- and sound transmitting (Table 121.1).

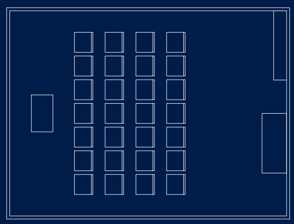
To decide which classrooms the different home areas, need the interview made with the schools comes in play (appendix 2).

The smaller classes need as few distractions as possible, both visual and sound. The older classes doesn't get that easily distracted.

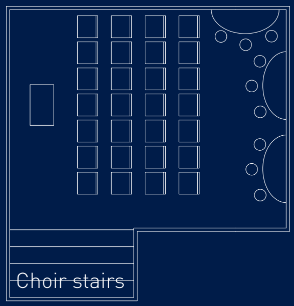
The smaller classes need flexibility to move around. In the older classes they study with computer, which means they can sit everywhere, so they need a higher variation of seating.

CONCLUSION

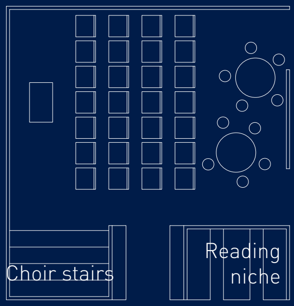
The L-shaped classroom will be used for every grade. Instead of making an open classroom, the classroom will be closed for listening and learning and only have the seating for this, while large common areas and small niches will be placed around each home area for workshops or other with other kind of seating.



Ill. 120.1: Traditional classroom



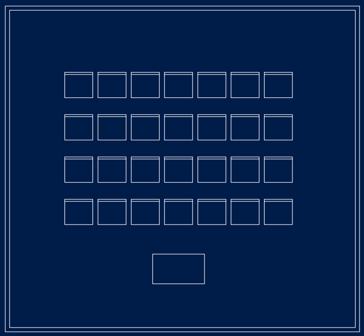
Ill. 120.2: L-shaped classroom



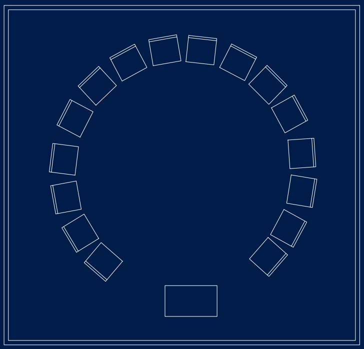
Ill. 120.3: Open classroom

	Functionality	Spatial quality	Flexibility	Visual	Sound
Traditional classroom	Low	Low	Medium	Low	Low
L-shaped classroom	High	Medium	High	Low	Low
Open classroom	High	High	High	High	High
Comment	The tradition-al classroom doesn't have the choir stairs/ reading niche.	The open class-room both have a reading niche in class and out of class.	All have room for rearrange-ment, however the L-shape offers more.	The open class-room doesn't have any doors. Windows can raise this factor.	The open classroom have noise from the common area.

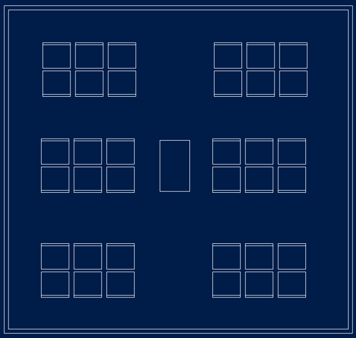
Table 121.1: Class room table



Ill. 121.1: Traditional arrangement



Ill. 121.2: Circle arrangement



Ill. 121.3: Group arrangement

PLAN: HOME AREA

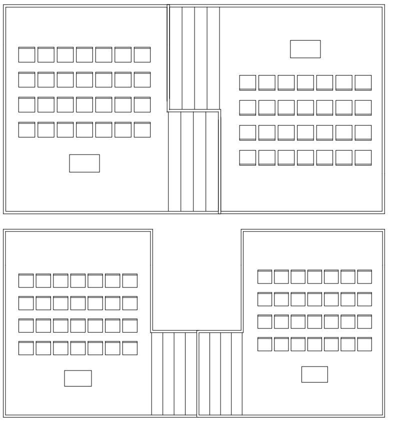
A lot of different iterations has been made over the plan drawing. There has been a parallel process for the plan drawing together with the design process of the composition, which means different plans has been made for some of the different designs. The process mediated here are for the final design.

A lot of small corrections has been made throughout the process. Here are four of the more major corrections, which has had a large impact on the design.

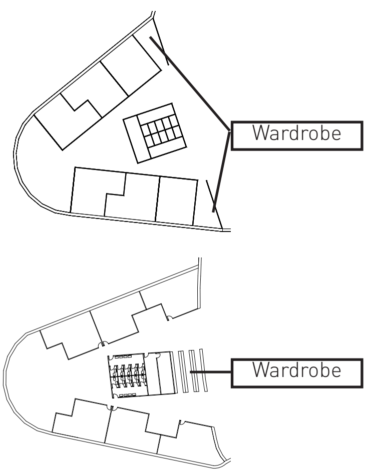
The home areas have been through a process to find the most optimal placement of the classrooms, common room, toilets, depot, service room and wardrobe as a core.

First of all, the classrooms were placed. The L-shaped classrooms were placed into each other so the final form of two classrooms was a square. This resulted in a dark area in the classroom with the short end toward the outer facade. The classrooms where then turned to make every long wall face the outer facade and get more light into the room.

At one point the wardrobe was placed in the beginning of each home area in the outer corners, so the children could place their shoes and jacket. However in-



Ill. 122.1: Classrooms



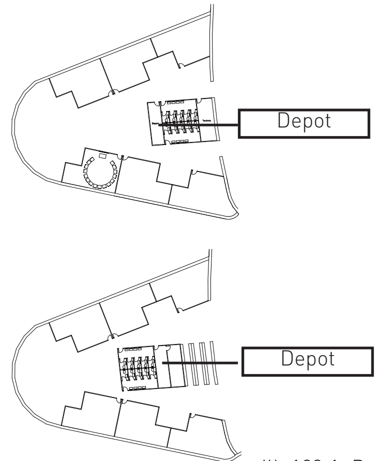
Ill. 122.2: Wardrobe

stead of having this room, which doesn't need daylight towards a facade they where moved into the middle of the home area in connection with the core.

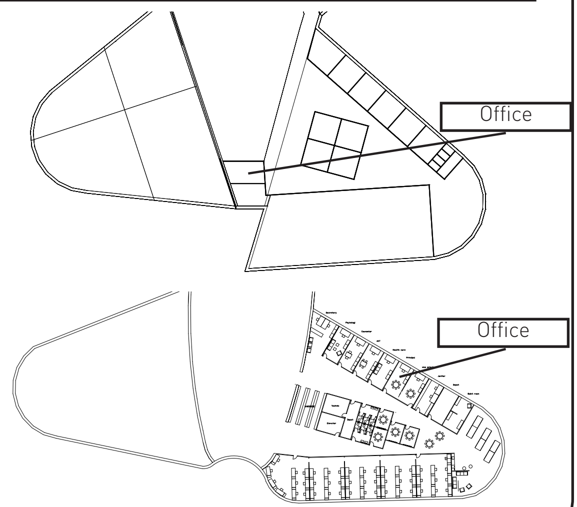
The depot was placed in the middle of the home area, to have it in short distance between every classroom. However, it was moved in between the service room and the toilets, away from focus. This also made it possible to have a door from the depot into the service room, instead of having it out to the common space.

At one point in the process the principal and vice principals offices were placed on a balcony in the common room. The meaning with this was that the principal should have a window towards the large common room and then he/she would have an overview.

During the process the wing that the administration is placed in got bigger, because of the classrooms turns explained on the opposite page (Ill. 122.1). This meant that there was more space in the administration wing and there was no longer need for moving these two offices. They were then placed inside the wing together with the other offices.



Ill. 123.1: Depot



Ill. 123.2: Office

PLAN: COMMON AREA

The large common area is the heart of the school. It is the first thing everyone enters, and it distribute every student, teacher or other out to their designated area. The common room should consist of a bunch of different things.

First of all, it should accommodate the PLC. PLC is the pedagogic learning center. The meaning with the center is to support learning- and well-being related activities and it shall support the relation between the school and the cultural offers the city has. The purpose of the center is to create an overview of the different resources the school have, that can help the students learn (Undervisningsministeriet, 2015).

The PLC consist of the library, digital learning resources and working stations with a variation of seating.

More than the PLC the common area should consist of the scene. Every school in the case studies either had and loved a large staircase/auditorium or wanted one. Instead of making an auditorium, which will take up a lot of space and not be used every day, there will be placed some sort of scene/auditorium in the common area.

It shall also contain the canteen and food kiosk. Instead of making a large canteen which only will be used from 12pm to 12.30 pm the canteen will be a mix with the workstations placed in the common area. The students can then either eat their food in their home areas or in the common area.

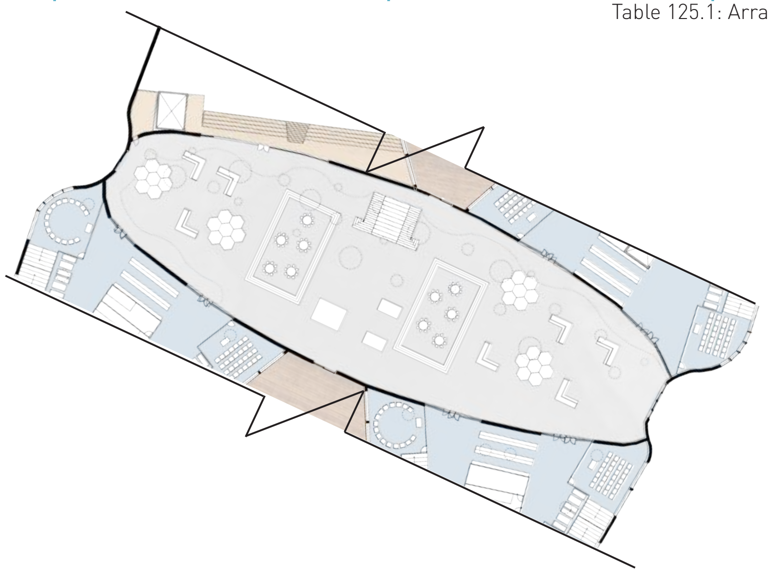
The common area should have access to some toilets. This is to use if there is an arrangement on the school where the home areas are closed off or to use as a guest to the school.

CONCLUSION

The most optimal placements are marked with blue on table 125.1. However, in the final design a mix of the three has been made do to the room's placement. The PLC and the canteen has been made into one by making bookcases and seating in to one furniture. The canteen should not be a place where the children only go to eat, but seating arrangement they can use for eating, studying, recess, etc. Two plateaus has been made where the stairs can be used for seating and on top of them seating arrangement has been placed for these purposes.

		SCENE	CANTEEN	PLC
EAST (ENTRANCE)	👍			Close to the outside world and to the youngest.
	👎	Placed in the arriving area	Placed away from home economics	
IN THE MIDDLE	👍	Scene as the gathering point, close to subject area		Close to everyone and the subject area
	👎		Could become gathering point instead of scene	Away from the outside world
WEST	👍	Close to the subject area	Close to home economics and the older students	Close to the subject area
	👎	Placed far away from the youngest		Away from the outside world

Table 125.1: Arrangement of Common Room



Ill. 125.1: Common room 1:1000

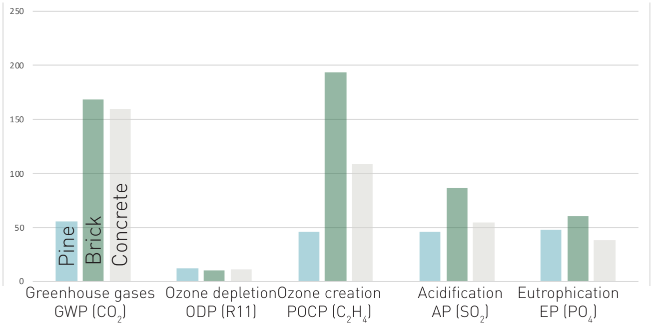
CONSTRUCTION AND MATERIALS

The decision of which materials and construction are going to be used is based on different things like life time, maintenance, LCA and u-value.

The different construction tested are a brick construction with bricks on both sides (1), a wooden construction with wood on the outside and gypsum on the inside (2), a brick construction with brick on the outside and gypsum on the inside (3) and a concrete construction (4).

The architectural expression for the building should be heavy, so it shows the users it can withstand the heavy weather in the area.

CONCLUSION
When looking at the different results an optimal compromise is a concrete construction. The width is small, the u-value is under the 2020 wish of 0,09 W/m^{2}C, the LCA assessment is a little worse than wood, however the lifetime is long, and the architectural expression is heavy.



Ill. 126.1: LCA Calculation

	Brick (1)	Wood (2)	Brick (3)	Concrete (4)
U-value	0,085 W/m^{2}C	0,090 W/m^{2}C	0,085 W/m^{2}C	0,086 W/m^{2}C
Width	0,52 m	0,61 m	0,41 m	0,47 m
LCA	■□□	■■■	■□□	■■□
Maintenance	Low	High	Low	Low
Lifetime	100+y	Construction: 40-100y Cladding: 10-60y	100+y	Outdoor: 40-100y
Architectural expression	Heavy	Light	Heavy	Heavy

■□□ = Worst ■■□ = Better ■■■ = Best

Table 126.1: Construction assessment

ROOF AND DAYLIGHT

To achieve the most optimal conditions in the large common room it is a wish to get daylight in from every corner of the world. As the design is now the daylight only comes in from south west where the building are low. Three different method has been tried out to see which one works the best both for daylight factor, aesthetics and the overall design.

The three designs have different possibilities for solar cells. Design 1 is weak with the flat roof, design 2 and 3 are a bit stronger with the inclined roof.

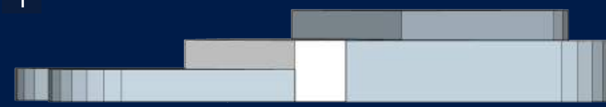
The daylight in design 2 and 3 are strong because daylight comes into the large common area from all corners of the world, however the facade towards south is very large.

The overall design is more sympathetic when looking at design 1 compared to the other, with the flow between the different storeys.

CONCLUSION

The solar cells can be worked with to fit a flat roof. The overall design is weighed highest, because daylight can be worked in to the project from the roof instead of all four corners of the world. Because of this design 1 wins.

1



Raised common room, light intake from south west and north east

Ill. 127.1: Design 1

2

Roofs incline towards common area (not common areas roof)

Ill. 127.2: Design 2

3

Roofs incline towards south (not common areas roof)

Ill. 127.3: Design 3

■□□ = Good ■■□ = Better ■■■ = Best

	1	2	3
Solar cells	■□□	■■□	■■■
Daylight	■■□	■■■	■■■
Overall design	■■■	■■□	■□□

Table 127.1: Assessment of Design 1,2 and 3

SUN HEAT AND DAYLIGHT

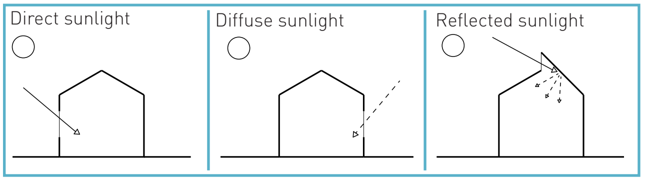
Daylight in a building is all about creating good conditions, controlling the direct sunlight and the passive heat gain. The aspects when talking daylight among others are: facade, spatial experience, view, privacy, overheating, daylight factor, room layout, etc. There are three ways to utilize sunlight: direct, diffuse and reflected.

The daylight and windows functions are determined for the classroom. A daylight factor of at least 2% is needed (Sbi, 2004), orientation either west or east for daylight without overheating and glare is preferred, view and connection to nature is important and privacy is not. Lastly it is important, that the room doesn't have a high level of daylight in one side of the room and a very low in the other.

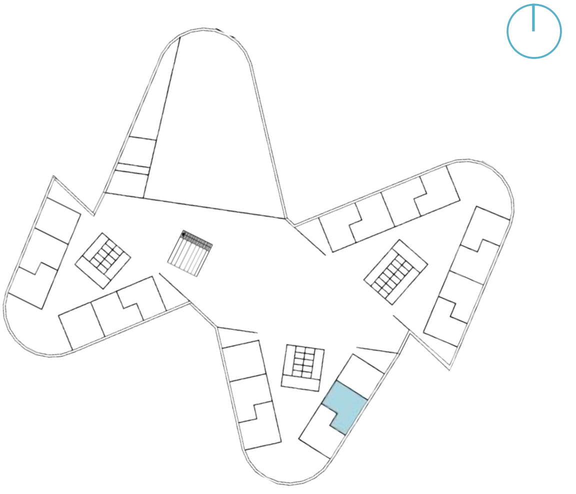
A workshop has been made (Table 129.1). The first iteration was made with the showed classroom (Ill. 128.2). The daylight simulations were made for June 21st at 12 noon.

CONCLUSION

This iteration showed that there is a need for a window in the deepest part of the room. Design 2 and 5 has the highest DF in the deepest part of the room. The different height of the windows creates both seating variations in the windows and gives a playful light in the room. Design 2 and 4 is chosen.



Ill. 128.1: Kinds of Daylight



Ill. 128.2: Placement rated

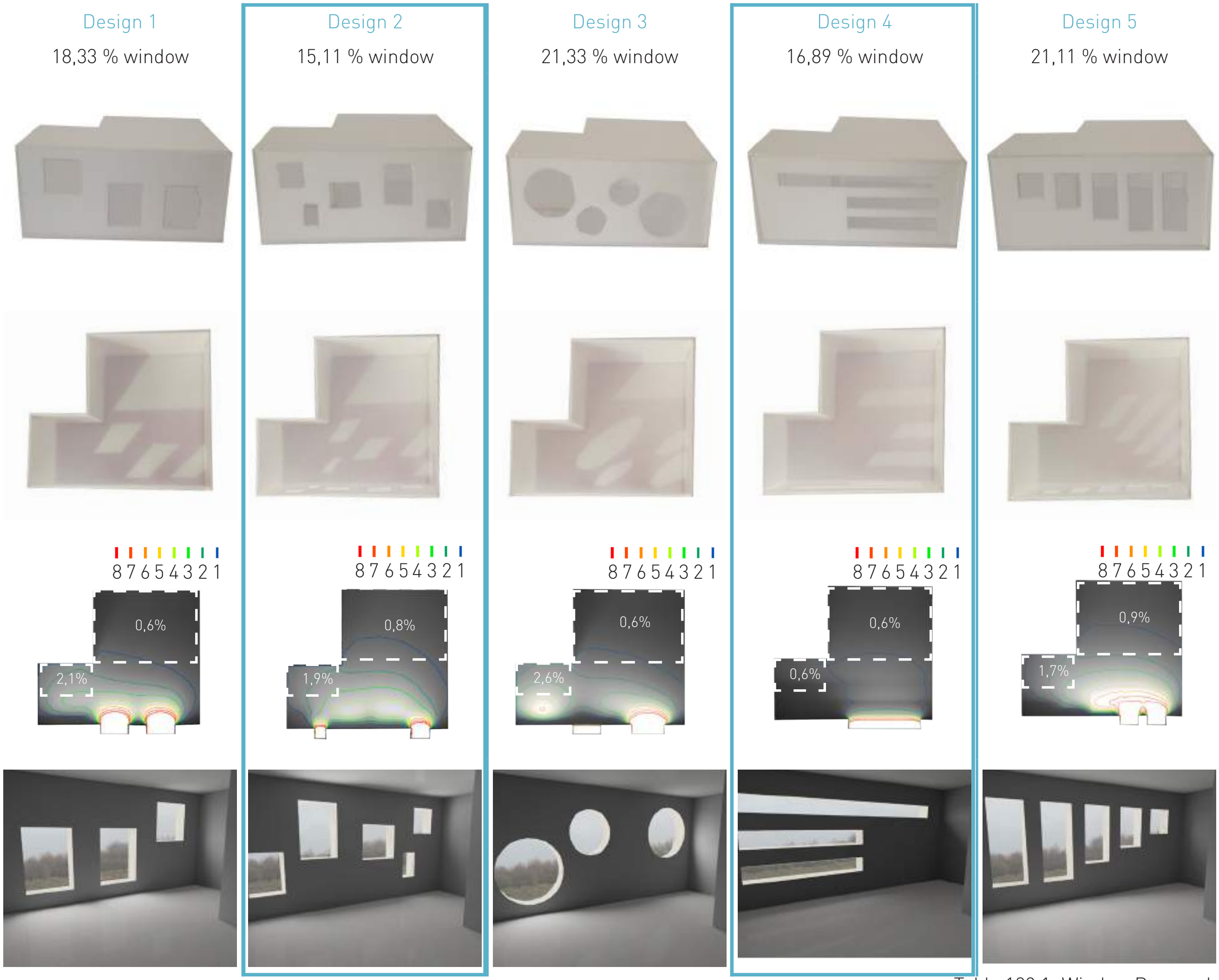


Table 129.1: Window Proposals

DESIGN PROCESS

WINDOWS IN THE CLASSROOM

From the workshop the chosen windows has been made on a facade to see it in connection with each other.

Design 2 and 4 has been made on one facade to examine the architectural expression for the whole building. Another Daylight factor analysis has been made to see the different results on the different class rooms.

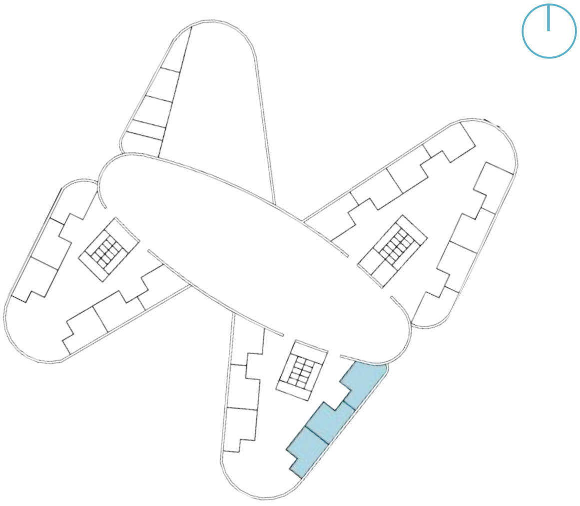
The two window designs gives different things to the building.

Design 2's random system gives dynamic to the building facades and create a little controlled chaos.

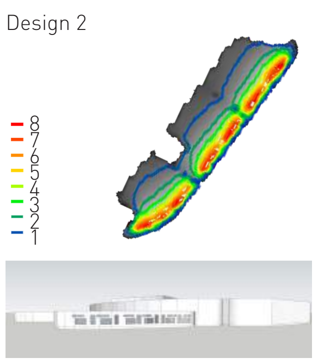
Design 4 with its long windows emphasizes the overall shape of the building with its ribbon shape. The design is easy to regulate to make the light fall in the right places.

CONCLUSION

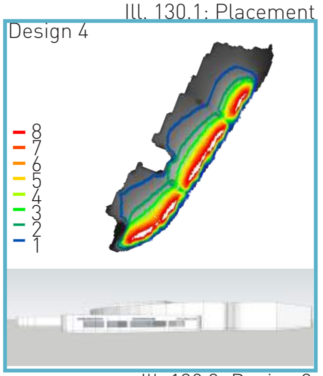
The chosen design to work further with is design 4, where the windows will be placed based on the function behind. The composure is more easy to the eye and gives the overall design a whole and connected expression.



Ill. 130.1: Placement



Ill. 130.2: Design 2



Ill. 130.3: Design 3

After deciding on the window compositions, a process over how to specific arrange them, the placement and size of them has been made. The process is made over one classroom.

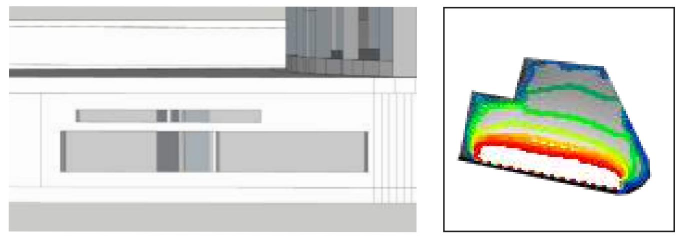
The decisions are based on the daylight factor, the function and the overall architectural expression.

In every design the daylight factor is a little high in the dark side of the room because they are placed directly next to the common room and a window is placed to get light in from there.

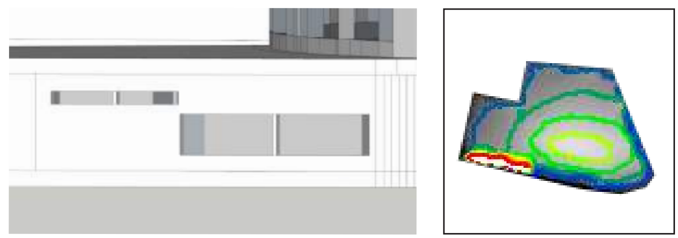
CONCLUSION

Design 1 gives the highest daylight factor to the room, however the windows fills up almost the whole facade, and with windows as large as these it is not possible to make this design on every classroom because of the small size difference.

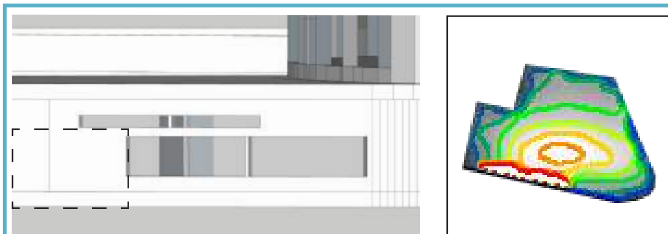
Design 3 is chosen. Here the large windows are four meters and the small windows are three meters. This opens up for use of the wall in the niche in the classroom (dashed area). The windows are 4m x 1.3m and 2m x 0.4m.



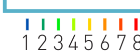
Ill. 131.1: Design 1



Ill. 131.2: Design 2



Ill. 131.3: Design 3

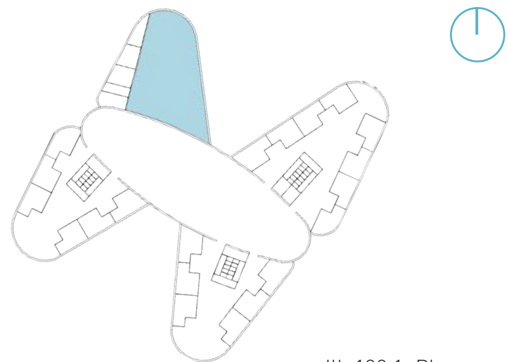


WINDOWS IN THE MULTI HALL
The windows in the multi hall needs to have other functions than in the classrooms.

First of all, it is important to remember that it is a room used for gym, which means the windows need to be able to resist balls. However, it isn't a sports arena, so the balls used will be softer and with a solid window type it will not be necessary to have a grid. They need to be 3 meters over floor height to have room for ribs, where the standard measurement are 2,6 m. Direct daylight on the floor is not preferred and northern light is most optimal, to prevent glare (Klingenberg, 2014).

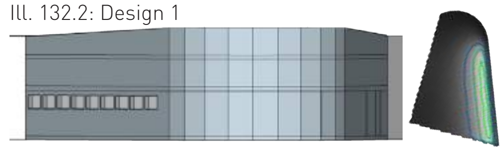
CONCLUSION
In all four designs there is made room for ribs along a wall. Design 1 and 3 does not provide enough daylight for the room. Design 2 will give a lot of daylight from east on the floor, which leaves design 4. Design 4 gets its primary daylight from north and it has good daylight conditions in most of the room.

The darkest part in design 4 is right in front of the changing rooms and close to the large common area. With a transparent facade towards the large common area, some of the daylight from there can be pulled into the dark part of the multi hall.



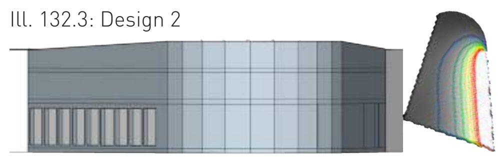
Ill. 132.1: Placement

Ill. 132.2: Design 1



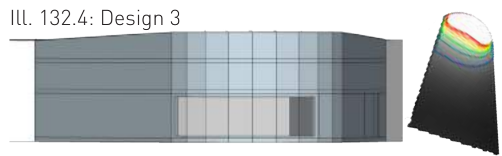
38,12% of the facade are windows.

Ill. 132.3: Design 2



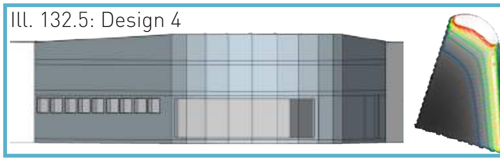
94,19% of the facade are Windows.

Ill. 132.4: Design 3



88,57% of the facade are windows.

Ill. 132.5: Design 4



60,31% of the facade are windows.

WINDOWS IN THE MULTI HALL

The multi hall needs to have a temperature between 17° and 19°. This is tested with a simple excel sheet: 24-hour-arverage. The inputs are the different square meters of the walls, windows, floors, etc. The activity level, the equipment watt level, etc. The output is then the temperature.

A calculation of the air change needed for CO_2 and olf has been made with a result of 5,4 h^{-1}.

The temperature calculation has been made with a case with 60 people using the hall. The activity level is set to 10 met, which means really active. This gives 15300W, which is placed on the slots from 8-16, with an exception of at 12, where there would be lunch.

The results show that with the demand of 17° - 19° that the air change is to low. The first change is using external shading. This makes a small change. Afterwards a change in the air change from 5,4h^{-1} to 10h^{-1} shows that this doesn't change the result enough. Lastly a change in the inlet temperature shows a significant change.

CONCLUSION

Because of the low temperature demand and the high activity level, the multi hall needs an inlet temperature of 16,5° instead of the same as the outdoor temperature.

Change	Starting point	Shading factor	Vent. air temp.
Shading factor	1,0	0,2	1,0
Air change	5,4 h^{-1}	5,4 h^{-1}	5,4h^{-1}
Vent. air same temp. as outdoor	Yes	Yes	No, vent. Air temp 16,5°
24-hour-average	21,8°	21,5°	17,9°
Max. Temperature	25,6°	25,0°	18,8°
Goal	17° - 19°	17° - 19°	17° - 19°

Table. 133.1: Iterations

FACADE

A lot of different materials has been tested on the facade to find the most optimal fit for the building.
The different materials has been evaluated on page 126, however this was for the bearing construction.

Brick will fit well together with the architectural expression of the surrounding buildings. It is a robust material, both in strength and expression, which fit well together with the desired expression.

Design 1-9 has a socket which is pulled 100mm back from the facade, which gives the facade a more light expression, which is a contrast to the heavy look the material has.

Wood could fit together with the nature theme and the close by 'Vadehav'. However, the expression is not as heavy and does not express a resistant to wind and weather like brick does.

CONCLUSION
The final decision falls on design 1. It has a red look, however not as a traditional red brick, but more a burnt expression where the bricks overlap each other. It is the material with the longest life time and it is easier to maintain than wood, which need treatment. Brick also have a good thermal conductivity, which means the bricks leads a lower amount of heat out of the house than for example wood.

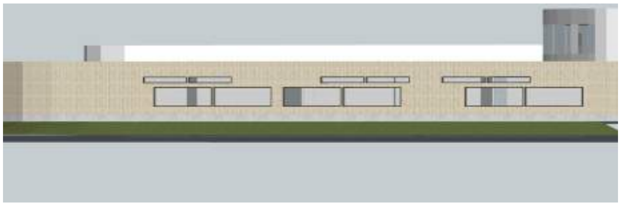
Ill. 134.1: Design 1: Bricks

Ill. 134.2: Design 2: Bricks

Ill. 134.3: Design 3: Bricks

Ill. 134.4: Design 4: Bricks

Ill. 134.5: Design 5: Wood



Ill. 134.6: Design 6: Wood

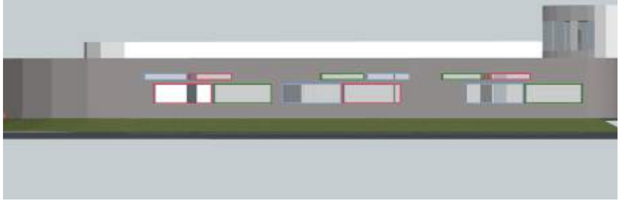
Ill. 134.7: Design 7: Wood

Ill. 134.8: Design 8: Wood

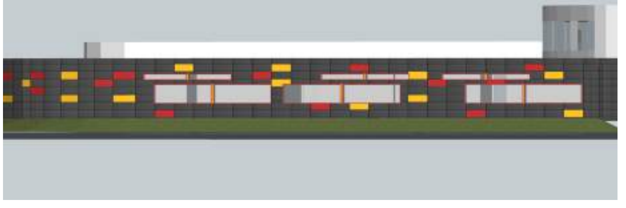
Ill. 134.9: Design 9: Coten steel

Ill. 134.10: Design 10: Bricks

Ill. 134.11: Design 11: Fiber cement



Ill. 134.12: Design 12: Fiber cement



BUILDING ON A MOUND

Some of the inspiration for the project came from the mound buildings in the area (Se page 34-35 for analysis). One of the design choices which were up for discussions was if the school building should be raised 1-2 meter above the ground on a mound like the reference.

Different parameters has been in play when deciding for example the issue about handicapped friendly terrain, flood, Geo-technical factors. The Geo-technical factors are that the ground is not suitable for underground building sections (Competition material, 2017). By raising the whole building 1-2 meters there will not be a problem with lowering some of the building elements into the ground, for example the multi hall which has a higher ceiling than the rest of the first floor.

CONCLUSION

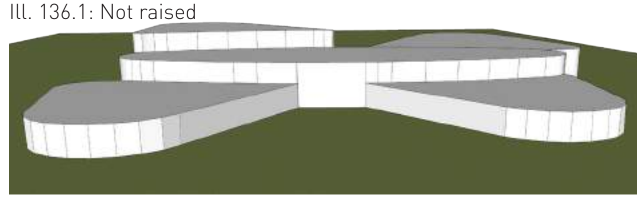
When looking at the factors it is clear that all three solutions has their advantages. However The solution with a 1 meter high mound both opens up for a possibility for basement and is protective for the flood. At the same time one meter is a low disadvantage for the handicapped and a problem with a solution easy to work into the design.

	Not raised	Raised 1 m	Raised 2 m
Handicap friendly	■■■	■■□	■□□
Possibility for basement	■□□	■■□	■■■
Protective during flood	■□□	■■■	■■■

■□□ = Low ■■□ = Medium ■■■ = High

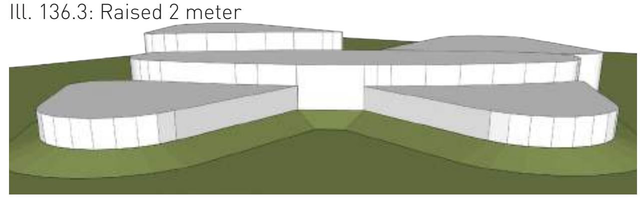
Table 136.1: Rated

Ill. 136.1: Not raised



Ill. 136.2: Raised 1 meter

Ill. 136.3: Raised 2 meter



NATURAL VENTILATION

The school needs to be ventilated with mechanical ventilation however a supplement of natural ventilation will be added. The home areas are designed with a classroom in one side, a common room in the middle and another classroom in the other side. This means there are a possibility to have single sided- , cross ventilation and thermal buoyancy.

To have natural ventilation it is necessary to have one side with negative pressure and the other side with positive (Ill. 137.1).

CONCLUSION

The ventilation used in the classrooms will be Thermal buoyancy. The classrooms only have one facade free for windows, however to accommodate the daylight wishes there need to be two facades with windows.

The natural ventilation in the large, central common area will be cross ventilation. The openings between the building sections will function as doors and the window section on top of the room by the balcony will have some open-able windows. Again it will only be a supplement to the mechanical ventilation.

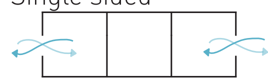
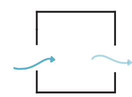
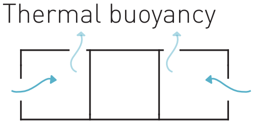
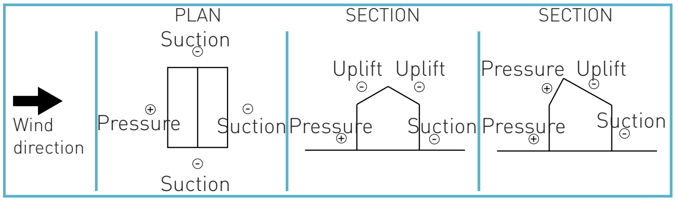
	Advantages	Dis-advantages
Single sided 	One facade only	No defined exit Depth restricted to 2 x height
Cross ventilation 	Open air flow path minimum resistance Better in practice than single sided	Cross flow of used air into occupied space should be avoided Plan layout more complicated
Thermal buoyancy 	Good winter driving force Relieve the problem of single sided ventilation	Shared ducts can result in contamination Flow can be upset by wind forces

Table 137.1: Natural Ventilation



Ill. 137.1: Pressure and Suction

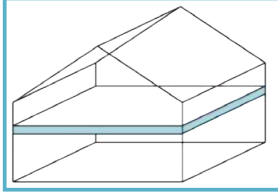
MECHANICAL VENTILATION

The main air supply will come from mechanical ventilation, according to the building regulation (Building regulation, 2018).

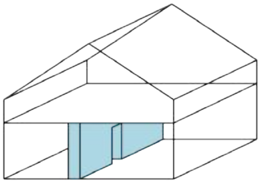
VENTILATION ACCORDING TO OLF AND CO_2
First the needed air supply based on olf and CO_2 are calculated for one classroom. The equation used for olf are: $V(L) = 10 * q / c + Ci$ and for CO_2: $V(L) = Q / c + Ci$
Where Ci is fresh air pollution, c is experienced air quality and q is pollution for respectively olf and CO_2.
The result for both of them equals 3,8 h^{-1}.

Afterwards the required air supply is calculated according to temperature with the 24-hour-average excel sheet. The equation used is:
$t_i = (B_t t_u + \Sigma B_r t_r + B_L t_L + \Phi_i + \Phi_s) / (B_t + \Sigma B_r + B_L)$
Where: B_t is the specific heat loss towards outdoors.
t_u is the outdoor temperature
B_r is the specific heat loss toward ground and surrounding rooms.
t_r is the ground temperature.
B_L is the specific heat loss for ventilation.
Φ_i is the internal heat gain
Φ_s is the sun heat gain

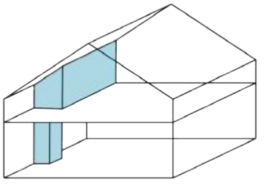
The max temperature is found using:
$\Delta\Phi_k = \Delta\Phi_{k1} + \Delta\Phi_{k2}$
Where $\Delta\Phi_{k1}$ is looking at the max. heat gain and $\Delta\Phi_{k2}$ is looking at the heat loss.



Ill. 138.1: Place the ventilation under ceilings.
Consider the ceiling height.



Ill. 138.2: Place the ventilation as a multi functional element. Inside a wall. Use the extra wall thickness as storage. Easy access to canals for maintenance.



Ill. 138.3: Place the ventilation under a low ceiling under eaves. Utilizes the space with a low ceiling height. Supplement with the technical room.

VENTILATION ACCORDING TO TEMPERATURE.
To ensure the right ventilation a calculation of the temperature in the classroom is needed. This is done with the 24-hour-average excel sheet and afterwards with a calculation in BSim.

The calculation for 24-hour-average was made on the classroom marked on illustration 139.1.

By using external shading with a shading factor of 0,2, the demands are reached. By using a constant inlet temperature of 16,5° like in the multi hall the temperature will be to low.

CONCLUSION
There need to be an inlet at the same temperature as the outdoor air and there need to be external shading such as blinds.

Ill. 139.1: Placement

Change	Starting point	Shading factor	Vent. air temp.
Shading factor	1,0	0,2	1,0
Air change	3,8 h^{-1}	5,4 h^{-1}	5,4h^{-1}
Vent. air same temp. as outdoor	Yes	Yes	No, vent. Air temp 16,5°
24-hour-average	25,2°	23,4°	21,5°
Max. Temperature	29,5°	26,7°	23,9°
Goal	22° - 26°	22° - 26°	22° - 26°

Table 139.1: Iterations

STAIRS

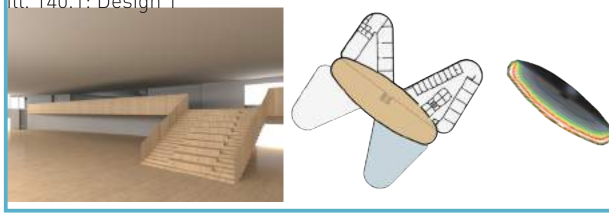
In the common room a large staircase will give access to the first floor. This staircase should also function as a gathering point where the principal could gather all the students and teacher and make announcements.

The solution for the final staircase has been made in three different ways.

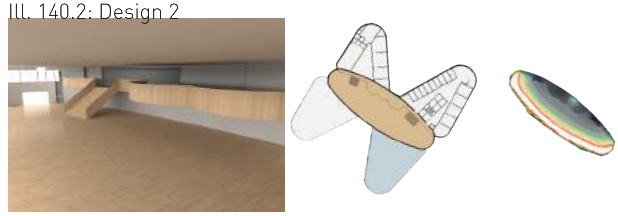
CONCLUSION
Here design 1 is the chosen. First of all it is one staircase, which therefor can gather people and transition activity one place. Second of all it is in the middle between the two parties on the first floor which the staircase service.

The balcony and the specific shape of the staircase is here an example and is worked on in the further process.

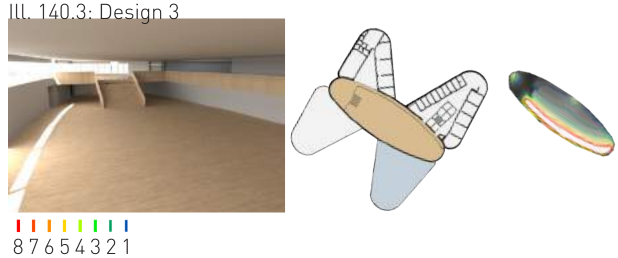
Ill. 140.1: Design 1



Ill. 140.2: Design 2



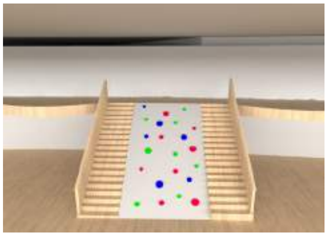
Ill. 140.3: Design 3



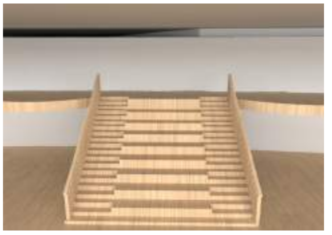
SHAPE OF STAIRS
The large staircase in the middle of the common area is a multi functional element. It should of course be used to access the first floor, but it should also, together with the balcony, be used for audience looking down on a speaker standing on the ground floor. The staircase should be used as a seating element for students to sit and study, eat, have recess, etc.

The different designs can be used together to make a stair case which accommodate every wish.

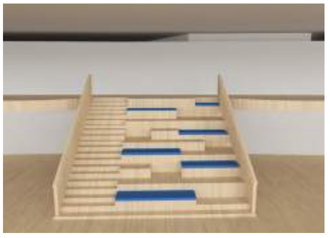
CONCLUSION
Design 4 has been chosen, because of the inviting start to the stairs. It has a simple expression, which can be used as seating with pillows.



Ill. 141.1: Design 1: Staircase on each side with climbing wall in middle, to promote activity during the day.

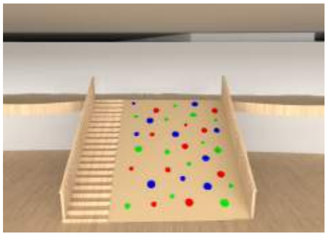


Ill. 141.2: Design 2: Staircase on each side with seating in the middle to use for speeches, recess, study, etc.

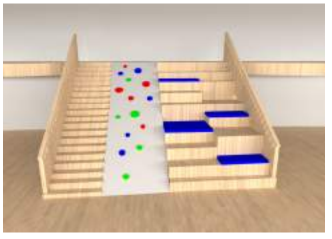


Ill. 141.3: Design 3: Stair case in one side and different seating options to the other.

Ill. 141.4: Design 4: The same as design 2, however here the stairscase meet the users from both east and west.



Ill. 141.5: Design 5: Staircase at one side and climbing wall at the other, it is larger to nudge people to activity.



Ill. 141.6: Design 6: A combination of the three design cases.

RAILING

A sketching process has been made over the railing in the common area alongside the staircase and the balcony.

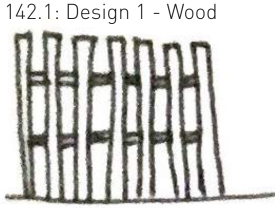
There is set different wishes for the railing in the project, which is: the material should be warm and give an expression of softness and homeyness, it should be some sort of translucent to let light into the balcony, the architectural expression should be modern, fit with the rest of the building and into a school atmosphere.

CONCLUSION

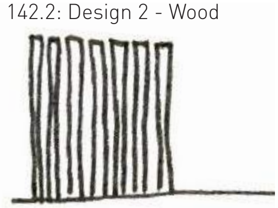
Design 10 possesses the qualities wanted. It is a playful design for a school with children, it is made of birch and it is transparent. It need to have a handle above the wood.

Design 5 was not chosen because glass would quickly get dirty. Design 8 is not as safe, without a handle. The demand for holes diameter are made based on a child's head, so they doesn't get stuck.

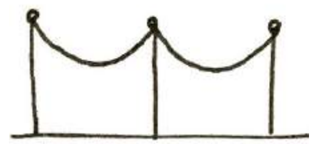
Ill. 142.1: Design 1 - Wood



Ill. 142.2: Design 2 - Wood



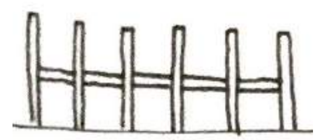
Ill. 142.3: Design 3 - Steel



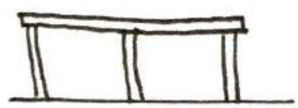
Ill. 142.4Design 4 - Wood

Ill. 142.5: Design 5 - Glass

Ill. 142.6: Design 6 - Wood



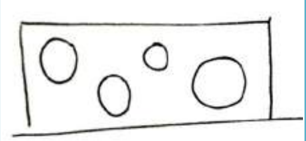
Ill. 142.7: Design 7 - Steel



Ill. 142.8: Design 8 - Wood

Ill. 142.9: Design 9 - Wood

Ill. 142.10: Design 10 - Wood

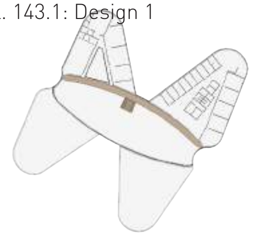


BALCONY
The balcony, which the stairs goes up to has had a process to see how the shape and function of it should be.

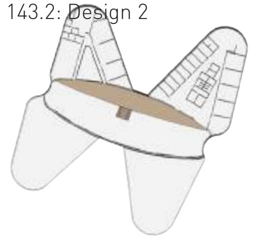
Different iterations has been made and four different solutions has been chosen to evaluate.

In all cases the design can be used for announcements. The principal can stand on the ground floor and the students can sit on the stairs and stand on the balcony.

CONCLUSION
Design 3 is chosen because of the wave-looking design which is used. The outwards waves can be used for group work or stays.



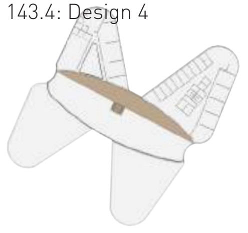
Ill. 143.1: Design 1



Ill. 143.2: Design 2



Ill. 143.3: Design 3



Ill. 143.4: Design 4

BALCONY
The decision to make the balcony on only one side has been worked with. A solution where the balcony goes all around the common room has been tested with a passageway of 2m and 3m in width. The 3m takes to much sunlight from the common room, however the 2m could work.

With the balcony going all around the common room it opens up for use of the fifth facade. The roof over the two lowest home areas can be used.

This will give an extra 1900 m^2 if both is used an 950m^2 if only one is used.

The use of the fifth facade can open up for an extra outside area dedicated to one group. Outdoor areas can be placed with shielding from the wind and in good sunlight conditions. With the extra area a third play-ground can be placed for the oldest children.

CONCLUSION
The fifth facade on the south west most arch building section will be used for recreational use for the oldest children to be during recess and the balcony will stop a bit after the door, so it doesn't go all the way around and still allow a lot of daylight into the common room (Ill. 144.1).


Ill. 144.1: Balcony


Ill. 144.2: Roof top Terrace

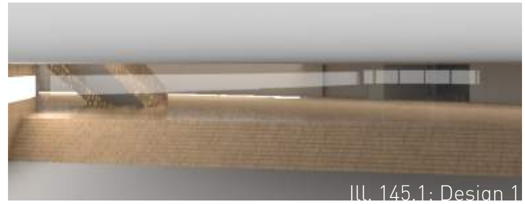
MULTI HALL
The multi hall is lowered two meters into the ground to make the first floor in one level. The multi hall is five meters from floor to ceiling to make it accommodate the different activities, and the other functions are only 3 m in height from floor to ceiling.

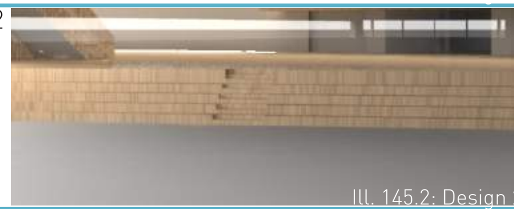
To access the multi hall a staircase from the common room has been placed. Different iterations over this staircase has been made to reach a satisfying design that is integrated in the rest of the building.

Design 1 has stairs from wall to wall. Design 2 has stairs of two meters in the middle and stairs of double height on each side for audience. Design 3 starts inside the common room to save space in the multi hall. Design 4 has two stairs in each side. Design 5 has one staircase in one side.

CONCLUSION
Design 2 is chosen, because it relates to the room and is an integrated part of the design for example compared to design 1. It relates to the room because of the space for audience. The staircase can be used as an active part of the multi hall. It can be used for gym, music, gatherings, etc.

The walls to the common room from the multi hall should be somewhat transparent. Both to get light into the darkest part of the room but also to have a view to the activity from the common room.

1

Ill. 145.1: Design 1

2

Ill. 145.2: Design 2

3

Ill. 145.3: Design 3

4

Ill. 145.4: Design 4

5

Ill. 145.5: Design 5

EPILOGUE

EPILOGUE

The epilogue contains a conclusion, a reflection, a literature list and an illustration list. It sums up the project and reflect upon the different decisions made/left out. The literature list contains the different books and websites used throughout the project and the illustration list contains the origin of every illustration in the report.

CONCLUSION

The result of this thesis is a design proposal for a Danish elementary school located in Skærbæk in Tønder municipality in Denmark. The studied problem statement has been:

How can a Danish public school be designed with a holistic sustainable approach, where the architecture enhances learning through an open school solution and with indoor climate as a main focus?

The school has been designed with a holistic approach through the integrated design process. By using this method both the architectural- and the engineering aspects of a building design has been in play throughout the whole process and the result is a building design, which emphasizes the importance of both aspects.

The final project is 8.941 m2 consisting of home areas for the three groups of students (0th -3th-, 4th - 6th- and 7th - 9th grade), a subject area for the different disciplines, administration, a multi hall and a common area.

The concept of the project is utilizing a common area to minimize the square meter used on hallways and transition areas. The design is based on this large common area which function as a transition area that distributes the user to their designated area. As the large common area is the center for each home area and the subject area, the classrooms in the home areas also surrounds a common area. They are made as a cluster system surrounding a common area. By making the design follow this functional principal the form eliminates the majority of hallways, which makes the footprint smaller, which is a sustainable design approach.

The building design is made through several iteration using the integrated design process. Each time a design has been made it has been evaluated on the design criteria made in the analysis phase. The design criteria both consist of architectural and engineering aspect. Through the design process a constant back and forth between design and simulations has been made to make sure the different design proposals has been based on passive initiatives such as wind and weather, sun, shadow and daylight. Wind and pressure simulations have been made in Flow design, sun and shadow simulations have been made in Sketch-up and daylight simulations have been made in Velux daylight visualizer.

Together with mechanical ventilation natural ventilation will be used to ventilate the school. The school has been oriented to enhance natural ventilation by facing the classrooms towards west and east. This is also done to keep the classroom from overheating and to have natural daylight in the common rooms towards south.

In the classrooms and common area large windows have been placed which the students can use for seating. Narrow windows have been placed higher in the classroom to drag the daylight further into the room and lastly a skylight has been placed in each classroom and some in the common area to get the natural light all the way into the room.

In the large common room there has been placed a double door in each direction (north, south, west and east). These are placed to get natural light into the room, to get a view and an access outside and to make sure fire regulations are respected. Besides these windows has been placed along the south façade to get natural light into the common room. In extension to these skylights has been placed over the balcony.

The building is located approximately in the middle of the site. The location is based on the flow between the nearby leisure center, Hjemsted Oldtidspark, the mudflat (Vadehavet), the day care center and the city to enhance the feeling of cohesion between the different places. The different home areas are then connected to a function and the placement of them are based on this connection. The youngest children need the shortest distance to the leisure center and the day care, the oldest children need the shortest distance to Hjemsted Oldtidspark and the subject area have an observatory on the top floor which needs a good view to the mudflat.

When arriving at the site from the south road trees are the first thing visible. The large field of trees placed between the roads and the school is done for several things. The trees make a noise barrier to keep the sound from the school buses and other traffic shielded from the nearby neighbor, they keep the feeling of transitioning from city to nature experienced when visiting the site and they help shield the children in without using fences.

The building is made in four levels. The first level consisting of the multi hall. The multi hall is five meters from floor to ceiling while the rest of the rooms only is three meters. To have the first floor on one level the multi hall is extruded two meters into the ground. This has been done possible by lifting the whole building up one meter on a mound. The ground level consisting of the different home areas and the common room. The first floor is the subject area and the administration with a balcony in the common room which service access to the roof top terrace. The second floor is the rest of the subject area.

The materials used for the school is primary bricks and wood. Skærbæk is a small town which consist of red and yellow brick buildings. To make a link between the new school building and the context red bricks are chosen for the facades. However, to make a distance between them and to make the school different screen bricks has been chosen instead of regular bricks and the screen bricks are mounted so they overlap each other. Dark pine is used for the terraces and the window sills to give the building a warmth. Inside light pine is used for the different design element implemented in the building like staircases, furniture and the balcony. The wood gives the building a warm and homey feeling.

The school has been made to an open school, which interact with the local community. Through the competition program a wish for a partnership with the close by leisure center has been respected. The partnership would consist of utilizing the leisure centers functions such as football fields, meeting rooms and sports arena and in return the leisure center would use the school's facilities for sleepovers during competitions, meeting rooms or the smaller multi hall.

Besides this partnership the school's large common area will be an open room for the public to visit and use. It can be used by the public as a library or as an assembly hall. The room will function as the school's canteen, a workshop area a place to enhance encounters between students of different ages and teacher, PLC with a library and distribution.

These partnerships are made as a sustainable approach. Another is the use of PV solar cells. The school accommodates the demands of energy frame 2020 by the use of solar cells placed on the roof as an active initiative. The indoor climate and the energy calculations has been made using BSim and Be18. The rest of the roofs will be green roofs, which will enhance the nature feeling and mirror the sense of the place, help isolate and collect rainwater. The rainwater will be used for watering the urban areas and the football fields.

REFLECTION

Through the process of the thesis project several complications have occurred. These have been weighed according to importance to the project. Some of these have been solved using the integrated design process through iterations, while others have been downgraded because of the time and therefore not been a priority. The following is a reflection over the different issues which would have been worked with if the time line had been longer.

A long process has been over the plan solutions and several iterations have been made to make sure the plan drawings worked and were made with the best conditions for the users. However, through the process some complications have been found which could have used more iterations to make the design better.

One place is the common areas in the home area belonging to the 4th - 6th- and 7th - 9th grade. These rooms are placed directly towards south. A 24-hour-average calculation have been made on one of the rooms (page 106), which shows the expected that the room will get very hot. A process over this area have been to make the windows smaller, however, a longer process would have been preferable. Different design solutions have been thought of and one was ending the room earlier and making the area into a covered outdoor area, so the form of the building is kept but the room is shielded by an overhang.

Besides this a differentiation in the windows could have been made. At the moment the windows in the home areas common area are the same size and in the same height. For example, a door could have been placed and windows in different sizes to give the room a less monotonic expression.

Another home area which need more work is the north turned belonging to 0th - 3th grade. The other home areas have skylights to get natural light into the deepest areas. However, because of the floor above it is not possible to have skylights here. Different design solutions could have helped on this. For example, the class rooms could have been moved away from each other so there was a gap for daylight between each classroom. This would however result in a larger wing and further studies would have been needed.

At the moment the home areas are similar. In the competition program there is a wish for different focus for each home area (page 43). This could have been worked further with by making the home areas different. For example, the oldest students could have a more open plan solutions with less classic classrooms where the lines between classroom and common area becomes blurred while the youngest students could have a more classic classroom solution with several classrooms to keep them focused.

Because of a late iteration on the plan solution placing an elevator and toilets by the subject area the group rooms in the culture subject room was demoted from three to one. This correction needed more iterations to make it fit better with the rest of the design. The culture subject room didn't need a large subject room but more quiet places for group work (App. 2, p. 167).

A wish from the competition program was to make rainwater an integrated part of the building design (page 42). Throughout the process different solutions have been thought of to integrate rainwater into the design, however because of the time limit thoughts haven't been made to reality. The final design has rainwater collector on the roof and the tank on the southern terrace. This means the school can use the rainwater both for watering but also as a teaching tool. However, have the time line been longer iterations integrating the rainwater as a design element would have been an option. Several thoughts about having a small stream going through the large common area or making a lake in connection with the playground have been. However, complications with both solutions makes it need several iterations.

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ILLUSTRATIONS

TABLES