SPACES FOR LEARNING

A BOARDING SCHOOL

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ABSTRACT

This thesis project treats the subject of learning environments at Danish boarding schools in an architectural and sustainable perspective. The integrated design process forms the base of the project in corporation with Vitruvius' three principles of architecture: Structure, function and aesthetics which combined form great architecture.

The project is developed for a site by Limfjorden near the city of Nibe, Denmark. The site is situated in an undulating landscape on the top of a slope which ensures the users great views of the surroundings. The boarding school is specializing in sports, thus movement and exercise are used as generators in the design.

Our motivation for this master thesis has been to develop a new typology for boarding schools, as they often are located in old disused village schools. By choosing to build new there is a greater possibility to organize the functions, ensure a fluent flow between them and to create a building with an inviting atmosphere that supports the personal development of the individual student.

GUIDE OF READING

The project is divided into seven chapters that present the project in a chronological order. Each chapter is completed with a small summary of the knowledge and progress made in each chapter.

THEME ANALYSIS
The project is initiated with analyses of the theme that explores the historical background and technical perspectives on the subject.

SITE ANALYSIS
The site analysis clarifies the qualities and problems with the location in relation to the physical site, its surroundings and climatic conditions.

PROGRAM
The analyzes sets the stage for the program, which illustrates the desires and demands for the project.

PROCESS
The process presents the progresses throughout iterations between the sketching and synthesis phase of the integrated design process.

PRESENTATION
The presentation of the final project is illustrated through text, visualizations, plans and sections.

PROLOGUE
The prologue summarizes the project through a conclusion and reflection upon the final design and process.

APPENDIX
The appendixes include additional calculations and documentation of the design.

Illustrations are marked with the number of the current page, and the order of the illustrations at the page.

TABLE OF CONTENT

INTRODUCTION

Since the retreat of the financial crisis, the amount of student applications boarding schools has been increasing steadily and once again caused a continuous demand for additional schools. This fact forms the base of this thesis project that will be located near the city of Nibe by the Limfjord in the Northern part of Jutland, Denmark.

A year at a boarding school is a unique experience with togetherness and socializing with equal others and an obligation to simultaneously pursue personal interests. With educational principles that are based on maturation and general upbringing of the individual student, the stay prepare them to attend college or vocational educations and further increase their level of knowledge.

Boarding schools are typically located in old existing buildings, and with the evolvement of approaches and technologies for educational purposes entail an increased demand for the architecture and indoor environment in learning environments. With an additional awareness of how bad indoor environments affects students' ability to learn [DCUM, 2013] there is a need to rethink the boarding school architecture to enable sustainable and comfortable learning environments.

With a focus on spaces for learning in a sustainable perspective in relation to boarding school architecture, this master thesis will investigate how sustainable learning environments can be designed. Effective learning environments are very sustainable in the long run as it affects and increase the overall level of knowledge among the students and population in a greater extent.

Ill. 6.1- Point out of the site

METHODOLOGY

This master thesis is developed with the Integrated Design Process, which is a method to organize and structure a project and maintain a holistic approach to sustainable architecture. The Integrated Design Process is defined as a synthesis between Problem Based Learning, architectural and engineering aspects. The Integrated Design Process is very complex, but it can be simplified into five phases as illustrated in ill. 7.1.

The problem phase is the initial part of the project where the problem is outlined with an idea, an objective or a statement.

The analysis phase involves research and analyzes of the theme, site and other relevant topics. The phase accumulates in a program that contains concept, vision, design parameters and a statement of technical demands and target values for energy demand and indoor climate.

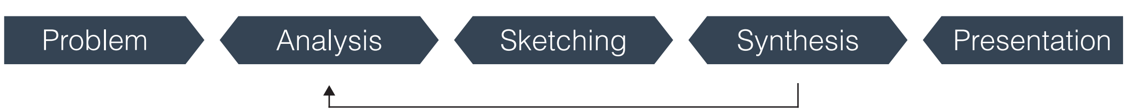
The sketching phase is where the professional knowledge of architects and engineers is combined into design solutions that are considered according to the defined criteria and target values. The sketching phase is a repeatedly estimation of how different choices regarding the design affect the energy demand and indoor climate.

The various problems are illustrated through sketches and modeling with analog and digital tools.

The synthesis phase is where the iterations and parameters from the previous phases merge into one unified form that meets the demands and criteria in the program. In the synthesis phase the project should be optimized and the performance of the building should be documented.

The presentation phase shows the final result of the project through visualizations, illustrations and text. The project should be presented to demonstrate its qualities and clarify how the aims, design criteria and target values have been fulfilled.

The method should be seen as an iterative process where it might be necessary to go backwards in the phases to gain more knowledge or try out new solutions before finding the optimal design.



Ill. 7.1- The phases of the Integrated Desing Process

THEME ANALYSIS

THEME ANALYSIS

THE EVOLUTION OF BOARDING SCHOOLS

The Danish school has evolved much through time. In the beginning it was only children of the upper class households that could attend school due to economic reasons. Major evolvements happened in the 1730s where confirmation became a social obligation and education became compulsory for all children. The school and church were closely connected and the lessons aimed to teach the students about the fundamentals of Christianity and prepare them for their confirmation which was a symbol of the transition from child to adult entailing civil rights. The education lasted seven years and the conformation was the final test. The students were organized in genders and the mandatory education lasted seven years. Except an enrollment sum and the cost of books, the education was free, but if the student wanted to learn how to write and do calculations they had to pay an additional sum. [Pedersen, 2012]

THE FIRST BOARDING SCHOOLS

After finishing the elementary school, some still had a need for extra education. As a result Sunday schools were established in the greater Danish cities in the 1800s. This made people at the countryside feel discriminated. In an attempt to follow the development of educational opportunities in the city, local farmers and groups of residents hired teachers to educate the young in the outskirts of Denmark. These schools were called “continuation schools” as they were a continuation of the elementary school. The teaching at the continuation schools was seen as a supplement to the previous seven years of mandatory education. The lessons followed the educational thoughts of N.F.S. Grundtvig and Christen Kold regarding the common formation of the students. In the beginning there was a wide admission age at these new schools, but with time, another school meant for students above 18 was established. It was a student of Christen Kold that established the first known boarding school in 1879 at the island Mors in the north western part of Jutland.

With a new school system in 1949, it became common to mix the genders and have the students live at the schools. With this new school system, the boarding schools started to appear like the boarding schools we know today. In 1967 the boarding schools were allowed to have final exams like the common public schools and thereby able to offer the same educational potential as the common public schools 8th, 9th and 10th grade. In addition to the traditional lessons, boarding schools has since the 1970s focused on various methods of teaching and specialized in musical, artistic, creative and practical lessons. [Pedersen, 2012]

BOARDING SCHOOLS TODAY

Boarding schools is denoted as free schools and has a certain freedom to operate from a specific ideology or approach. It is up to the individual school to decide which qualifications their teachers should have and which students to accept. Boarding schools is supported by the government, but to obtain these grants the schools have to be approved by the ministry of children and education. [UVM.dk, 2014]

Today the boarding schools are very popular among the young and almost half the total amount of students at 10th grade in 2011 chose boarding schools [Den store danske, 2012]. It is expensive to attend a boarding school, typically it cost from 35.000 and up to 70.000 dkr per year and during the financial crisis the schools experienced a reduction in student applications because the families didn’t have money to send their children to a boarding school. Especially the amount of students in 8th and 9th grade decreased in the period, but during the last years, the amount of student applications has increased once again. Currently there are 249 boarding schools in Denmark [efterskole.dk], and there is a continuous effort to create additional schools.

Students choose to attend boarding school because they want a unique experience, and want to try something else than the traditional elementary school. Another essential factor for choosing boarding schools is the togetherness and socializing with the other students in a wider extent than at a regular high school. At the boarding schools the students are able to pursue their interests and make new friendships.

The educational focus at the boarding schools is still related to the human development, maturation and general upbringing of the students and is heavily focused on social interaction between the students. The relation between teacher and student at a boarding school is very different from the one at a traditional high school. At the boarding school the teachers and students are around each other all day and therefore have a closer relation to one another. The academic level at the boarding schools are as a minimum corresponding to the level at the public high school and therefore the education ends with final exams from the official Danish board of education.

THEME ANALYSIS

LEARNING AND ARCHITECTURE

Good learning environments depend on the correlation of didactics and the physical environments. Boarding schools goes under the term “free schools” and has freedom to choose their own didactics as long as the education consummates the one at Danish public schools. Therefore the didactics and views on how students learn differ from one school to another. [UVM, 2014]

This project is based on the use of various educational principles from regular classroom lessons, individual assignments, group work and physical tasks around the school. The frequently changing didactics combined with knowledge of the effect that surroundings have on the individuals well-being and ability to learn, clarifies that the learning environment should be adjusted to fulfill the special needs of a boarding school.

People learn in different ways, with different means and the physical environment should be developed to enhance these different ways of learning. Anne Taylor, an American professor that specializes in learning environments for children and how the buildings affect their ability to learn describes her theories in the publication: The ecology of the Learning Environment. Even though her theories are based on children’s ability to learn in different environments, the basis of the learning methods can in a great extent be reflected to older children and grownups as well. She makes a direct comparison between “designing the whole building” and “reaching the whole learner” with a reference to Vitruvius. According to Vitruvius, architecture and form is created through a combination of structure, function and aesthetics. In the same way A. Taylor states that a learning process is created through the use of body, mind and spirit. [A. Taylor, 2009] A person learns through movement and the use of its senses. The human body has five senses, sight, hearing, taste, touch and smell, but the mind also sense through the general feeling of consciousness of the entire body, also known as the kinesthetic sense. We learn with our mind by studying, solving problems and developing ideas while we learn with our spirit through emotions and values.

> *“The building should be considered as a servant of the pedagogics and contribute that the pedagogic intentions are realized.”*
>
> – Kirkeby I. M

The space it itself can’t practice teaching, but it should be able to facilitate several learning activities and differentiated teaching.

A good learning environment is an extensive triad of physical, functional and psychological needs with possibilities for activities on different levels. It is important to design spaces for different degrees of privacy as the students spend a lot of time at the school and in a great extent need private or semi-private spaces where they can retreat from the others. [Larsen K, 2005]

REACHING THE WHOELE LEARNER	REACHING THE WHOLE BUILDING
BODY - physical leraning MIND - cognitive learning SPIRIT - emotional learning	FIRMITAS - structure UTILITAS - function VENUSTAS - aesthetics

Ill. 13.1 - Holistic goals of educational facility design

VENUSTAS	Facility is a visionary, motivational, sustainable, healthy, high-performance teaching tool
UTILITAS	Facility is functionally flexible, functionally proximate, structurally adaptable and instructionally supportive
FIRMITAS	Facility is safe and secure, accessible, meets codes and regulations, minimum thermal, acoustic and lighting requirements

Ill. 13.2 - Vitruvius and learning environments

THEME ANALYSIS

LEARNING AND INDOOR ENVIRONMENT

In the western world people spend up to 90% of their time indoors in their homes, school, at work or in transportation. It is well documented and accepted that the indoor environment in office buildings are leading to reduced productivity and quality of work.
The same effort isn't made when it comes to the young students and indoor environments at schools as the educational environment act doesn't have the same demands as the working environment act. The students are often spending the early and most important years of their lives in classrooms with indoor environments that would never be accepted by adults. This is going on even though it is well documented that the indoor environment have a clear effect on human wellbeing, health, performance and that children are more sensitive to bad indoor environment than adults.

An investigation made by DTU and FOA at 13% of the Danish schools shows that 56% of them did not meet the minimum requirements. The investigation was conducted in September and October, but in this period the outdoor average temperature was higher than normal for this season. The higher temperatures resulted in a higher natural ventilation rate and therefore the result doesn't show the worst-case scenario. In some of the cases the CO_2 concentration reached 4000 PPM (Parts Per Million) which is the maximum value that the equipment can measure, and it is possible that the concentration was even higher. When the results from the analyses are divided into regions it is the region of Zealand that has the best results with 53% of the measured schools meeting the requirements. The northern part of Jutland is the worst of the five regions with only 35% of the measured schools meeting the requirements. The middle- and the southern part of Jutland and the capital region are placed in between with 42 to 44%. [Toftum, Wargoocki and Clausen, 2011]

The analysis shows that 56% of the Danish schools have insufficient ventilation. Compared to Sweden and Norway, the corresponding numbers shows that the indoor environment is much better than in the Danish schools. In Sweden the number is 16% and in Norway its 21%. In Sweden the educational environment are covered by the law of working environments which ensures a much higher ventilation level than the Danish schools. Another influence on the numbers is that Swedish and Norwegian schools use more mechanical ventilation than Danish schools. [Toftum, Wargoocki and Clausen, 2011]

The Danish requirements are based on an average person, but people react differently on the indoor environment. People with allergies and children are more sensitive and therefor reacting stronger to a bad indoor environment than the average person. The effects of a bad indoor environment on a person are many and the common designation is "Indoor Environment Symptoms". The general symptoms are a heavy and oppressive feeling in the head, fatigue, difficulty with concentration and malaise. Less frequent symptoms are skin irritation and mucosal irritation in eyes, nose and throat. These symptoms can be caused by other factors, but if a group of people from the same building is showing the same symptoms it will in some cases be termed as "Sick Building Syndrome". It is believed that the symptoms are influenced by various indoor environments and that the symptoms will disappear when the person leave the room or building.

There are a clear connection between the student's opinion about the indoor environment and their experience of their own academic level and effort in classes.

It is essential for the students to be able to concentrate in order to gain new knowledge. The level of concentration is affected by the physical- and indoor environment on the school and in the classrooms. 84% of students that are satisfied with the indoor environment tell that they rarely or never have difficulties with concentration in class.

Schools that use natural ventilation have a higher sickness absence than schools that use hybrid ventilation. At a school with 400 students that uses natural ventilation this corresponds to 160 days with absence out of 210 days in a school year.

The bad indoor environment is affecting the students' grades. In average the grades at schools with mechanical ventilation is 1,5% higher than at schools with natural ventilation. In individual test the difference is between 0,4 and 2,0%. The schools with the highest sickness absence scores worst in the tests and compared to the schools with the lowest sickness absence the difference is 8,0% in average. [Kjeldsen, Toftum, Wargocik and Clausen, 2011]

CASE STUDIES

INGSTRUP EFTERSKOLE

KEY NUMBERS
- Ca 7300 m^2 gross area
- 125 students
- 17 teachers

BACKGROUND
Ingstrup Efterskole is located near Løkken in the northern part of Jutland and was founded in 1980. The school possesses several buildings and the main building is an old historic manor constructed in 1857. Over the years, the school has gone through many renovations and the physical environment appears bright and welcoming. The school specializes in action sport, handball, soccer, music and the academic development of the students. Furthermore they have a special class with interdisciplinary project work and a business class with elements from the business high school. The education at Ingstrup Efterskole is based on the thoughts of N.F.S Grundtvig and the focus is therefore as much on the academic development as it is on the common formation of the students.

LOGISTICS
The school is divided into eight detached buildings and the logistics is not always optimal due to their placement according to each other. The main building is the heart of the school and has a fluent connection from the kitchen and dining room to the common area where there is a casual atmosphere. The teacher's office is connecting the common area with the administration and it is a shared room where students and teachers can retreat and have informal meetings. Some of the classrooms are gathered in the main building and has space for group work. The first floor of the main building is mainly exploited as an apartment for the principal.

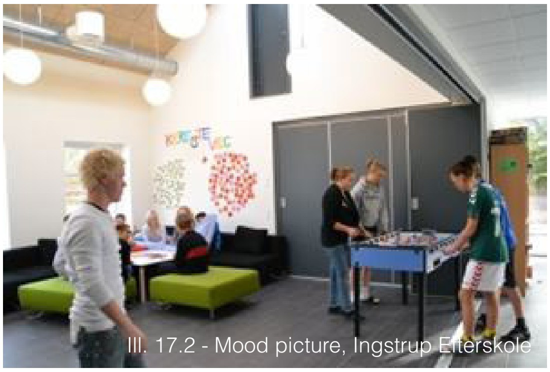
The building across the courtyard is used for the musical education. Behind it, there are two other buildings where the smallest are the physics class


Ill. 16.1 - Ingstrup Efterskole

and the largest is for the school caretaker including a workshop area. To the east of the main building across the road there are two identical buildings containing the students' dorm rooms. The students are divided into rooms with two or four persons of the same gender and the boys and girls rooms are mixed in the two building. The rooms are all the same size and include a bathroom and one closet. In each of the buildings there is a shared space, but the students prefer to use the new common area in the main building where they all can be together at once. Behind the dorms towards north the school's sports center is located together with a new soccer field. Included in the sports center, there is two classrooms on the first floor. Finally there is a building which contains a dance studio, fitness area and the last classroom. All the outdoor activities are gathered east of the dorms and include a fireplace and a climbing tower.

MUSIC FACILITIES
The school has an entire building for the musical specialization. This building contains a concert hall with a small scene, a music room, small rooms for practice and a professional sound studio. The concert hall is the place where the students all gather for common information and meetings.

Ill. 17.1 - Typology, Ingstrup Efterskole



Ill. 17.2 - Mood picture, Ingstrup Efterskole

SPORTS FACILITIES
For the physical specializations they have a sports center with locker rooms and class rooms, a dance studio, a building for equipment and a soccer field with artificial grass that can be used all year. Furthermore they have multiple outdoor fields for soccer, basketball, tennis, beach volley, beach handball and a 16 meter high outdoor climbing tower.

SCHOOL POLITICS
The school has high focus on healthy food, and the students are obligated to be present in the dining area at breakfast and lunch. Furthermore there are healthy snacks two times a day so the students never starve. The students are encouraged to use all the school facilities in their free time and they are allowed everywhere at the school with the exception of one room where the teachers can retreat and focus on preparation.

There is always something planned in the weekends, but the amount of students that stay at the school varies a lot from week to week. Sometimes there are 15 students and other times 60 students. It depends on which activities there are planned. The students participate in the planning and the once that stay at the school are expected to participate in the planned activities. There are at least two teachers present in the daytime, while the night shifts often are covered of the principal that live in the main building or the teachers who live next to the school. This is a unique example for this particular school that might change with time.

LYNGS IDRÆTSEFTERSKOLE

KEY NUMBERS
- Ca 5300 m^2 gross area
- 124 students
- 15 teachers

BACKGROUND
Lyngs Idrætsefterskole is located at Thyholm and was founded in 1997. The school was originally an old elementary school, and the property is very limited. Over the years the school has expanded and the floor area ratio of the property is very high. It is evident that the school has expanded several times, but in general the facilities appear bright and welcoming. Furthermore the sports facilities and furnishing is new and modern, which complements the older building. The school specializes in handball, soccer and gymnastics, but also at the academic development of the students. At Lyngs Idrætsefterskole the education is also based on the thoughts of N.F.S Grundtvig and the focus is just as much on the academic development as it is on common formation of the students.

LOGISTICS
As the building is one connected unity, the logistics is good. There is a fluent movement from the students' dorm rooms to the dining, classrooms and sports facilities. At the same time the separation between school and home is clear due to the central aula that also is the heart of the school and acts like a sanctuary for the students as well as teachers. The logistics could be even better with other placements of the facilities according to each other. The students are divided into a boys wing and a girl wing. The dorm rooms are placed in clusters of four. Each cluster is divided into two levels and has a shared entrance and a common bathroom. There are two students living in each dorm room, which makes it eight students per cluster.

Ill. 18.1 - Lyngs Idrætsefterskole

The school has extended over several times, and some students live in barracks which form one story clusters. The common room and the dorm rooms are directly connected which result in lot of activity in the common area. The distance from the dorm rooms and common area to the classrooms is creating a balance between school activities and free time.

The schools property is very limited, and as a result of this the placement of the sports center isn't optimal. It is placed in front of windows in the existing building which causes poor views and bad daylight conditions in the rooms. The classrooms are placed at two different places in the building. The optimal solution would be to have the classrooms placed together as they often have the same lessons at the same time and would benefit from the adjacent rooms. Furthermore all the students is gathered eight times a week in their auditorium, which is placed the farthest from bedrooms and the main common facilities and the students have to walk through the old gymnasium and the handball court to reach it.

Ill. 19.1 - Typology, Lyngs Idrætsefterskole

Ill. 19.1 - Mood picture, Lyngs Idrætsefterskole

SPORTS FACILITIES

The school has new, modern and attractive facilities for their specializations. They have a new soccer field with artificial grass that they use all year.

Their sports center was built in 2003 and is used mainly for handball but also other kinds of indoor sports, performances and various arrangements. The sports center has recently been extended with a modern hall with facilities for gymnastics, tumbling and fitness.

SCHOOL POLICY

As a boarding school specialized in sports, healthy food is crucial. The school has a food policy and the students are obligated to be present at all servings during the day.
Nothing is locked at the school and the students have access to all rooms except one where the teachers can retreat to prepare lessons or discuss sensitive matters. There are only showers at the dorm rooms and in order for the students to shower without unpleasant surprises they are separated by genders. The socializing is important at Lyngs and they enhance the students to go to the aula in breaks and free time.

There is always something planned in the weekends and in average there is 35 students each weekend. The students are involved in the planning of activities, and sometimes it's just movie nights. The students are not obligated to participate in the weekend arrangements, except for the mandatory weekend where all students are expected to participate. There is at least one teacher present in the daytime, dependent on the amount of students that stay at the school. The teachers distribute the night shifts between them and there is always one that stays overnight.

SUSTAINABILITY

THE DEFINITION OF SUSTAINABILITY

During the last decades, there has been a growing awareness of the climate and the increasing concentration of greenhouse gasses in the atmosphere. The climate is going to change differently around the world. In Denmark the temperatures are increasing, the weather is going to be more extreme and the sea level is rising. The Danish government expects the country to be carbon dioxide neutral by 2050 and by then only depend on renewable energy. The current changes are caused by human activity especially in the field of transportation and households. Therefore the buildings' energy consumption needs to be significantly reduced. Denmark is one of the leading countries in terms of sustainable initiatives and the government has high ambitions that push the industries. [Et bæredygtigt Danmark, 2014]

The most common definition of sustainability was defined by the Brundtland commission in the report 'Our common future' from 1987. In this report it is stated that: "A sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their need".

Sustainability is not just related to the climate, but has a social and economic aspect too. Sustainability is a balance between these three aspects. The Danish government's sustainable vision for Denmark is a country in control of economy, a welfare state, where everyone regardless of their background can live a rewarding and dignified life in a clean environment, rich nature, and healthy climate. [Et bæredygtigt Danmark]

ECONOMIC SUSTAINABILIY

In a national perspective, economic sustainability regards the economic growth and its importance in relation to the welfare state. In Denmark every citizen should have access to health service and education. As a part of the Danish strategy in economic sustainability, the investments in research, innovation and education should be converted into growth and employment. It is therefore important that the children thrive in school and find an interest in learning that encourages them to continue school and get a higher education.

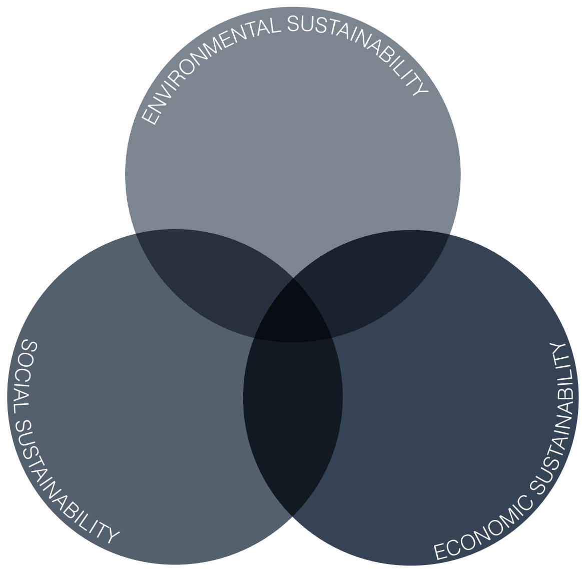
In relation to architecture and the building industry, the economic sustainability regards the amount of money it will cost to maintain a building throughout its life cycle. It is important to develop a long-term strategy with minimal expenses for maintenance and operation to secure a better economy during the lifetime of a building. [Dac.dk, 2016]

SOCIAL SUSTAINABILITY

Social sustainability is the ability of a social organization to function on a defined level of social wellbeing and harmony indefinitely. The human factor is essential in the development of sustainable societies. When seen in relation to architecture and cities the social sustainability regards the creation of spaces with diversity and a place for the citizens to live in a safe environment. It takes into account that there is a correlation between the physical and social environment meaning that the experience and use of the building is supported by good architecture, outdoor facilities and the local environment. [Dac.dk, 2016] Social sustainability in the architectural context also concerns the indoor climate and the general wellbeing of the users. [Birgisdottir, 2013]

ENVIRONMENTAL SUSTAINABILITY

In relation to the architectural field, the environmental sustainability regards the buildings impact on the environment. The Danish government has the intention to fully rely on renewable energy rather



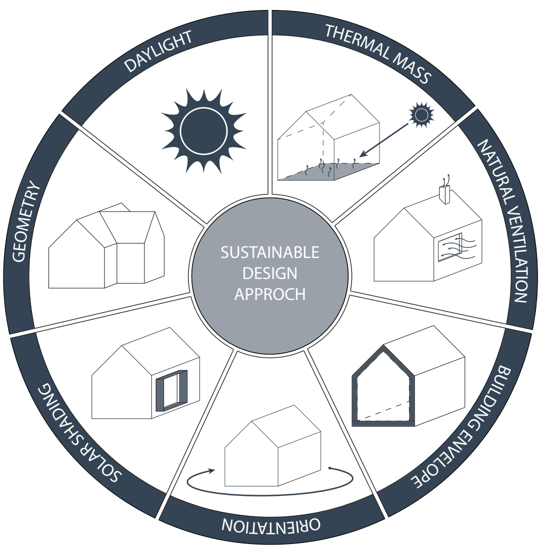
Ill. 21.1 - The three aspects of sustainability

than fossil fuels and thereby become a carbon dioxide neutral country by 2050. Therefore new buildings must operate within a certain energy frame and have a healthy indoor environment. The environmental sustainable development is related to the buildings effect on the environment, its energy demand, materials and the resources it uses through its lifecycle. [Birgisdottir, 2013]

PASSIVE DESIGN STRATEGIES

When designing a building that has to live up to sustainable demands it is crucial to have focus on sustainable aspects from the beginning. In order to avoid problems with the building fulfilling the high expectations and then having to redesign it, there are some design approaches that should be incorporated from the beginning of the process.

In this project there will be a main focus on passive design strategies to lower the buildings energy demand. These design strategies regards the orientation and layout of the building, utilization of solar radiation and natural ventilation principles.



Ill. 22.1 - Passive design strategies

BUILDING ORIENTATION AND LAYOUT

The orientation of the building according to the context and corners of the world, have an effect on the buildings energy consumption. Therefore the local climate should be analyzed before the commencement of the design. Information about the wind and orientation of the sun and shadows on the site are important to consider when designing a building and the result of these analyses has an impact on which passive strategies to use and how they are utilized best at the particular site. [Lehrskov et al., 2012]

The relation between the buildings dimensions, the placement and disposition of rooms and functions in the building have a high effect on the buildings energy use. Often sustainable buildings are shaped after a basic geometry, like a circle or a square, to minimize the facade area and avoid cold bridges.

The rooms' placement is determined by their need for passive solar gains. People feel comfortable in a warmer living room, while they prefer a colder bedroom in order to sleep better. This has impact on the placement of rooms, as it then would be ideal to place the living room against south in order for it to utilize the solar radiation. At the same time it would not be ideal to place the bedroom against south as it then would require a high cooling demand. Thus bedrooms are often placed against north. [Lehrskov et al., 2012]

The building envelope is one of the most important and most essential parameters regarding passive design strategies. The envelope contributes to creating energy balance in the building and is effective in order to achieve a good indoor environment. The envelope should minimize the primary energy supply for heat, cooling and electricity. In the past the primary function of the building envelopes was to protect people from the weather and create shelter. Today the demands for the envelope are much higher and more complex. The important function of the building envelope is to optimize the sun- and daylight incident and control the transmission of heat and air. [Lehrskov et al., 2012]

THERMAL MASS
When the solar radiation enters the building, it is ideal to store it. Heavy building materials as concrete, bricks and tiles have a high thermal mass and the ability to create temperature balances by storing the heat during the day and release it overnight. The temperatures in thermal mass can be controlled by water-carrying tubes in the material. This can be effective if there is a need to use the thermal mass for cooling. A building with high thermal mass requires night time cooling to be able to stabilize the temperatures during the next day. Lighter building materials as wood are easier to heat up and cool down. [Lehrskov et al., 2012]

SOLAR SHADING
In some cases buildings have too much solar radiation and thereby bad indoor environments with a high cooling demand. A way to contribute this is through solar shading. Buildings with a high internal heat load have a greater demand for solar shading to avoid overheating. Today there are many kinds of solar shading divided into external or internal devices. Solar shading can be integrated in the facade, as curtains, vegetation or constructions in front of the window. It is important to remember that when the solar rays have passed the glass, the heat is in the building. Therefore the external shading is preferred, as it prevents the radiation from entering the building. Solar shading can also take shape as an external gallery, balconies, hanging gardens or eaves that are shading for the sun in the summer period.

DAYLIGHT
Buildings should be designed to take advantage of the daylight. In order to optimize the natural light in the rooms, a decrease in the depth - an increase in the height of the room could be beneficial. By utilizing the natural light, the demand for artificial light and thereby electricity decreases. [Lehrskov et al., 2012] A rule of thumb regarding design of daylight in buildings is to have a room depth of maximum 11 to 13 meters. [Henning Larsen Architects, 2012]

NATURAL VENTILATION
It is possible to use natural ventilation on most locations in Denmark but in the heating season it is recommended to use a mechanical ventilation system with heat recovery, because of the low temperatures of the outside air. A ventilation system that utilizes the natural ventilation when possible, and is supplemented by mechanical ventilation is called a hybrid ventilation system.

Natural ventilation can be divided into single sided ventilation, cross ventilation and stack ventilation. The driving forces for natural ventilation are either caused by pressure differences or the buoyancy effect. For the single sided- and cross ventilation the relation between the room height and depth affects the efficiency. [Anvisninger.dk, 2015] When designing for the natural ventilation principles it is important to analyze the local climate and context of the building in order to know which driving forces to utilize and how to do it. [Lehrskov et al., 2012]

ACTIVE DESIGN STRATEGIES

In order to develop an integrated building design it is crucial to integrate renewable energy sources in the building during the design process. The usage of solar energy has an effect on the shape and orientation of the building as the solar radiation is highest from south according to the movement of the sun during day and year.

PHOTOVOLTAICS

The sun is a renewable energy sources that can be utilized everywhere. Photovoltaic panels produce electricity during the day when it is light outside even though the sky is overcast, but they produce more energy in the summer when the amount of sun hours is highest. In Denmark the efficiency of the photovoltaics is best when they are placed against south and in an angle of 40 degrees but they can also be placed facing south east or southwest in an angle of 15 to 60 degrees without reducing the performance significantly. [Energitjenesten.dk]
Photovoltaics are highly sensitive of shadow as they are serial connected and shadow on one corner affects the efficiency of the entire system. A typical crystalline panel lasts for around 30 years and the repayment period is 7 to 9 years according to the size and placement of the system. [Energimagasinet.dk] There is different types of photovoltaics, but the most common is polycrystalline- and monocrystalline panels and thin film cells.

The polycrystalline panels are the most efficient model compared to its price, it is therefore the most common type of photovoltaic. The panels have an efficiency of 12-14 percent and are often blue or blueish. [Energimagasinet.dk]

The most efficient and also expensive type of photovoltaic on the marked is the monocrystalline panels which are often black or grey and they collect 14-16 percent of the solar energy. [Climacare.dk]

The price and effect of thin film cells are remarkably lower than the crystalline panels. Thin film photovoltaics are very flexible and they function well in cloudy weather their efficiency is 10-12 percent and they often have a homogenous black surface. [Climacare.dk]

SOLAR THERMAL COLLECTORS

Solar thermal collectors utilize the solar energy to heat up water for space heating and domestic hot water. Just as described previously, the sun is everywhere and can be utilized all year. Solar thermal collectors are most efficient in the summer, but also function in the winter and overcast weather. They should as well as photovoltaics be placed facing south but in an angle of 30 to 60 degrees for the highest performance. [Energitjenesten.dk] The typical repayment period for a solar thermal installation is 8 to 17 years according to its size and which energy source it replaces.

HEAT PUMPS

A heat pump collects energy from the earth or air and utilizes it to heat up water for space heating or domestic hot water. There are three main types of heat pumps named after the way they utilize the energy from its surroundings: brine to water, air to water and air to air heat pumps. [Sparenergi.dk]

A brine to water heat pump is expensive to purchase and install as it should be dug into the ground. The hoses could be placed vertically or horizontally in the ground dependent on the price and assigned area of land. The brine to water heat pump can be used for domestic hot water and space heating and have a high efficiency due to the stable temperatures in the earth. [Sparenergi.dk]

An air to water heat pump is easy and cheap to install as it doesn’t require digging. Due to the low temperatures in the air during the winter, the air to water heat pump requires defrosting. An air to water heat pump can be utilized for domestic hot water and space heating but is 15 percent less efficient than the brine to water heat pump. [Sparenergi.dk]

An air to air heat pump is also easy to install, and it also requires defrosting in the winter due to the low temperatures in the outside air. An air to air heat pump can only be utilized for space heating and as it has a fan it can cause noise problems. An air to air heat pump is only recommended as a supplement to other heat sources. [Sparenergi.dk]

SUMMARY

SUMMARY OF THE THEME ANALYSIS

Since 1879 where the first boarding school were established, the principle of boarding schools has evolved distinctly and today the schools can offer the same educational goals as the public high school but with a greater focus on the students' interests. The boarding schools are very popular and almost half the amount of students in 10th grade spends the year at a boarding school. The schools offer the students unique ways to spend the last years of high school and prepare them for college.

Boarding schools are free to choose their own educational principles. That requires a special design of learning environmental according to the schools specializations and educational principles. The School must support the various teaching methods in academic, creative and physical subjects outside the classroom through activities and movement. People learn through body, mind and spirit and the building should enhance that. Furthermore, the indoor climate has a huge effect on the students' ability to learn and should therefore be optimized to secure the best conditions for the students, motivate them and keep them engaged.

The students are at the school all day, most of the days during a year. They will need different environments with private, semi-private and public spaces. The social interference is one of the most important things at a boarding school, and the architecture should reflect that. This project is going to regard a school specialized in sports, and it is important to create an environment that emphasizes movement.

When investigating the two schools in the case studies, the flow was noticed as a place to optimize the school through placement of functions and movement patterns. As the project is going to be developed as a completely new building, there is a great potential to achieve an optimized flow.

The project should have its main focus on the environmental and social aspect of sustainability and fulfill the 2020 energy frame. This should be achieved with a minimization of the energy demand through passive design strategies that will be supplemented by renewable energy sources to create sustainable energy for the school complex.

SITE ANALYSIS

SITE ANALYSIS

THE SELECTED SITE

The new boarding school should be located in an area with no nearby competing schools. To find a site to meet this desire, the locations of competing schools are mapped at Ill. 31.1. The map makes it clear that the northern part of Jutland only have a few widely spread schools, and would be an appropriate place for the new school.

The new school should specialize in handball, soccer, adventure and action sport. For this reason the site should be close to water, woods and nature to contain possibility for outdoor activities for the adventure and action sport specialization. However it is not desired to be completely isolated from the surroundings, and the distance to the nearest town should not be too extensive.

A site near Nibe is chosen for the new boarding school. It is placed close to the fjord, wooden areas and in an undulating terrain. The site is furthermore placed high in the terrain with stunning views of the fjord. Public busses connect the site to nearby towns, including Aalborg. It is therefore easy for the students to travel to and from the school. Furthermore the site is located close to a local rowing club and Nordjyllands Landbrugsskole and has high opportunity for collaboration and engagement in the community. Today the site contains a farm, which will be disregarded in this project.

Ill. 31.1 - Schools with similar specializations

SITE ANALYSIS

SUROUNDINGS AND DISTANCES

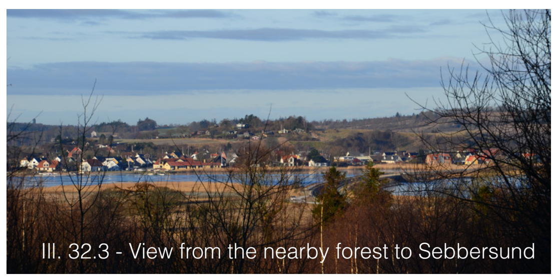
The site is located close to one of the main roads between Thy and Aalborg, which provides easy access to the site by car. It is also possible to get to the site by public transportation and the closest bus stop is placed at the main road only 200 meters from the site. The main road follows the coast and from the site there is only 300 meters to the edge of the water. From the site there is visual connection to Nordjyllands Landbrugsskole which is located 600 meters west of the site. The school is placed on the edge of a small forest area that extents further to the west.

The site is located in between a small town and two villages. Nibe is a town with 5093 inhabitants [Aalborg kommune, 2014], and it is located 3,1 kilometers to the north east of the site. Nibe has a class A marina where 200 boats docks [Nibe-havn.dk, 2016]. In between the site and Nibe, there is a camping area and a local rowing club.

The village of Sebbersund with 362 inhabitants is located 3,4 kilometers to the west of the site and Bislev which have 232 inhabitants is placed 1,1 km from the site. Neither Sebbersund nor Bislev has stores due to their low and declining population.


Ill. 32.1 - View from the road to the fjord


Ill. 32.2 - View from the site to the fjord


Ill. 32.3 - View from the nearby forest to Sebbersund


Ill. 32.4 - View from the road to the site

DISTANCES

Public transport	0,2 km
Shopping	3,1 km
Rowing club	2,4 km
Town	1,1 km
Forest	1,1 km
The fjord	0,3 km

Ill. 33.1 - Point out of nearby locations

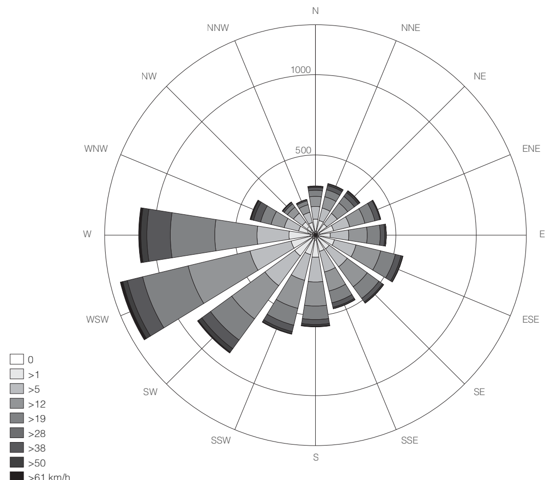
MACROCLIMATE

The Danish climate is categorized as a temperate climate with mild summers and winters where the average temperature during the summer is 16 degrees and the average temperature during the winter is 0,5 degrees. [denstoredanske.dk]

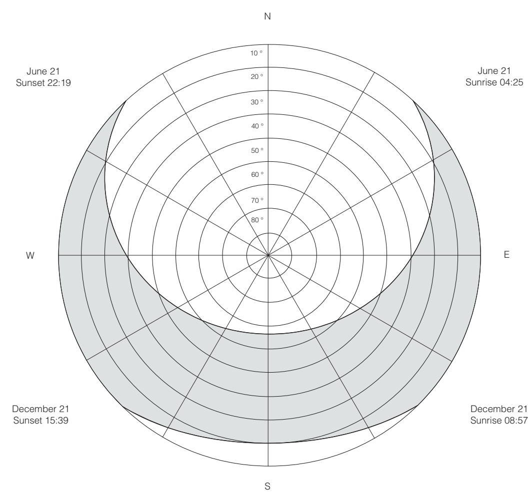
In Denmark, it is common known that the sun rises in the east and sets in the west, but this is only the case in the spring and fall seasons. The days are shorter in the winter, where the sun rises in the south east and sets in the south west, likewise the days are longer in the summer where the sun rises in the north east and sets in the north west. In an average year, there is 1495 hours of sun in Denmark. [rummet.dk]

Nationwide the average yearly wind speed is 5,8 m/s, with a dominant direction from the west. The wind speed and velocity changes with the seasons and is most dominant in the winter. In the context around Aalborg the dominant wind direction is from the west south west. [Windfinder.com, 2016]

The average rainfall in Denmark is 745 mm throughout an entire year, with most rainfall in the fall season.



Ill. 34.1 - Wind rose, average year, Aalborg Airport



Ill. 34.2 - Sun diagram, Danish average year

> “We must begin by taking note of the countries and climates in which homes are to be built if our design for them are to be correct. One type of house seems appropriate for Egypt, another for Spain . . . . one still different for Rome . . . It is obvious that design for homes ought to conform to diversities of climate.”
>
> Vitruvius
> Architect, first century B.C.

MICROCLIMATE

In the field of architecture, the local microclimate is just as important as the indoor environment of a building. The local context in which a building is placed affects the building as much as the building affects it. The macroclimate represents the overall Danish climatic conditions, but it is important to analyze the microclimate to be able to utilize the local conditions in the design process.

TEMPERATURES
The site is placed close to the fjord. The placement by the water affects the climatic conditions, as water has a high heat capacity and doesn't heat up and cool down as fast as the land. The summers will be cooler and the winters warmer as the yearly maximum and minimum temperatures are softened out when the wind carries the milder temperatures from the sea to the land.

WIND CONDITIONS
The wind velocities are measured at the airport of Aalborg where the measuring equipment is placed 10 meters above the ground. The measured velocities have to be adapted to a height closer to the ground and be accounted for the local typography and surroundings. The highest velocity measured in the airport from the west south west is 61 km/h, with the correction to be 1,5 meters above the ground and account of terrain and surroundings, the velocity is 23,63 km/h at the site.

In close connection to the site, there are small wooden areas. These are placed to the north and south west of the site and as the most dominant wind direction in the area is from the west south west, the wooden areas won't provide much shielding from the winds.

The openness to the west south west is optimal in order to utilize the wind pressure as a driving force for natural ventilation. In the fall and early winter the wind comes from a more southern direction, and the wooden area to the south west of the site will provide shielding in this season. The wind break protection will be approximately 3 to 5 times the height of the trees [Sustainable building design manual, 2004], which makes the distance up to 50 meters from the barrier assuming that the land is flat, which it roughly is in this case.

TERRAIN
The terrain is undulating and the site is elevated from the highway north of the site. The noise limit from the highway is reduced due to the sites higher placement and the fact that there are trees between the highway and the site. To the south and south east of the site, the terrain rises, this could affect the amount of solar radiation when the sun is low on the sky in the morning and winter season. To the west and south west of the site, the terrain is steady or lowering, but the wooden area might shade from the low angled sun in the evenings and winter season. In order to visualize the shadowed area, the solar access boundaries are analyzed at the next pages.

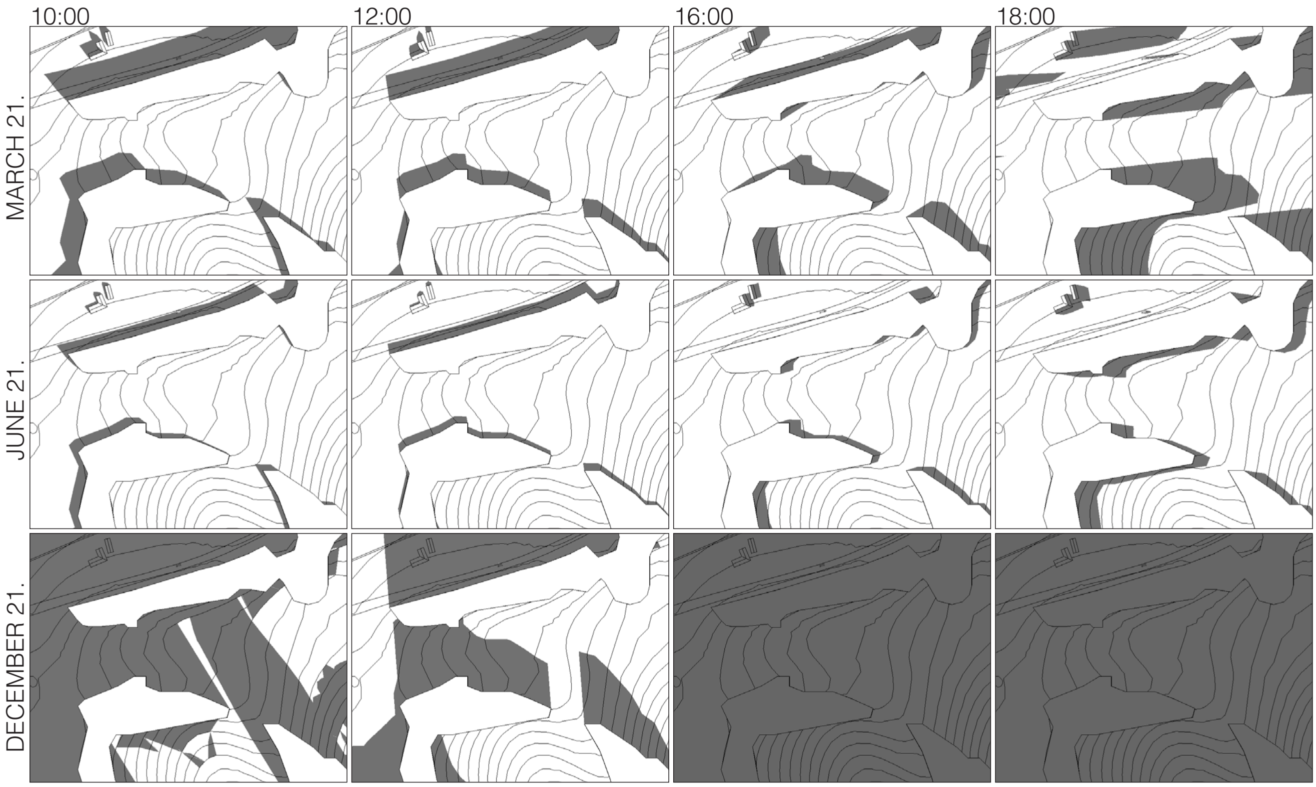
Ill. 35.1 - Section through the site

SOLAR ACCESS BOUNDARIES

In order to be able to design optimal outdoor areas according to solar radiation, and to be able to utilize the solar gains in the building, the solar access boundaries are analyzed to gain knowledge on which areas of the site that are in shadow during the year.

The trees around the site are mature and approximately 10 meters high and they will shade for the soar access to the site differently during the day according to the solar movement on the sky. Furthermore the site is placed in a valley, and the higher ground also shade for the solar access to the site.

The solar access boundaries are visualized for 10, 12, 16 and 18 o'clock at the equinox at the 21st of March and at summer –and winter solstice at the 21st of June and 21st of December. The visualizations make it clear that the solar radiation will reach most of the site in the summer solstice and equinox, while the trees and terrain will shade the site from the solar access of the low angled solar movement in the winter solstice. In the winter, most of the site will be in shadow in the morning and in the afternoon the entire site will be in shadow. In the winter the site will experience most solar radiation around noon in the northern area of the site.



Ill. 37.1 - Solar access studies of the site

SUMMARY

SUMMARY OF THE SITE ANALYSIS

The selected site has multiple advantages regarding its placement in undulating terrain close to the fjord, wooden areas and the town of Nibe. The nearby context and nature is desired to be utilized in the design and elaboration of the facilities for the adventure- and action sports specialization. Due to the placement close to Nibe, there are numerous sports associations to collaborate with and there is great possibility to engage as an active part in the local community.

It will be easy for the students and teachers to get to and from the school due to the highway north of the site both by car and public busses. The site is elevated from the highway and has undisturbed views to the fjord, provided that the wooden area between the site and the road is thinned.

As the site is located in Denmark the climate is temperate and due to the placement close to the fjord, the temperatures will be steady, the summers cooler and the winters warmer than at a site placed further into the land. The wooden areas around the site can be utilized to create pleasant windless outdoor areas if the building is designed with this in matter. The wind will enter the site from the west south west, which is the most dominant wind direction in the area, and this can be utilized as a driving force in the design of natural ventilation. The undulating terrain south of the site and the wooden area south west of the site will have a negative impact on the solar access boundary at the site especially in the winter where the suns movement is low on the sky. In the summer solstice and equinox, the majority of the site is exposed to solar radiation and can be utilized for production of renewable energy sources applying the sun.

PROGRAM

PROGRAM

DESIGN CRITERIA

FLOW
The different functions should be organized to create natural movement patterns in the building.

The common area should be the heart of the building and function as a place for gathering, activity and as well as a distribution space.

The dorm rooms should be directly connected to the common area to ensure easy accessibility and visual overview of the life in the building.

LEARNING ENVIRONMENTS
The learning environments should be flexible to accommodate different teaching methods.

The indoor environment in the learning environments should comply with the demands for indoor climate class A.

INTERACTION WIT CONTEXT
The building should interact with the context and utilize the different levels to create interesting movement patterns.

PRIVACY
The building should offer rooms and spaces with different degrees of privacy to accommodate the physical and mental need of every student.

SUSTAINABILITY
The building should through passive and active strategies be brought to fulfill the building class 2020 energy frame.

The final design of the building should reflect the environmental and social aspects of sustainability.

VISION

The aim for this thesis is to design a sustainable boarding school in close connection with the nature that provides spaces for social interaction, personal development and literary learning. The building should create an environment where the students feel like home and white space for individuality and different forms of socializing. The boarding school should have flexible learning environments where the atmosphere is used to enhance the human senses. The boarding school should contain various functions and it is essential that there is a functional flow in and around the building.

Ill. 43.1 - Weighting of the design criteria

PROGRAM

ROOM PROGRAM

EDUCATIONAL	QUANTITY rooms	UNIT AREA m^2	TOTAL AREA m^2	ACTIVITY LEVEL	DAYLIGHT	VIEW	OCCUPANTS persons	OUTDOOR CONNECTION
Classroom	5	65	325	■□□	■	■	26	□
Creative workshop	1	80	80	■■□	■	■	26	□
Auditorium	1	120	120	■□□	■	■	149	□
Group area	1	130	130	■■□	■	■		□
Physics room	1	80	80	■■□	■	■	26	□
Music room	1	65	65	■■□	■	■	26	□
OTHER								
Administration	1	15	15	■□□	■	■	2	□
Kitchen	1	70	70	■■□	■	■	4	■
Dinning area	1	160	160	■■□	■	■	149	□
Changing room	1	15	15	■■□	□	□	2	□
Common area	1	180	180	■■□	■	■	132	□
Laundry room	2	10	20	■□□	□	□	2	□
Depot	2	10	20	□□□	□	□		□
Technique	2	115	230	□□□	□	□		■
Caretaker office	1	10	10	■□□	■	■	1	□
Caretaker workshop	1	50	50	■■□	■	■	1	■
STUDENTS								
2 person dorm rooms	25	20	500	■■□	■	■	2	□
4 person dorm rooms	20	30	600	■■□	■	■	4	□
TEACHERS								
Guardroom	1	20	20	■□□	■	■	1	□
Preparation room	1	60	60	■□□	■	■	17	□
Teachers office	1	15	15	■□□	■	■	10	□
Principal office	1	10	10	■□□	■	■	1	□
Meeting room	1	40	40	■□□	■	■	20	□

SPORTS FACILITIES	QUANTITY rooms	UNIT AREA m^2	TOTAL AREA m^2	ACTIVITY LEVEL	DAYLIGHT	VIEW	OCCUPANTS persons	OUTDOOR CONNECTION
Handball court	1	800	800	■■■	■	□		□
Gymnastics field	1	400	400	■■■	■	□		□
Climbing wall	1	50	50	■■□	□	□		□
Fitness	1	60	60	■■■	□	□	10	□
Student changing room	2	40	80	■■□	■	□	20	■
Teachers changing room	2	10	10	■■□	■	□	1	□
Toilets	4	5	10	■□□	□	□	1	□
Depot	1	25	25	□□□	□	□		□
Room for soccer boots	1	10	10	□□□	□	□		■

OUTSIDE FACILITIES								
Soccer field	1			□□□	□	□		□
Beach field (Volley/handball)	1			□□□	□	□		□
Campfire	1			□□□	□	□		□
Bicycle shed	1			□□□	□	□		□
Depot	1	15	15	□□□	□	□		■
Adventure storage	1	15	15	□□□	□	□		■
Bicycle workshop	1	20	20	□□□	□	□	3	■

TOTAL NETTO			4290 m^2					
TOTAL GROSS			4925 m^2				149	

PROGRAM

TECHNICAL DEMANDS

EDUCATIONAL	CATEGORY	CO_2 CONC. [PPM]	OP. TEMP. SUMMER	OP. TEMP. WINTER	DAYLIGHT FACTOR [%]
Classroom	A	< 700	24,5 ± 1	22,0 ± 1	> 3
Creative workshop	A	< 700	24,5 ± 1	22,0 ± 1	> 3
Auditorium	A	< 700	24,5 ± 1	22,0 ± 1	> 3
Group area	A	< 700	24,5 ± 1	22,0 ± 1	> 3
Physics room	A	< 700	24,5 ± 1	22,0 ± 1	> 3

OTHER					
Administration	B	< 850	24,5 ± 1,5	22,0 ± 2	> 3
Kitchen	B	< 850	24,5 ± 1,5	22,0 ± 2	3
Dinning area	B	< 850	24,5 ± 2	22,0 ± 2,5	3
Changing room	B	< 850	?	?	-
Common area	B	< 850	24,5 ± 1,5	22,0 ± 2	3
Laundry room	-	-	-	-	-
Depot	-	-	-	-	-
Technique	-	-	-	-	-
Caretaker office	B	< 850	24,5 ± 1,5	22,0 ± 2	> 3
Caretaker workshop	B	< 850	24,5 ± 1,5	22,0 ± 2	3

STUDENTS					
2 person dorm rooms	B	< 850	24,5 ± 1,5	22,0 ± 2	3
4 person dorm rooms	B	< 850	24,5 ± 1,5	22,0 ± 2	3

TEACHERS					
Guardroom	B	< 850	24,5 ± 1,5	22,0 ± 2	3
Preparation room	B	< 850	24,5 ± 1,5	22,0 ± 2	> 3
Teachers office	B	< 850	24,5 ± 1,5	22,0 ± 2	3
Principal office	B	< 850	24,5 ± 1,5	22,0 ± 2	> 3
Meeting room	B	< 850	24,5 ± 1,5	22,0 ± 2	> 3

SPORTS FACILITIES	CATEGORY	CO_2 CONC. [PPM]	OP. TEMP. SUMMER	OP. TEMP. WINTER	DAYLIGHT FACTOR [%]
Handball court	B	-	18 ± 1	18 ± 1	-
Gymnastics field	B	-	18 ± 1	18 ± 1	-
Climbing wall	B	-	18 ± 1	18 ± 1	-
Fitness	B	-	18 ± 1	18 ± 1	-
Student changing room	B	-	24,5 ± 1	24,5 ± 1	-
Teachers changing room	B	-	24,5 ± 1	24,5 ± 1	-
Toilets	B	-	-	-	-
Depot	-	-	-	-	-
Room for soccer boots	-	-	-	-	-
Adventure storage	-	-	-	-	-
Bicycle workshop	B	-	-	-	-

PROGRAM

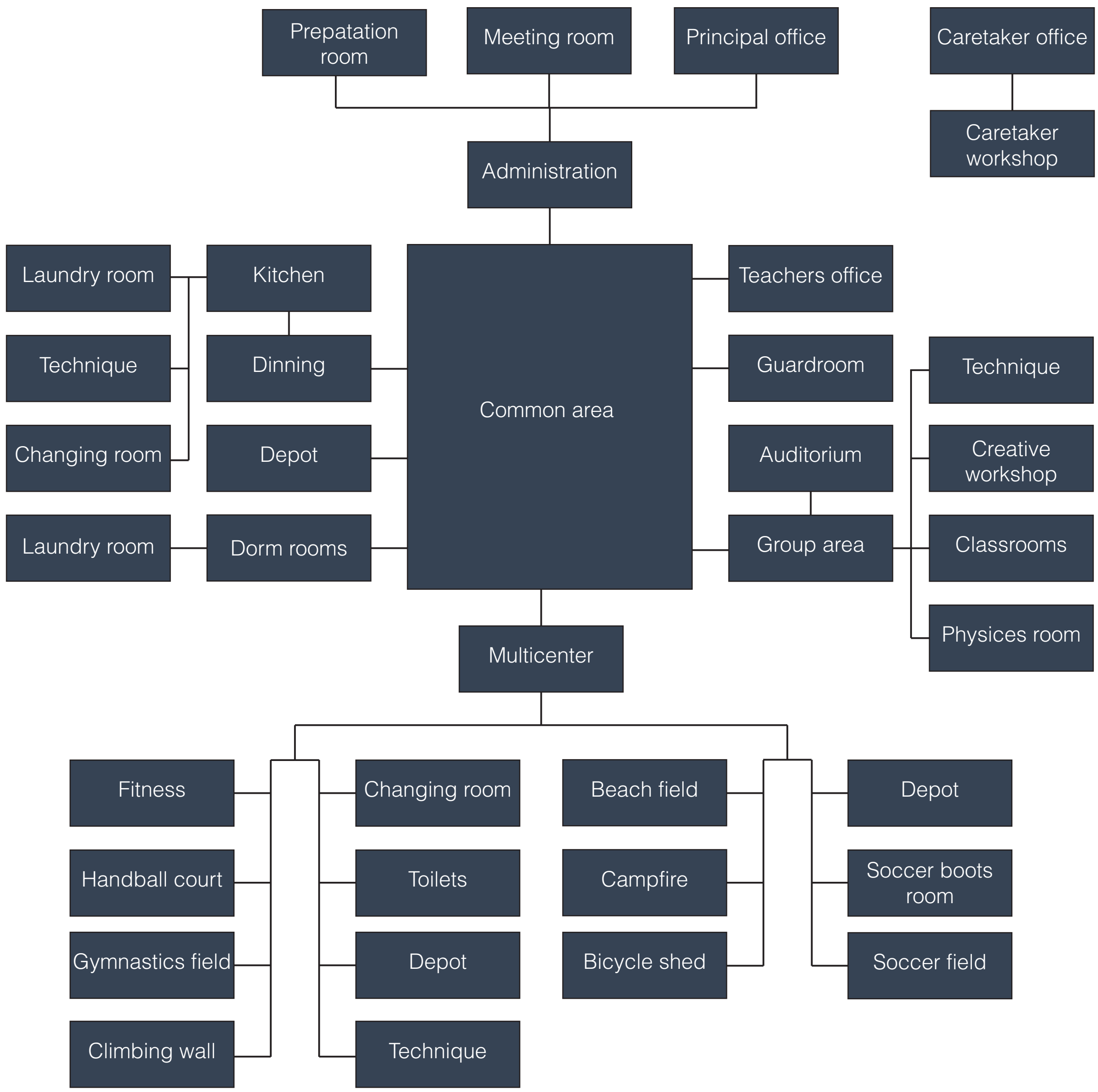
FUNCTION DIAGRAM

The common area is the heart of the building and is closely connected to most of the functions at the boarding school. The common area functions like a living room and should provide areas for different forms of socializing. The students' dorm rooms should be placed right next to the common area in order for it to be the main gathering point for the students instead of them meeting at their rooms. The students spend most of their free time in either the common area or their rooms and therefore the atmosphere in these rooms should be relaxed.

The common room should act like a gathering point, and at the same time a barrier between the learning environments and the dorm rooms. The learning environments are gathered in a section of the building to enhance the abilities for interdisciplinary teamwork and teamwork across classes.

The investigations of the two case studies showed that the teachers office are open for the students, and act like a niche of the common area where students and teachers can retreat from the main common area. This room is therefore very important in order to establish the close connection between the teachers and students. The guardroom is thought to be placed in close connection to the common area so the teacher staying overnight always is close to the students.

The student attending boarding schools with focus on sports are often very focused on it and the multicenter is therefore not only used as a part of the education, but also by the students in their leisure. The multicenter is a gathering point of all the sports activities and it should be placed in connection to the common area. By minimizing, the distant from the common area to the sports facilities makes it more attractive for the student to use the facilities outside school hours.



Ill. 49.1 - Function diagram

SUMMARY

SUMMARY OF THE PROGRAM

The new boarding school will be designed for 120 to 130 students, in the age of 15 to 17 years old. The school is going to specialize in soccer, handball and adventure sports with outdoor activities. To attract students to the school, it needs good facilities for the specializations and an architecture that engages the students to socialize and give them a feeling of belonging.

Social activities should be supported through attractive common areas. This should be achieved through spaces for different needs and with different atmospheres. The social aspect at boarding schools is dominant, and some students will have a need to retreat to a quiet place where they can be themselves for a while. Furthermore the common area needs to have room for all the students, and provide niches where smaller groups can gather.

The desire to have an adventure line, set some demands to the placement of the school as nature and outdoor activities is needed. The chosen site is placed near the fjord, wooden areas and fields. 2,5 kilometers from the site, there is a rowing club that the school can engage with and enable the students to use the fjord.

A school that specializes in soccer needs to provide facilities that can be used during the entire year regardless of the weather. As the school also specializes in handball they will need a handball court too. Furthermore a fitness area is necessary for general physical improvement, but also in case of injuries and the need of rehabilitation. For students in 8^{th} and 9^{th} grade it is mandatory to have general physical education, and a modern boarding school will therefore need a separate gymnasium for these lessons so they don't interfere with activities at the handball court.

PROCESS

SHAPE STUDIES

INITIAL STUDIES

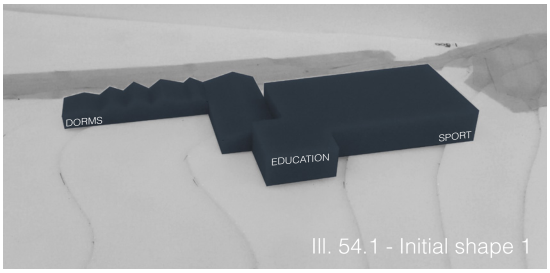
The first ideations derive from the closest surroundings, the view to the fjord and openness to the south.

The illustrations are an extract of the different ideations that was made and illustrates different ways to relate to the terrain and context. Furthermore the different ideations work with aspects of how to divide the different functions from each other and how the overall shape of the building will frame the settings and divide the site into different zones.

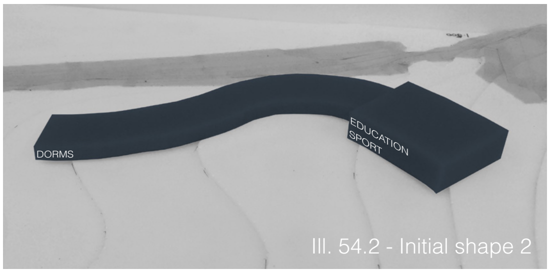
During the modeling phase of the first design proposals the technical, functional and aesthetic parameters were included to evaluate the ideations. The technical parameters include sustainable considerations of daylight, natural ventilation and implementation of renewable energy sources. The functional parameters concern the division and separation of the different spatialities in the building volume while the aesthetic parameter regards the architectural expression and the buildings relation to the terrain and context.

The ideations work with different ways to divide the functions and different architectural expressions that each has potential to either relate to or contrast with the terrain.

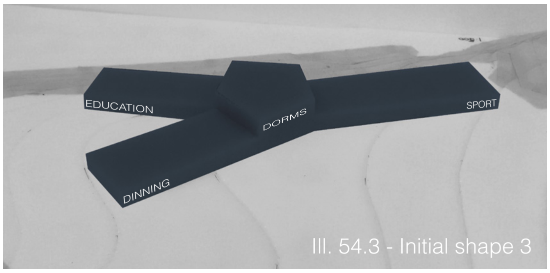
The analysis and initial studies generated a desire to work with a unified building volume.



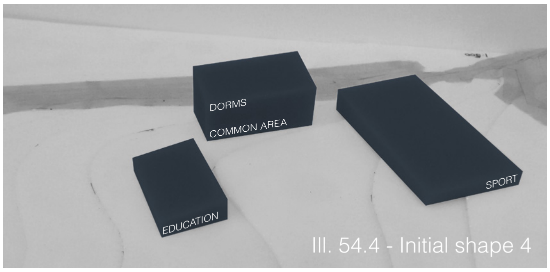
Ill. 54.1 - Initial shape 1



Ill. 54.2 - Initial shape 2



Ill. 54.3 - Initial shape 3



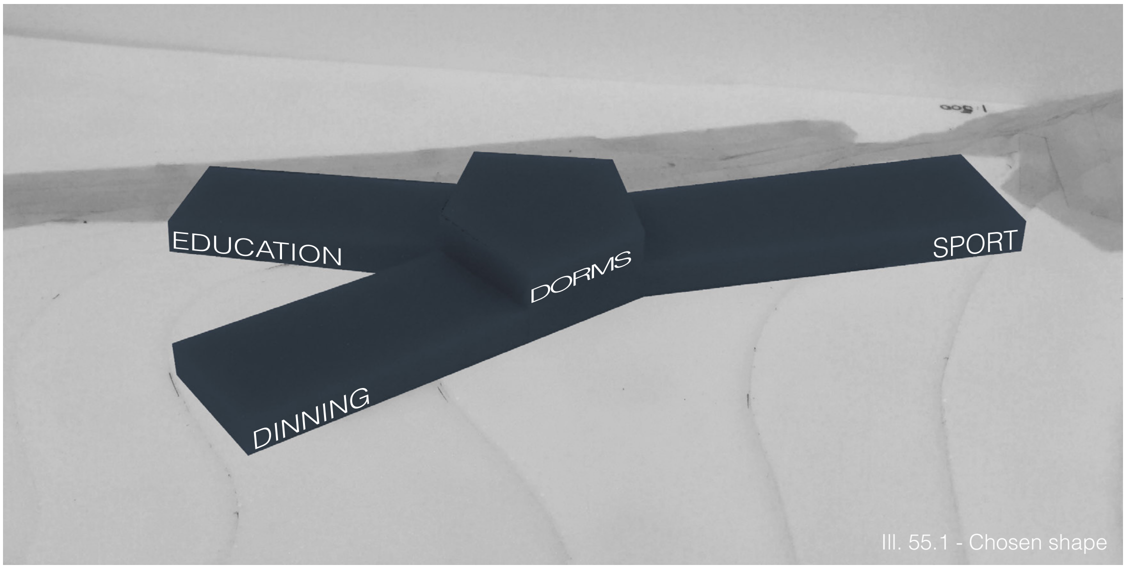
Ill. 54.4 - Initial shape 4

CHOICE OF SHAPE

The chosen shape separates from the others as it has a clear division between the different functions but still is a unified volume. This allows the students to walk around the school without the need to go outdoors in uncomfortable weather to move between functions. The common area literary becomes a connector for every function in the building both physical and visual and thereby it become the heart of the building. The favor of this form is the possibility to arrange the dorm rooms in stories around the common area and thereby create an internal atria.

The building volume breaks the large outdoor area down and defines tree smaller areas. The angle of the building volumes to the west underlines the entrance area as it leads visitors in by the narrowing angle.

The current state of the model demands processing of the levels in the terrain and the overall shape of the main building to make it look more integrated. Furthermore the shape of the roofs needs processing to relate to each other and the context.



Ill. 55.1 - Chosen shape

SHAPE STUDIES

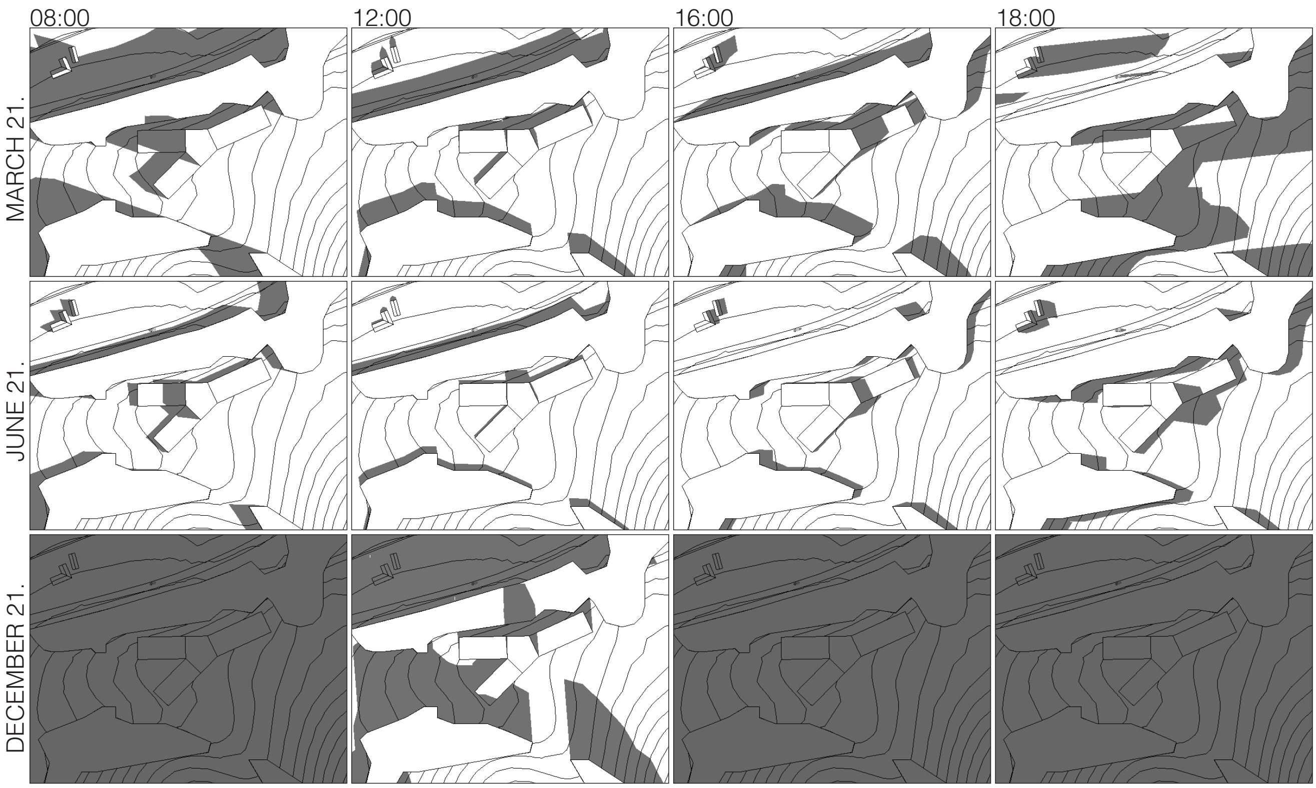
SUN AND SHADOW

The overall shape of the building is analyzed according to the suns movement to observe how the building volumes shade for each other and the surroundings.

The three wings of the building are one floor high with flat roofs while the main part of the building is extended to be four floors high also with a flat roof. The analysis is made for equinox, summer and winter at four relevant time intervals according to the everyday life at the school. They show that the main building will cast shadows on the north western wing in the morning hours. The building will unavoidably cast long shadows because of its height and volume, but the shape of the main building will affect the area of the shadow, and should therefore be further developed. The analysis gives indications of how the roofs could be adapted without interfering with the solar incidences.

The outdoor areas will have plenty of sun hours during the days in the equinox and summer where it is natural to be outside. It will be possible to utilize the evening sun around the two western wings of the building in the equinox and summer as the building and wooden areas won't cast shadows on the outdoor areas west of the building. If the outdoor areas to the west should be utilized it is important to remember that the areas is very exposed to the western winds.

In relation to implementation of renewable energy sources it is possible to install photovoltaic- or solar heating panels on the southern facade as it will be exposed to the solar radiation most of the day in the equinox and summer months. Furthermore the roof of the main building and the south western wing could be adapted to photovoltaic- or solar heating panels as they are exposed to the solar radiation the entire year with almost no shadows on them.



Ill. 57.1 - Solar access studies with the building at the site

SHAPE STUDIES

PROCESSING THE OVERALL SHAPE

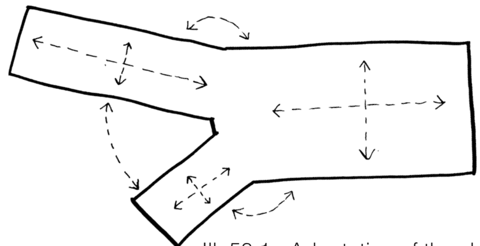
Subsequent the analysis of the exposure to the sun, the building volumes were processed according to the volumes' angles according to each other as well as their length, depth and placement in the terrain. This was done from an inside/out perspective where the spatialities were arranged in the tree wings and the main building.

The main building was also processed from an outside/in perspective as the overall expression of the building should have a coherent expression and appearance. It has been studied how different shapes affect the overall appearance and how the hierarchy between the different volumes likewise changed. A rectangular shape relates the main building to the other volumes while a circular, triangular or divergent form creates a strong contrast.

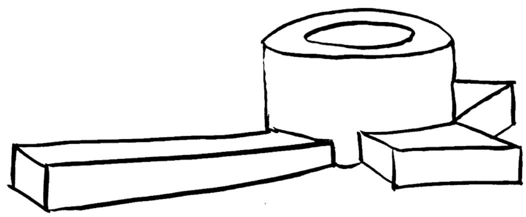
The building volumes were also processed according to each other in relation to the outdoor spaces they create and embrace. Towards south, the two wings form a space that is exposed to the sun during most of the day, and at the same time is sheltered from the winds because of orientation of the south western wing.

The two wings facing north create a great surface area with possibility for views against the fjord and Nibe. This facade will be the one visible from the road, and therefore be the public image of the school.

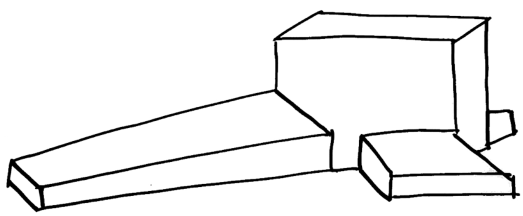
The two western wings create a natural movement towards the main building which clearly frames a natural entrance area.



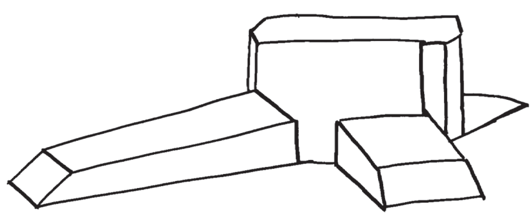
Ill. 58.1 - Adaptation of the shape



Ill. 58.2 - Volume study of the main building



Ill. 58.3 - Volume study of the main building



Ill. 58.4 - Volume study of the main building

SHAPEMENT OF THE ROOFS

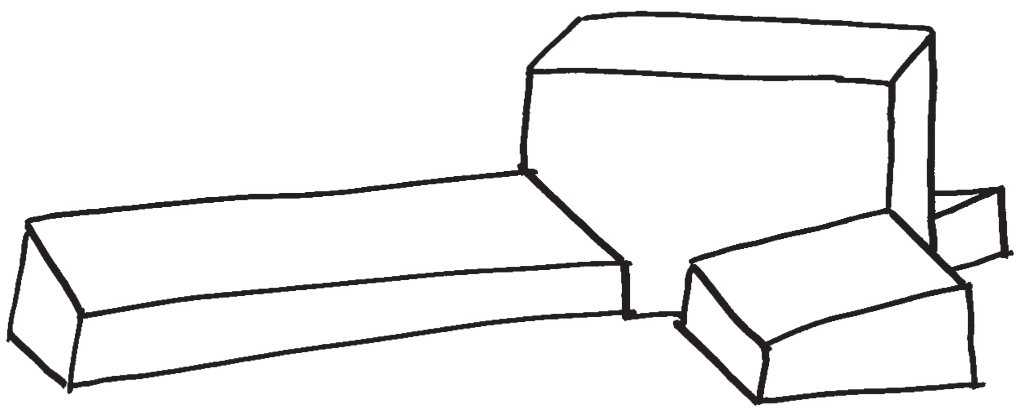
The sloping of the roofs was processed in different ways. The studies clarified that a single sided slope maintained the simplest expression and the different ways to design a single sided slope were studied further.

With a positive slope from the main building towards the ends illustrated at Ill. 58.2 creates an open expression and it enhance the height of the main building.

Negative slopes from the main building towards the ends illustrated at Ill. 58.3 create a sensation of grasping the nature. This principle was also adapted to make the ends connect with the ground illustrated at Ill. 58.4 which enhanced the sensation of bringing the nature over the building while it also makes it possible for people to walk on the roofs.

Another version with single sided slopes were tested ill. 59.1 This study has the slope on the long indent of the roof. This principle creates orientations towards the outdoor area south of the building and the view to the fjord north of the building. With the lowest point of the slope being inwards, the framing of the entrance area became more dominant and open at the same time.

The roof of the main building should have a sympathetic layout to contrast to the lower building volumes.



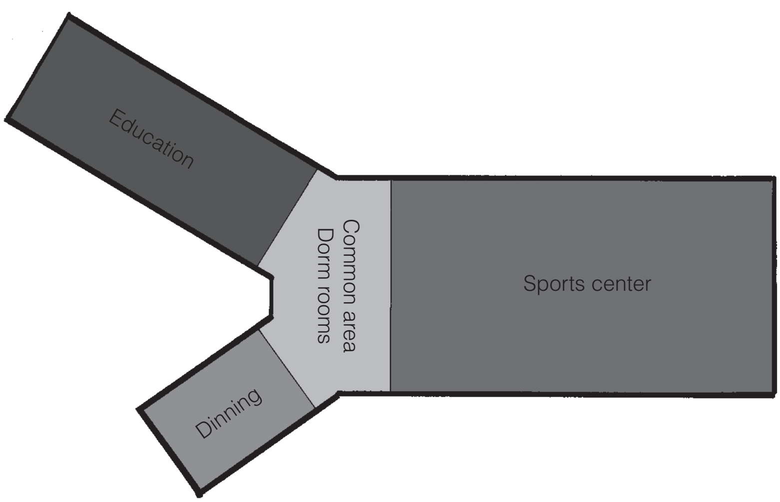
Ill. 59.1 - The chosen expression

SHAPE STUDIES

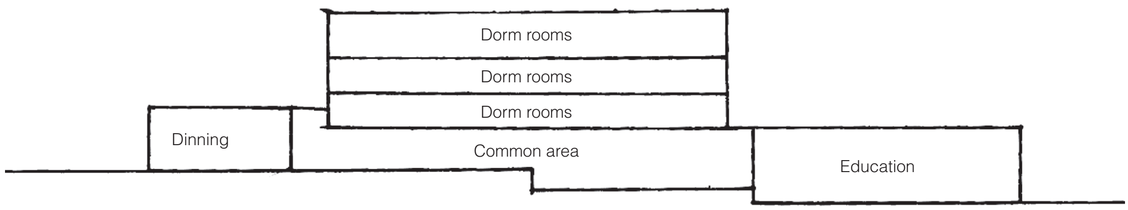
ORGANIZATION

One of the main design criteria is to have a clear division between the different spatialities, but at the same time have easy access between them. The overall shape of the building emphasizes this by having four volumes, the north western wing for education, the south western wing for dinning, the eastern wing for sport and the middle and main part of the building for common facilities and dorm rooms.

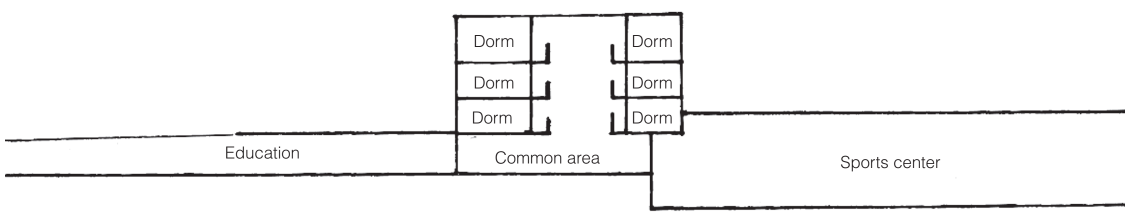
The middle building is the heart of the school, it is vertical orientated with dorm rooms on the tree upper floors and a common area on the ground floor. This creates a vertical organization in the building regarding privacy, as the upper floors are more private than the ground floor which is a shared space for everyone in the building. The dorm rooms are placed around an internal atrium which allows visual and physical contact between all the dorm rooms. The bottom of the atrium is the common area which acts like a distribution space between every part of the building.



Ill. 60.1 - Organization of functions



Ill. 61.1 - Cross section



Ill. 61.2 - Longitudinal section

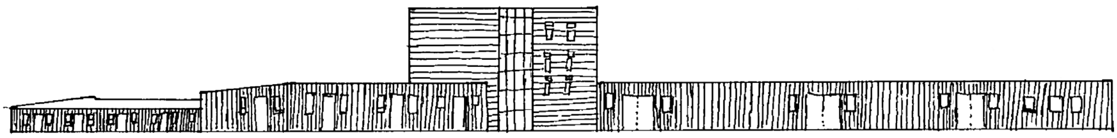
FACADE MATERIALITY

It has been studied how different materials creates different expressions of the building. The materials should interact with the nature and compliment the building volumes.

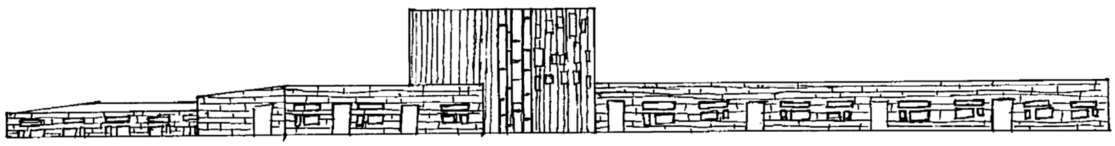
The orientations of the lower volumes are longitudinal with the terrain due to their proportions, while the orientation of the main volume is less defined, but with a desire to make it rise from the ground, a vertical cladding is preferred.

Horizontal cladding for the lower volumes could be bricks, wooden planks or fiber cement boards. A uniform material like concrete or a plastered facade would also appear horizontal due to the length of the volumes.

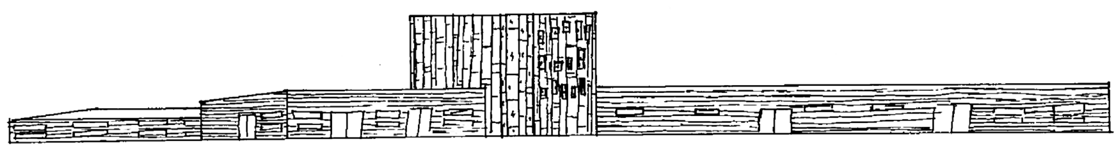
Vertical claddings could be fiber cement boards, slim concrete elements or wooden lamellas. The thin and high proportion of wooden lamellas enhance the height of the building the most, while it also make the building look light and natural.



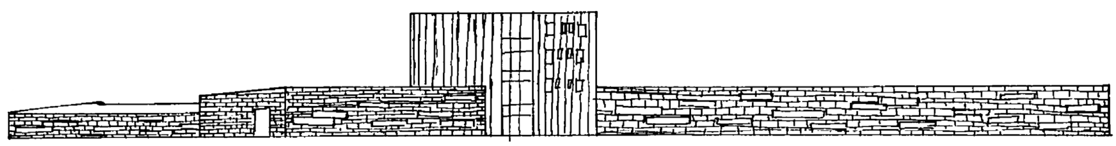
Ill. 63.1 - Facade with wooden lamellas and planks



Ill. 63.2 - Facade with fiber cement boards and wooden lamellas



Ill. 63.3 - Facade with wooden lamellas and fiber cement boards



Ill. 63.4 - Facade with brick and wooden lamellas

ROOM STUDIES

LEARNING ENVIRONMENTS

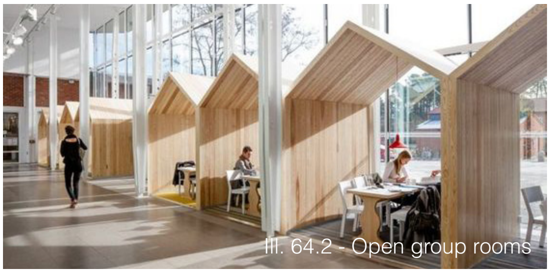
The physical learning environments should accommodate different learning principles, and the different needs of the student. As the school specializes in sport and movement, the didactics and physical environment must additionally also enhance movement and exercise. With frequently changing didactics comes a need for different spatialities.

There should be classrooms for gathering, group rooms for contemplation and common rooms for debate and educational activities. The students are divided into 5 classes that each should have a classroom where they can retreat and receive regular classroom lessons where the teacher is in focus. The classrooms are seen as a place where knowledge can be gained, shared and evaluated.

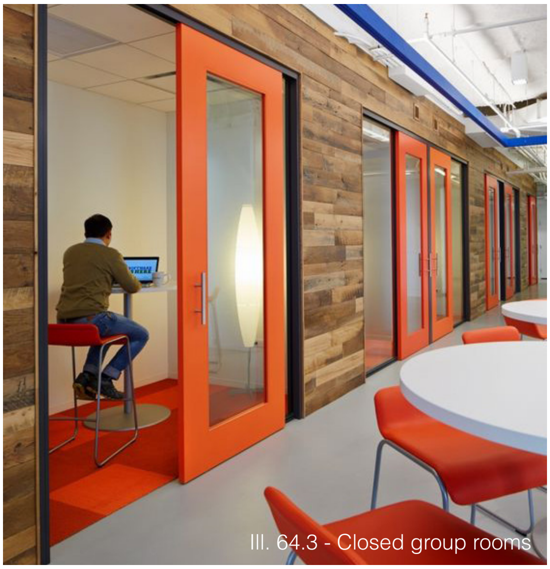
To ease the ability for the teachers to teach across classes, the walls between the classrooms are sliding folding walls. The ability to merge the classrooms together creates a great common area where the students and teachers can inspire each other. The walls not only create multifunctional spaces, they also function as whiteboards. Thus the possibility to furnish the rooms for the different conditions with every student being able to see the whiteboard is numerous. The great amount of whiteboard area can also benefit the students' assignments, as they can use the boards in the problem solving phase.

In addition to the possibility to open up the classrooms, the educational wing also contain a permanent group area with places for studies either individual or in smaller groups. The room enhances contemplation and the ability to gain new knowledge. The rooms should therefore provide spaces where students can retreat and immerse on their assignments.

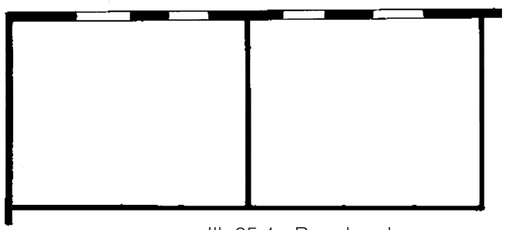
Ill. 64.1 - Whiteboards as dividing walls

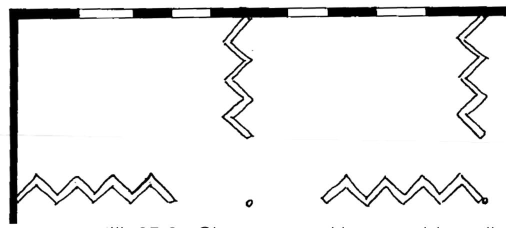


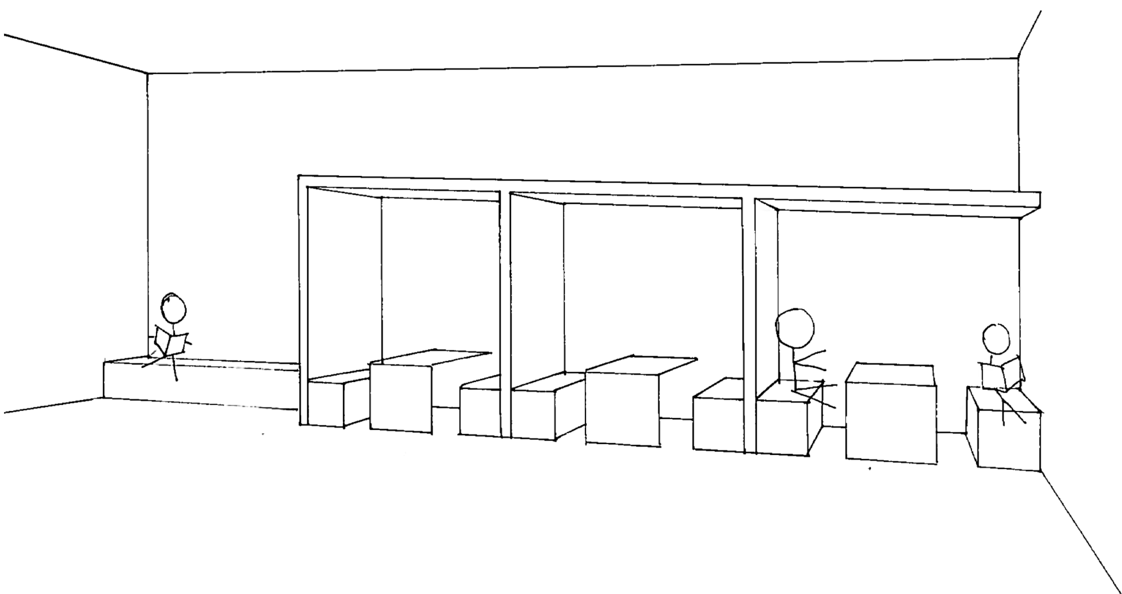
Ill. 64.2 - Open group rooms



Ill. 64.3 - Closed group rooms


Ill. 65.1 - Regular classrooms


Ill. 65.2 - Classrooms with moveable walls


Ill. 65.3 - Sketch of group area

ROOM STUDIES

COMMON AREAS

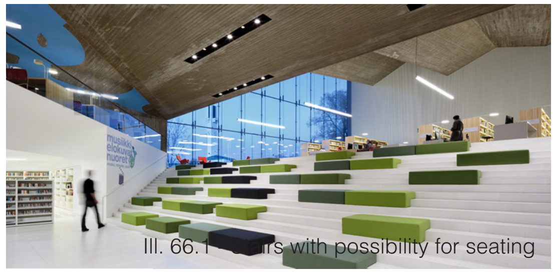
The common area is the heart of the building. It is the place where guests enter the building for the first time, so it should be open and inviting to welcome them. When the guest arrive, they will experience atrium more voluminous the farther into the room the get. The common area is a large transit area as it connects the different building volumes and spatialities.

The common area also needs to contain different activities and spaces for gathering in small and larger groups. At a school where 130 students are gathered all day, there will be a need for smaller spaces to retreat in order to spend time alone or in smaller groups. The different levels in the common area divides the great open room into smaller parts where some naturally becomes suitable for smaller gatherings.

As the common area is a central place in the building, it would be ideal to be able to gather all the students at once in this space. The room have different levels the ability to integrate seating in the steps between the levels has been investigated.

The space will have an atrium that connects all the floors, and an open staircase brings both visual and physical qualities to the space as both horizontal and vertical activity in the room would be visible from each floor.

The profile of the school is very active, and it is desired to highlight this in the architecture and interior design. The height of the atria encourages to be utilized for some kind of activity, and a climbing wall will be a good way to utilize the height. Furthermore there will be a need for a safety mat in the bottom, which will provide an inviting space for the students to hang out and relax.

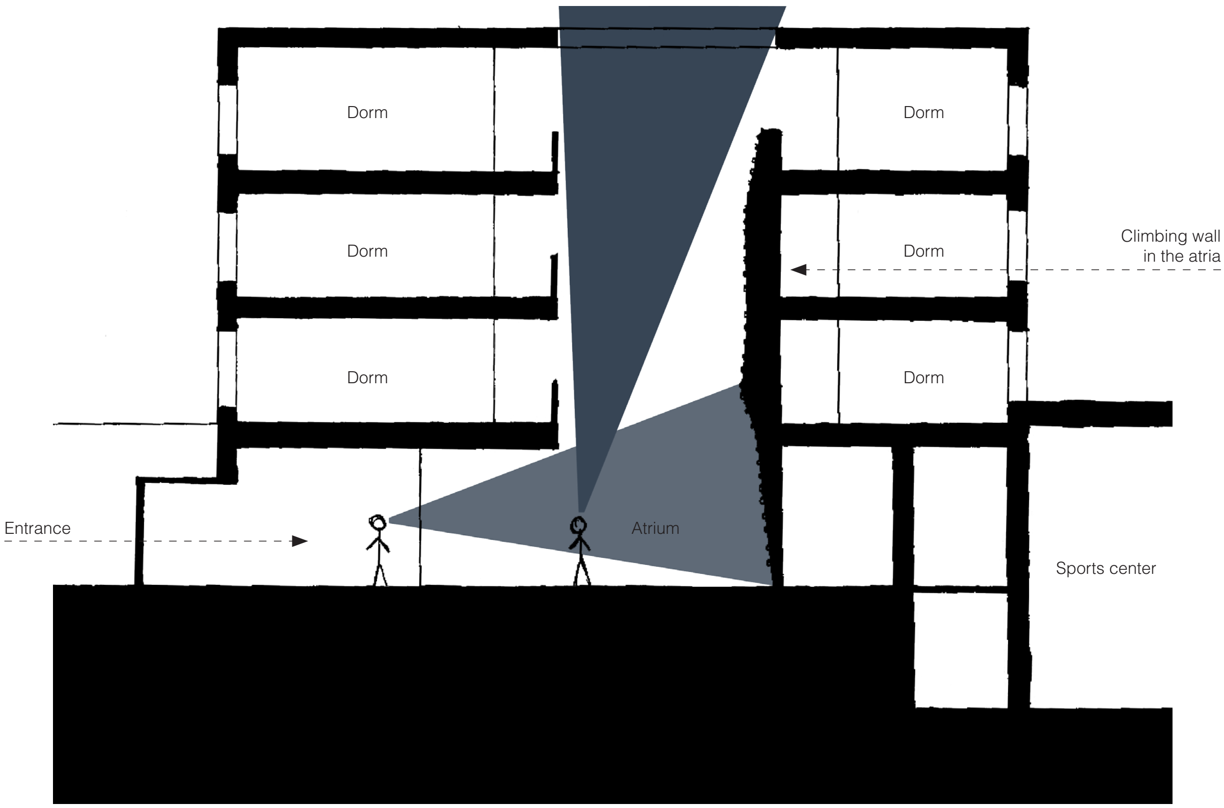


Ill. 66.1 - Stairs with possibility for seating

Ill. 66.2 - Materiality

Ill. 66.3 - Climbing wall in an atrium

Ill. 66.4 - Private niche



Ill. 67.1 - Cross section in the common area

Visual field when entering the building.

Visual field when going further into the building, the atria impresses the guest by its dominating size.

ROOM STUDIES

THE DORM ROOMS

The students should have a place with a sense of belonging and a place to call home while they are at the school. The dorm rooms are a private space where students can retreat if they need to spend time alone or in smaller groups.

To help enhance the feeling of home and belonging, it is important that the students have ability to decorate the room and put a personal touch to it.

The dorm rooms need space for beds, desktops and storage while each room also should have an associated toilet and bathroom. The rooms should have plenty of floor area and seem open, bright and modern. A way to save space on the floor is to furnish the rooms with modern bunk beds. To avoid the sensation of scout houses, it is desired to create light fixed furniture's along the wall. The rooms should also have places for the students to do homework and projects individually at their own desktop.

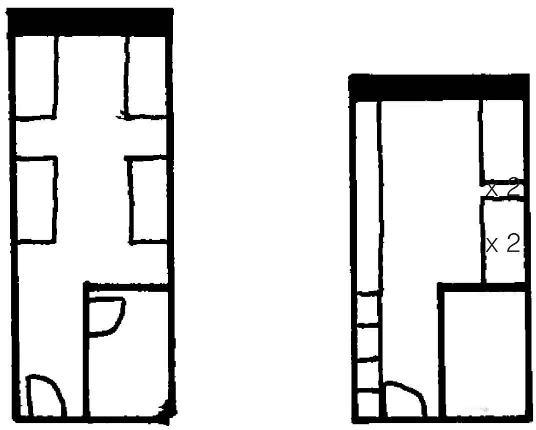
To help the students have order in their rooms, the integrated furniture could have space for storage so it is easy for them to put away their things and make the room look clean and neat.

Ill. 68.1 - Integrated furniture

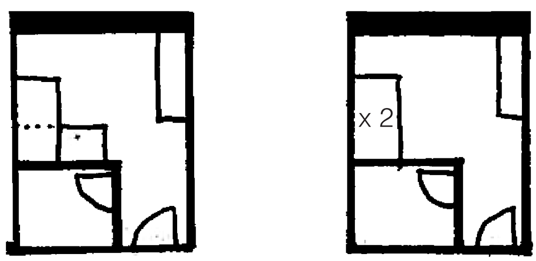
Ill. 68.2 - Seating in windowsill

Ill. 68.3 - Integrated furniture

Ill. 68.4 - Minimalistic bunk beds



Ill. 69.1 - Ideations with furnishing of four person dorms



Ill. 69.2 - Ideations with furnishing of two person dorms

ROOM STUDIES

THE SPORTS CENTER

Sport and movement is a great part of the school profile and the handball court is therefore an important facility that would be in use every day for multiple hours. Opening between the common area and the sports center integrates the sports in the design and stages the activities at the court by clear visual contact between the spaces.

The locked proportions of a handball court make it beneficial to build it into the terrain. The shift in levels can with a great advantage be utilized for spectator seats to distinctly stage the activities at the court, which is valuable during tournaments and events. In the everyday life at the school, the tribune can be used for various exercises and seating during breaks. By placing the handball court in the ground, the height of the building above ground decreases which are beneficial for the dorm rooms above it according to window areas and daylight conditions.

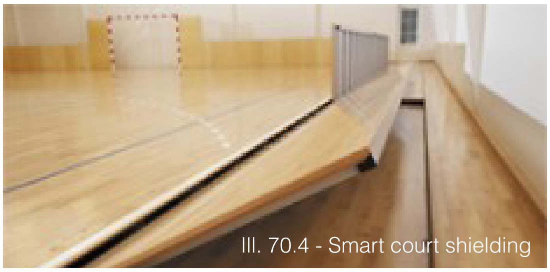
The sports center should also contain a gymnasium, a fitness center, locker rooms and storage space for utensils and gear for the two halls.

Shielding for the court to use when playing indoor soccer, can be integrated in the floor to minimize the need for storage and at the same time ensure a fast shift between the setup for handball and indoor soccer. Another advantage of choosing this way of shielding the court is the limited noise level when hitting it with a ball compared to the traditional shielding methods that rattles and makes loud noises.

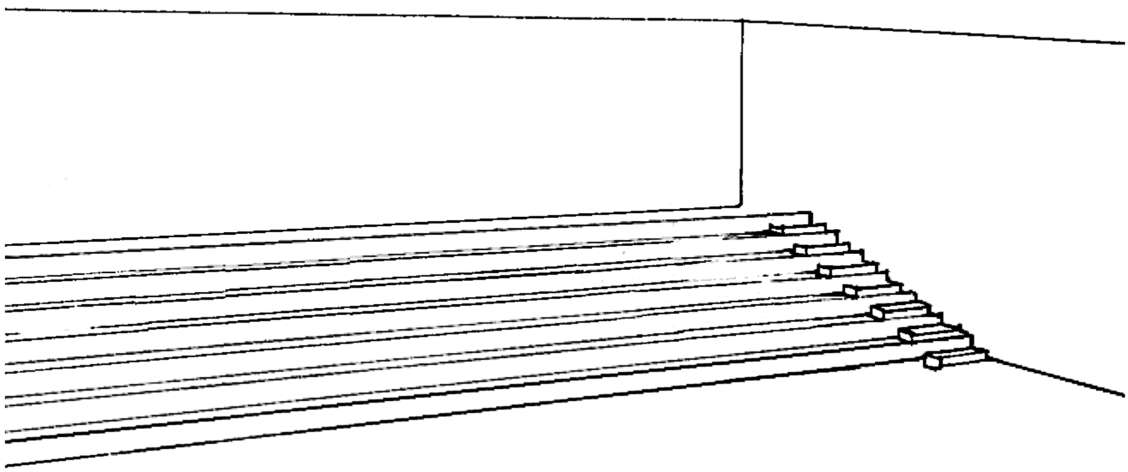
Ill. 70.1 - Simple tribune

Ill. 70.2 - Modern gymnasium

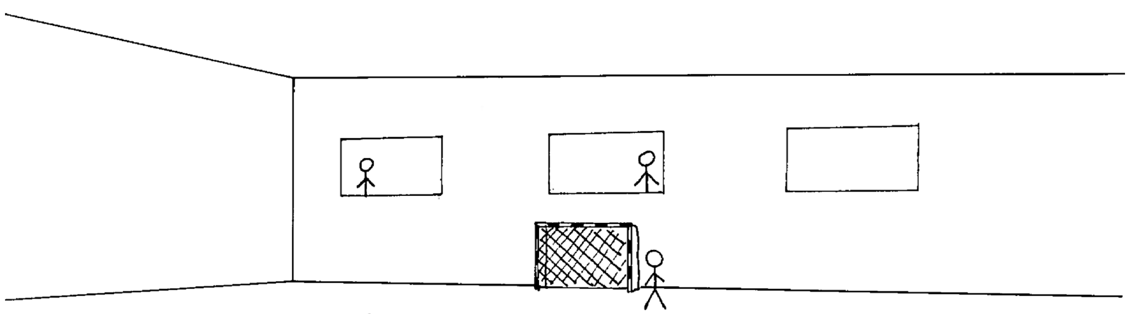
Ill. 70.3 - Modern gymnasium



Ill. 70.4 - Smart court shielding



Ill. 71.1 - Ideation with shape of tribune



Ill. 71.2 - Idea of visual contact from the common area to the sports center

ROOM STUDIES

OUTDOOR SPACES

The orientation of the building volumes defines tree outdoor areas respectively against north, south and west. The outdoor areas must include a soccer field, facilities for the action and adventure specialization, a fireplace, multiple open areas for stays in the sun and smaller private spaces where couples and smaller groups can retreat.

The wooden area north of the building is dense and needs to be thinned and controlled. It should still appear dense, but lower and more inviting as it is a part of the view to the school from the nearby road. Furthermore it should be possible to overview the fjord from the northern oriented rooms.

The building volumes facing south frame and embrace the nature. The area is shielded from the wind and directly against south which means it will have good conditions according to stays. Furthermore the area is visible from the common area and atria and it would therefore be an ideal place for the soccer field to have visual contact from the building. The wooden areas south west of the building appear wild and untouched, it is desired to equip this area with climbing facilities and mountain bike tracks with respect of the nature.

The arrival to the site is from the west where the building volumes stage the entrance and direct visitors towards the entrance area. The terrain slopes from the entrance to the site and upwards towards the building, this frames the building as it gets more visible the closer once get. The building volumes adjoining the entrance area are placed in different levels, and an adaption of the terrain has been an important parameter when developing the entrance area to allow satisfying window areas and daylight levels in the educational rooms facing south.


Ill. 72.1 - A private space


Ill. 72.2 - A place for two


Ill. 72.3 - Mountain bike track in forest

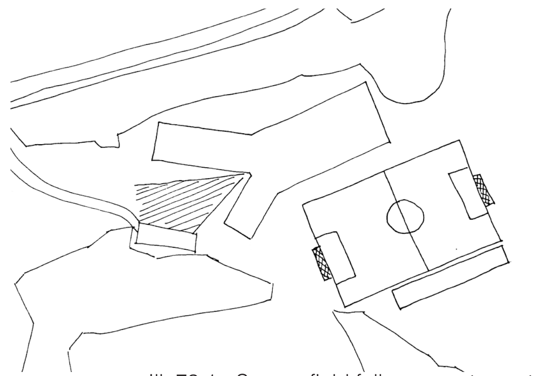

Ill. 72.4 - Climbing track in forest

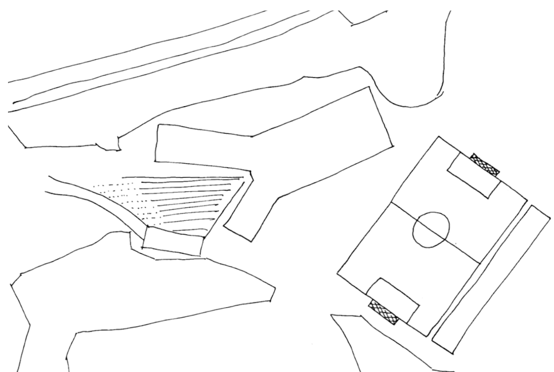
The first ideation works with the soccer field following the facade of the sports center. This creates a long and narrow area in between the building and the soccer field that would be an odd area to utilize. Near the dining area there would be plenty of space to have terraces and seating, but this would be behind the goal for the soccer field, and the place wouldn't invite for spectators to the soccer games. Instead the ideation works with a tribune south of the field integrated in the sloping terrain.

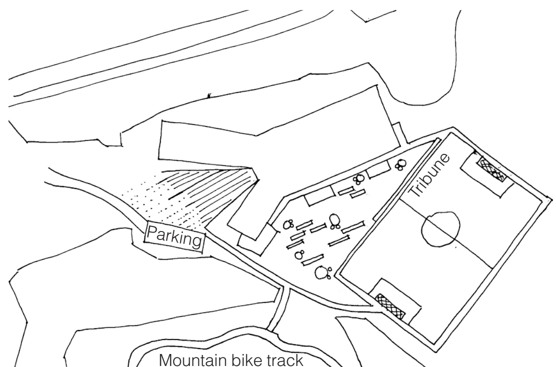
The second ideation works with another orientation of the soccer field that follows the dining wing. This creates a greater area in between the building and the soccer field that would invite for stays during soccer games, but also during the day, as the area would be shaded for the winds from west, and at the same time be exposed to the sun most of the day.

The third ideation works with a placement of the tribune along the longitudinal side to the north of the soccer field in order to provide better conditions for the spectators according to solar exposure as people would rather sit on a slope or bench with the sun in front of them than behind them. The area between the building and the soccer field are adapted and broken up with grouped seating areas but still with the thought to have grass areas that can be used for multiple purposes.
The great area south of the site is very undulating which would be an advantage for a mountain bike track with multiple challenges with different levels of difficulty.

The paving in the entrance area is thought to follow the orientation of the building volumes to open up against the access way and parking lot which is placed in an area that is in shadow most of the day.


Ill. 73.1 - Soccer field follows sports center


Ill. 73.2 - Soccer field follows dining wing



Ill. 73.3 - Adaption of the outdoor area

TECHNICAL STUDIES

INTRODUCTION

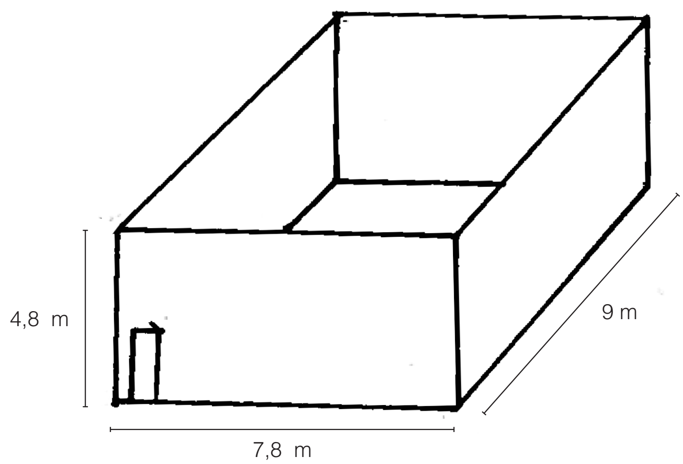
The main method used to develop the project is the integrated design process why it has been important to consider the technical aspects of the project early in the process. The technical aspects affect the design process and clarify the possibilities and challenges the different initiatives may involve.
The technical studies are done simultaneously with the shape and room studies and have been an important part of the decisions made in connection with the design.

The goal is to achieve category A regarding the indoor climate in the classrooms. One of the classrooms has therefore been studied in relation to atmospheric, thermal, and visual comfort. Furthermore one of the dorm rooms has been studied similarly. In addition to the studies of the indoor climate in the two rooms, the energy performance of the entire building has been studied to clarify how the different approaches affect the energy frame.

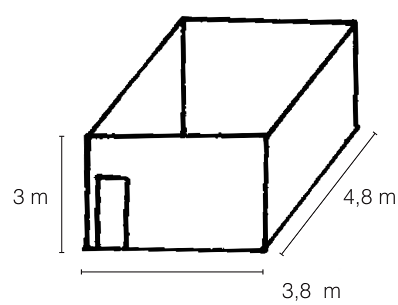
A standard classroom must, according to the Danish building regulations have a volume of at least 12 m^3 per adult. Thus the volume should be 324 m^3 but as the students at boarding schools are young, it can be accounted that the volume can be slightly lower per student.

The dimensions of the rooms for the technical studies are defined as:

	Classroom	Small dorm
Room width	7,8 m	3,8 m
Room depth	9 m	4,8 m
Room height	4,5 m	3 m
Area	71 m^2	18 m^2
Volume	320 m^3	54 m^3



Ill. 75.1 - Classroom



Ill. 75.2 - Small dorm room

ENERGY AND INDOOR CLIMATE

The buildings performance is verified through two separate simulation tools.

Be15 is a monthly calculation tool that is developed to demonstrate the energy requirement of a building on a yearly average. The program can help secure a good energy balance by clarifying different possibilities and challenges with the building in the design process. The energy frame constitutes of energy for heating, ventilation, cooling and domestic hot water.

The simulations are done under stationary conditions and require information about the building envelope, internal heat supply, the heating and ventilation system, hot water supply and renewable energy sources.

The initial Be15 simulations show that the total energy requirement of the building is 52,4 kWh/m^2 year which is unacceptable according to the 2020 energy requirements of 25 kWh/m^2 year for a public building. It is possible to have a supplement to the energy frame for special conditions as the normal usage time, ventilation rate and lightning level is very high compared to the fact that it isn't a residential building. This supplement is calculated to constitute 28,7 kWh/m^2 per year and make the energy requirement 53,7 kWh/m^2 per year instead of 25.

The energy demand can be brought down by solar shading and hybrid ventilation to avoid and remove excess temperatures in the building and thereby decrease the energy demand.

The thermal indoor environment is demonstrated through the simulation tool BSim. The simulations are done based on a design reference year and compared to Be15, this program is more detailed as the results go down to hourly values. The simulations are based on information about the building envelope, windows and solar shading. Furthermore the program needs clarification about the usage of the building, which is entered in several systems.

To evaluate the quality of the indoor climate, the temperatures and CO_2 concentration are compared with different categories. The temperatures must not exceed 26 degrees more than 100 hours per year and 27 degrees more than 25 hours per year [DS474, 1993]

ENERGY FRAME 2020	
Total energy requirement	52,4 kWh/m^2 year
CONTRIBUTION TO THE ENERGY REQUIREMENT	
Heating	10,0 kWh/m^2 year
Electricity for operation of building	23,8 kWh/m^2 year
Cooling	3,6 kWh/m^2 year

	CLASSROOM	SMALL DORM
EXCESSIVE TEMPERATURES		
Hours above 26 deg.	1365 hours	275 hours
Hours above 27 deg.	954 hours	71 hours
CO_2 CONCENTRATION		
Category A	23,12 %	12,68%
Category B	22,23 %	3,28 %
Category >B	54,65 %	84,04 %

DAYLIGHT AND WINDOW AREA

It is important to utilize the natural light in buildings to ensure a good visual environment for work and learning. A high amount of natural light will decrease the demand for artificial lightning and thereby also the energy demand. To utilize the daylight in the best possible way, different window configurations are tested with Velux Daylight Visualizer to clarify the necessary area and layout of the windows in the facade.

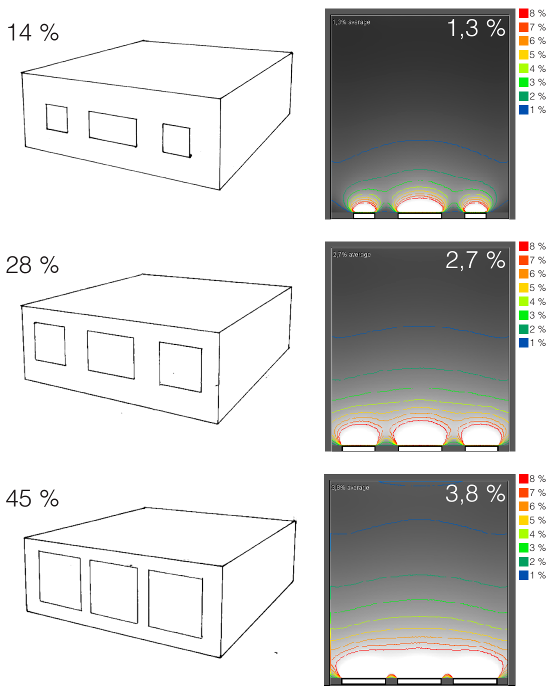
This chapter presents the analysis of the classroom with a standard room height of 2,5 meter. It is the goal to achieve a daylight factor of minimum 3% and it is therefore tested how great a window area that is needed.

The sketch and associated analysis, ill. 78 - 1 to 6, shows that the window area needs to be between 35 to 40% of the facade area to reach an average daylight factor above 3% in the room.

When investigating the possibility to break up the window areas to create a more coherent and horizontal expression of the windows, with a long window placed high in the facade, it slightly decreases the daylight factor, but it is still above the desired 3% in ill. 78 - 7 to 12.

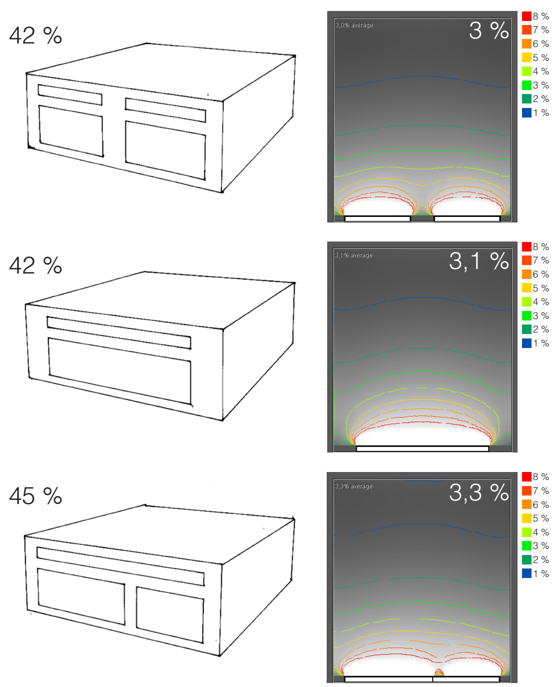
The results of the analysis shows that the higher the windows are placed, the further into the room the daylight gets.

WINDOW AREA



Ill. 78 - 1 to 6 - Daylight analysis in classroom

WINDOW LAYOUT



Ill. 78 - 7 to 12 - Daylight analysis in classroom

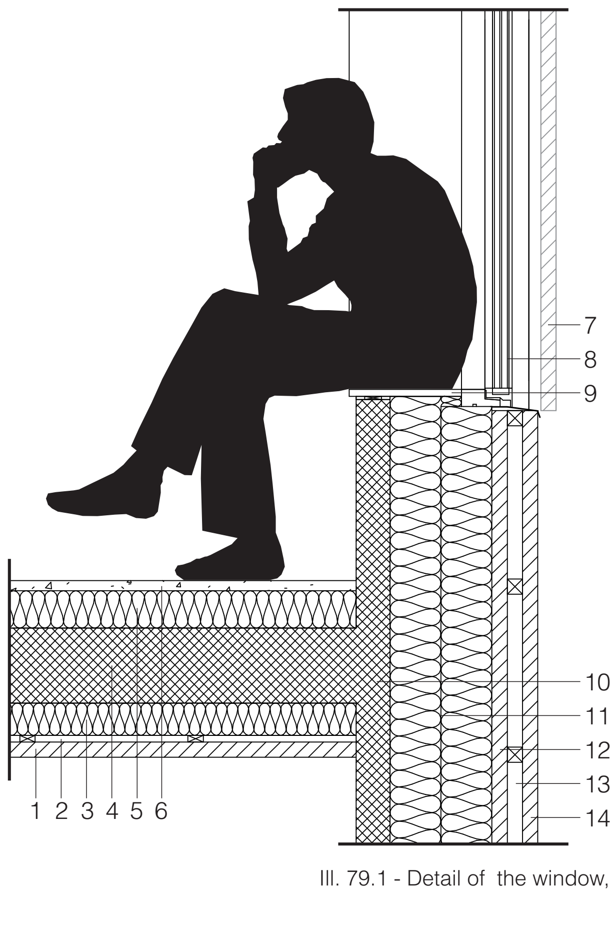
WINDOW DETAIL

As a part of the passive design strategies, the facade construction is insulated with 300 mm Rockwool to ensure a low u-value and lower the buildings energy consumption. The thick layer of insulation makes the facade 490 mm thick. When the window is placed near the exterior side, the windowsill obtains a depth which is pleasant to use as a place to sit. To enhance the windowsill as a furniture, the cavity in the wall is framed with a prominent wooden cladding.

The detail Ill. 79.1 illustrates how the windowsill functions as a furniture in the dorm rooms. The principle is also used in the classrooms, where the windows are greater and has room for several students.

The detail also illustrate shutters on the exterior side of the wall, these are used as solar shading while they also creates character and dynamics in the facade. The shutters will be further explained in the next pages.

1 45 mm wooden lamella
2 20 mm lath / air space
3 95 mm rockwool
4 220 mm reinforced concrete
5 110 mm rockwool
6 30 mm concrete floor
7 Exterior wooden shutter
8 Window with 3 layer-glazing
9 Wooden window sill
10 100 mm concrete
11 300 mm rockwool
12 45 mm wooden lamella
13 45 mm lath / air gap
14 45 mm wooden lamella



Ill. 79.1 - Detail of the window,

SOLAR SHADING

The initial simulation of the indoor climate clarifies a need of cooling in the classrooms but also in the dorm rooms. The most sustainable ways to decrease the cooling demand is to avoid excessive temperatures in the building. This can be done through optimization of window specifications and solar shading.

When optimizing the window specifications, there is a balance point between getting too much heat in and letting too much heat out. After finding this balance point there is still excess heat in the building and it is therefore optimal to introduce solar shading.

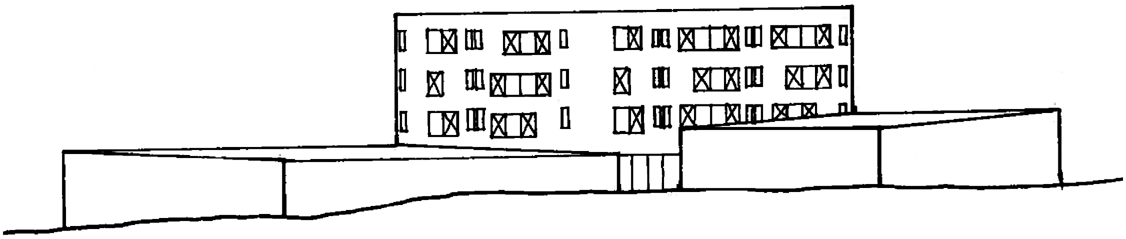
The classrooms facing south will in some extent be shielded from the low angled morning sun due to the volume of the main building and in the evening when the sun is angled low in the sky again it is outside the usage time of the rooms. This means that the main percentage of the shading device should shield the windows from the high angled sun in the middle of the day. This could be done by one or multiple horizontal blades, an outrigger system, external shutters, external blinds or blinds integrated in between the layers of glass in the window.

As the outdoor area between the classrooms and the dining wing is the main entrance area for the building, it isn't desired to have elements protrude from the facades and the solution with blinds integrated in between the layers of glass in the window are chosen for these windows.

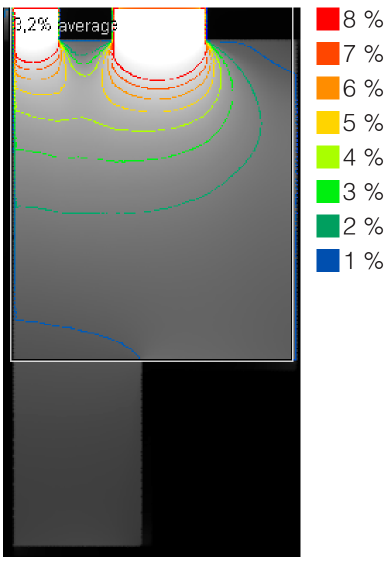
The dorm rooms have a more differentiated time of use than the classrooms and they are oriented towards east and west. They will therefore need shading that protects from the low angled sun in the mornings and evenings. This could be vertical or slanted vertical fins, external shutters, external blinds or blinds integrated in between the layers of glass in the window.

As the main building has many similar windows with multiple repetitions, it is decided to have external shutters with vertical fins to allow daylight in and views out when the shutters are placed in front of the windows. The shutters will create a dynamic facade that varies throughout the day.

The shutters should be able to be away from the windows and the window area is therefore changed. This has an effect on the daylight factor in the rooms which is therefore simulated once again to support that the shutters are a valid solution. With the slightly decreased window area, the daylight factor is 3,2% in average in the occupied zone, which is above the desired level.



Ill. 81.1 - Western facade with shutters



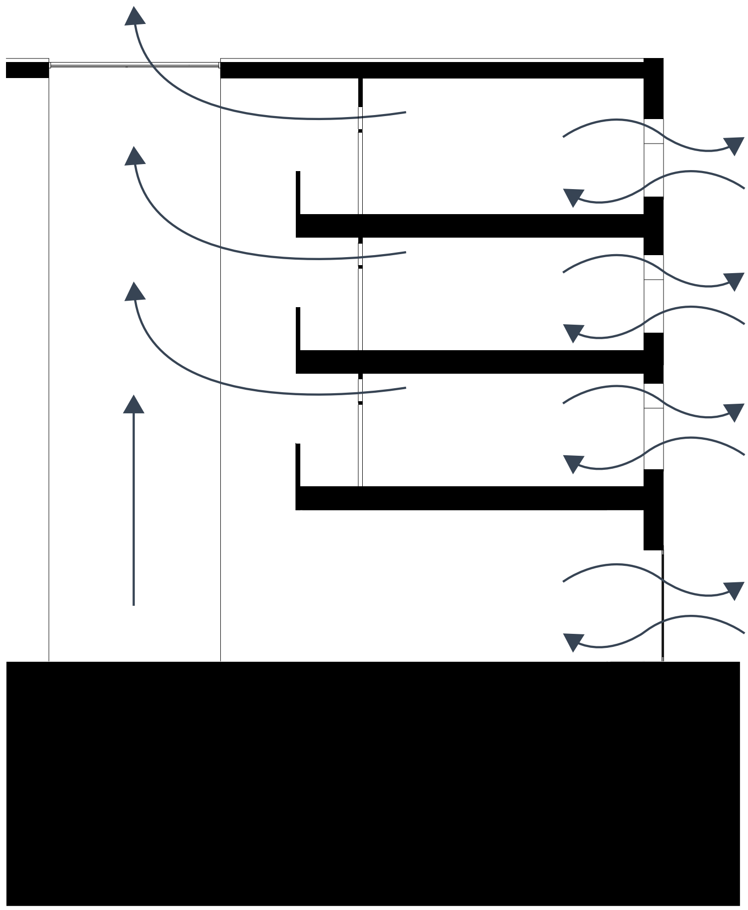
Ill. 81.2 - Daylight analysis of the dorm with new windows

NATURAL VENTILATION PRINCIPLES

It is ideal to utilize the high atrium with openings in the top to ventilate the common area and dorm rooms with buoyancy as a driving force. With an opening above the door to each room, the warm air would move towards the atrium and out of the openings in the roof.

The dorm rooms could also be ventilated with pressure differences as a driving force due to their orientation against east and vest with pressure on the western facade and suction on the eastern facade.

The classrooms are oriented almost parallel with the wind direction, which isn’t optimal according to pressure differences on the facades and the difference would be relatively low and the air change rate would consequently rely more on the air movement caused by temperature differences between the room and the outdoors.



Ill. 83.1 - Natural ventilation principles in the dorm rooms and common area

THE FACADES AND THE ENERGY FRAME

After optimizing the window area and adding solar shading to the facades, the excessive temperatures have decreased significantly but never the less the temperatures are still too high.

The natural ventilation in BSim are set to be controlled automatically when the temperatures exceeds 24,5 degrees in the summer and 22 degrees in the winter. With the solar shading and decrease of excessive temperatures, the need for natural ventilation decreases too. This affects the CO_2 concentration in the rooms, which slightly increases with the implementation of the solar shading.

The demand for cooling is still high, and when analyzing the results in Be15, it is clear that the southern oriented windows and the glazed areas in the atrium collects a great amount of passive heat. The roof of the atrium is therefore also adapted to let the daylight in, but keep the solar gains out.

The tall glazed area facing south isn't optimal according to the energy frame, as it is hard to shield from the sun while obtaining unobstructed views to the outside and it will therefore let a lot of heat into the building during the day. Solar shielding for this type of window could be external blinds or blinds integrated in between the layers of glass in the window. It is desired to have great views through this window area during the entire day, and no solar shading is therefore added to the window.

ENERGY FRAME 2020	
Total energy requirement	51,4 kWh/m^2 year
CONTRIBUTION TO THE ENERGY REQUIREMENT	
Heating	10 kWh/m^2 year
Electricity for operation of building	23,8 kWh/m^2 year
Cooling	2,5 kWh/m^2 year

	CLASSROOM	SMALL DORM
EXCESSIVE TEMPERATURES		
Hours above 26 deg.	144 hours	138 hours
Hours above 27 deg.	24 hours	24 hours
CO_2 CONCENTRATION		
Category A	20,27 %	11,81 %
Category B	19,43 %	2,51 %
Category >B	60,30 %	85,68 %

VENTILATION

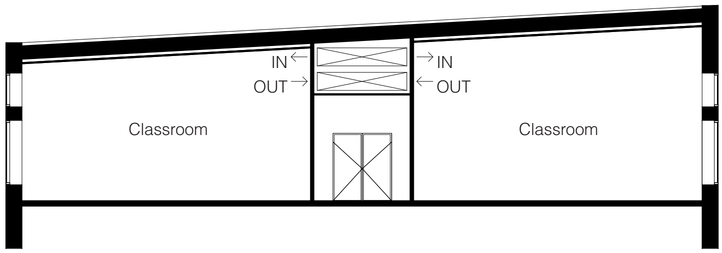
It is desired to hide the ventilation pipes above suspended ceilings, and the dimensions of the different pipes are therefore determined. The pipes are dimensioned to allow the necessary air flow to every room, but without the risk of noise problems. The calculations of the pipe dimensions can be found in appendix 3.

Due to the high air flow rates, the sectional area of the pipes is quite big and it is therefore decided to have rectangular pipes as they are a better fit above the suspended ceiling.

The ventilation system is a centralized low pressure system placed in between the sports center and the common area. From its central placement, the pipes are placed in the ground below the floor of the common area and brought up in a storage room in the education wing and in a handicap toilet in the dining wing. The pipes for the dorm rooms are brought up in connection with the elevator shaft. A plan of the piping is attached in appendix 4.

It is desired to use mixing as the ventilation principle in the classrooms and dorm rooms. This is where air is blown in with high velocity outside the occupied zone. As the classrooms are desired to have folding walls, the supply and extraction needs to be placed either in the ceiling or high in the wall and to maintain a high ceiling it is decided to supply and exhaust the air through openings in the wall just below the ceiling. To minimize the amount of pipes, they are placed above the central hallway and can service the rooms on both sides at once.

The ventilation system controls excess temperatures and the CO_2 concentration in the entire building and thereby improves the indoor climate. But as the exhaust and inlet is controlled by a fan, the ventilation system consumes energy that contributes adversely to the energy frame, which is why the total energy requirement has increased by applying the ventilation system.



Ill. 87. 1 - Section through two classrooms

ENERGY FRAME 2020	
Total energy requirement	57,8 kWh/m^2 year
CONTRIBUTION TO THE ENERGY REQUIREMENT	
Heating	12,7 kWh/m^2 year
Electricity for operation of building	27,8 kWh/m^2 year
Cooling	0,0 kWh/m^2 year

	CLASSROOM	SMALL DORM
EXCESSIVE TEMPERATURES		
Hours above 26 deg.	84 hours	50 hours
Hours above 27 deg.	14 hours	3 hours
CO_2 CONCENTRATION		
Category A	99,23 %	63,97 %
Category B	0,13 %	5,89 %
Category >B	0,64 %	30,14 %

RENEWABLE ENERGY SOURCES

The building has been improved as much as it can by passive initiatives and ventilation to secure a good indoor environment and is still just above the 2020 energy requirements.

The biggest contribution to the energy frame comes from electricity to operate the building. The energy that is added to the building in form of district heating and electricity is weighted differently. The primary energy factor for district heating is 0,6 while it is 1,8 for electricity. This means that electricity have a greater impact on the energy requirement than heating and therefore it would be a good idea to produce renewable energy to cover the high demand.

Photovoltaics create renewable electricity and are chosen for the project. During the design process it has been considered how the shape and layout of the building would be suitable to exploit the sun to produce heat or electricity for the building. The building has a great facade area facing south and two rooftops suitable for photovoltaics, this being the roof on the educational building and the main building. It is desired to have a uniform expression of the visible rooftops and facades, so due to aesthetical reasons the southern facade and the roof on the educational wing are excluded as possible placements of the photovoltaics. This leaves the roof of the main building as the most suitable placement.

As the rooftop isn't visible from the outside areas or rooms in the building, there are no visual preferences according to colors, materiality or layout of the panels. It is decided to have polycrystalline panels as they are the most efficient compared to price.

The available area for the photovoltaics at the roof is at a maximum 669 m^2, but the maximum amount of energy that can constitute to the energy frame in Be15 is 25 kWh/m^2 year. This demand can be covered by 170 m^2 of photovoltaics on the roof. The peak power of the modules is calculated in appendix 6.

ENERGY FRAME 2020	
Total energy requirement	36,8 kWh/m^2 year
CONTRIBUTION TO THE ENERGY REQUIREMENT	
Heating	12,7 kWh/m^2 year
Electricity for operation of building	17,8 kWh/m^2 year
Cooling	0,0 kWh/m^2 year

SUMMARY

SUMMARY OF THE DESIGN PROCESS

The overall shape is chosen due to its clear conceptual division of functions and the way it implies and treats the common area. The conceptual shape rethinks boarding school architecture with the different and innovative placement of dorm rooms around an internal atrium.

The sun and shadow studies clarifies that the building volume doesn't shade for itself during the majority of the day and that the outdoor areas around the building are irradiated by the sun in the periods they preferably would be used.

The further treatment of the building volume adapts the building to the landscape and outdoor areas in a simple and respectful manner. The sharp and straight lines of the building make it a contrast to the soft terrain. With a treatment of the facades materiality a clean and calmed expression that compliments the orientations of the terrain is obtained.

The different spatialities are treated with care and creativity to make the most of the spaces. Multifunctional and adaptable spaces with a contrast in between open/closed create the diverse spaces that is desired. Inspirational pictures ads spatial understanding of the thoughts, materiality and furnishings of the different rooms.

The building are designed from the integrated design process with the technical aspects developed in parallel with the architectural once. Throughout the process, the different approaches effect on each other has been related to the indoor climate and the energy frame of the building. With solar shading, mechanical ventilation and photovoltaics on the roof, the building obtains an indoor environment and a energy demand within the established demands for the project.

PRESENTATION

PRESENTATION

MASTERPLAN

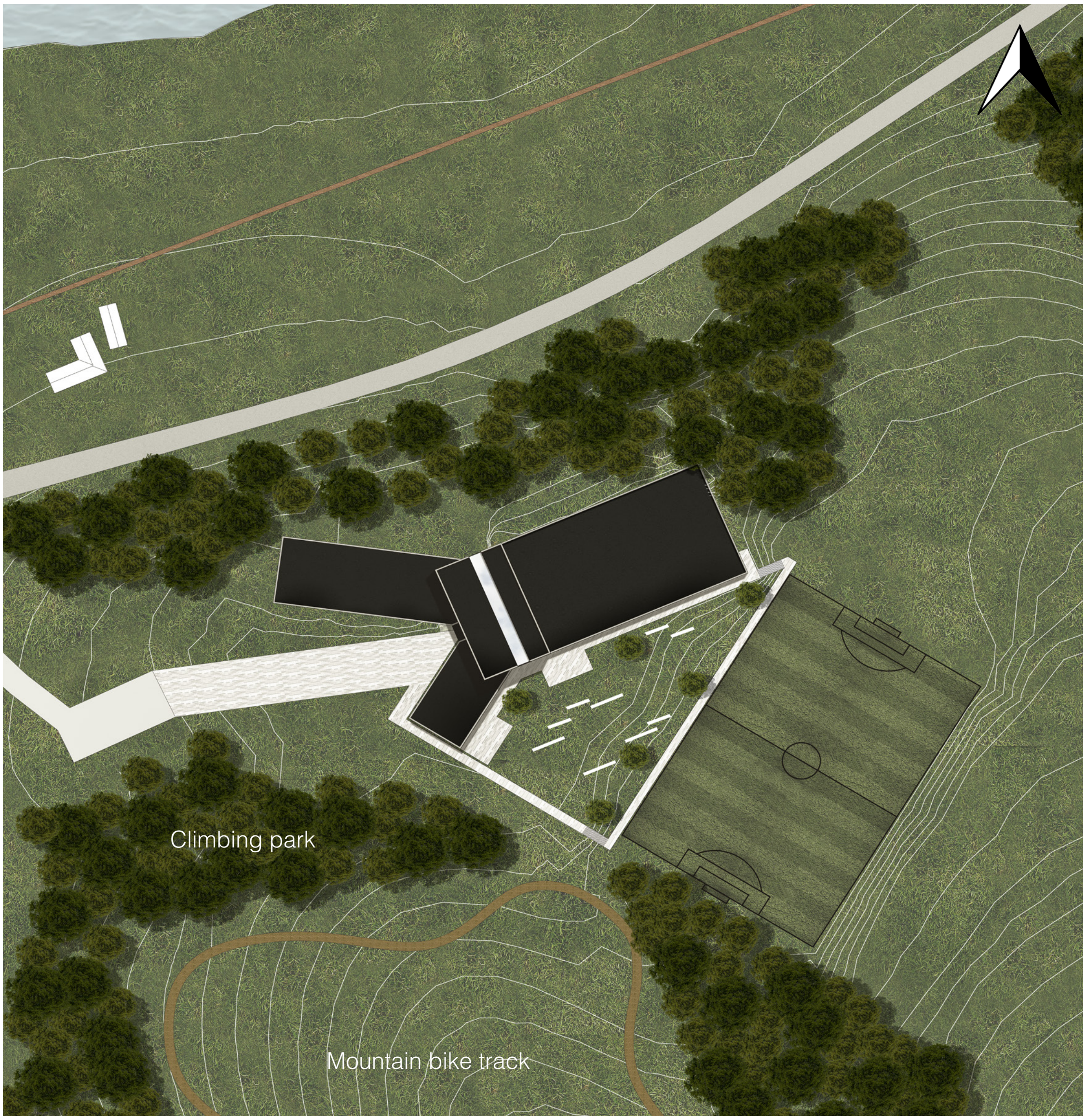
With the placement at a relatively remote location near Nibe at a site lifted from the access way, the approach to the site and building is an experience in itself. The building is designed with this in matter, and the distinctive form amplifies the experience of approaching the building. The form of the school derives from an idea of dividing the internal functions physically from each other.

The three building volumes divide the previous undefined area into three minor parts. The area towards west is the above mentioned approach and entrance for the building.

The northern area is the foreground that stages the building viewed from the road passing the site. This area is a controlled, but natural wooden area with openings that ensure views to the fjord from the building and further frames the building when viewed from the road. When passing the site, the building appears dominant and voluminous due to the proportions.

The southern area is the main outdoor area with good climatic conditions to ensure opportunities for pleasant stays. The area contains open grass areas for diverse use, niches for gathering in smaller or larger groups, terraces for dining outside and the important soccer field which is staged by sloping terrain.

The wooden areas surrounding the site frames and embraces outdoor facilities for action and adventure sport with a mountain bike track in the undulating terrain and climbing areas in the forests.



Ill. 95.1- Masterplan

ARRIVAL

The main road that leads to the site moves along the coast between Nibe and Sebbersund which creates positive frames for the arrival. When watching the building from the road it appears iconic in the beautiful natural surroundings and when the visitors and users turn away from the main road into the site, the building seems greater and higher the closer they approach.

The building volumes frames the entrance by their angulation according to each other and the slope of the roofs which are lower towards the entrance area and rises with a unilateral inclination towards respectively north and south.

The building is entered through a weather porch that ensures the building from drafts associated with the entrance being placed against west. When people enter the building for the first time, they are entering a big open atrium where they are greeted by a receptionist behind a desk directly next to the entrance.

Ill. 97.1 - Perspective from the road

Ill. 97.2 - The entrance area

COMMON AREA

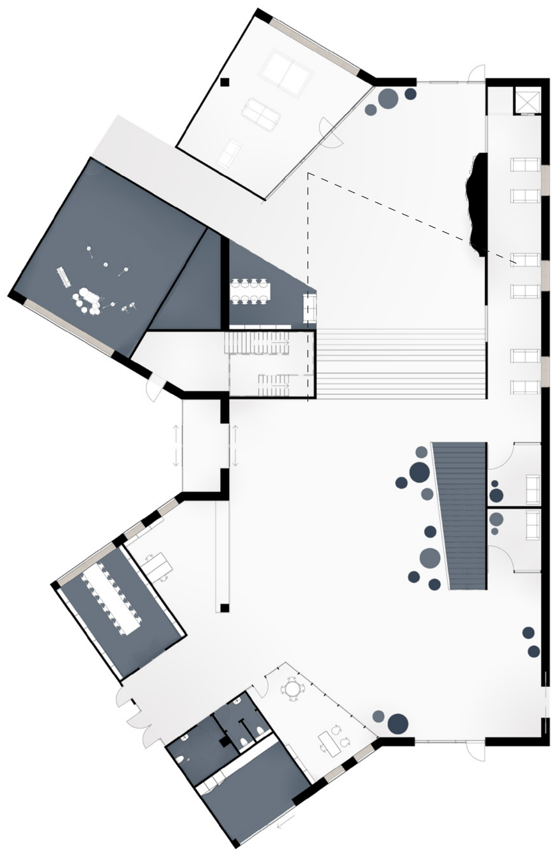
The open common area is the heart of the building. It connects every part of the building both physically but also visually. The great open stairway and the open hallways emphasize the contact between the stories and enhance the sensation of life in the building.

The atrium is opened up by a grand glass section that is open against north, south and in the roof. The glass connects the life in the building with the outside areas. From the road, it will be possible to watch the students walk around the building at all times of the day and from the building the students will have great views of the fjord.

The ground floor is split into two levels and divided into minor zones for differentiation between public and more private gatherings. The stairway between the two levels is an integrated sitting furniture. Moveable pillows are placed at the steps to improve the seating comfort. These pillows can be moved around or removed during arrangements with a need for a greater stair area.

The active profile of the school is also represented in the furnishing of the common area. A massive climbing wall dominates the north eastern corner of the atria going from the lower ground floor to the top floor. For safety reasons a large mattress is integrated in the floor, this mattress also invite the students to hang out when the wall isn't in use. Climbing equipment can be stored in drawers and cabinets in the wall next to the climbing wall.

There is also room for minor gatherings in the huge room. Niches and smaller closed rooms provide privacy for those students who might need places to retreat and be themselves for a while. From the semi closed area behind the climbing wall where smaller groups can hang out, there is visual contact to the sports center, and the niche is a great place to be for semi privacy, but great overview of the activities and movement in the building.



Ill. 98.1 - Plan of the common area

Ill. 99.1 - The common area

LEARNING ENVIRONMENTS

The learning environments have been developed with the knowledge gained in the theme analysis in mind. People learn in different ways, and the physical environments are designed to facilitate several learning activities and differentiated teaching methods. The educational wing contains five classrooms, a mandatory physics room, an auditorium and a creative workshop and a music room for elective lessons. The classrooms are divided by folding walls, to provide possibilities to merge them together in different ways while all of them can be opened to create one big space for projects across classes.

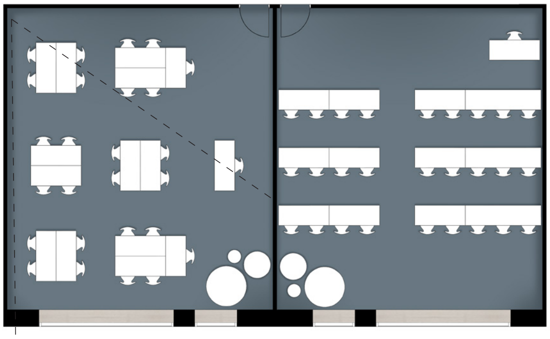
The classrooms have great daylight conditions and the large deep windows simultaneously form comfortable seating niches in the relatively large rooms. Each classroom has a cozy corner for reading and possibility to retreat and focus on individual assignments and reading books.

Besides the closed rooms the educational wing also consists of an area for group work, assignments and physical tasks. The auditorium allows the school to have lessons and gatherings with all the students at once.

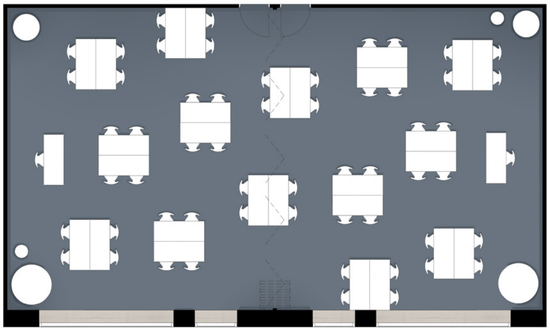
The educational wing provides different degrees of privacy which is particularly important at a boarding school where the students are gathered all day and sometimes needs to retreat and work alone to focus on specific tasks.

The facilities have a minimalistic appearance and provide an orderly and pure expression to calm the mind and permit it to focus on impressions and details from the lessons.

Ill. 101.1 - A classroom



Ill. 101.2 - Two classrooms in the basic setup



Ill. 101.3 - Two classrooms merged together

DORM ROOMS

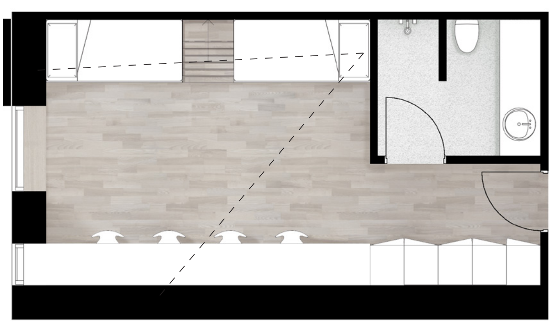
The dorm rooms are designed in two sizes for respectively two and four students. The largest rooms are placed towards west and have views towards the entrance area, the agriculture school, Sebbersund and the fjord. The smaller rooms are placed towards east with views of the soccer field, the fjord and Nibe. The large windows in both types of room are designed as integrated seating. On the exterior side, the large windows are equipped with shutters for controlling the temperatures in a passive way. The shutters are designed to blend in with the vertical lines in the facade material, but with greater distance between the lamellas to ensure possibilities for views to the outside even when the shutters are placed in front of the window.

In the large rooms, the small window flows into a long desktop with plenty of space for all four students at once. The desktop is built together with a huge wardrobe with room for the students' clothes and personal belongings.

Both types of rooms have bunk beds to keep the floor area free. The bunk beds are with a modern light twist so they don't appear heavy in the room. The upper beds are mounted on the wall and the bottom beds are extra high with drawers underneath them to secure enough storage space for the students. All the furniture and the windowsills are crafted in ash and the rooms appear bright and inviting. The fixed furniture makes the room look alike, but with great possibilities for the students to personalize the rooms with posters, pictures, light chains and other personal artefacts.

Every room has its own toilet and bathroom with plenty of storage space. The interior is bright and the tiles white which make the small room seem big despite its small size.

Ill. 103.1 - Perspective of a four person dorm room



Ill. 103.2 - A four person dorm room

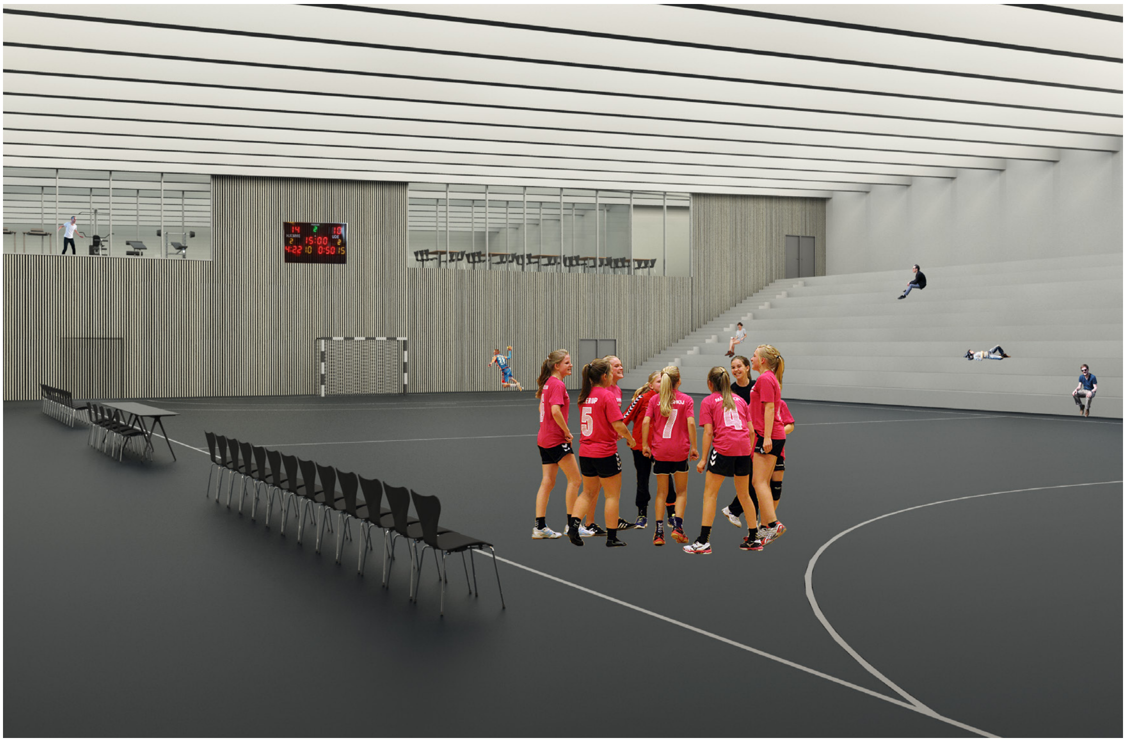
Ill. 103.3 - A two person dorm room

SPORTS CENTER

The sports center is entered from the common area, and the handball court is located in a lower level. The level difference is utilized as a tribune for visitors and audience for the matches and activities at the court. Windows in the two ends of the hall ensures visual contact to the common area in the one end and a fitness and canteen environment in the other.

The facade is closed against south to ensure that the players don't get blinded by the sun when they are at the court. To secure some daylight and views for the audience standing on the tribune, windows are placed in the northern facade in a height where they don't disturb the activities at the court.

The sports center also consists of an ordinary gymnasium with mattresses, ribs and ropes hanging from the ceiling. Equipment for gymnastics and other activities are stored in a shared storage room between the gymnasium and the handball court. Above the storage room is a great fitness area that is shielded from the two adjoining rooms by curtain walls which is favorable if some students experience injuries as it leaves them with a visual contact to the activities when they can't participate physically.



Ill. 105.1 - Perspective of the handball court and tribune

THE SOCCER FIELD

The schools soccer field is placed south of the building in relation to the main outdoor area. The terrain increases against south, and the soccer field is elevated one storey from the ground floor of the building. The field is visible from the common area, dorm rooms, dining area and principal's office.

Spectators for the soccer games can watch the game from seats along the northern longitudinal side of the field where they simultaneously can enjoy the sun. The spectator's seats are closely connected to the main outdoor area where various niches and terraces invite to gathering, barbequing and dining outside.

Ill. 107.1 - Perspective from the soccer fielt towards the building.

FACADES

Ill. 108.1 - Northern facade

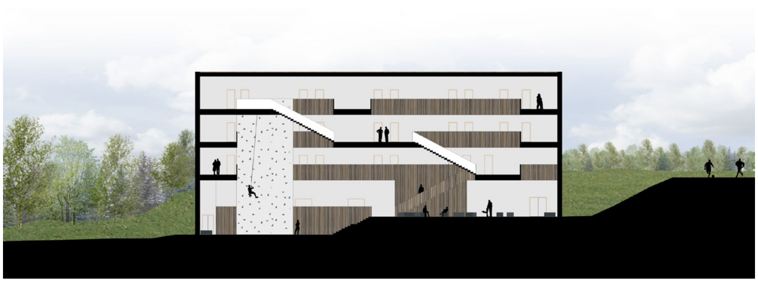
Ill. 108.2 - Southern facade

Ill. 108.3 - Eastern facade

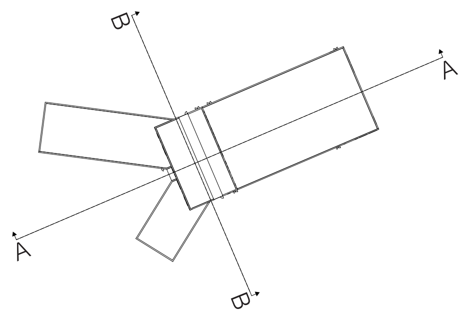
Ill. 108.4 - Western facade

SECTIONS

Ill. 109.1 - Longitudinal section, section AA



Ill. 109.2 - Cross section, section BB



Ill. 109.3 - Section plan

The drawings are with accurate dimensions can be found in the appended drawing folder.

MATERIALS

The exterior materials emphasize the orientation of the building volumes. The lower volumes touching the ground have a horizontal orientation, while the orientation of the main building is more vertical. The horizontal material is an oblong black brick that creates a heavy expression of the lower part of the building. Bricks are a very sustainable material as it has a long lifetime, a low maintenance demand and a good ability to retain heat. [teglklinker.dk] The only dominating environmental indicator with bricks is the energy used to burn the clay to harden, secure frost resistance and prolong the lifetime of the brick.

The vertical material is a cedar cladding. Cedar grows mainly in North America, but is used elsewhere in the world due to its durability and minimal need for maintenance. Cedar doesn't necessarily need treatment as it has a natural antibacterial substance that makes it last for years without further treatment [moelven.com]. The material has a natural warm brown nuance but if it isn't treated it will turn silver with time. It isn't desired to have the patina on the facade in this project, as the shutters will make the material patinate uneven and it is therefore decided to treat the material with special UV protective oil.

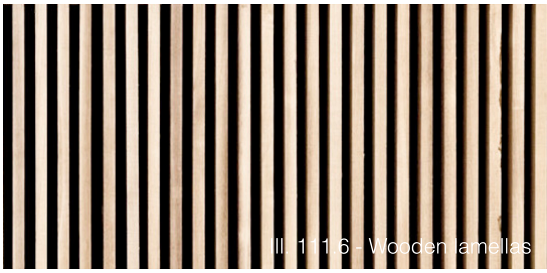
Inside the building, Ash is the main material used. Wooden lamellas on the walls and ceilings in the common area improve the acoustics in the great room. The wooden ceilings continue into the educational wing as well as the dining wing. The floors in the dorm rooms are made of ash, and the windowsills in every part of the building, except from the sports center are also made of ash.
In the ground floor and in the hallways the floors are coated with epoxy in a light grey and a dark blue nuance.

It has been important to create a bright and orderly atmosphere with cleanliness, and a slightly formal atmosphere that still have room for fun. The atmosphere of the building should follow the students' development towards adulthood and calm their minds to let them focus on teaching and impressions they experience daily.

EXTERIOR MATERIALS

Ill. 111.1 - Brick, Kemano langformat, Schwarz

Ill. 111.2 - Cedar cladding

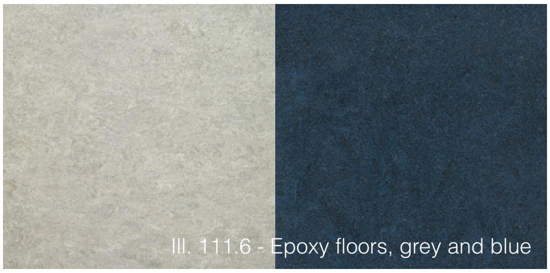


Ill. 111.6 - Wooden lamellas

INTERIOR MATERIALS

Ill. 111.4 - Ash

Ill. 111.5 - Ash floor



Ill. 111.6 - Epoxy floors, grey and blue

PROLOGUE

PROLOGUE

CONCLUSION

The result of this thesis is a design proposal for the Danish boarding schools. The design is developed with a holistic approach to sustainability and a focus on the connection to the nature and outdoor activities that can be included in the education. The indoor environment has a great effect on the students learning outcomes and therefor the classrooms are fulfilling the indoor climate class A to secure optimal conditions for learning. The learning environment should be flexible to accommodate different teaching methods and the create focus on the individual student and there ways to learn.

The indoor climate in the learning environments has been adapter to fulfill the indoor climate class A regarding daylight, temperatures and CO_2 concentration. The first steps towards the satisfying indoor climate and low energy demand was taken by using passive strategies as natural ventilation, solar shading and a well-insulated and optimized building envelope. As the natural ventilation isn't enough to secure a satisfying CO_2 concentration in the building due to the high demand for the ventilation rate without causing draft and discomfortable low temperatures in the winter, a mechanical ventilation system is implemented in the building. This system is driven by electricity, and causes the energy demand of the building to increase. With implementation of photovoltaics, the total energy demand is brought back into the 2020 energy frame.

The sustainability is not only seen as energy frames and indoor climate, but in a great extent also in relation to social aspects as improving the livability and well-being of the users in and around the building.

For the students at a boarding school, the school is not only an educational institution but also their home. It is therefore important for the students that there are a clear transition between the classrooms and the students' dorm rooms as well as there should be rooms and areas with different degrees of privacy to accommodate the physical and mental need of every student. At a boarding school the social interaction are very important and the building should have a functional organization where the flow between the different functions should provide and support spaces for the social interaction, personal development and their affection for sports.

The common area is the heart of the building and functions as a place for gathering, activity, semi-private areas and a distribution area that are connected vertical and horizontal to all other rooms in the building.

At the entrance level there are a dining area, a kitchen, a bicycle workshop, semi-private areas and offices placed along with the common area and the entrance to the sports center. From the common area, there are windows to the sports center that create a visual contact and emphasize the focus on sports at this boarding school and make the socialization between the students easier in a large building through the transparency.

The common area is designed in two levels with a large staircase that can function as a gathering place for information meetings. The lower level of the common area includes an open teacher's office where the students and teachers can meet in an informal environment, a game room, classrooms, a workshop and auditorium.

The dorm rooms are placed around the atrium and are directly connected to the common area to ensure easy accessibility and visual overview of the life in the building.The common area therefor truly becomes the heart of the building. Every movement through the building goes through the common area either horizontal or vertical, and there will always be life in the big open room. To accommodate every students physical and mental need, different degrees of privacy is provided in the entire building and in the outdoor areas. The conceptual idea of having the rooms around an internal atria innovates and cultivate a new boarding school typology with multiple advantages compared to traditional halways or subdivided cabins regarding the togetherness and socializing among the students beyond their own room, cabin or neighbors.

The building are designed with passive and active strategies and calculations show that the building fulfil the governments requirement for the building class 2020 energy frame and reflect the environmental and social aspects of sustainability.

REFLECTION

The project has been developed with the integrated design process to ensure that both technical and architectural parameters are consistently considered throughout the process. With the limited amount of time to do the project, it has been a challenge to accomplish the intended plans.

All of the specified design criteria are implemented in the design of the building, which appears as a new boarding school typology with the centrally placed dorm rooms gathered around an open common area.

The conceptual principle with the division of functions and central placement of dorm rooms could to a great extend be transferred to any other type of boarding school not specializing in sport. By eliminating the great volume of the sports center, the building could appear very different, more unified and compact.

The good learning environments is achieved through multifunctional rooms that ensure spaces for gathering, contemplation and discussion, though it is considered that especially the spaces for group work could be further developed to be more enclosed to shield from aural and visual noise.

The orientation and layout of the educational volume could be more integrated by either another orientation to utilize the wind pressure as a driving force for natural ventilation or another layout of the plan and roof with high placed openings to amplify the buoyancy effect in the classrooms and enhance the natural ventilation rate.

The integration of the building in the terrain creates a split level in the ground floor which both divides the common area and adds motion and quality to the spaces. Furthermore the level differences enhance a clear separation from the educational part of the building to the others.

The sustainable approach during the project has mainly focused on the environmental and social aspects of sustainability and in a lesser extent the economic aspects. The primary vision has been to obtain environmental sustainability through energy consumption, indoor climate and production of renewable energy. The latter could in addition to the electricity created by photovoltaics supply renewable energy for heating, as this factor too is a great contribution to the energy frame.

The social sustainability has been processed through the human factor and creation of space for diversity to create a general well-being for the users. The social sustainable aspect would have been optimized with an adequate user analysis to influence and support the decisions made according to the design.

The economic sustainable aspects has been treated by the creation of spaces that enables the students to thrive in school and encourages them to continue studying to gain a higher level of knowledge which in a broad perspective affects the economic growth of the Danish welfare state.

REFERENCE LIST

BOOKS

A. Taylor, 2009
Taylor, Anne. Linking Architecture and Education: Sustainable Design of learning environments University of new mexico, 2009.

Kirkeby I.M, 2006
Kirkeby, Inge Mette. Skolen Finder Sted. Hørsholm: Statens Byggeforskningsinstitut, 2006.

Lehrskov et al., 2012
Lehrskov, H., Øhlenschlæger, R., Kappel, K., Klint, B., Klint, J. and Vejsig Pedersen, P. Energi + Arkitektur. 2nd ed. København, 2012.

Pedersen, 2012
Pedersen, Erik Helmer. Mere end en skole Odense: Syddansk universitetsforlag, 2012.

Sustainable building design manual, 2014
Darbari, Seth Block. Sustainable Building Design Manual. The Energy and Resources Institute, India 2004.

WEB

Aalborg commune, 2014
http://www.aalborg.dk/om-kommunen/statistik-og-noegletal/befolkning
[Accessed 12.02.16]

Anvisninger.dk, 2015
Anvisning om Bygningsreglement 2015.
http://anvisninger.dk/anvisninger/Pages/258-Anvisning-om-Bygningsreglement-2015-1.aspx#/6-Indeklima
[Accessed 18 Feb. 2016]

Brigiddottir, 2013
Birgisdottir, H., H. Mortensen, L., Hansen, K. and Aggerholm, S. Kortlægning af bæredygtigt byggeri. 1st edt.
København: Statens Byggeforskiningstitut, Aalborg Universitet, 2013.
[Accessed 20.02.16]

Climacare.dk
http://climacare.dk/pages/id25.asp
[Accessed 08.04.16]

Dac.dk, 2016
Dansk arkitektur center. Hvad er bæredygtighed?
http://www.dac.dk/da/dac-cities/baeredygtige-byer/om-baeredygtige-byer/hvad-er-baeredygtighed/
[Accessed 8 Feb. 2016].

DCUM,2013
http://www.airmaster.dk/Files/Billeder/Diverse%20PDFer/Indeklima%20og%20fagligt%20udbytte_DCUM.pdf
[Accessed 21.05.16]

Den store danske, 2012
http://denstoredanske.dk/Erhverv,_karriere_og_ledelse/P%C3%A6dagogik_og_uddannelse/Skole_og_SFO/dansk_skolehistorie
[Accessed 10.03.16]

Denstoredanske.dk
http://denstoredanske.dk/Geografi_og_historie/Geografi/Naturgeografi/Klimatologi_og_klimatyper/Danmark_-_klima
[Accessed 18.03.16]

efterskole.dk
http://www.efterskole.dk/da/Schools
[Accessed 09.03.16]

Energimagasinet.dk
http://www.energimagasinet.dk/solceller/polykrystallinske-solceller/
[Accessed 08.04.16]

Energitjenesten.dk
http://www.energitjenesten.dk/placering-af-solceller.html
[Accessed 08.04.16]

Et bæredygtigt Danmark, 2014
Regeringen, 2014. Et bæredygtigt Danmark – Udvikling i balance.
http://www.fm.dk/~/media/publikationer/imported/2014/et-baeredygtigt-danmark/et-baeredygtigt-danmark_udvikling-i-balance_web_a.ashx
[Accessed 20.03.16]

Henning Larsen Architects, 2012
https://issuu.com/henninglarsenarchitects/docs/dagslys_web
[Accessed 20.02.16]

Kjeldsen, Toftum, Wargoocki and Clausen, 2011
Uldahl Kjeldsen, B., Toftum, J., Wargoocki, P and Clausen, G. Sammenhæng mellem luftkvaliteten i grundskoler og elevers indlæring 1st edt.
http://www.airmaster.dk/Files/Billeder/Diverse%20PDFer/Kjeldsen%20et%20al%202013%20Indl%C3%A6ring%20BUPL.pdf
[Accessed 22.02.16]

Larsen, K, 2005
Larsen, Kristian. Arkitektur, krop og læring
København, Hans Reizels forlag, 2005
[Toftum, Wargoocki and Clausen, 2011]
Toftum, J., Wargoocki, P and Clausen, G. Indeklima I skoler – status og konsekvenser 1st edt.
http://orbit.dtu.dk/da/publications/indeklima-i-skoler--status-og-konsekvenser(c6583448-1e49-4e93-8f9a-ae7482ad0e2b).html
[Accessed 21.02.16]

moelven.com
https://www.moelven.com/Documents/Wood%20AS/Brosjyrer/Wood%20prosjekt/Cedertr%C3%A6%20Teknisk%20vejledning%202012.pdf
[Accessed 21.05.2016]

Nibe havn.dk, 2016
http://www.nibe-havn.dk/index.php?B%E5dpladser_%2F_havneplan
[Accessed 12.02.16]

rummet.dk
http://www.rummet.dk/solsystemet/jorden/scene4.swf/view
[Accessed 18.03.16]

Sparenergi.dk
http://sparenergi.dk/forbruger/varme/varmepumper?gclid=CjwKEAiA9c-2BRC_vaaJ0Ybps30SJABlqxDelK7nWoYT3Yt0P9eWu_zL9Ocl_2qRewB7BuZxJ1wZERoCF5Hw_wcB#widget-2
[Accessed 08.04.16]

teglklinker.dk
http://www.teglklinker.dk/baeredygtighed/
[Accessed 21.05.16]

UVM.dk, 2014
http://uvm.dk/da/Uddannelser/Anden-uddannelse-og-undervisning/Efterskoler/Kort-om-efterskoler
[Accessed 08.03.16]

Windfinder.com, 2016
https://www.windfinder.com/windstatistics/aalborg?utm_source=www.windfinder.com&utm_medium=web&utm_campaign=redirect
[Accessed 18.03.16]

ILLUSTRATION LIST

All illustrations lot listet, are created by the authors.

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http://imageservice.nordjyske.dk/images/nordjyske.story/2012_05_13/cda8f858-5d2c-468f-9f15-da788c8040f3.jpg?max-width=620&height=398&crop=auto&scale=both&bgcolor=white

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http://www.s0s.biz/wp-content/uploads/2016/05/Beautiful-shaw-carpet-platinum-texture-tonal-In-Small-Home-Decoration-Ideas-with-shaw-carpet-platinum-texture-tonal-Home-Decoration-Ideas.jpg

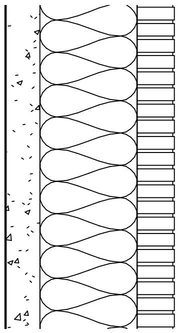
APPENDIX

APPENDIX 1

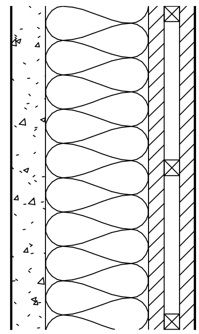
CONSTRUCTION STRUCTURE

BUILDING ELEMENTS	THICKNESS	U-VALUE	MATERIALS (EXTERIOR TO INTERIOR)
External wall, brick	535 mm	0,10	108 mm brick 327 mm insulation 100 mm concrete
External wall, wood	535 mm	0,11	45 mm wood lamellas 45 mm lath / air gap 45 mm lath 300 mm insulation 100 mm concrete
Slab	1000 mm	0,08	30 mm concrete 130 mm rockwool 300 mm polystyrene 300 mm leca 240 mm sand
Deck	520 mm	0,14	30 mm concrete floor 110 mm rockwool 220 mm reinforced concrete 95 mm rockwool 20 mm airspace 45 mm wooden lamellas
Roof	592 mm	0,09	8 mm asphalt 25 mm lath / air gap 50 mm rockwool 395 mm rockwool 50 mm rockwool 19 mm lath / air gap 45 mm wooden lamellas

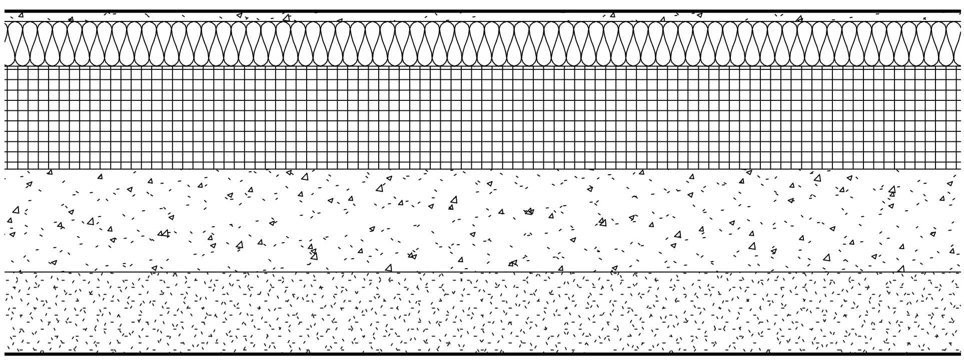
EXTERNAL WALL, BRICK



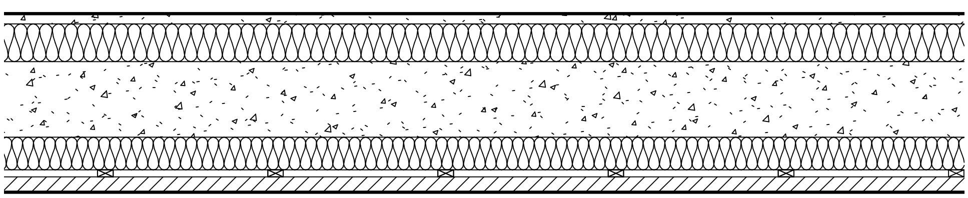
EXTERNAL WALL, WOOD



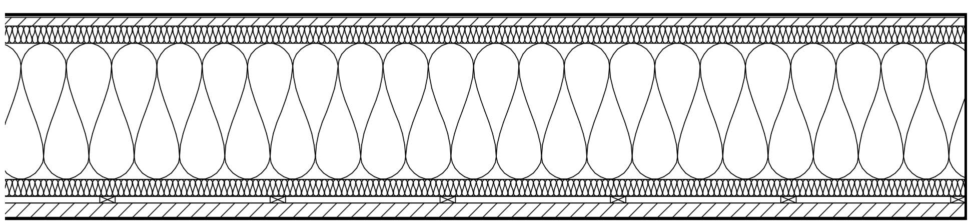
SLAB



DECK



ROOF



APPENDIX 2

CALCULATION OF U-VALUE

U-value calculation, external walls

The u-value is calculated for the two different external walls.
To calculate the u-value of a building element we need to know the thermal conductivity and the thickness of the different materials.

The following formula is used:

$$U = \frac{1}{Rse + \left(\frac{l_1}{\lambda_1}\right) + \left(\frac{l_2}{\lambda_2}\right) + \left(\frac{l_3}{\lambda_3}\right) + \left(\frac{l_n}{\lambda_n}\right) + R_{si}}$$

R.se: External transition value [m^2K/W]
R.si: Internal transition value [m^2K/W]
l: Length of material [m]
λ: Heat transfer coefficient [W/mK]

The external transition value is 0,04
The internal transition value is 0,13

The thickness of the materials in the brick wall is:
Brick: 0,108 m
Insulation: 0,327 m
Concrete: 0,100 m

The thickness of the materials in the wooden wall is:
Wood: 0,045 m
Lath: 0,045 m
Lath: 0,045 m
Insulation: 0,300 m
Concrete: 0,100 m

The heat transfer coefficients are:
Brick: 0,6
Insulation: 0,035
Concrete: 2,640
Wood: 0,120

The u-value of the brick wall is:

$$\frac{1}{0.04 + \left(\frac{0.108}{0.6}\right) + \left(\frac{0.327}{0.035}\right) + \left(\frac{0.1}{2.640}\right) + 0.13} = \underline{\underline{0.1}}$$

The u-value of the wooden wall is:

$$\frac{1}{0.04 + \left(\frac{0.045}{0.120}\right) + \left(\frac{0.300}{0.035}\right) + \left(\frac{0.1}{2.640}\right) + 0.13} = \underline{\underline{0.11}}$$

APPENDIX 3

AIR CHANGE RATE 1

Air change rate, experienced air pollution:

As we want to achive the indoor air quality class II standards, theese calculations of the air change rate is based on a sencory calculation.

The calculations is made with the following pollution loads:

- From one person = 1 olf
- From building materials, furniture etc. = 0,2 olf pr. m^2

The atmospheric comfort class A (percentage og dissatisfied - PD) = Maximum 15%

The formula used to determine the necessary air flow supply in the building is:

$$c = c_i + 10 \cdot \frac{q}{V_l}$$

c is the experienced air quality (dp)
c_i is the experienced air quality of the outdoor air (dp)
q is the pollution load (olf)
V_1 is the necessary air flow supply (l/s)

The experienced air quality i determined from the PD to a value of 1,1 dp
(Grundlæggende klima- og bygningsfysik figure 1,18)

The experienced air quality of the outdoor air is 0,05 dp
(Grundlæggende klima- og bygningsfysik figure 1,7 coresponding to a low moderate air pollution)
the formula to find the pollution load is as follows:

$$q := (1 \cdot 25) + (0.2 \cdot 71) = 39.2 \quad \text{olf}$$

The necessary air flow supply is then determined:

$$1.1 = 0.05 + 10 \cdot \frac{39.2}{V_l}$$

$$V_1 = \frac{10 \cdot 39.2}{(1.1 - 0.05)}$$

$$V_l = 373.33 \quad \text{l/s}$$

Hereby is the air change rate:

$$n = \frac{V_l \cdot 3600}{1000 \cdot V_{rum}}$$

$$n := \frac{373.33 \cdot 3600}{1000 \cdot (233.62)} = 5.753 \quad h^{-1}$$

AIR CHANGE RATE 2

Air change rate, CO_2

The nessecary air flow to dilute the concentration of CO_2 in the room is found by the "fortyndingsligning" that says how many times pr. hour a room needs to be ventilated to dilute the concentration of CO_2 to a comfortable pollution level.

The "fortyndingsligning" is:

$$c = \frac{q}{n \cdot V} + c_i$$

The formula is rearanged to isolate n:

$$n = \frac{q}{(c - c_{.i}) \cdot V}$$

n: Air change rate [h^{-1}]
q: Supplied pollution [m^3/h]
V: Volume of the room
c: The concentration of pollution in the room, provided full mixture thus the extracted air has this pollutiuon. [m^3/m^3]
c.i: The concentration of the pollution in the supplied air [m^3/m^3] (GKB page 28)

Supplied pollution:

One person with an activity level of 1,2 met pollutes 19 l/h (CR1752 page 26)

$$q := 19 \cdot 25 = 475 \text{ l/h} = 0.475 \text{ m}^3\text{/h}$$

The room volume:

V = 233,62 m^3

The concentration in the room:

If sedentary occupants are assumed to be the only source of pollution, the CO_2 concentration above the outdoor level corresponds to 460 PPM in indoor climate class A. (CR1752 page 23)

$$460 + 350 = 810 \text{ x}10^6 \ \frac{m^3}{m^3} = 0.00081 \ \frac{m^3}{m^3}$$

The concentration of the pollution in the supplied air:

$$350 \text{ x}10^6 \ \frac{m^3}{m^3} = 0.00035 \ \frac{m^3}{m^3}$$

The nessecary air change rate to gain a satisfying dilution of the CO_2 concentration:

$$n := \frac{0.475}{(0.00081 - 0.00035) \cdot 233.62} = \underline{\underline{4.4 \ h^{-1}}}$$

APPENDIX 3

AIR CHANGE RATE 3

Air change rate, thermal load

The necessary air change rate to acieve satisfying thermal conditions is calculated by the "massetransport ligning":

$$\phi = C_v \cdot V \cdot \Delta t$$

The "massetransport ligning" is rewritten to isolate V:

$$V = \frac{\phi}{C_v \cdot \Delta t}$$

ϕ: Thermal load
C.v: Soecifik heatcapacity, dry air, 1213 [J/m^{3}K]
V: Volume flow
Δt: Temperature difference

ϕ, Thermal load:

The sun protection factor is 0,5 as not all windows are shielded (GKB page 168 table 5,4)

The thermal load:

$$\phi_{sun} = A_{window} \cdot sunload_{south} \cdot sunprotectionfactor$$

A.window: 6 m^2
Sun load: 355 W/m^2 (South)

$$\phi_{sun} := 6 \cdot 355 \cdot 0.5 = 1065\,\mathrm{W}$$

Thermal load, ligthning:

$$\phi_{ligthning} = A_{floor} \cdot ligthning$$

A.floor: 77,87 m^2
Ligthning: 20 W/m^2 (GKB table 5,5 300 lux)

$$77.87 \cdot 20 = 1557.4\,\mathrm{W}$$

Overall thermal load:

$$1065 + 1557.4 = 2622.4\ \mathrm{W}$$

Temperature difference:

$$\Delta t = t_{comfort} - t_{supply}$$

$$21 - 18 = 3$$

The necessary air flow rate:

$$V = \frac{\phi}{C_v \cdot \Delta t} = \frac{2622.4}{1213 \cdot 3} = \underline{\underline{0.721\,\mathrm{h}^{-1}}}$$

DIMENSIONS OF VENTILATION PIPES

Dimensioning the ventilation pipes

The formula used to calculate the cross section area of the pipes is:

$$q = V \cdot A$$

q: The air flow rate [m^3/s]
V: Velocity [m/s] (Desired to be 3 m/s)
A: Cross section area of the pipe [m^2]

As we want to find the cross section area, the formula is rewritten to isolate A:

$$A = \frac{q}{V}$$

The formula to calculate the air flow rate is:

$$q = P \cdot N_A \qquad q = P \cdot N_B$$

P: Number of persons in the room
N.A: Necessary fresh air supply category A [l/s pr person]
N.B: Necessary fresh air supply category B [l/s pr person]

The nessecary fresh air supply is read from DS 447:2013 page 53 to be:

N.A 10 l/s pr person
N.B: 7 l/s pr person

Therefore the air flow rate in the educational wing of the building is:

1 x WC:
$4 \cdot 7 = 28$

1 x printer room:
$1 \cdot 7 = 7$

8 x class rooms::
$(27 \cdot 10) \cdot 8 = 2160$

1 x auditorium:
$149 \cdot 10 = 1490$

1 x teachers office:
$10 \cdot 10 = 100$

1 x group area:
$90 \cdot 10 = 900$

The total air flow rate is:

$28 + 7 + 2160 + 1490 + 100 + 900 = 4685$ l/s = 4.685 m^3/s

Thereby the sectional area of the pipe becomes:

$$\frac{4.685}{3} = \underline{\underline{1.562}} \text{ m}^2$$

Similar calculations are made to find the cross section area for the ventilation pipes in the other parts of the building:

The dinning wing:
0,48 m^2

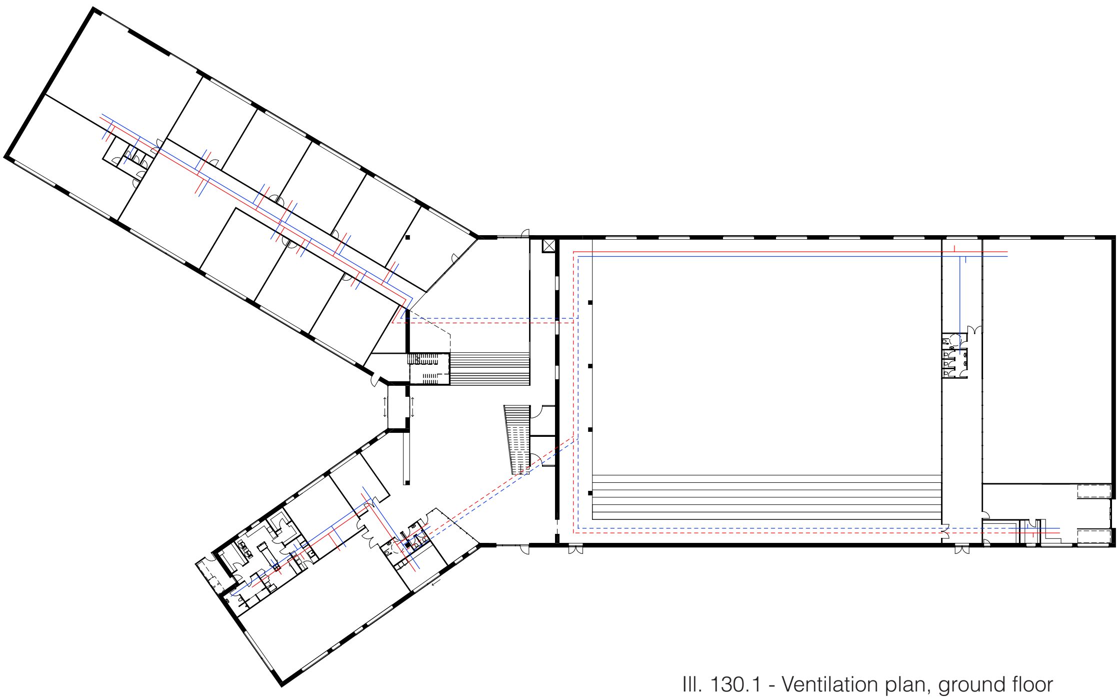
The sports center:
1,01 m^2

The dorm rooms:
0,77 m^2

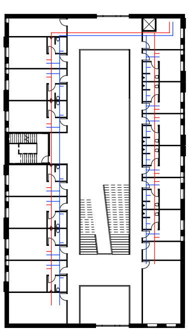
As some of the pipes have a large cross section area, it is desided to have square pipes, as they will fit better above a suspended ceiling.

APPENDIX 4

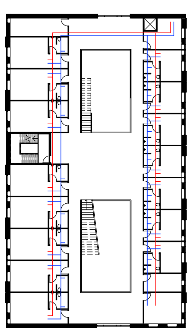
VENTILATION PLAN



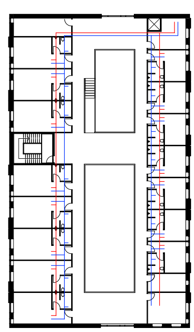
Ill. 130.1 - Ventilation plan, ground floor



Ill. 130.2 - 1. floor



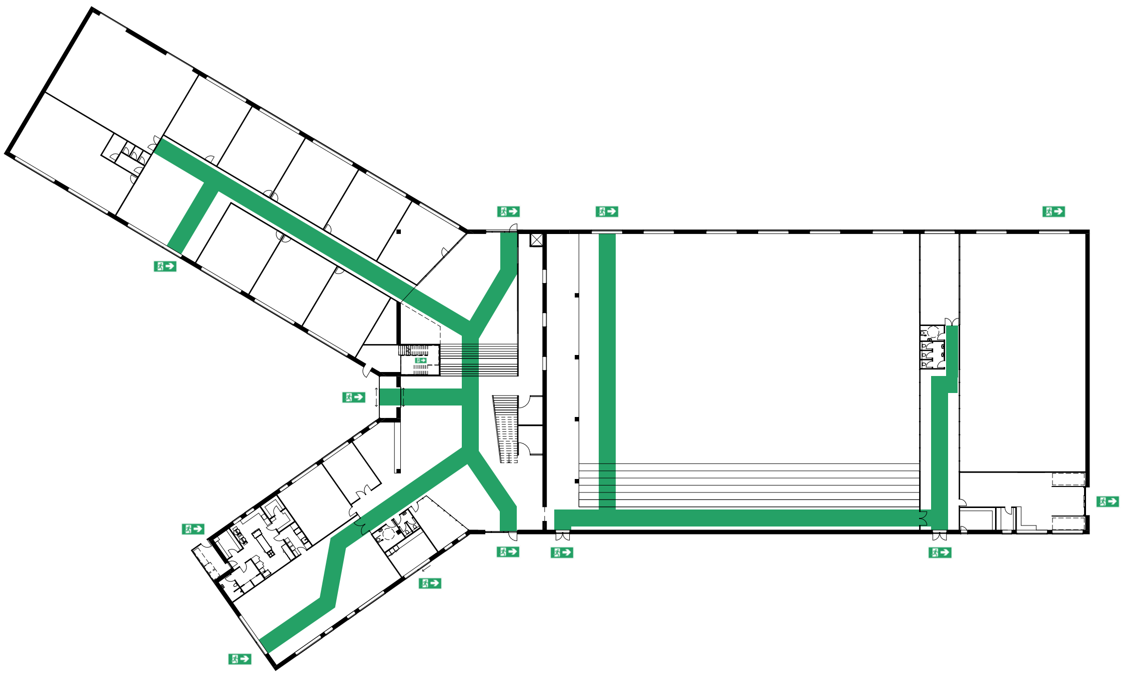
Ill. 130.3 - 2. floor



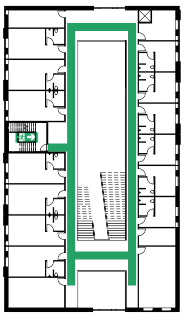
Ill. 130.4 - 3. floor

APPENDIX 5

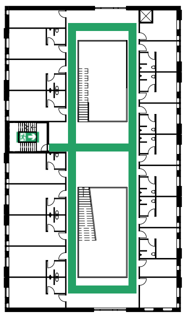
FIRE PLAN



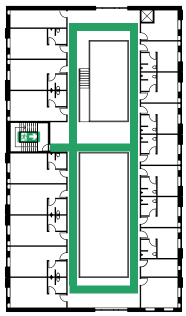
Ill. 131.1 - Fire plan, ground floor



Ill. 131.2 - 1. floor



Ill. 131.3 - 2. floor



Ill. 131.4 - 3. floor

APPENDIX 6

PEAK POWER OF PHOTOVOLTAICS

Calculation of the necessary peak power of the photovoltaics to supply the needed electricity.

The photovoltaics should provide the needed electricity for operation of the building of 27,8 kWh/m^2 year. This number needs to be multiplied by the primary energy factor for electricity to get the true amount of energy that we need to supply.

$$27.8 \cdot 1.8 = 50.04 \text{ kWh/m}^2 \text{ year}$$

This is the entire need that the photovoltaics needs to provide based on square meters. To get the total energy need, we need to multiply with our total heatet area:

$$50.04 \cdot 7442 = 372397.68 \text{ kWh year}$$

Based on the "PV-dimensioneringsguide-nomogram.pdf" We assess our panels to be standard polycrystaline panels with an efficiency of 12%. The area for the photovoltaic modules are located on the roof of the main building where 669 m^2 are free.

To identify the necessary peak power of the modules, we assume (based on the "PV-dimensioneringsguide-nomogram.pdf") that our system factor D is 0,7 which mean that they are integrated in the building and have a standard efficiency.

The E factor is set to be 999 as the modules face south and are placed in an angle of 0 degrees.

$$C \cdot D \cdot E = \text{annual}_{\text{profit}}$$

$$372397.7 = C \cdot 0.7 \cdot 999$$

$$C = 532.6 \text{ kW peak}$$

To insert this value in Be15 we need to find the peak power per square meter solar cell:

$$\frac{532.6}{669} = 0.796 \text{ kW peak per m}^2$$

The maximum amount of energy that can constitute to the energy frame in Be15 is 25 kWh/m^2 year in this case. This can be covered by 170 m^2 of photovoltaics with the calculated peak power per m^2.