SUSTAINABLE LEARNING

LYDENS BY SKOLE

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KATRINE RAVN MØLLER - LARS KROG JENSEN - LOUISE ABILDTRUP NICKELSEN

SUSTAINABLE LEARNING

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SUPERVISORS
Michael Lauring
Claus Topp

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Katrine Ravn Møller

Lars Krog Jensen

Louise Abildtrup Nickelsen

PREFACE

Sustainable Learning – *Lydens By Skole* is a thesis project created by group 47, MSc04 2015 of Architecture and Design, Aalborg University. The project takes its point of departure in the new Danish public school reform, which is an initiative by the government to improve and challenge learning environments. Architectural and sustainable values are emphasized in *Lydens By Skole*, a project introduced by the municipality of Struer to create a contemporary and cultural public school in an urban environment. The project is supervised by associate professor Michael Lauring and Claus Topp, lecturer and engineer in indoor climate and energy. Their help and guidance throughout the thesis project is greatly appreciated.

Ill. 1. Girl on climbing frame

ABSTRACT

Sustainable Learning forms the development of a public school project in Struer, *Lydens by Skole*. This project investigates exploratory learning environments with architectural and sustainable value. The integrated design process sets the framework for the project, which includes the Vitruvian virtues of architecture, considering aesthetic, functional and technical parameters when aiming for a perfection of form.

The project deals with the initiatives of the new Danish public school reform with longer school days, room for exercise and movement, and learning in multiple ways, both in and outside the classroom. For optimal learning conditions, high requirements are set for the indoor climate with focus on daylight and acoustics. The building is designed to fulfil the energy demand appointed by the Danish government for 2020. With active design strategies, the building reaches the standard of a zero energy building.

In addition to the subjects of sustainability and movement, the conceptual focus investigates a public zone uniting different age groups of students, teachers, and citizens. The school is a place for gathering with an inviting and playful identity, emphasizing the school as an icon for the *City of Sound*, Struer.

GUIDE OF READING

This report communicates the process and outcome of the development of a new public school in Struer, focusing on sustainable learning. The methodological approach of integrated design is used to organize the project phases. The project is initiated with a theme analysis, exploring the new Danish public school reform and the requests for a new school facility in Struer. This is followed by a site analysis, investigating potential sites and relevant contextual observations. Sustainable strategies are outlined, describing principles of energy and indoor climate in relation to a sustainable school environment.

The design process includes the sketching and synthesis phase, developing through iterative loops, combining technical, functional and aesthetic values in form making. A presentation phase finalizes the project and illustrates the final design solutions through visualizations, plans, sections and elevations. A conclusion and reflection summarize important parameters explored and considered in the thesis. This is followed by appendix, including additional documentation of the design process.

References for relevant literature and illustrations are carried out in accordance with the Harvard referencing system.

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Ill. 2. Boys in the school yard

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A new school of sound is an extraordinary opportunity to create a thorough connection between sound and acoustics, the public school reform, the municipalities goals for at future school and new tendencies within school architecture, which has developed comprehensively since the original public schools was built in the city."

[Lydens by skoles støtteforening, 2015, p.3]

INTRODUCTION

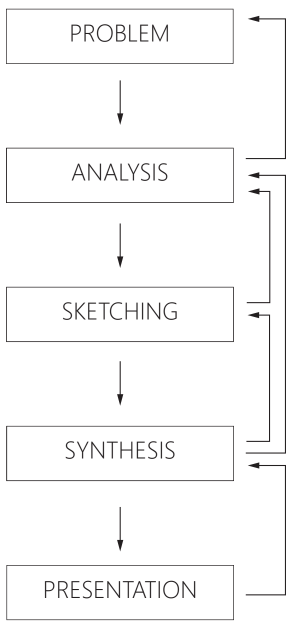
Ten years after public school, one out of seven students still haven't completed a secondary education. Therefore, one of the main objectives for the new Danish public school reform is to ensure that all children obtain the necessary academic and social competences to complete a secondary education.

Creating a school in a Nordic context involves considerations of secondary education and ensuring all children future employment. Some of the values of a Nordic society are ambitions, quality and community feeling. The Danish public school is not only an educational institution, it is also a cultural institution teaching about history, traditions, literature and language. The Danish government claims that Denmark has accomplished some of the best opportunities for education globally [UVM, 2013]. However, the educational system can become even better by facing the challenges of educating our children to the highest degree possible, independent of social heritage.

The new school reform calls for learning environments that support different types of teaching and learning. Many existing school buildings are outdated with an unsatisfactory quality of the indoor environment and spaces that restrict teaching methods and academic development. In the new school reform, exercise and movement play a larger role in the school schedule, because of an increased awareness of our children's health. This must be an integrated part of the architecture and outdoor spaces in the design of a school facility.

The municipality of Struer expresses this need for a new contemporary school building, which reflects local school policies and the notion of the Danish public school reform. The city brands itself as the *City of Sound*, and the new school building should reflect this theme while creating a cultural institution that gathers the local community.

METHODOLOGY



Ill. 3. Integrated design process

The Integrated Design Process, as defined by Mary-Ann Knudstrup, is used as a method to organize and structure the thesis project.

The process is organized in five phases, emphasizing the progression from project description to final presentation. These phases include the problem phase, analysis phase, sketching phase, synthesis phase and presentation phase. This method is used iterative throughout the project, considering architectural, technical and functional aspects while designing a sustainable learning environment [Knudstrup, 2010].

The problem phase defines the project description emphasizing a relevant challenge or case of improvement. The new Danish public school reform, introduced by the government, is used as a basis for defining a problem.

The analysis phase involves analysis of relevant topics including theme analysis and site analysis, accumulated in a program. The program includes concept, vision, design parameters, function diagram and a room program initiating architectural and technical ideas for the design process.

The sketching phase includes aesthetic, technical and functional considerations using modelling, graphical and digital tools as exploratory methods. Thus, potential ideas develop from conceptual sketches to design solution.

The synthesis phase unites the parameters from the analysis phase and the sketching phase into a symbiosis. Design solutions are detailed considering the program definition, thus the conceptual intentions are fulfilled.

The presentation phase assembles the project report and includes illustrations for the final project solutions.

A coherent progression ensures consistent implementation of aesthetic, technical and functional fields. The phases influence one another and loops allow a flexible progression. In addition to this, the Vitruvian virtues of architecture are implemented, emphasizing the consisting interrelation between Utilitas, Firmitas and Venustas. These phenomenological components describe architectural value through function, technique and aesthetics, perceiving a perfection of form. Individually, the elements are highly different, however, in a combination they are dependent on the presence of the second and third to create winning architecture [Vitruvius, 2015].

TIME SCHEDULE

The Gantt Chart illustrates the organization of project phases as defined by Mary-Ann Knudstrup in the integrated design process [Knudstrup, 2010]. This includes the problem phase, analysis phase, sketching phase, synthesis phase, and presentation phase, emphasizing the project progression from initial problem description to final design. This schedule is an interpretation of the expected process, though in reality, the phases may overlap and the process includes loops of going back and forth. When organizing the project phases, additional time is allowed for the presentation phase, where the final architectural finish and value is accomplished.

Ill. 4. Gantt Chart

THEME ANALYSIS

The following section investigates themes that are central to the task of designing a school facility. Point of departure is taken in the new Danish public school reform and the development of school typologies. In order to create a design that supports learning processes of children, the relation between architecture and learning is explored.

The project is based on the need for a new public school in Struer. In relation to this, the goals of the municipality is reviewed with emphasis on the actual requirements and request, as well as the intended users for the new school; *Lydens By Skole*.

Ill. 5 Children

DANISH PUBLIC SCHOOL REFORM

IMPROVING DANISH PUBLIC SCHOOLS

FOCUS ON THE INDIVIDUAL STUDENT

The Danish public school reform is an initiative by the government to improve public schools in Denmark and increase the educational level to international standards [UVM, 2015]. The reform focuses on learning rather than teaching and emphasizes integration of the students in lessons, by motivating a positive learning environment.

Some of the key parameters in the new reform are to enhance personal development and learning achievements. All students must become as talented as possible regardless of culture, ethnic and social conditions [UVM, 2015]. Thus, a focus on well-being, comfort and happiness are important when discussing successful learning environments.

The school must create awareness of the individual student, his needs and encourage personal motivation. Too many students finish public school without the abilities to attend a secondary education. Other students are not sufficiently challenged and need motivation for learning [UVM, 2015]. One of the initiatives by the government is to form a more including public school.

"It's the government's objective to create a strong academic public school for all students. This involves that more students with special needs shall be included in the general public school with the necessary support and challenges." [UVM, 2014]

In practice this means that about 10.000 students who used to receive special education should now be included in regular classes together with other students [TV2, 2014]. This sets high demands for the teachers and the students themselves. Children with a diagnosis need more attention and may find it harder to adapt. If a child finds it difficult to concentrate, there is also a risk of disturbing the remaining children. Even though the right circumstances and efforts are required for the inclusion to be a success, the intentions behind it are good; to create equal opportunities for all children and to create room in our society for everyone no matter background.

This also relates to children from a different ethnic background who are often behind in school. These children are a difficult point of discussion for the Danish government, a point that may easily offend many Danes. Children from immigrant families are a growing part of the Danish public schools and an important parameter when discussing the future of the academic society. These students may have other needs than many traditional Danish children and must fight a harder battle defeating their social heritage.

An analysis performed by AKF, Anvendt Kommunalforskning, about young groups of different ethnic backgrounds in the Danish public schools, describes high personal intentions of the students and many hours spent on homework every day. Many of these students have parents without an education and without abilities to support their children academically [Mehlbye, 2011]. In order to positively integrate these students, help with homework is included in the new Danish public school reform.

EXERCISE AND MOVEMENT

The reform describes exercise and movement being included in the education system every day for 45 minutes, to strengthen health, motivation and abilities to learn for the students [UVM, 2015]. Learning can also be achieved through movement and other methods than traditional classroom lessons. By providing space for movement and activities inside the classroom, on hallways, common rooms and in outdoor spaces, multiple scenes for exercise are provided.

> *I think we should involve academic learning through movement in games, activities, and exercises when it makes sense in relation to what the students are working with. [...] When the above is not possible, movement, where the pulse is raised and the mind is cleared, is good."*
>
> Grete A. Thing [AAU, 2015]

Movement can be used as a method to carry out the curriculum in schools, but it is also health improving and can help children to stay focused during a school day. By offering space for activities in lessons and during breaks, the academic results may change positively. However, many of the current Danish public schools are not equipped to offer room for exercise and movement, a problem the government must be aware of.

LONGER SCHOOL DAYS

A part of the reform includes longer school days, more lessons, diverse teaching and a focus on knowledge and well-being. In addition to this, teachers are expected to spend more time in the work environment, preparing lessons and evaluating students' academic progression. Some of the subjects with increased lessons are Danish, math, technical subjects and music. New subjects as crafts, design and food are introduced to the schedules together with more elective courses for the older students, to inspire and guide future educational choices [UVM, 2015]. Thus, a modern and present public school is created, educating students for today's society and preparing them for current realities.

REACTIONS TO THE SCHOOL REFORM

Before the school reform became a reality, it was a large point of discussion in the Danish society, especially between the government, teachers and parents of school children. A general interpretation of the teachers' position towards the reform was scepticism and frustration. This relates to the balance between time for preparation and lessons, which was not realistic according to the teachers. The consequence of this was more stress, poor preparation and lack of motivation. This was also one of the key parameters for the lock-out of the teachers in 2013 between Kommunernes Landsforening, the government and the teachers. A conflict about working hours, distribution of preparation

Ill. 6. Students of different ethnic backgrounds

and lessons, and dissatisfaction of not being included in the considerations of a new public school reform, resulted in a lock-out of the teachers that closed nearly all Danish public schools for 25 days [TV2, 2013].

Change is often connected with a feeling of insecurity and uncertainty, which may have been the cause for some of the initial resistance towards the new school reform. However, when asking the involved parties today, there are still mixed opinions. Some teachers' interpretation of the reform is positive, believing that the intentions of the reform can lead to progression. Especially the point of focusing on the individual student and offering help for homework at school are important parameters, thus the potential of improving less academic children increase.

> *I have to be at work for a longer time, and I have considerable less time for preparation which affects the teaching that the students receive. I don't mind staying longer at school, it is nice be to off when the school day ends. (The municipality received much more working hours from their employees before, than they do now)."*
>
> Rikke Sørensen [AAU, 2015]

Teachers appreciate that their workday now ends when they leave the school in the afternoon, but the problem is that there is not enough time for preparation during school hours, which may affect the quality of lessons.

The reform sets high demands to the teachers, and not enough time or resources to carry them out. This has made the school teacher profession less attractive. Recent numbers show that more than 10% of teachers have left their job during the last year, which is a considerably higher number than usual. One might assume that most of these people were older teachers accustomed to the previous school system, but the numbers show the same tendency with younger teachers [TV2, 2015].

Not only teachers, but also many parents, are sceptic about the new Danish public school reform and are afraid that their children may not have time for after school activities or spend time with their friends. In some cases it may be a reflection of the parents themselves rather than a concern for their children. One mother states on a public debate that she is displeased with the longer school days [TV2FYN, 2013].

> *I get of work 12.45 every Thursday – then I go straight to pick up my children!! I want to continue doing that. Besides I am happy with my daughter's school and her after school activities – which I don't want to change."*
>
> Anita Rasmussen [TV2FYN, 2013]

In order to bring comfort in the eyes of concerned parents, they must be adequately informed about the new Danish public school reform. Educators and pedagogues must cooperate to form motivated and engaged children, who participate in the classrooms and obtain the desired knowledge to fulfil the future goals of Denmark.

NORDIC REFLECTIONS

The most important aspects of the reform are education and formation of children. Students must learn about Nordic values and create individual personalities. Freedom of speech and the ability to form individuality are basic values in Nordic societies.

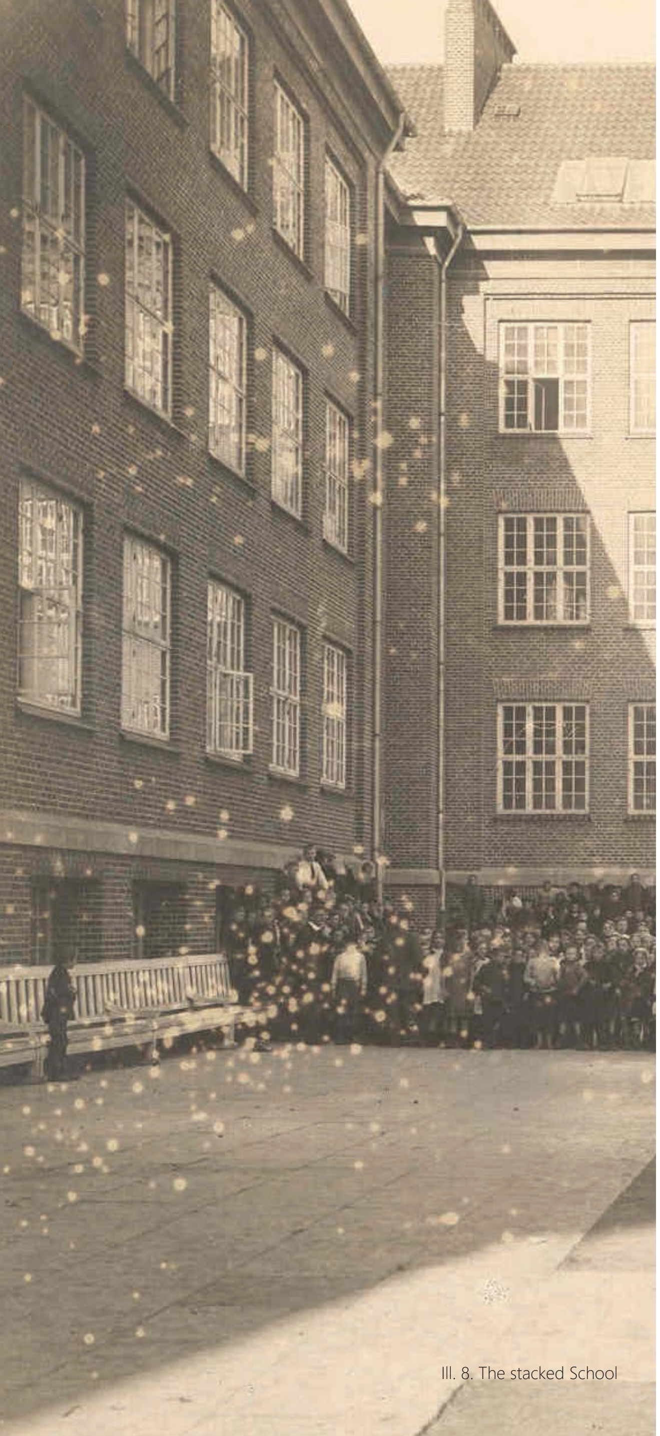
The Nordic values, according to the international acknowledged expert in education, Roland Østerlund [UVM, 2013].

- Democracy and citizenship
- Individuality and community
- Spirit and freedom of speech
- Conversation and discussion
- Commitment and job satisfaction
- Ambitions and quality
- Form, aesthetics and function
- Craft and spirit
- Creativity and creation

The public school has a central role when developing integrity of the individual student [UVM, 2013]. Freedom of speech allows an open dialogue and discussion of opinions and ideas that intent to develop us as individuals. You are allowed to disagree but only in the light of respect and with qualified arguments. Discussions and the act of forming a dialogue are used in the public schools as a part of the daily learning environment, in the open student to teacher relationship and as a part of the evaluation.

The ability to learn is based on curiosity, engagement and astonishment, and both teachers, parents, and the students themselves are responsible for achieving this. Thus, the public schools must challenge these learning disciplines in order to continue the academic development of children. The schools must show discipline and enthusiasm, attention and focus on the students while being realistic of future goals. The academic development of students is a balance of disciplined teachers and motivated children, who are aware of their own responsibility in their learning progression.

Ill. 7. Teacher helping girl

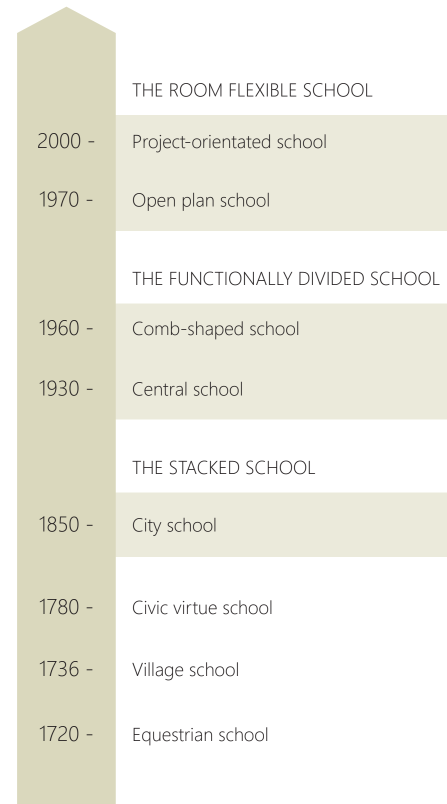


Ill. 8. The stacked School

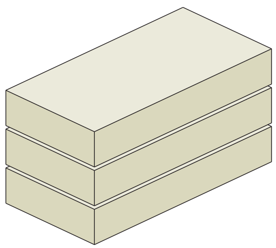
SCHOOL TYPOLOGIES
HISTORICAL PERSPECTIVE

Throughout the history of the Danish public school, new schools have been built to reflect tendencies and educational principles of the corresponding time. Schools have been built in various shapes and sizes, but historically the typologies of school buildings can be described with three different categories, referred to as the stacked school, the functionally divided school, and the spatially flexible school, which each represents one-third of existing schools in Denmark [Erhvervs- og Byggestyrelsen, 2010].

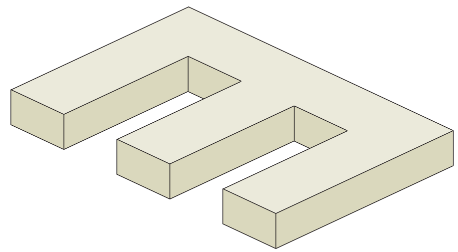
An analysis of these typologies will bring light on both previous and current tendencies within school architecture and account for some of the advantages and disadvantages that can be found in each typology in an educational, functional and environmental perspective.



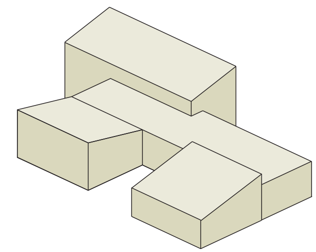
Ill. 9. Time line



Ill. 10. The stacked school



Ill. 11. The functionally divided school



Ill. 12. The spatially flexible school

THE STACKED SCHOOL

The typical design of the stacked school consists of 3-4 storeys with a central entrance and staircase leading to the different floors. The structure of each floor is hallways and classrooms arranged as cells. The schools' outdoor areas are covered with asphalt.

The architecture supports the principles of teaching of the time where teachers are placed on a podium addressing the sedentary children [Erhvervs- og Byggestyrelsen, 2010].

THE FUNCTIONALLY DIVIDED SCHOOL

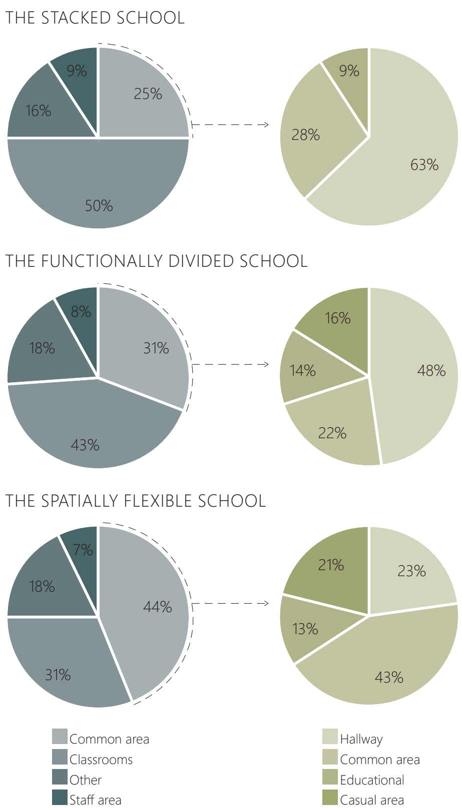
Many of the schools built in the 60's are shaped as a comb where the functions as classrooms, subject-specific rooms and staff rooms are allocated to separate parts of the building. The school is normally just one storey, which means that it spreads out over a larger area.

This type of school was often placed in new residential areas at the edge of the city with large areas for sport facilities and playgrounds. The horizontal structure conveys the idea that teachers and students are equal [Erhvervs- og Byggestyrelsen, 2010].

THE SPATIALLY FLEXIBLE SCHOOL

The spatially flexible school covers more recently built schools originating from the open-plan schools of the 70's. The schools are divided into different areas with 'home' areas where the interior can be modified to establish different smaller spaces.

The spatially flexible school reflects current tendencies within pedagogy, where learning is achieved through collaboration between students, teachers and other interested parties. The schools are flexible to support various forms of teaching or project and group work [Erhvervs- og Byggestyrelsen, 2010].



Ill. 13. Distribution of area

As a result of the cell structure in the stacked school typology, a substantial part of the total area of the school is used for hallways and staircases leading to the different rooms and levels. The hallways are typically long, narrow, without much natural light and unsuitable for other purposes than internal traffic. But the principle of the stacked school with multiple levels also has advantages in its design, leaving a smaller footprint on the ground with more room for outdoor activities. The building volume is more compact than the other typologies with a smaller surface area for heat loss. Additionally, this typology has potential when designing for natural ventilation and the use of thermal buoyancy compared to single storey buildings.

The principle of the functionally divided school and the comb structure results in long hallways and long distances between the different functions. This typology makes it easier to connect the inside with the outside from several parts of the building. Each classroom may have exits to the outside, which is an advantage when aiming for variation and movement during school hours. The division of functions, and the fact that there is only one storey, result in a large footprint and surface area of the building.

The design of the spatially flexible school is less defined, but it often include larger common areas that can be used for different purposes. Also the hallways are more spacious and can be used in multiple ways, for instance for exhibitions, recreational areas or for working in smaller groups. This typology seems to correspond best with the goals of the new school reform, where the individual student is in focus and there should be room for movement, creativity, and different learning processes.

The development of the school typologies has in general shown an increased focus on common areas compared to classrooms and subject-specific rooms, ill.13. This supports the development of educational principles, which have developed from one-way communication to a dialogue and varied teaching methods. But this also sets requirements for the common areas, which should have a purpose and be used by children and teachers, to avoid wasted space.

The design should not only use the features of the spatially flexible school, but also some of the good features from the previous typologies, as the proximity to nature from the functionally divided school, as well as the advantages of the stacked school with its smaller footprint and potentials for natural ventilation.

ARCHITECTURE AND LEARNING
THE WHOLE INDIVIDUAL

The Danish school reform has made an awareness of the need for new methods and new learning environments. This need is not unique for the school system in Denmark, it is an international development and it has been a long way coming. With the changing roles of the students and teachers over the last centuries, with rapidly developing technology and an increasing knowledge about the effect that our surroundings have on our well-being and our ability to learn, it is time to adjust our school system and our learning environments to the current and, if possible, future tendencies.

The goal of the Danish school system is not only to educate. More precisely it is to create and develop 'whole individuals' in a democratic society, with people knowing how to get ahead in the world [UVM, 2013]. An increased discussion of the 'whole individual' has arrived with the new school reform, emphasizing that everything cannot be learned through books and rote learning. Instead, children learn in different ways and with different means. The teaching and learning environments should be adapted to these different ways of learning.

> *"The ideal educational environment is a carefully designed physical location composed of natural, built, and cultural parts that work together to accommodate active learning across body, mind, and spirit."*
>
> [Anne Taylor, 2009, p. 31]

Anne Taylor makes a direct link between 'designing the whole building' and 'reaching the whole learner', ill. 14, with a reference to the Vitruvian Triad [Taylor, 2009]. Just as architecture is created through structure, function and beauty, a learning process happens through body, mind, and spirit. We learn with our minds by studying, problem solving and the development of ideas, and we learn with our bodies, through movement and the use of our senses. But we also learn through our spirit, our feelings and values, developing our self-expression.

REACHING THE WHOLE LEARNER	REACHING THE WHOLE BUILDING
BODY (physical learning)	FIRMITAS (structure)
MIND (cognitive learning)	UTILITAS (function)
SPIRIT (emotional learning)	VENUSTAS (beauty)

Ill. 14. Holistic goals of educational facility design

FIRMITAS	Facility is safe and secure, accessible, meets codes and regulations
UTILITAS	Facility is functionally flexible, structurally adaptable, instructionally supportive
VENUSTAS	Facility is a visionary, motivational, sustainable, high-perfomance teaching tool

Ill. 15. From Vitruvius to the modern school facility

BODY

A large part of the learning process happens through the body with the use of different senses as seeing, hearing, and touching. Children also learn with movement of their bodies through play, exercise, and hand-eye coordination [Anne Taylor, 2009].

For this reason a school facility must provide good conditions for the use of these senses with sufficient amount of daylight, great room acoustics and a tactile learning environment, where children can learn with their hands and the use of their body. Children must have the possibility to learn outside the classroom in different environments as playgrounds and sport facilities.

One of the most essential things, that must be fulfilled before being able to learn, is the feeling of being safe and comfortable. This means that the physical needs must be met and the building should be up to all health and safety standards and regulations.

MIND

For a school facility to be successful the functional needs must be satisfied offering sufficient space, the flexibility and adjustability needed to support the mind in the physical environment. There must be room to experiment and develop ideas alone or in small or large groups. The building design itself has the opportunity to inform or teach children about physics, about materials and the way things are put together, about sound, sun and shadows, and everyday technology.

A school facility must host many different activities and teaching styles, meeting all the functional needs that this involves. But there must also be concerns about the materials, the area, and the cost used for creating the facility for both practical and sustainable reasons. If the building is executed in a flexible way, where spaces can be adjusted to different activities and a changing number of people, materials and square meters can be saved.

SPIRIT

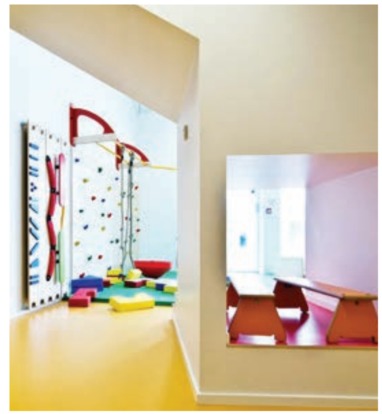
Another dimension of learning, that is not found in many textbooks, is getting to know yourself, creating an identity, an opinion and finding your own strength and weaknesses. To know about one self, one must also learn about society, different cultures and develop respect for nature and other people. The design of the school should be developed to encourage teamwork as well as individual reflection.

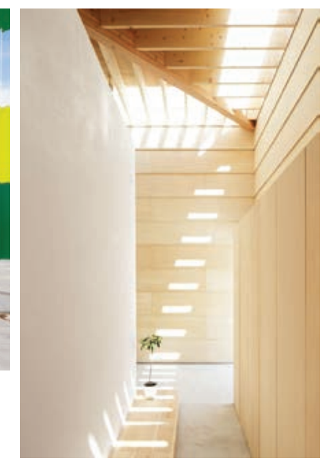
A good state of mind is important when learning, and a building may help achieving psychological comfort with the use of natural daylight and careful selection of colours and materials. An aesthetic environment that stimulates the senses can offer inspiration and motivation to learn and to be creative. In this way, one could argue that *venustas* is not only related to the spirit but also to the bodily senses.

THE LEARNING ENVIRONMENT

Children learn in multiple ways and one of the problems with most schools is the restrictions that the facilities set on children's possibilities to develop. Schools are built for academic and scientific teaching rather than personal and creative development. The many rules that most people are familiar with from school as 'no running' and 'no yelling' depict some of the issues that schools have today [Steinø et al., 2003]. Children spend a large part of their lives in school, and they should have room to run, to play, to sing and shout and develop in every way possible. This does not mean that children should be able to do whatever, wherever they want, but a school facility must first and foremost be designed on the terms of children.

The relation between the whole building and the whole learner illustrates the importance of the physical environments in schools for optimal learning conditions, as well as the importance of accommodating both physical, functional, and psychological needs.



Ill. 16 - 19. Architecture and learning

GOALS OF THE MUNICIPALITY

PEOPLE, TECHNOLOGY AND NATURE

The municipality of Struer has a goal of making Struer an extraordinary place to live. A place, where inhabitants stay for longer periods and a place, that attracts new settlements. This must be acquired through the strategy 'Close to people, technology and nature'; three focus areas for the future, defined by the municipality of Struer [Struer kommune, 2011]. They express a desire of making the city attractive for young families participating in local business. By addressing career opportunities and offering educational facilities, the city emphasizes spatiality and professionalism.

In relation to this, public schools have an important role in the progression of Struer as an attractive city. Cooperation between public schools, secondary educational facilities and local business, can inspire young people to complete a qualified education. After school activities such as sports and hobbies are also important aspects of the strategy, where the municipality intents to offer cultural and recreational activities for the inhabitants, to develop affiliation and a community feeling for both children and parents [Struer kommune, 2011].

Technology is a key parameter for the city's growth, where many business developers settle and must be able to attain the right knowledge and resources. The municipality's vision is to use the spirit of developers and innovation as branding for the city regarding both technology, creativity and economics [Struer kommune, 2011]. A collaboration between public and private sectors, as well as local business and educational facilities, is important to ensure new settlement in the area.

Struer has a unique location with nature, the harbour and varied landscapes in the nearby environment. The municipality values greenery in urban spaces and city nodes, and focuses on communicating knowledge of natural and cultural landscapes in the local environment. This could furthermore be included as a method of learning in the local public schools.

Ill. 20. Children in contact with nature

Ill. 21. Boy experiments with sound

STRUER - A CITY OF SOUND

Sound is as a key parameter for Struer with Bang & Olufsen as predecessor. B&O is a Danish company, established in Struer, designing and developing different high-end products as music systems, loudspeakers, televisions and telephones. The company is recognized globally for innovative technologies and elegant design [B&O, 2015]. The municipality of Struer intents to use sound as a method of branding by implementing sound in activities of the local business industry, culture, and tourism. Struer seeks to become the best city in Denmark to host companies working with sound, especially with BusinessPark Struer, an environment of innovation for young companies to share knowledge.

With the theme of sound as a tool for innovation, the municipality will use acoustics to improve everyday life for inhabitants, children, adults, and residents with disabilities by including sound in urban spaces, public schools, and other educational facilities [Struer kommune, 2015].

LOCAL SCHOOL POLICY

In order to make the city more attractive for new citizens, favourable conditions for children and teenagers are important elements. The municipality focuses on these areas in relation to preschools, public schools, and recreational activities [Struer Kommune, 2011]. Focus should be given to the individual student, his or her academic and social competences, and they should be challenged to think creatively and innovatively. The individual student must be prepared to become an active part of the society and gain affiliation to the city within social and professional aspects.

The municipality of Struer has defined four key parameters with valuable and important aspects for the city: Vitality, Knowledge, Community, and Equality [Struer kommune, 2010].

"

VITALITY

We will prepare every child to handle their life by considering the individual child's possibilities through learning, formation and well-being.

KNOWLEDGE

The centre focus in the public schools is education of high academic value. It is healthy to wonder, and knowledge is understood in a wide perception, where children are challenged in both academic and social competences, creativity and innovation.

COMMUNITY

The children's social and academic competences are strengthened through engaged and committing communities on all levels. Especially between children, parents and teachers, but also between recreational-, business- and other educational institutions. The right to be different should be cherished by teaching each child about the local community. Teaching and learning environments should be developed to benefit all children.

EQUALITY

With an acknowledging approach, children and adults are interpreted equally – not equivalent – but as persons in a dialogue characterized by empathy, tolerance and respect.

[Struer kommune, 2010]

LYDENS BY SKOLE
A NEW PUBLIC SCHOOL

The municipality of Struer has asked a research firm, Deloitte, to perform an in-depth analysis of the current public schools in the area. The purpose of the analysis is to understand the current challenges of the existing schools with an aim for improvement, following the goals of the new Danish public school reform.

The number of students in the city of Struer is expected to decrease from 1.208 students to 940 students in 2024. The total student capacity of the municipality covers 3.860 students, which is 1367 more than what is actually needed. Together with the challenges of running smaller schools, compared to larger, more efficient, and academic sustainable schools, the municipality considers combining some of the educational institutions [Deloitte, 2014].

The research, performed by Deloitte, furthermore describes that the efficiency of the performance of students do not change according to smaller class sizes, the level of learning will remain the same. However, the size of the school has an influence on the economy, thus a school size of 800 students is ideal [Deloitte, 2014]. As the population of Struer is decreasing, Deloitte suggests keeping Parkskolen in the West of Struer, and decrease the number of schools in the East of Struer from two to one. Thus, the analysis suggests closing Østre Skole, which is poorly maintained, worn and outdated [Deloitte, 2014]. By combining Østre Skole, 436 students, and Gimsing Skole, 329 students, a new school of approximately 765 students is considered in Struer.

Reflecting on the school sizes, larger schools may have more potentials to include specialized and high educated teachers, while smaller schools may feel more comfortable and secure. When asking different teachers about preferred classroom sizes there are different opinions. One teacher states that she believes 10-15 students are adequate in order to supervise and help all students. This could be implemented in larger classes by including more teachers or divide the class in smaller teams for elective courses or other more active lessons. Another teacher states that she prefers classrooms of 20-24 students, but that it is not always the number of students defining a well-functioning learning environment. The discussion is much more differentiated, determined by the combination of students, their abilities to cooperate and the teacher's skills.

"*An ideal class is 10-15 students. Large classes influences the students' work, the environment in the classroom, and the teacher finds it difficult to help all students right away. A lot of time is wasted if you can't move on without the help of the teacher.*"

Rikke Sørensen [AAU, 2015]

"*About 20 students with room for 24. It is not always the number of students that determines how good a class is and how much you learn as a student. It depends on many things for example the social composition of students, their abilities to co-operate and much more.*"

Grete A. Thing [AAU, 2015]

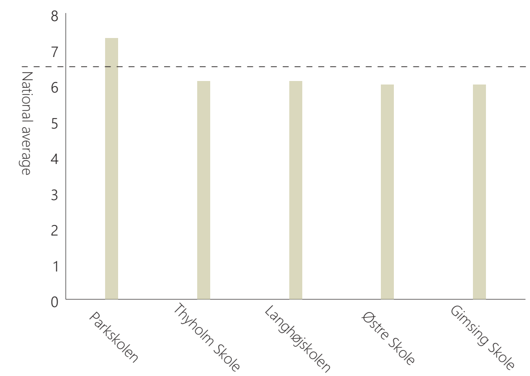
THE LOCATION OF A NEW SCHOOL

Within the municipality it is discussed whether to extend Gimsing Skole or create a new school in the centre of Struer [Østre Skole, 2015]. If it is decided to build a new school, the location must create a connection to local industries and secondary educational facilities. The municipality value following aspects when considering location for a new school:

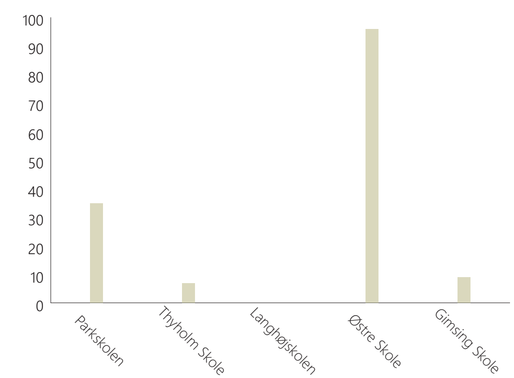
- A cultural facility
- Near other cultural facilities
- Near residential houses
- Short distance to Parkskolen
- Central position

The new Danish public school reform includes demands to the organization of schools, new methods of learning, sport and movement every day. Furthermore, attention on academic results are important, including longer school days. Looking at the national average grading of 6.5, Gimsing Skole and Østre Skole has a negative result of 6.0 measured for the last five years as a comparison to Parkskolen with average of 7.3. Furthermore, the schools have a negative educational efficiency compared to what is expected from the parents' background, and a lower number of students taking a secondary education.

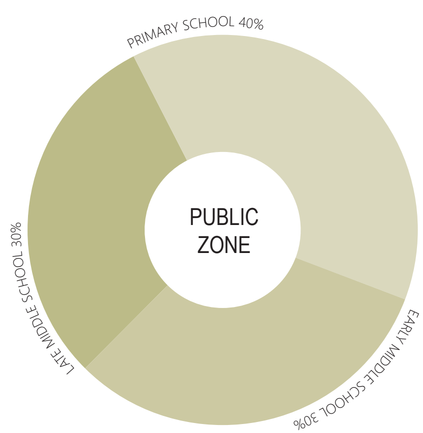
A general interpretation of Parkskolen being the most successful and academic orientated public school in Struer is stated. An analysis of the teachers' educational focus describes that Parkskolen focuses on the students' academic performance, while the other schools in Struer focus more on social development and well-being. The low average grade for Østre Skole is likely to be related to the social composition of students, where the school hosts the majority of the special education classes in the municipality and also the largest part of children with different ethnic backgrounds [Struer Kommune, 2007].



Ill. 22. Average grade in schools



Ill. 23. Number of students with a different ethnic background



Ill. 24. Area distribution

A SCHOOL OF SOUND

The municipality aims to use the surrounding nature, culture and urban spaces as room for learning, as well as inviting the inhabitants to use the building at any time, creating a school for the city. By building the school in the city centre, the dense area of Struer will gain a public node and a new landmark. A local cultural institution and a cultural meeting point accessible every day.

A public zone forms a conceptual idea of a strong academic centre from where knowledge and inspiration arise and motivate the students to learn. It is a point of navigation and a place of comfort and security. Different zones, primary school (*Indskoling*), early middle school (*Mellemtrin*) and late middle school (*Udskoling*), are organized near the public zone, emphasizing a spatial learning environment. The school is a stage where teachers and students create and change the scenes of activities. The building must be organized by humanistic, scientific and creative subjects and include movement and acoustic as key parameter [Struer Kommune, 2014].

Lydens By Skole is a project using sound and acoustics to creative innovative solutions for improved learning environments. A number of studies show improved abilities to observe, solve problems, remembering and take decisions as a result of including acoustics in learning environments. The new school will offer two directions with sound as central focus, created in near cooperation with the local community [Lydens by skoles støtteforening, 2015].

Science and technology

Creativity, music and aesthetics

Lydens By Skole thereby becomes an initiative by the municipality to change the negative progression of the city of Struer by creating an attractive public school. This school aims to invite new citizens to Struer, families with children or young couples who may have business interest in the city and see potentials of settling down. The two proposed school directions, science and technology, creativity and music could be implemented in the school design through labs and elective courses. This specialization mainly accounts for older students in the late middle school, to motivate and generate ideas for secondary educational choices.

Ill. 25. Music and nature

DEFINING THE USERS

ADAPTING DIFFERENT NEEDS

The public school must create spaces for a large user group with different needs, orientated around children in the age of 6-16. It is furthermore a working facility for teachers, pedagogues, leaders and other administration.

STUDENTS

The students on the school have different needs and ways to learn according to their specific age. It is therefore important to accommodate these needs specifying how different rooms should be designed and organized accordingly. By arranging the facility in different age groups it is ensured that all students are able to form affiliation and are challenged every day in an environment that feels welcoming and meaningful for everyone. The school will be organized in three categories, primary school from 0.-3. grade (*Indskoling*), early middle school from 4.-6. grade (*Mellemtrin*) and late middle school from 7.-9. grade (*Udskoling*).

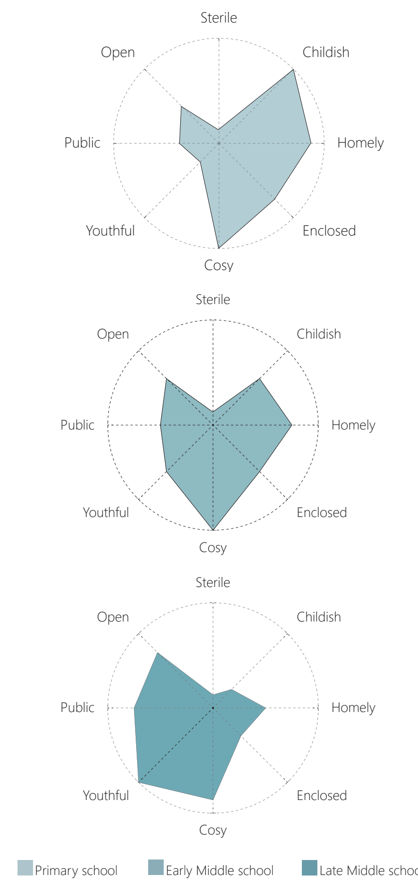
Children are different. Girls are often better to sit quiet and obtain information or silently play in breaks. Boys have larger needs for being active, which is expressed during classes, where boys often become restless or inpatient. Similarly, activities performed by boys in the breaks are often more intense and oriented to physical environments [Gitz-Johansen et al., 2001].

PRIMARY SCHOOL 0.-3. GRADE

Children in primary school are the youngest users of the building within the age of 6-10. Primary school is influenced by hierarchy, where the youngest children have a tendency to seek security and comfort, avoiding areas where older children are playing [Aarhus Kommune, 2012]. This relates to the illustrations, ill. 26, focusing on a cosy, childish and homely environment for the younger students. It thereby becomes important to separate the areas for younger students, emphasizing a need for familiar surroundings, which feels recognized and accustomed.

EARLY MIDDLE SCHOOL 4.-6. GRADE

Children in the early middle school have the age of 11-13. In this stage students develop from being a child to a young person, becoming more individual and starts developing opinions independent of others [Aarhus Kommune, 2012]. The students gain a desire of exploration and experimentation with subjects and individual projects. The educational level for these students increase in intensity and so does the requirements for the students.



Ill. 26. Atmosphere

LATE MIDDLE SCHOOL 7.-9. GRADE

Late middle school is the last stage of the public school, from the age of 14-16. A focus of preparing the students for their further academic journey choosing a secondary education is emphasized, where attention is oriented to the students' individual interests [UVM, 2014]. By including more elective courses, such as technical, creative, scientific and humanistic subjects, the school enhances the student's ability to form interests. This also sets demands to the physical condition of classrooms and facilities as workshops, music rooms, kitchens, laboratories etc.

TEACHERS AND OTHER EMPLOYEES

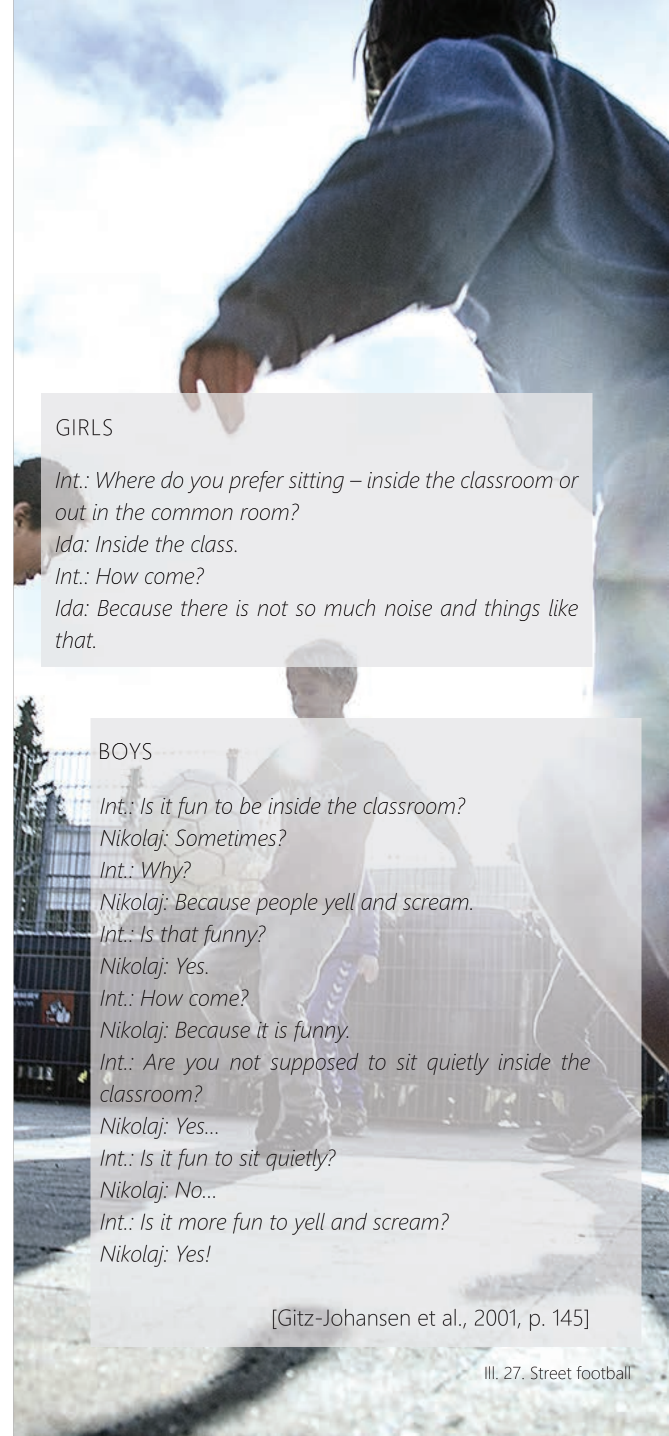
Teachers and pedagogues use the public school as a working facility and spend a lot of time in the environments for children. They must relate to the students' needs and consider how to create a functioning learning environment. In the traditional school organization, classrooms are an important point of gathering between student and teacher, allowing exhibition of projects, drawings and learning methods.

As a result of the reform teachers spend more hours inside the school facility, which creates a physical need for workspaces to prepare lessons, correct assignments and study learning methods.

The school staff also includes leaders, administration, janitors, cleaning, healthcare, school psychologist and others, which sets demands to the physical organization of the school to allow all employees to perform their job as requested.

CITIZENS

The citizens must be considered, when designing a new public school, to invite the city as a cultural institution. By creating a social landmark for the citizens in Struer, a level of affiliation can be obtained. In addition, the collaboration between the school and recreational facilities can be strengthened [Lydens by skoles støtteforening, 2015]. By using the sport facilities of the school after school hours, an inviting environment is created for children and adults to gather. Furthermore, the many rooms, empty during night, can possibly be used for evening classes addressing the requested facilities.



GIRLS

Int.: Where do you prefer sitting – inside the classroom or out in the common room?
Ida: Inside the class.
Int.: How come?
Ida: Because there is not so much noise and things like that.

BOYS

Int.: Is it fun to be inside the classroom?
Nikolaj: Sometimes?
Int.: Why?
Nikolaj: Because people yell and scream.
Int.: Is that funny?
Nikolaj: Yes.
Int.: How come?
Nikolaj: Because it is funny.
Int.: Are you not supposed to sit quietly inside the classroom?
Nikolaj: Yes...
Int.: Is it fun to sit quietly?
Nikolaj: No...
Int.: Is it more fun to yell and scream?
Nikolaj: Yes!

[Gitz-Johansen et al., 2001, p. 145]

Ill. 27. Street football

SUSTAINABILITY

The last few years, and even decades, have brought an increasing awareness about sustainability. It is widely agreed upon today that current changes in our climate is caused by human activity, and more changes will come in the future. Changes that may have large influences on nature and biodiversity, extreme weather situations, and sea levels, and thereby the possibility to live and survive in the affected areas.

Sustainability is not only related to our climate, it also concerns people and economy. These three aspects were discussed in the Brundtland Report from 1987, also known as *Our Common Future*, and are today known as the three pillars of sustainability; economic, social, and environmental [World Commission on Environment and Development, 1987].

Denmark is one of the leading countries with sustainable initiatives, and have large ambitions for what can and must be achieved both nationally and internationally. In a report from 2014, *Et Bæredygtigt Danmark*, the Danish government describes their goals for a sustainable development. Their 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 [Regeringen, 2014].

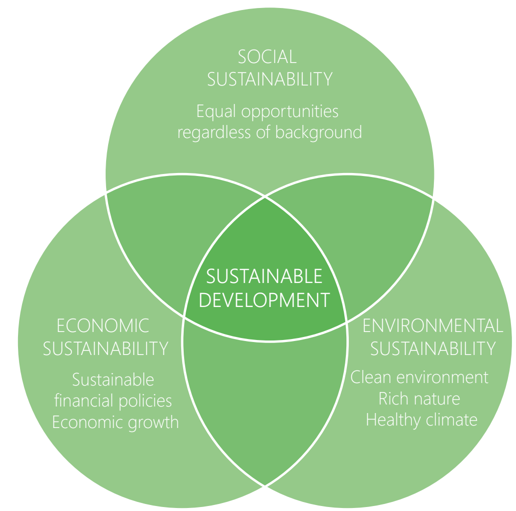
ECONOMIC SUSTAINABILITY

From a national point of view, economic sustainability is about economic growth and a high employment rate. Growth is important to be able to develop as a welfare state, where everyone has access to health services and education. As part of the strategy for growth, more young people should aim for a higher level of education [Regeringen, 2014]. It is therefore important that children thrive in school and find an interest in learning and developing early on.

With regards to architecture and economic sustainability, it is important to find long-term strategies with minimal expenses for maintenance and operation, for a better economy concerning the lifetime of a project.

SOCIAL SUSTAINABILITY

One of the most essential aspects of social sustainability is equal opportunities for everyone. In this context important goals are to prevent social vulnerability and negative social heritage [Regeringen, 2014]. This is closely connected to the new school reform, where the individual child is in focus and diverse teaching methods are encouraged.



Ill. 28. Three pillars of sustainability

A new school facility should be accessible and inclusive, welcoming to all groups of society. The school should support the different ways of learning that children have and it should bring attention to the individual as well as the community. A school has the potential to be a centre of activity and communication between children, teachers, parents, politicians, and citizens of the surrounding community.

ENVIRONMENTAL SUSTAINABILITY

The Danish government has already implemented several initiatives to reduce our greenhouse gas emissions and to rely increasingly on renewable energy rather than fossil fuels. This also applies for the building industry, where all new buildings must operate within a certain energy frame while providing a healthy indoor climate.

We all have a responsibility to take care of the environment and protect our natural resources, but this requires a general awareness for everyone to participate. In this connection schools play an essential role to make our way of living more sustainable in the future. Children should learn where their food comes from, they should learn to respect nature and understand that the choices we make as consumers influence the industries and the natural environment. These things can be taught in classes, but if the children should get a true understanding of the way things work, they must experience it with their own eyes and hands. This can be done with visits to farms and factories, but why not bring some of these elements to the school facility? A school garden, taken care of by the children, can give them a sense of responsibility and teach them about nutrition. Natural elements and a wide biodiversity can teach children to appreciate and respect our natural environment. Children in regular contact with nature has shown to be less sick, more considerate and creative, and find it easier to focus [Dansk Center for Byøkologi, 2002].

"*I hear and I forget.*
I see and I remember.
I do and I understand."

Confucius [Dansk Center for Byøkologi, 2002]

There are also other potentials in creating a school building that teaches about, and makes sustainable principles noticeable. There are different ways to utilise the heat from the sun for heating, while on the same time shielding from unwanted solar radiation. The building can be designed for natural ventilation to save energy and also call attention to the production of energy from renewable sources by integrating solar panels. How exactly some of these sustainable initiatives can be implemented in the school building will be presented later on in relation to the site analysis.

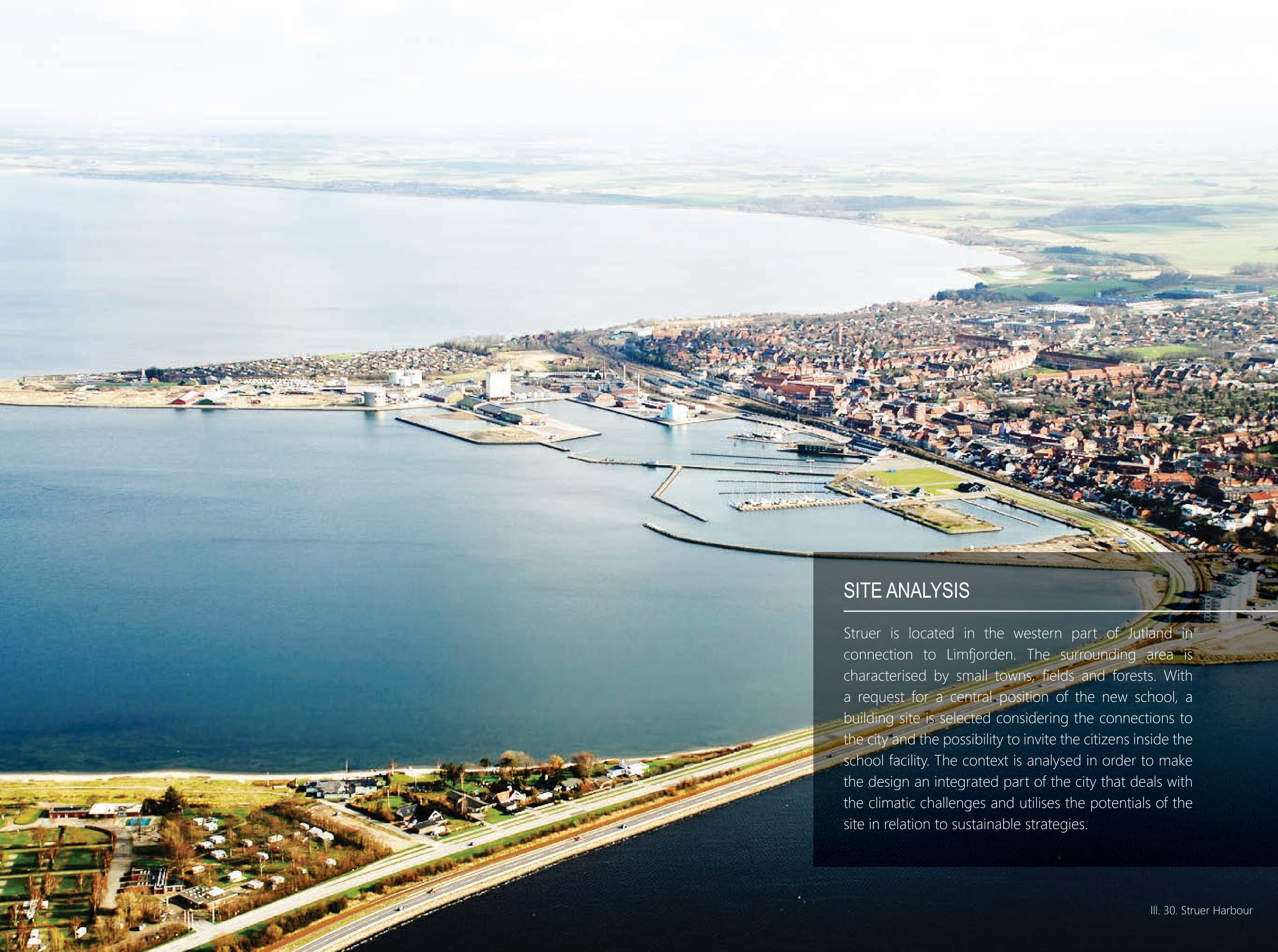
Ill. 29. Lessons in nature

SUMMARY THEME ANALYSIS

Analysing the principles of the new Danish school reform, it is clear that it has brought large changes to the everyday of school leaders, teachers, and children. Changes that current school facilities in many cases are not prepared for. First of all, the initiative that teachers must prepare for lessons and correct assignments at school, and not in their own home, require more space and workstations. Secondly, the school must support varied teaching methods in both literary and creative subjects, where children also learn outside the classroom through activities and movement. They learn as a whole person through body, mind and spirit.

The typology of the new school building should support the initiatives of the school reform and current educational principles, but on the same time learn from history of school buildings and the potentials that existed in earlier typologies.

The municipality of Struer has large ambitions of making the city a more attractive place to live with a new central school, *Lydens By Skole*, as a draw for newcomers, and a mean to connect the city and its inhabitants. The school should not only address the students but also the local citizens, offering different activities and events outside school hours, where the school becomes a social landmark and node of life in the city.

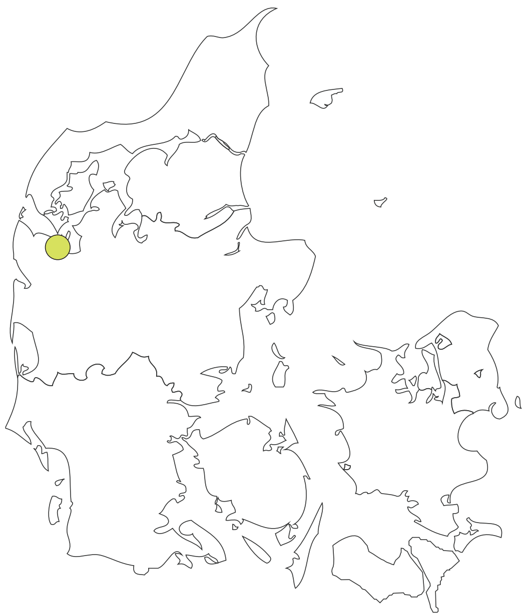


SITE ANALYSIS

Struer is located in the western part of Jutland in connection to Limfjorden. The surrounding area is characterised by small towns, fields and forests. With a request for a central position of the new school, a building site is selected considering the connections to the city and the possibility to invite the citizens inside the school facility. The context is analysed in order to make the design an integrated part of the city that deals with the climatic challenges and utilises the potentials of the site in relation to sustainable strategies.

Ill. 30. Struer Harbour

CHOOSING A SITE
CREATING A CULTURAL LANDMARK

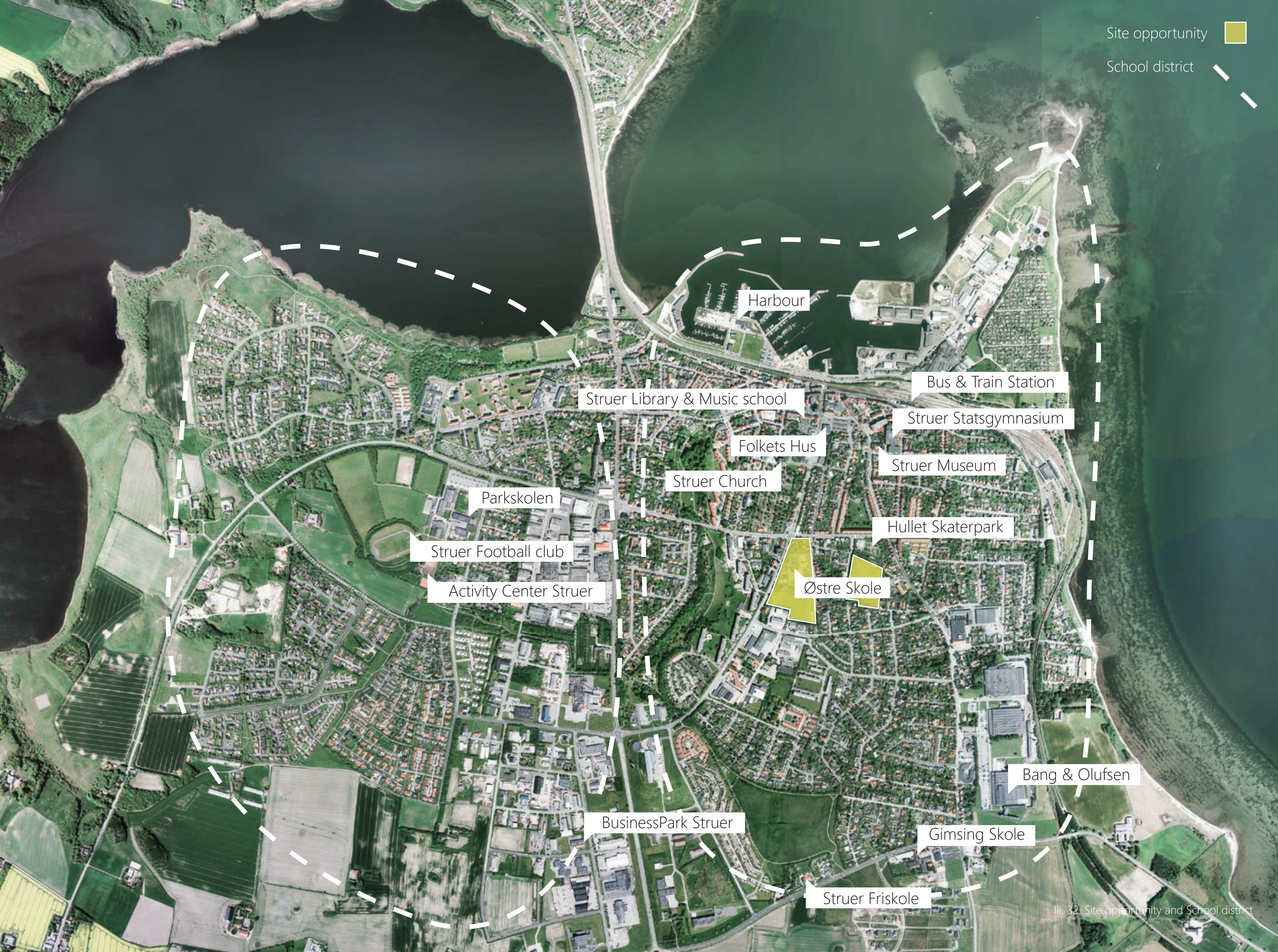

Ill. 31. Location in Denmark

The goals of the municipality are taken as point of departure when choosing a site. A desire of creating a cultural institution inviting the citizens to use the facilities at the school on a daily basis. The school must have a central location near other cultural facilities to enhance local cooperation. This accounts for institutions, for local secondary education, and industrial facilities, leading more students to a higher level of education. The site should furthermore be located near residential housing to allow short transportation for as many students as possible. For students traveling with public transportation, it is essential to have bus stops and the train station near the site. The school must be visible in the local area and be an urban landmark. A point of gathering for the citizens to enhance the community feeling.

The municipality has outlined two proposed sites for *Lydens By Skole*, ill. 32 [Østre Skole, 2014]. The first site is on the existing site of Østre Skole, which is intended demolished when a new school is constructed. This site is located on the corner of two major roads, Bredgade and Ringgade, from where the site is fully exposed to the area. Some residential houses meet the site, as well as some industrial buildings to the South.

The other site is located near a skater park 'Hullet', which is more private, quiet and protected from major roads. This site is surrounded by residential houses only, thus it appears more secure and protected compared to the site at Østre Skole.

Considering the goals of the municipality of creating a new public school visible for the city, it appears most accurate to choose the site at Østre Skole for the project. This site suggests creating a public node, a point of gathering with a visible entrance from the two major roads. The advantages from the site near "Hullet" of security and privacy, could potentially be implemented in the project by other architectural methods, as vegetation or pockets in the building envelope to create niches around the school.



Ill. 32. Site opportunity and School district

EXPERIENCING THE SITE

CAPTURING THE IDENTITY

A visit to the site forms an impression of the identity and characteristics of the area. This illustrates the current school building and outdoor facilities being outdated and unmaintained, with dismantled curtains and damaged brickwork. The current Østre Skole is surrounded by green areas, sport fields, a rough school yard with basketball facilities, and some wooden shelters nearby. The site shows few initiatives of placing outdoor activities, however the items appears discouraging and uninviting.

The site has an introvert appearance that is unappealing from the surrounding streets, with a thick edge of vegetation blocking the view. This private and uninviting expression must be dismantled in a new school project, to change the identity to something more extrovert and inhabitable. The solution for ensuring security for children is not necessarily a blocking layer of bushes and trees, but could potentially include more open and transparent elements allowing visibility. Furthermore, the feeling of being uninvited on site must be changed through more playful, colourful and exploratory elements. By including playgrounds for movement and active learning, inhabitable outdoor spaces could be created emphasizing a childish and imaginative environment.

Østre Skole is a functionally divided school with a comb shaped building structure. The school stands with red bricks and different sheet elements in dark colours, a slow steep roof and a low room height. The area surrounding the site has a general materiality in red and yellow brick, however newly developed areas of Struer, such as the harbour front, are bringing in a different appearance and new materials as dark concrete elements with a Nordic minimalistic expression. The new school must similarly express a new time, a beginning of something fresh and rewarding.

Ill. 33 - 39. Østre Skole

CONTEXT

ANALYSING THE SITE

Ill. 40. Functions

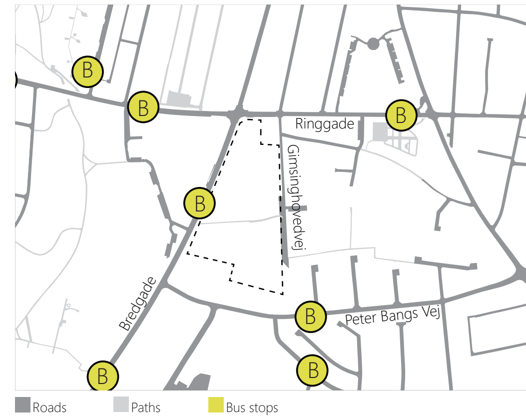
FUNCTIONS

The functions near the site are dominated by residential housing, with a few public facilities in the area. Educational institutions as a kindergarten, public school and after school facilities are located near the site. Industry and a grocery store are placed South from the site. Also, two dentists and other health functions are located in a near distance.

Ill. 41. Typologies

TYPOLOGIES

The typologies in the area are characterized by a majority of low open, concentrated to the Southeast with residential houses. This typology is typically seen as a majority in smaller communities with a large amount of families preferring a traditional type of housing. To the West, a number of high open typologies are placed defining an area of a diverse social heritage. Further to the West, some low dense buildings are located.

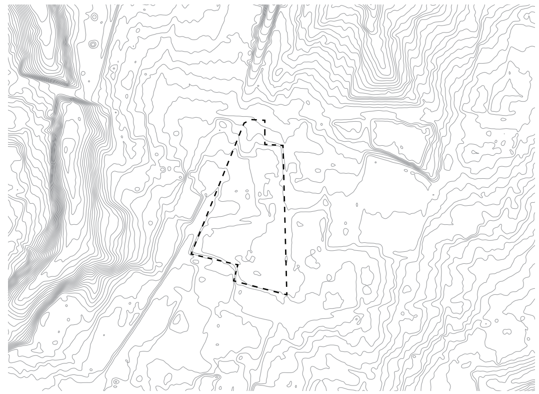


Ill. 42. Infrastructure

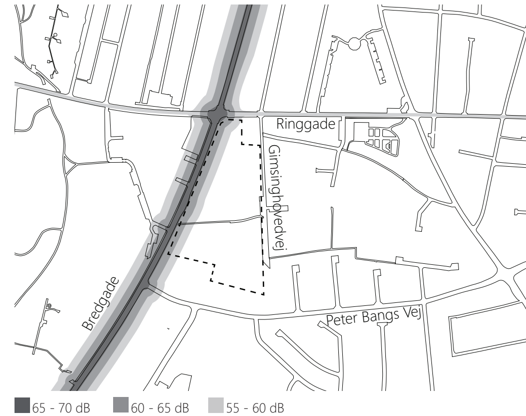
INFRASTRUCTURE

The infrastructure near the site has two larger roads crossing, Bredgade and Ringgade. These streets run perpendicular across the city. A smaller more private street, Gimsinghovedvej, defines the site to the East. Additional bus stops are located near the site enhancing public transportation for the students attending *Lydens By Skole*. Pathways connect the site with residential housing in the area, allowing students to walk safely to school.

Ill. 43. Vegetation



Ill. 44. Topography



Ill. 45. Noise

VEGETATION

The vegetation in the area is characterized by large green areas surrounded by trees. Near the site a large park is located, Struer Lystanlæg, with a small lake, pathways and outdoor activities. A large graveyard is situated Northwest from the site with a green expression. Furthermore, sport fields are located on site and near 'Hullet', which can be used by the school for outdoor activities.

TOPOGRAPHY

The site is located in the centre of Struer having a decreasing slope towards the fjord. The topography lines defines a height difference of 0,5 meter, resulting in a flat appearance of the site. The green park to the West has a steep slope down, thus the area lies protected as in a valley. The small steep on the site has a low impact on the architectural design, but it could be included in level differences.

NOISE

The noise on the site is dominated by the largest road Bredgade, running across the city from South to North. Less noise is produced from Ringgade, running perpendicular to Bredgade. In the project, architectural considerations must be included to distance the noise from Bredgade and protect younger students from running out on the street.

> "
>
> *The municipality of Struer will initiate from a good starting point to become known as the community performing an active and dedicated effort on the areas of climate- and energy."*
>
> [Struer Kommune, 2013]

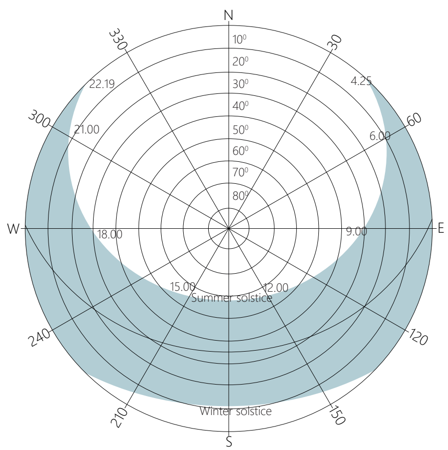
Ill. 46. High tide in Limfjorden

CLIMATE

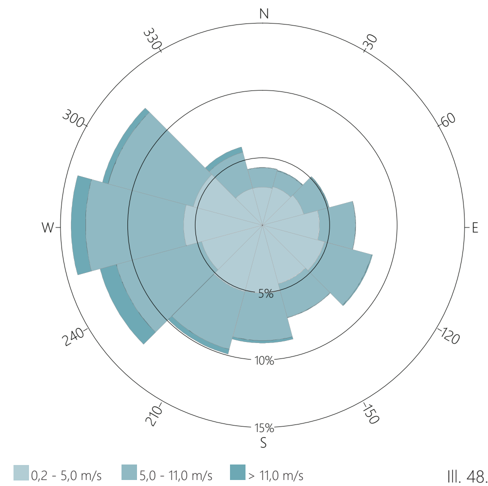
IMPLEMENTING CLIMATIC CHALLENGES

The weather in Denmark is very changeable, thus climate is an important parameter when designing a building. In the winter the climate is cold. During fall and spring seasons it is humid, while the summer is mild and warm. In addition to this, the world is confronted with climatic changes, which will affect how we experience the climate in the future. These climatic changes will result in warmer and more humid winter seasons together with longer summer seasons and more drought. Furthermore, extreme weather conditions will more frequently occur in Denmark [DMI, 2015].

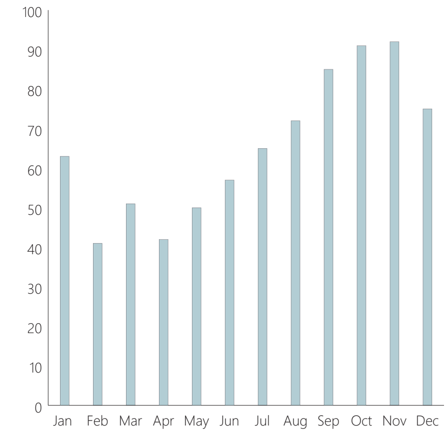
Struer is located near coastal conditions of the western Jutland characterized by windy and rough climate, which is a result of the dominant western wind from the northern hemisphere. Also, the landscape surrounding Struer is open with soft and undulating fields [Bjerg, 2012]. The municipality of Struer has created a strategic guideline of climate and energy concerns in the area. An objective of prospectively optimizing the local efforts intents to visualize environmental awareness towards the citizens and cooperation partners. The strategies for climate and energy focus on reducing the use of fossil fuels and being independent in 2035. Furthermore, strategies of decreasing CO_2 emission are included as well as considerations for energy efficient solutions [Struer Kommune, 2013].



Ill. 47. Sun



Ill. 48. Wind



Ill. 49. Precipitation

SUN

The solar conditions on site are seasonal, depending on the position of the sun during the day. On the longest day of the year, 21.06, the sun has an angle of 58 degrees on the horizon. During the shortest day of the year, 21.12, the sun reaches an angle of 10 degrees on the horizon [Gaisma, 2015].

These aspects can be included in the design process, by shielding for the high sun during the summer seasons and exploit the low angle during the winter for passive heat.

WIND

The wind on the site is influenced by western wind, where the strongest and most frequent wind is routed.

The measurements forming the wind rose are performed in Mejrup, near Hostebro, which is further inside the country compared to Struer. It must be regulated that the local climate near the fjord can appear more windblown. However, it is also a question of the specific site being placed in dense settlement creating shelter or possibly turbulence [DMI, 1999].

PRECIPITATION

Denmark is a country where most of the precipitation appears as rain more or less evenly divided over the year. The difference between the months, where it rains the least and most, is 41-92 mm [DMI, 2014]. Possibilities of how to collect and handle precipitation may be considered in the architecture and the urban design surrounding the building. This relates to collection of rainwater for a pond, lake or creek that can be used for academic purpose as an active learning environment.

SUSTAINABLE INITIATIVES

CONSIDERING THE ENVIRONMENT

ZERO ENERGY

New buildings must be designed and constructed to avoid unnecessary consumption of energy, while on the same time provide a healthy indoor environment. The goal for 2020 is that all new public buildings are nearly zero-energy buildings where the energy demand for heating, ventilation, cooling, and hot water is within 25 kWh per m^2 per year. Additionally, it is expected that all new public buildings must follow this demand already in 2018 [Energistyrelsen, 2014].

This strategy does not only apply for Denmark, but it is an initiative by the European Union to increase the general energy performance of buildings. A nearly zero-energy building is defined by the Energy Performance of Buildings Directive as "*a building that has a very high energy performance,... [ ]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*" [Ecofys, 2013, p. 18]

The goal of the project is to fully reach zero energy, by focusing on passive strategies to decrease the energy demand to the lowest degree possible, which should be compensated by renewable energy produced on site.

PASSIVE AND ACTIVE STRATEGIES

The approach to reach a building with high energy performance is first of all to reduce the energy consumption with passive means whereupon energy from renewable sources can be produced with active technologies. Passive strategies take advantage of natural energy such as wind or sunlight to achieve a comfortable indoor climate. During summer months, direct sunlight should be blocked to avoid overheating. This can be done by permanent or movable solar shading, or overhangs above windows, blocking the sun from a high altitude while allowing the low winter sun to enter. Another way to ensure a steadier temperature inside is to exploit the thermal mass of materials, which describes their ability to store heat. Heavy materials as stone have high heat storage capacity that can absorb the energy of the sun and release it again gradually.

Rooms should have a steady supply of fresh air for good air quality, and during summer time or in rooms with many people, ventilation is needed to remove accumulating heat. A large part of the energy a building uses can be reduced by ventilating naturally, where pressure differences makes fresh air move through the building caused by wind or thermal buoyancy.

Active strategies, unlike passive, are based on purchased energy in order to maintain a good indoor climate or produce more energy on site. The produced energy can be used for heating, cooling, and the electricity consumption of the users. One approach is to take advantage of energy from the sun through solar thermal collectors or photovoltaics. Installed PV panels will transform solar radiation into electricity, which can help covering the large electricity demand of a school facility. A different active strategy is to utilize the heat that can be found in the air, the ground, or in water with the use of heat pumps. Heat pumps run on electricity and transfer heat from a lower to a higher temperature which can be used for heating. Different types of heat pumps have different efficiency, but in general they produce three times as much energy as they consume [Triple E Heating & Air, 2015].

Another active strategy is mechanical ventilation, which makes it possible to control and adjust the indoor climate for comfortable standards. A problem with mechanical ventilation is the potential noise from shafts and aggregates, which could be avoided by natural ventilation. Together with the advantages regarding energy consumption, potential noise reduction is an argument for relying on natural ventilation as many months as possible during a year.

Ill. 50 - 52. Sustainable initiatives

INDOOR CLIMATE

A healthy indoor environment is essential in schools to optimize children's learning potentials. The quality of the indoor climate influences children's ability to focus as well as their physical and mental well-being. Many of our existing schools do not meet the recommended standards concerning the indoor climate.

50% of students are disturbed by noise

42% of students often feel too cold or too warm

36% of students experience bad air quality

[Sundhedsstyrelsen, 2012]

There are methods to measure and evaluate the quality of the indoor climate, and this project takes its point of departure in the recommendations from DS 3033, *Voluntary classification of the quality of the indoor climate in residential houses, schools, children's day-care centres and offices*, aiming for a building in category A+, which is slightly better than the requirements of the demands of the building regulations [DS 3033, 2011]. This is the minimum requirement for the project, while A++ is preferred when possible. The quality of the indoor climate can be divided into four categories: thermal-, atmospheric-, visual-, and acoustic comfort.

THERMAL COMFORT

Thermal comfort describes whether a person feels warm or cold. This is not only a result of the room temperature, but by the feeling of draught and the radiant temperature from hot or cold surfaces [VEB, 2011]. The room temperature should be balanced with heating and ventilation, and materials with high capacity of heat can help even out the temperatures affected by heat gain from the sun, people, and equipment, which are all varying factors.

ATMOSPHERIC COMFORT

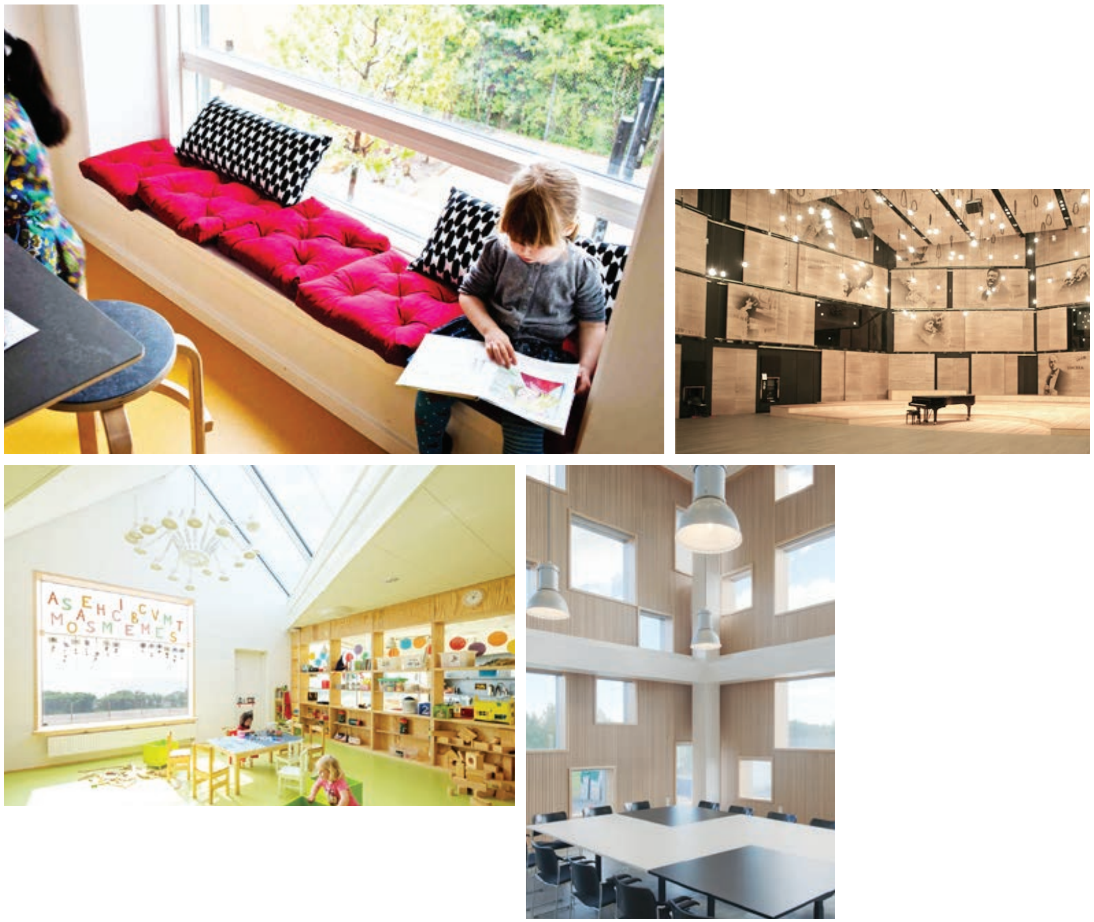
Atmospheric comfort describes the indoor air quality, which is influenced by smells, the relative humidity, and bioeffluents generated by building components and people as CO_2 [VEB, 2011]. This is often a problem in rooms with many people, such as classrooms or other learning facilities, where atmospheric comfort is important for optimal learning conditions. Bad air quality can be prevented with a satisfactory air change rate in each room.

VISUAL COMFORT

Visual comfort is subjective, but it can be achieved by pleasant colours and a suitable level of lighting. Natural daylight can decrease the need for electrical lighting, but it is also perceived as the most pleasant light when it is not blinding. Windows must be placed thoughtfully with bright materials to increase the daylight factor.

ACOUSTIC COMFORT

Soundproofing, room shapes, and materials' ability to absorb sound must be considered to achieve acoustic comfort. By working with acoustic methods, different sound experiences could be included in the learning environment. Adjustable panels allow students and teachers to change the acoustic experience and create a playful and exploratory room. Reverberation time is an indicator of the acoustic properties of a room, and a low reverberation time is recommended in schools, where many voices of children talking and playing can cause noise. The correct reverberation time in a classroom makes it easier to listen and form a dialogue.



Ill. 53 - 56. Indoor climate initiatives

CONCLUDING ON SUSTAINABLE INITIATIVES

First of all, it is essential to meet the energy goals of the government by reducing the energy demand and including renewable energy sources. This relates to passive strategies of a tight building envelope exploiting the use of thermal mass using heavy materials. Also, the climatic conditions of the site can be considered, relating to heavy wind from west relevant for natural ventilation to achieve a comfortable indoor climate. Furthermore, potentials of sunlight can be explored for passive heat and visual comfort. It is the purpose of passive strategies to remarkable decrease the energy demand of the building, from where active strategies may be considered.

An active strategy of photovoltaic panels exploit the potentials of the local climate to produce energy. This active strategy could potentially be visible to enhance the academic learning for students. By showing PV panels on the building, exposing ventilation shafts or shading for daylight, the sustainable initiatives can become an active part of the education. It is essential to consider these elements integrated in the architectural expression, to unite technique, function and aesthetics in a symbiotic whole.

SUMMARY SITE ANALYSIS

The site analysis initiated with choosing a site considering the goals of the municipality. Two sites suggest a central location, near cultural facilities, residential housing, and public transportation. The chosen site is located at the corner of two major roads in Struer, Bredgade and Ringgade, thus visibility and an extrovert expression is emphasized. When experiencing the site, it has an identity of being outdated, unmaintained, and uninviting. The green areas discourage outdoor activities, which the new public school must enhance. Also, a new school must invite the citizens into the site, expressing transparency and an extrovert appearance. The outdoor areas must be more playful, colourful and exploratory to enhance rewarding learning.

The contextual analysis describes considerations regarding functions, typologies, infrastructure, noise, topography, and vegetation. These analyses show a high amount of residential houses in the area with mainly low open typology. The area has rich vegetation and an even topography, emphasizing a green area attractive for families with children.

The climatic analysis suggests using the wind for sustainable initiatives, as natural ventilation, to enhance the quality of learning environments.

PROGRAM

The program sets out the overall goals and requirements, which apply for the project. The vision is presented, communicating the challenges and objectives, which are specified with a series of design parameters setting a frame for both the constraints and the aims for the design. A room program defines and organizes the required spaces and functions. All of these forms the basis for an exploratory and imaginative design process.

Ill. 57. Children reading

Ill. 58. Concept

CONCEPT

SUSTAINABILITY

In the project, sustainability is emphasized through passive strategies considering natural ventilation, passive solar heat and shading, integrated in the building design. In addition to this, active strategies will be implemented to reach the goal of zero energy. Sustainability also accounts for a healthy indoor climate with focus on daylight and acoustics as functional parameters. By visualizing sustainable initiatives, an exploratory and curious learning environment is created, while the students are informed about climatic changes and sustainable considerations.

SOUND

Sound is a key parameter for the municipality of Struer, which has initiated ideas of creating a new school, *Lydens By Skole*. From this perspective, the project includes a conceptual focus of sound as an architectural objective. This means, that sound becomes more than an aural comprehension. By looking at its scientific identification form is created within dynamic curves and circular waves unfolding one after another. Sound furthermore expresses a rhythm of repetitive elements, which could be used in the building design.

MOVEMENT

Movement relates to a national goal of improving all public schools with the new Danish school reform as guideline. Students must have additional learning environments, places to run, exercise, retreat, and contemplate. This relates to a close connection between indoor spaces and outdoor areas, to enhance multiple possibilities for creative and energetic lessons. When considering movement in architecture, it could be combined with a dynamic form to encourage exercise as a part of an active learning environment.

VISION

The thesis aims to develop a sustainable learning environment with an emphasis on passive strategies, supplemented by active initiatives to reach zero energy. Architectural focus on sound and movement should emphasize the municipality's goals of a new public school in Struer and implement initiatives of the new Danish public school reform.

Ill. 59. Girl in rain

DESIGN PARAMETERS

The design parameters describe technical, functional and aesthetic aspects regarding the design of a new school. The technical aspects relate to the subject sustainability by reaching the goal of zero energy and include mainly passive strategies with few active initiatives. It is desired to create a comfortable indoor climate with focus on daylight and acoustics.

The functional parameters relate to the organization of space, aiming for a flexible learning environment with a transformation between public spaces and individual zones. A near connection between in- and outdoor spaces enhance movement in multiple learning environments. Several elements with acoustic qualities emphasize sound as an inspiring and sensuous learning experience.

Considering the objectives of the municipality, the design must be visible and transparent as an exploratory learning environment. The project includes an aesthetic goal of translating sound and movement into architectural form by introducing repetitive elements, rhythm and a dynamic design.

TECHNICAL

Natural ventilation
Daylight
Acoustics

FUNCTIONAL

Individuality and community
In- and outdoor spaces for learning
Sound as a tool for learning

AESTHETIC

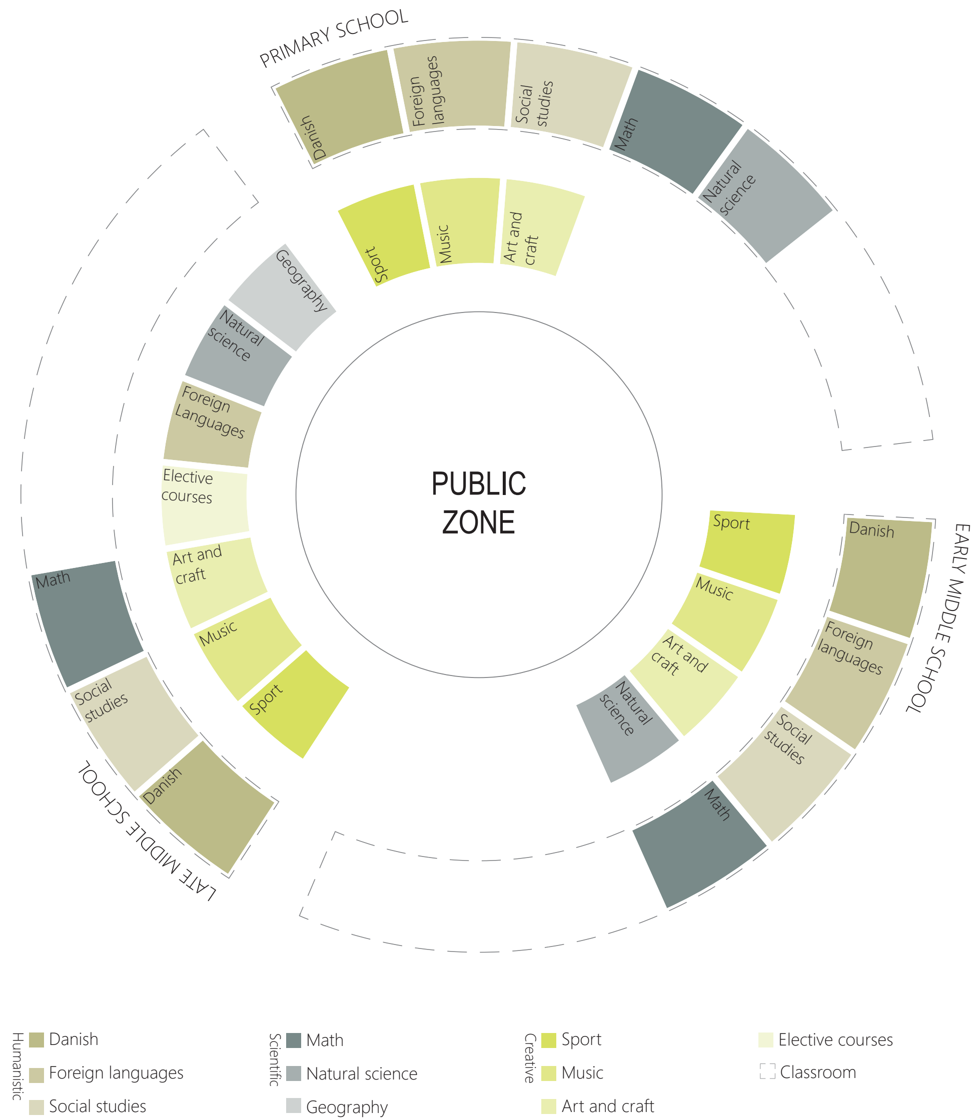
Learning through visibility
Sound as an architectural expression
Movement

FUNCTION DIAGRAM

DEFINING SPACES FOR LEARNING

As different age groups have different needs regarding their physical environment, the areas of the school will be divided into three categories: primary school, early middle school, and late middle school. The classroom is one of the most important rooms in a school, a place where students feel secure and at home. Especially young children need to feel safe in familiar surroundings. Additionally, primary school has less specific requirements for the materials and tools needed in classes than older students. This is why most subjects will be taught inside the classroom in primary school, where the students will move to more subject-specific rooms, or labs, as they move up in the school system.

The three divisions of the school must have access to a public zone, which is common and accessible for everyone connected to the school facility, but also for other citizens.



Ill. 60. Function diagram

ROOM PROGRAM

OUTLINING DIFFERENT SPECIFICATIONS

Ill. 61. Class

The room program illustrates different functional and technical requirements for the primary school, early middle school, late middle school, common facilities and service. According to the ministry of education a maximum of 28 students is allowed in each classroom [Information, 2010].

The school expects having a total area of minimum 11.200 square meters, based on calculations performed by the municipality with 14 square meters per student [Ladekjær, 2014].

Technical parameters include daylight factor, reverberation time, operating temperature and air flow rate. These values reflect initial interpretations of indoor climate and can be used as a guideline for the design process. A voluntary classification of the quality for the indoor climate in schools is used as guideline [DS3033, 2011]. The project strive for minimum A+ classification, which is the good indoor climate better than stated in the building regulations, see appendix 4 for further explanation. The air flow rate is calculated according to number of students and teachers in a room, see appendix 3.

Room	CAPACITY People	QUANTITY Rooms	AREA m^2	TOTAL AREA m^2	DAYLIGHT FACTOR %	REVERBERATION TIME Sec	OPERATING TEMPERATURE Summer	Winter	AIR FLOW RATE l/s
PRIMARY SCHOOL	320								
Classroom	max 28	12	65 - 70	780 - 910	3	≤ 0.6	23 - 26	20,5 - 23,5	1,7 l/s pr. m^2
Labs	-	2	60 - 70	120 - 140	3	≤ 0.6	23 - 26	20,5 - 23,5	1,7 l/s pr. m^2
Grouproom	2 - 8	8	6 - 24	100	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
EARLY MIDDLE SCHOOL	240								
Classroom	Max 28	9	65 - 70	585 - 630	3	≤ 0.6	23 - 26	20,5 - 23,5	1,7 l/s pr. m^2
Labs	-	4	60 - 70	240 - 280	3	≤ 0.6	23 - 26	20,5 - 23,5	1,7 l/s pr. m^2
Grouproom	2 - 8	10	6 - 24	140	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
LATE MIDDLE SCHOOL	240								
Classroom	Max 28	9	65 - 70	585 - 630	3	≤ 0.6	23 - 26	20,5 - 23,5	1,7 l/s pr. m^2
Labs	-	11	60 - 70	660 - 770	3	≤ 0.6	23 - 26	20,5 - 23,5	1,7 l/s pr. m^2
Grouproom	2 - 8	12	6 - 24	180	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
COMMON FACILITIES									
Library	-	-	600	600	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Multi Hall	-	1	800 - 1000	800 - 1000	3	1.1 - 1.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Changing Room	-	4	35	140	-	-	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Café	-	-	265	265	3	-	-	-	> 0.35 l/s pr. m^2
Toilets	-	62	2	124	-	-	23 - 26	20,5 - 23,5	10 l/s
Cloakroom	-	-	50 - 60	50 - 60	-	-	-	-	-
Storage	-	-	-	732 - 915	-	-	-	-	-
SERVICE	64								
Administration	4	-	7	28	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Staff Room	64	-	80 - 85	80 - 85	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Preparation Room	56	-	7	392	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Meetingroom	-	3	20	60	3	≤ 0.6	23 - 26	20,5 - 23,5	> 0.35 l/s pr. m^2
Kitchen	2	-	60 - 65	60 - 65	3	0.8	-	-	20 l/s
Cleaning	-	3	8	24	-	-	-	-	-
Technique	2	-	-	630	-	-	-	-	-

Ill. 62. Room program

DESIGN PROCESS

The design process initiates from the concept and design parameters stated in the program, intending to develop and evaluate form. The process is presented in a linear progression to ease the understanding, however in reality it has undergone several loops of going back and forth testing different aspects. Several tools have been used in the process including physical models, sketching, computer modelling, and calculations - all with the purpose of designing and evaluating within functional, technical and aesthetic parameters.

Ill. 63. Chalk on board

VOLUME STUDIES

CONTEXTUAL PERSPECTIVE

APPROACHING THE SITE

The design process initiates with contextual perspectives relating to how visitors and users of the school expect to approach the site. The two major roads surrounding the site forms an increased awareness of pedestrians from the Northwest corner. In relation to this, infrastructural lines from the surrounding context are taking into perspective, with smaller paths for bicyclists and pedestrians forming potential secondary entrances. In this way, it is intended to retain connections to Struer Lystanlæg, to skater park 'Hullet' and the nearby sports fields, which the students expect to use.

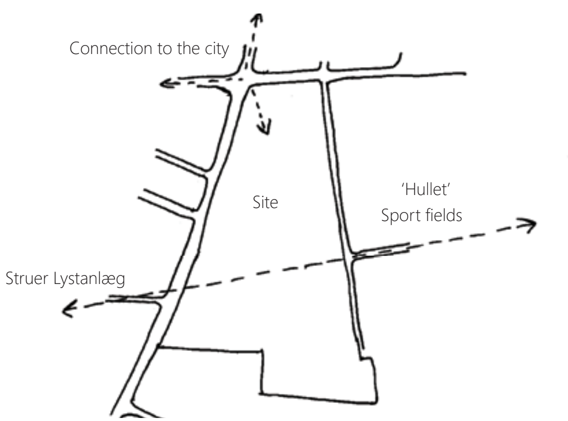
SCALE OF THE CITY

The site is located between the denser city centre to the North and a more suburban character to the South, recognized by a high amount of single family houses. This suggests an architectural transition of the scale of the city in the building volume.

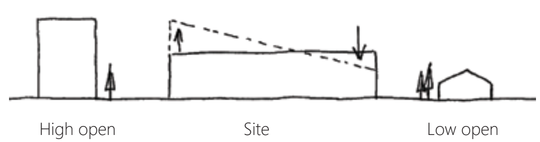
By raising the building to the North and lowering it to South, the building is transformed corresponding to the city. In this way, the building meets the city typologies, with high open typology to the North and low open typology to the South.

ZONING

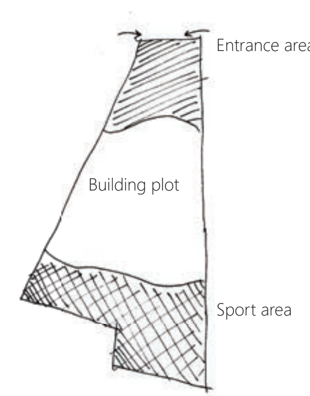
The site is divided into different areas to clarify the overall organization of the main outdoor spaces and the expected building plot. To the North a large main entrance area is expected to provide access for the many pedestrians from the main infrastructural roads. The school building is expected located in the centre of the site with sport facilities furthest to the South, hosting outdoor activities. From this, the objectives of meeting the scale of the city is emphasized by considering an urban character to the North and a green, natural character to the South.



Ill. 64. Approaching the site



Ill. 65. Scale of the city



Ill. 66. Zoning

VOLUME STUDIES

IDEATION

When modelling the first design proposals, technical, functional, and aesthetic parameters are included. This relates to a conceptual focus of sound and movement as key elements in the project, which the studies are also evaluated by.

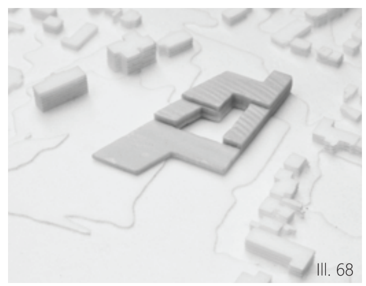
Inspired by the new Danish public school reform implementation of outdoor spaces have been studied, ill. 67-69. The reform suggests exercise and movement as an integrated part of the learning environment, which is considered in the studies. The models have an internal courtyard, which could be used by the younger students for more privacy and security, while older students may use roof terraces or surrounding outdoor facilities.

Another perspective relates to the municipality of Struer asking for a cultural institution open for the public after school hours, and presenting the city innovatively. Therefore, an ideation of creating a public zone and a differentiation between public and private spaces is initiated, ill. 70-72.

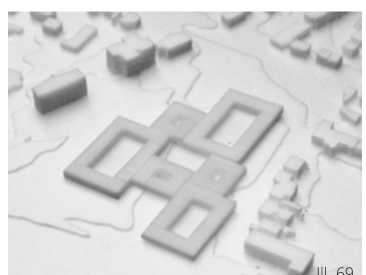
A sustainable objective includes technical studies of daylight, natural ventilation, and implementation of PV panels, ill. 73-75. The studies aim to clarify potentials of a compact building volume, in order to decrease heat transmission.

Outdoor spaces

Ill. 67



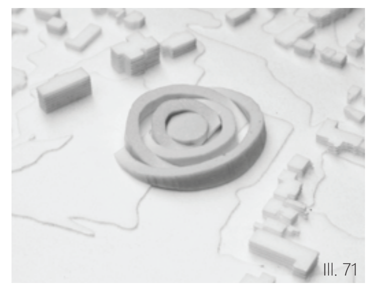
Ill. 68



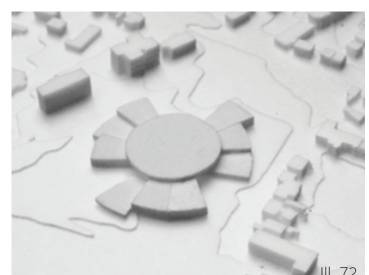
Ill. 69

Public/Private

Ill. 70



Ill. 71



Ill. 72

Technical studies

Ill. 73

Ill. 74

Ill. 75

VOLUME STUDIES

COMPARISON

THE X

The X is characterized by a clear public zone, allowing transit through the building as a public street. It is organized by four arms, three of them are for different age groups of students and the last for the multi hall. The model has potentials concerning daylight and has possibilities of integrating PV panels on the sloping roof. The roof decreases from North to South and meets the scale of the city. The model faces challenges of intimate outdoor spaces for younger students, and faces difficulties adapting on site, as the building volume open up to the North, where the site is narrower.

Ill. 76. The X

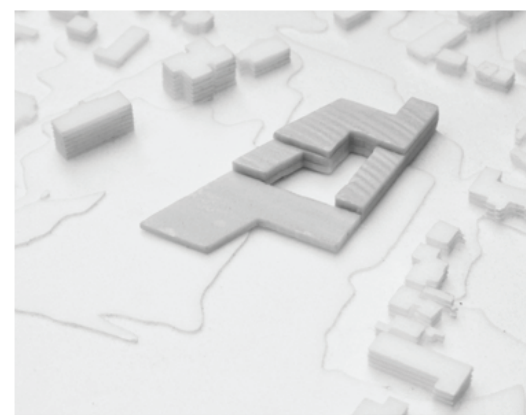
THE OVAL

The Oval expresses movement in its dynamic and playful design. The model stands as an icon in the surroundings, and presents itself as a landmark in the city. An internal courtyard provides private outdoor space for the younger students. The model furthermore includes technical advantages of placing PV panels on the sloping roof, which similar to the X decreases from North to South. By organizing classrooms near the exterior facade, potentials of daylight are included. However, the model faces challenges relating to the site and lacks contextual perspective.

Ill. 77. The Oval

THE STEPS

The Steps decreases to the South in moderate steps, while considering contextual lines, making it site specific. Private outdoor spaces are provided in the courtyard and on roof terraces, suggesting a vertical organization of students. The multi hall is integrated in the design as the last step, however the remaining public zone appears difficult to locate. The model faces challenges of integrating PV panels without compromising the many roof terraces for students. It also has long linear facades that may appear uninspiring regarding the conceptual focus of sound and movement.



Ill. 78. The Steps

VOLUME STUDIES

CHOICE OF FORM

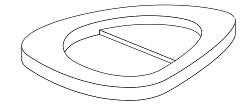
Remembering the conceptual objective of sound and movement the previous models have been compared regarding potentials and challenges in a functional, technical and aesthetic perspective. The Oval has potentials in its circular form emphasizing dynamics and movement. It also solves some of the requests by the municipality of creating an icon, visual in the city and inviting for the citizens as a cultural institution. However, the Oval lacks some contextual relations that the Steps contains. By using some of the contextual lines, the model becomes specific for the site and appears convincing in an urban perspective.

By combining different architectural qualities, a new model is suggested, see ill. 79. This model has many of the same potentials as the Oval with private outdoor spaces, integration of PV panels on the sloping roof and good daylight conditions along the narrow circle. The model has been modified according to contextual lines, creating a less symmetric shape that is narrower to the North and wider to the South. In this way, the model meets the scale of the city and creates an inviting entrance facing the two major roads surrounding the site.

Ill. 79. New model

VOLUME STUDIES

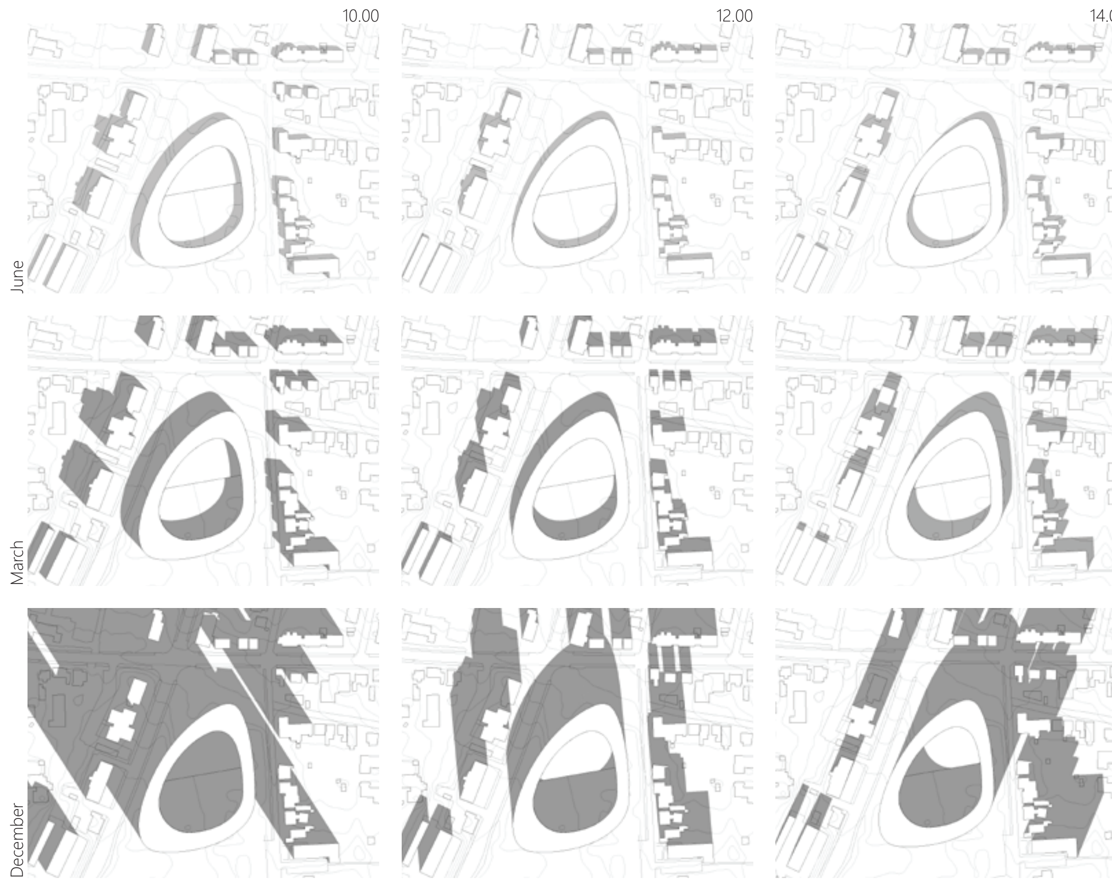
SUN & SHADOWS



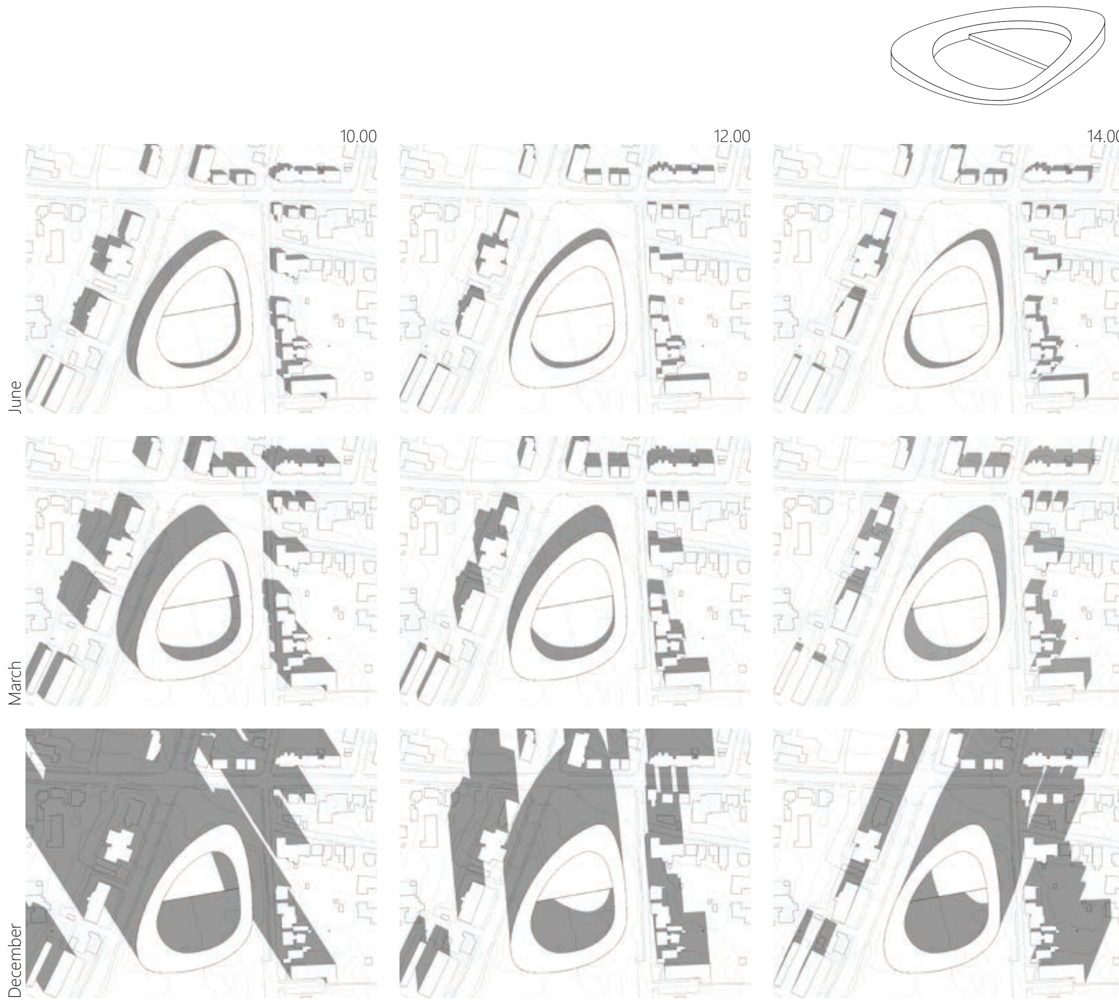
Moving on from a contextual perspective, studies of sun and shadows are performed, testing daylight conditions and qualities of the outdoor spaces surrounding the building. The area of the site and the distance to surrounding buildings show low consequences of shadows. This relates to the building not causing critical shadows for neighbouring buildings, nor is it in shadow by other buildings.

The first studies, ill. 80, show sun and shadow conditions for a model with three levels. During the summer months most outdoor spaces, internal and external of the building, have good sun and shadow conditions. However, the courtyard is in shadow all winter and partly during spring/fall seasons. To improve daylight conditions and sun in the courtyard, the model is lowered towards Southeast to utilize the morning sun, ill. 81. In this way, the students can play in the courtyard during breaks with more sun. Even during winter months the sun enlightens parts of the space. The roof terrace gets remarkable more sun during morning hours in the modified model.

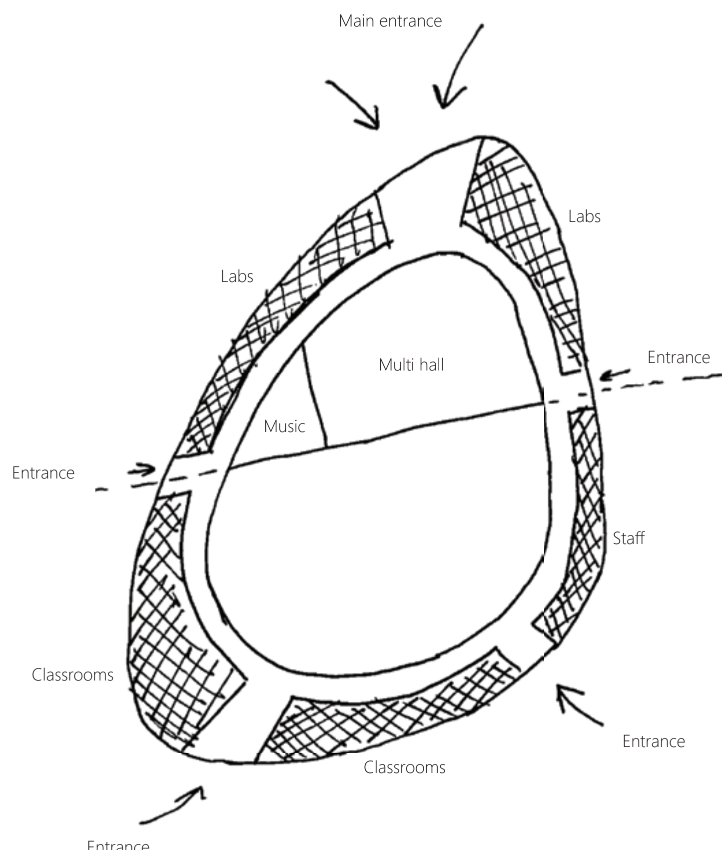
In relation to implementation of renewable energy sources, the modified model has potentials of installing PV panels on the sloping roof, increasing the solar radiation on the panels.



Ill. 80. Sun and shadow studies with three levels



Ill. 81. Sun and shadow studies with sloped roof



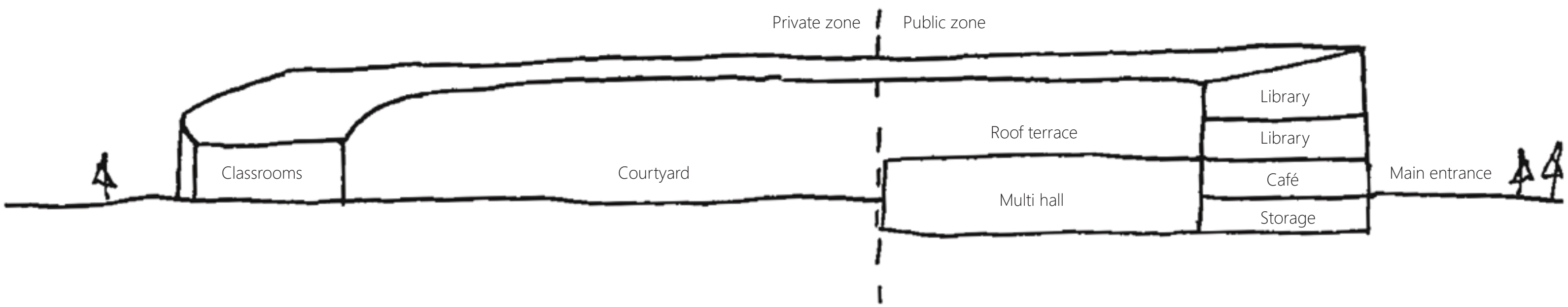
Ill. 82. Overall organization

VOLUME STUDIES

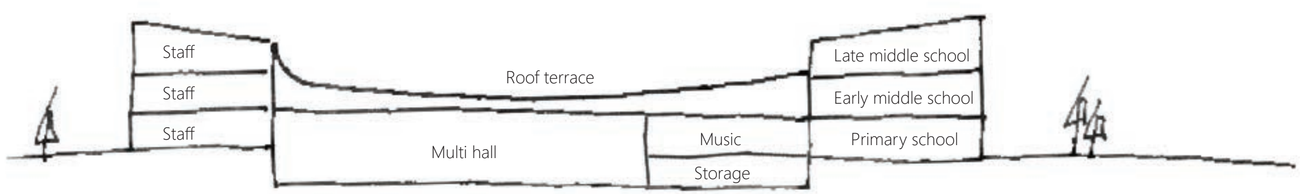
ORGANIZATION

The building is organized in zones following the outer circle, leaving an internal view across the courtyard, ill. 82. The zones consist of classrooms, labs and staff divided in a public and private section. The public zone is orientated around the main entrance to the North, inviting the citizens into the building from the two major roads surrounding the site. This area could include a public café, library, and access to music labs and a multi hall, ill. 83. Near the public zone, several labs are placed, which the citizens could use after school or in weekends.

Secondary entrances follow contextual pathways near the building, to enhance sustainable transportation for the many students, such as bicyclists and pedestrians. These entrances define different spatial organizations with classrooms and staff. The building has a vertical organization, with students in several levels, ill. 84. Younger students are located near the ground, from where they move up in the school. This leaves the courtyard primarily to students in primary school, and a roof terrace above the multi hall for older students in early middle school and late middle school. In the eastern zone staff is located on three levels having room for preparation, meetings and socializing. The teachers furthermore have a horizontal connection to their respective classrooms.



Ill. 83. Conceptual section of public zone



Ill. 84. Conceptual section of student zones

ROOM STUDIES
FUNCTIONAL PERSPECTIVE

LEARNING ENVIRONMENTS

When considering architectural quality in learning environments, visibility and spatial possibilities are key parameters. A Ph.d. study looks upon multidisciplinary reflections of architecture and learning. The paper includes studies of public schools in Copenhagen, concerning optimal learning environments in an architectural perspective. From this, spaces for learning are divided in three categories [Ricken, 2010].

Gathering (Classroom)
The classroom is a pedagogical base, where knowledge is shared, evaluated and collected. In this room activities initiates with the teacher in focus.

Contemplation (Group rooms)
The group room includes individual studies, alone or in smaller groups, with an atmosphere of contemplation and development of new knowledge. The room has a high degree of student participation.

Debate (Common rooms)
In the common room new activities negotiates, changes or modifies, thus discussions lead to clarification. Teachers and students inspire and invites new activities.

"The ability to choose and adapt different types of spaces and activities was a central point particularly for the teachers."

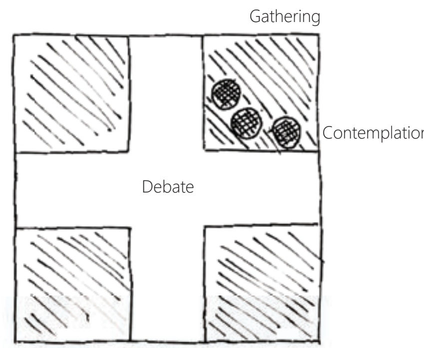
Winie Ricken [Ricken, 2010, p. 42]

Ill. 85-89. References of learning environments

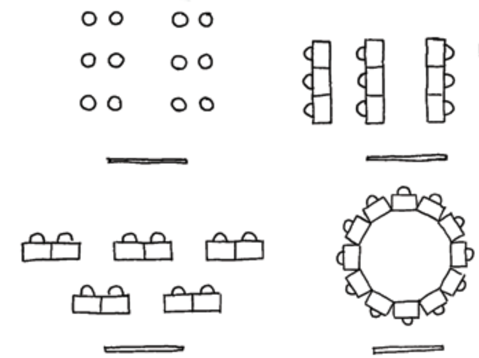
CLASSROOMS

The design includes a focus of rethinking the traditional learning methods by offering larger common rooms, which are inspiring as an active and energetic learning environment, ill. 90-91. The larger common rooms invite for debate between teachers and students to encourage activities and new learning methods. These spaces include smaller group rooms for contemplation, leaving the classrooms primarily for gathering. Group rooms are small pockets, where the students can retreat and immerse in their own pace. The atmosphere of these spaces could potentially graduate from the younger students to the oldest, from a childish atmosphere for the youngest to an independent identity for the oldest.

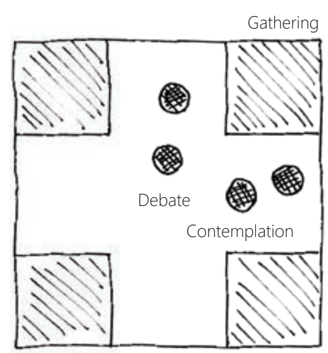
In the classroom, a flexible room organization allows different seating arrangements adjusted to the specific class of students, ill. 92. The furnishing may reflect different learning styles as visual, aural, verbal, or physical, referring to different personalities. To consider storage in the classroom, shelves are proposed as an integrated element of every classroom. This element becomes a furniture wall, with visual contact to the hallway through window openings, ill 93. Furthermore, the wall has a functional purpose in the classroom by storing books, drawings, and other learning equipment.



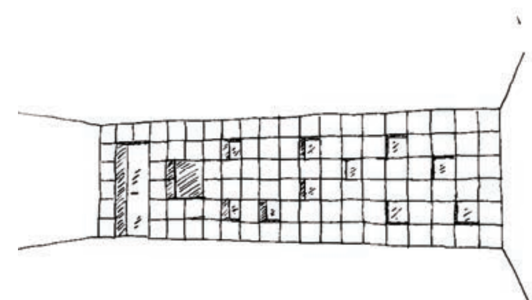
Ill. 90. Traditional learning environment



Ill. 92. Classroom organization



Ill. 91. Contemporary learning environment



Ill. 93. Furniture wall

ROOM STUDIES
FUNCTIONAL PERSPECTIVE

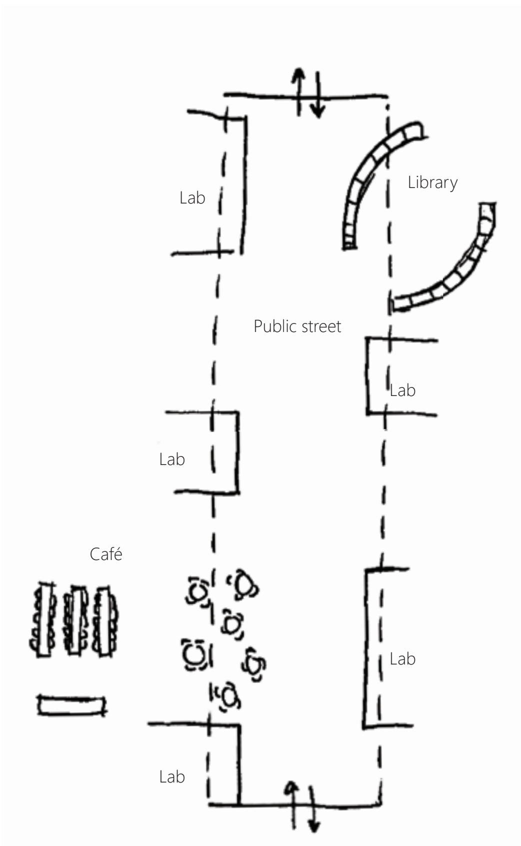
Ill. 94-97. References of a public zone

PUBLIC ZONE

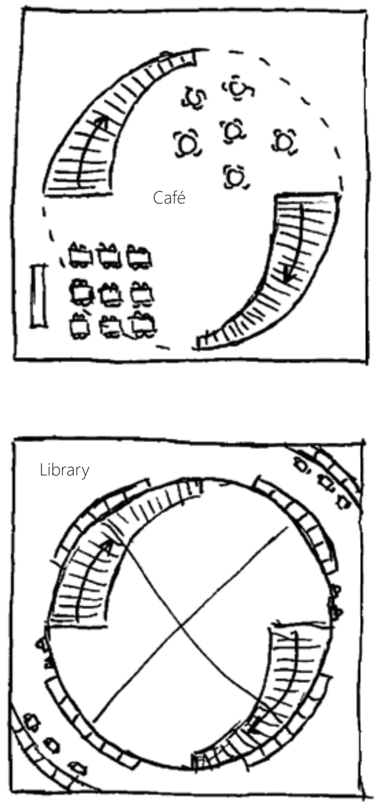
One of the objectives for the municipality of Struer is to create an inviting and extrovert cultural institution, functional for both students, teachers and the citizens. Studies of a public zone is important in the design of a new school. This zone allows access to a café, a library, multi hall, and a range of different labs used by the students and the public after school hours. The library is a centre of knowledge and a point of gathering between levels of students. It includes niches to read, study and contemplate.

Studies initiated with a main emphasis of placing the public zone in relation to the main entrance, functioning as a node and a point of gathering. As seen in ill. 98 a study of a public street is illustrated, leading the public from the main entrance to the sport fields to the South. The street has labs looking over the path with a visible and open atmosphere.

A different study, ill. 99, suggests a public zone with a circular staircase as a key element, emphasizing movement and dynamics. The café and library are placed on different levels looking into a high atrium creating an atmosphere of something enclosing and secure.



Ill. 98. Public street



Ill. 99. Circular atrium

ROOM STUDIES
FUNCTIONAL PERSPECTIVE

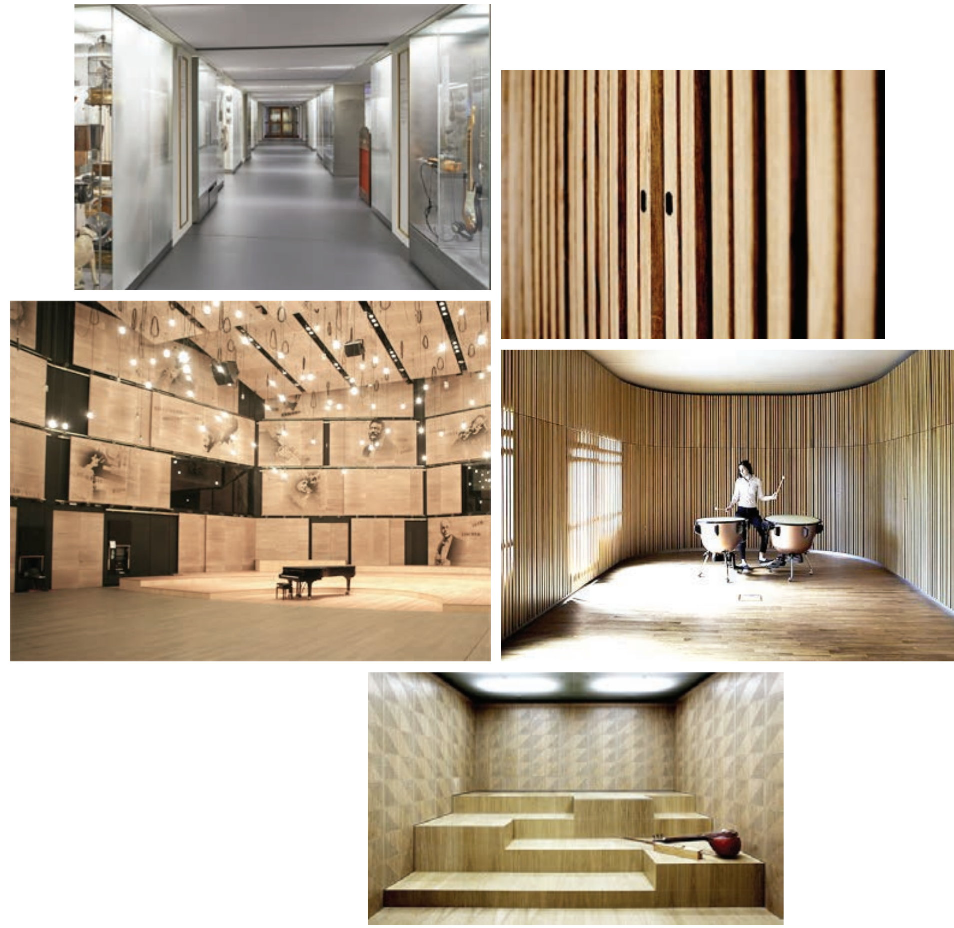
MUSIC LAB

The music labs reflect other key values of the project, *Lydens By Skole* - a school of music. This area should be an inspiring environment and enhance music as a tool for learning. The labs should include architectural quality with well considered materials for different acoustic performances. This relates to reverberation time corresponding to acoustic music and amplified music, which could be the two main music labs at the school, see ill. 105-106.

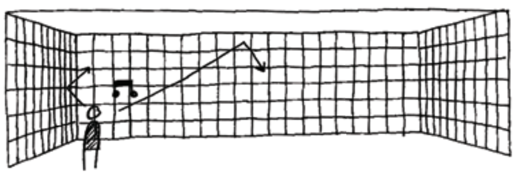
To enhance the intention of the municipality of creating a cultural institution for the city of Struer, the music labs should be located near the public zone for easy accessibility.

Instruments could be stored or exhibited in a furniture wall near the hallway or in a larger storage room, to visually inspire the environment. This also relates to functional intentions of providing sufficient storage.

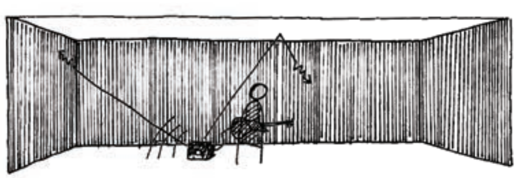
As illustrated in ill. 107 an idea of creating a moveable stage for concerts are considered. This forms a connection to the multi hall, and introduces possibilities of opening up for concerts.



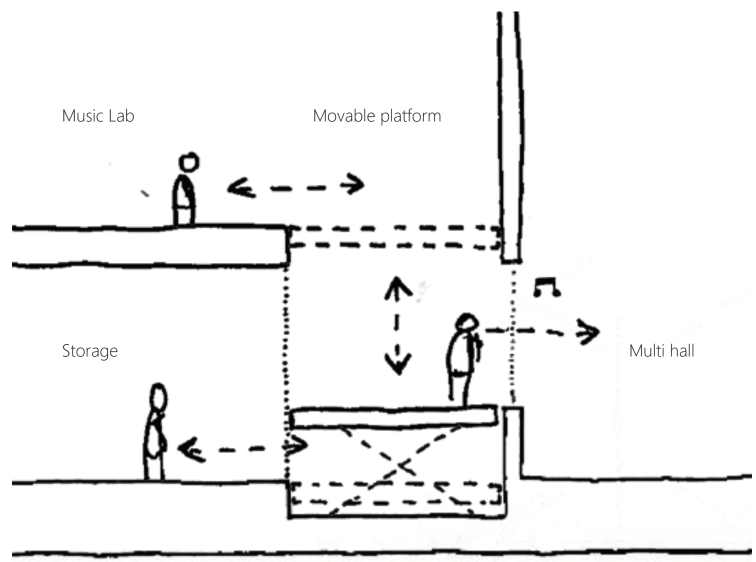
Ill. 100-104. References of music labs



Ill. 105. Acoustic music lab



Ill. 106. Amplified music lab



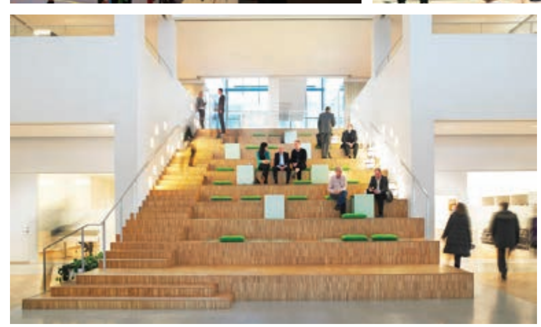
Ill. 107. Moveable Platform

ROOM STUDIES
FUNCTIONAL PERSPECTIVE

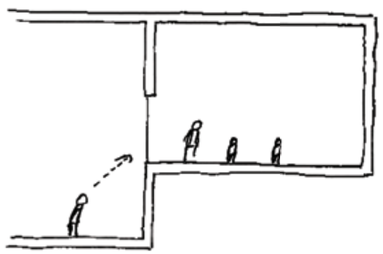
MULTI HALL

A part of the new Danish public school reform initiates exercise and movement as an active tool for learning. In relation to this, movement has become a conceptual focus in the project and an important parameter in the design. The multi hall has the functional perspective of achieving this objective, an active place to be used by students and the public, after school hours, in the afternoon, and weekends. Thereby, the space must have easy access from the main entrance and café to become an integrated part of the public zone. The space can also be used for concerts, gatherings and other common activities. As shown in ill. 112 and 113 studies are performed testing different views from the public zone to the multi hall. This allows visibility from the café or outdoor spaces, encouraging exercise and movement in the school.

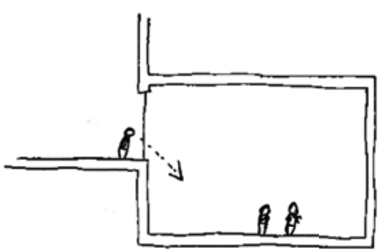
Seating for the audience is considered integrated in the staircase running from the public zone to the multi hall, ill. 114-115. Furthermore, different skylights are studied as seen in ill. 116 and 117. These windows allow additional daylight and visibility from the roof terrace above the multi hall. An idea of combining seating and vegetation near the skylights are reflected in the illustrations.



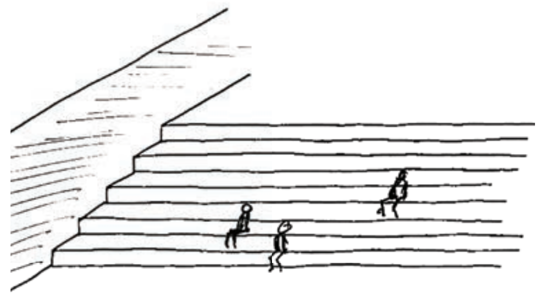
Ill. 108-111. References of multi halls



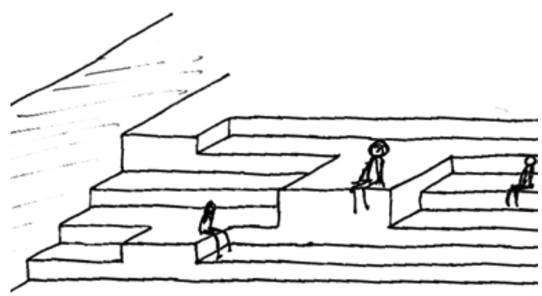
Ill. 112. Visual contact upward



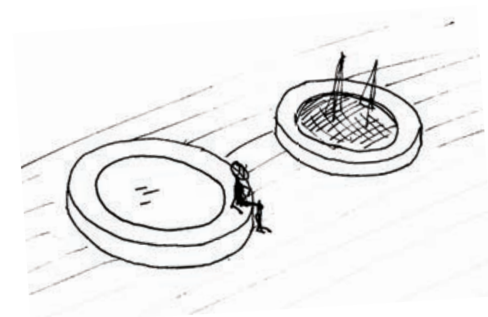
Ill. 113. Visual contact downward



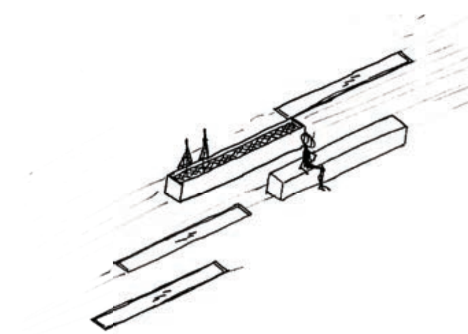
Ill. 114. Seating



Ill. 115. Seating



Ill. 116. Circular skylight



Ill. 117. Rectangular skylight

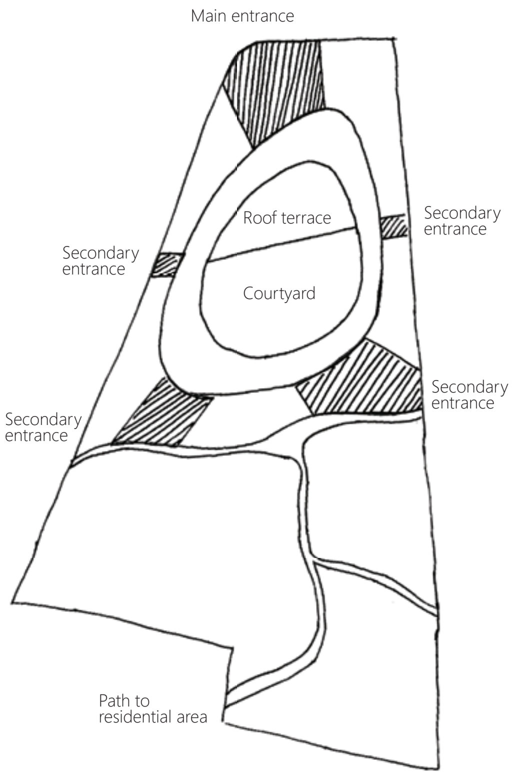
OUTDOOR SPACES
LEARNING ENVIRONMENT

The learning environments of the school are considered not only inside, but also with functional outdoor spaces that can easily be accessed and integrated in the lessons. This also relates to the new Danish public school reform, suggesting movement and exercise as important parameters. In relation to this, a sports field, running track, and athletic facilities are considered in the design.

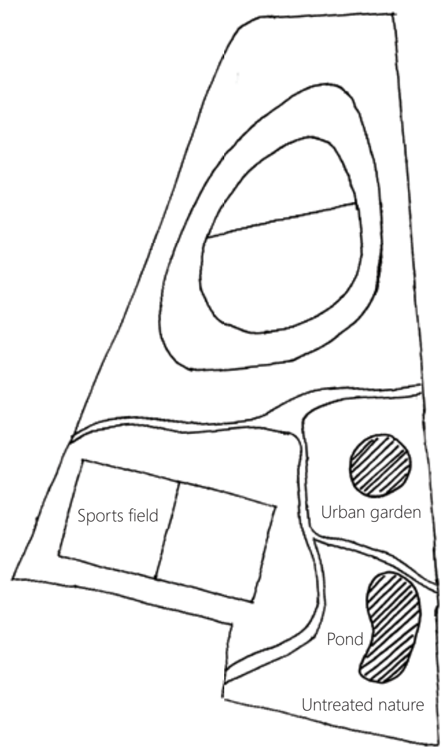
The outdoor spaces must also include playgrounds, seating arrangements and places to play during breaks. This accounts for both younger and older students, thus objectives of dividing the outdoor spaces in different zones are illustrated, ill. 123.

Furthermore, ideas of including a natural wilder environment is presented in the design, ill. 124, with a pond, urban garden and pavilion. This could be used in natural science lessons to look for wildlife or grow vegetables in the garden. Thus, the design includes awareness of the students' senses, to see, touch, feel and smell as a part of learning. A functional perspective of providing sufficient bicycle parking near all entrances relates to a sustainable focus of green transportation. However, to fulfil a functional level, parking for the staff is considered near the staff entrance, ill. 125

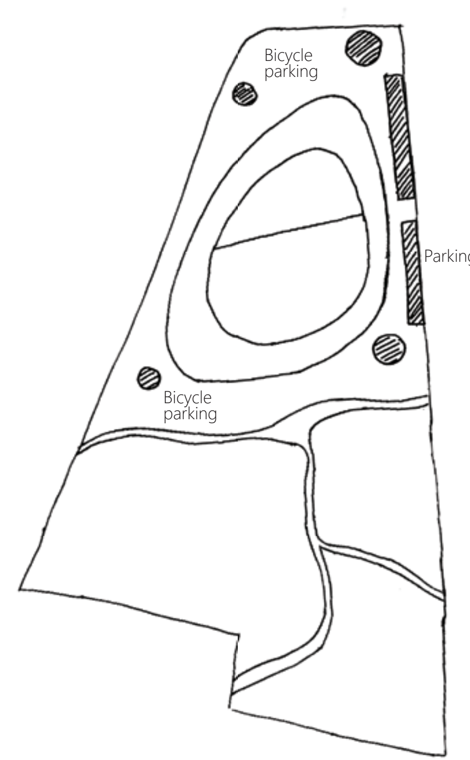
Ill. 118-122. References of outdoor spaces



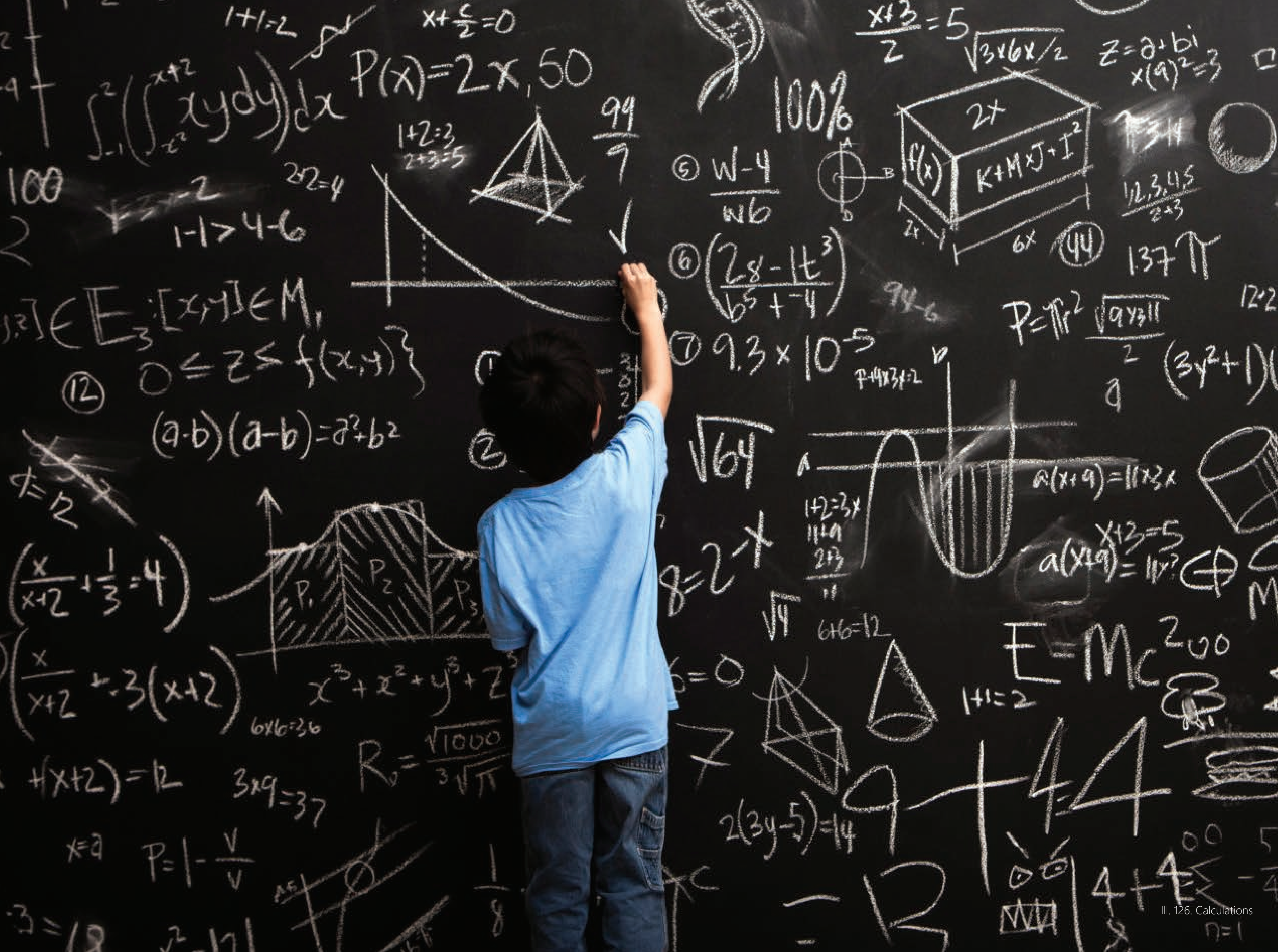
Ill. 123. Overall organization of outdoor spaces



Ill. 124. Natural environment



Ill. 125. Parking



Ill. 126. Calculations

TECHNICAL STUDIES
INTRODUCTION

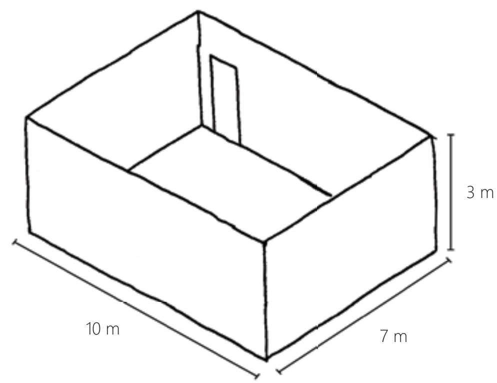
It is important to consider the technical aspects of a project early in the design process to lay out the relevant possibilities and restrictions it may involve. The studies are carried out parallel to volume- and room studies, and used as additional argumentation for the decisions that are made.

Following pages show preliminary studies of a standard classroom in relation to both atmospheric-, thermal-, visual-, and acoustic comfort, and ends with an early simulation of the energy performance and indoor climate of the building design.

According to the Danish building regulations, a standard classroom must contain at least 6 m^3 per student and 12 m^3 per teacher [dcum, 2013]. With a maximum capacity of 28 students and 2 teachers the volume of the classroom should be at least 192 m^3. For the technical studies, the dimensions of the classroom is defined as:

Room width: 10 m
Room depth: 7 m
Room height: 3 m

Area: 70 m^2
Volume: 210 m^3



Ill. 127. Classroom

TECHNICAL STUDIES
INDOOR CLIMATE

NATURAL VENTILATION

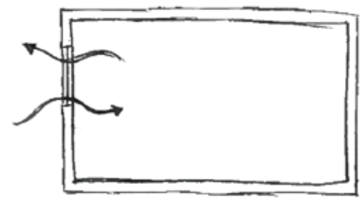
All rooms must be ventilated to avoid excessive heat and to keep the concentration of CO_2 on a satisfactory level. With natural ventilation it is possible to save energy, compared to a mechanical ventilation system. It also has the advantage that the users can be in control of their own environment by opening windows when needed.

Three different ventilation principles have been tested to study their effect in a standard classroom with two openings of the same size.

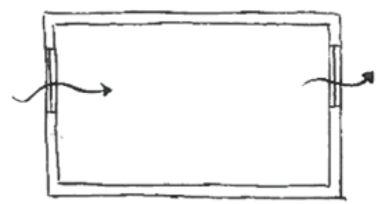
The needed air flow in a classroom is based on a calculation which can be seen in appendix 3.

Basic air flow: 0,119 m^3/s
Air flow on a hot summer day: 0,223 m^3/s

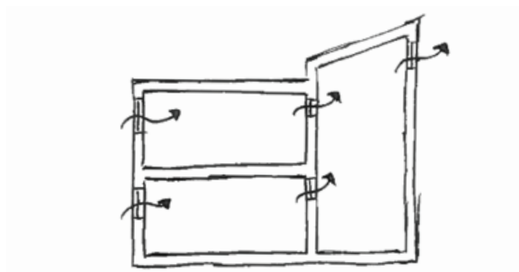
The results of the study show that cross ventilation is much more effective than single-sided ventilation, and that stack ventilation, where the air enters in one opening and exits at a different and higher opening, is the most effective. However, it should still be possible to achieve the needed ventilation rate with single sided ventilation.



Ill. 128. Single-sided ventilation



Ill. 129. Cross ventilation



Ill. 130. Stack ventilation

SINGLE-SIDED VENTILATION

Opening	Eff. area	Height	Press. coef.	Air flow
Inlet	0,7 m^2	2 m	0,2	0,28 m^3/s
Outlet	0,7 m^2	2,5 m	0,2	- 0,28 m^3/s

CROSS VENTILATION

Opening	Eff. area	Height	Press. coef.	Air flow
Inlet	0,7 m^2	2,5 m	0,2	0,91 m^3/s
Outlet	0,7 m^2	2,5 m	-0,25	- 0,91 m^3/s

STACK VENTILATION

Opening	Eff. area	Height	Press. coef.	Air flow
Inlet	0,7 m^2	2,5 m	0,2	1,154 m^3/s
Outlet	0,7 m^2	4 m	-0,4	- 1,155 m^3/s

Table 131-133. Ventilation principles

TECHNICAL STUDIES

INDOOR CLIMATE

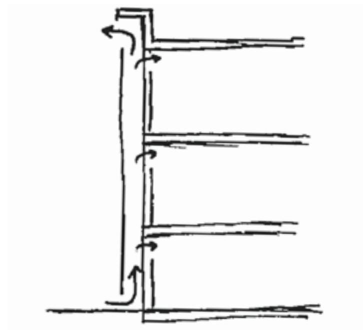
THERMAL COMFORT

Ventilation is one of the most important factors regarding thermal comfort. It is used to remove excessive heat on hot days, but there is also a risk of causing draught, especially during winter.

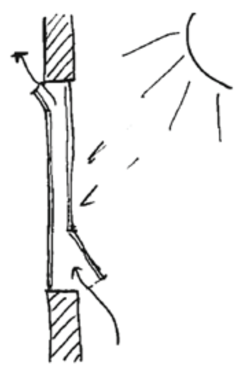
Ways to preheat the ingoing air is considered with the use of double glazing or double facades, ill. 134-135. An alternative to this is heat recovery, which is most common with mechanical ventilation systems.

It is important to avoid excessive heat to ensure a comfortable indoor climate. The temperature is influenced by internal heat gain such as people and equipment. This is something that cannot be controlled with the design of the building as opposed to heat gained from the sun. This is tested by calculating the 24-hour average temperature in a classroom with different parameters for the windows: area, shadow factor, and orientation, ill. 136-138.

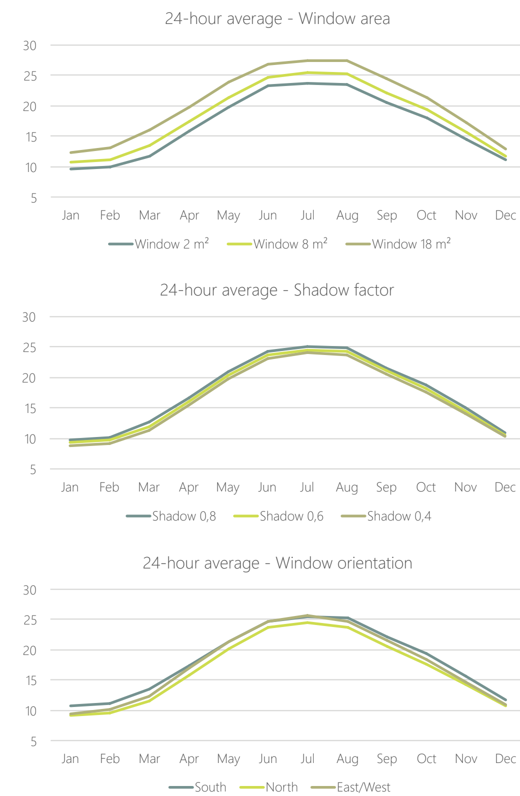
The results show that the temperature is highly influenced by the total area of windows, which can also be adjusted with the use of solar shading. It also shows how high temperatures are just as likely to occur in rooms orientated towards East and West as to the South.



Ill. 134. Double facade



Ill. 135. Preheated air



Ill. 136-138. 24 hours average

TECHNICAL STUDIES

INDOOR CLIMATE

DAYLIGHT

Natural light is important to create a good visual environment for working and learning. A high amount of daylight will also decrease the need for artificial lighting and thereby the yearly electricity consumption of a building.

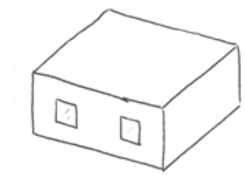
Different window situations are tested with Velux Daylight Visualizer in a classroom to study their impact on the daylight factor. With a goal of an average daylight factor of minimum 3%, explained in appendix 4, it is first of all tested how much window area is needed to reach the goal, ill. 139-141. It is concluded that 30% of the facade, or more is satisfactory in a classroom that is 7 meters deep.

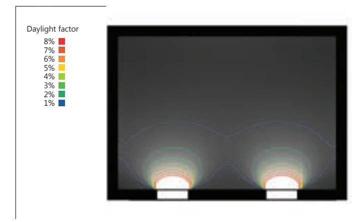
Testing the same area, but a different number of windows, shows that fewer but larger windows provides the highest daylight factor, ill. 148-150. However, the light is more evenly distributed in the room with more windows.

Finally the window height is tested, which clearly shows a relation between the placement of windows and how far the light reaches into the room. The higher the windows are placed, the higher is the daylight factor, ill. 154-156.

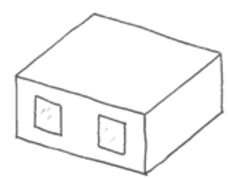
WINDOW AREA | AVERAGE DAYLIGHT FACTOR

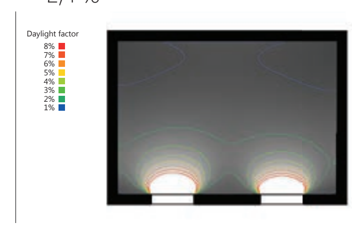
15 % | 1,4 %



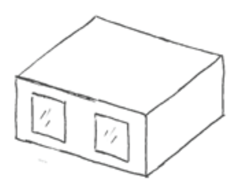


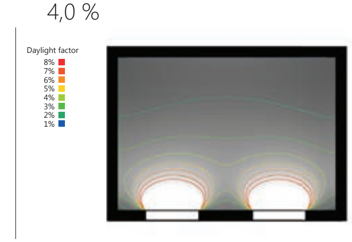
27 % | 2,4 %





42 % | 4,0 %



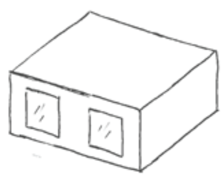


Ill. 139-141. Window area

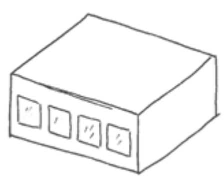
Ill. 142-144. Daylight factor

NUMBER OF WINDOWS

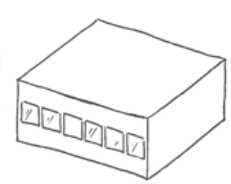
2



4



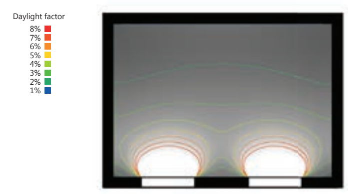
6



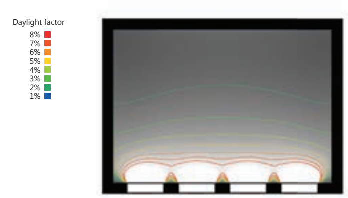
Ill. 145-147. Number of windows

AVERAGE DAYLIGHT FACTOR

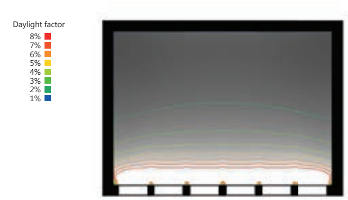
4,0 %



3,8 %



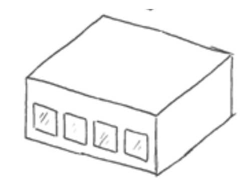
3,4 %



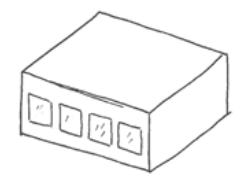
Ill. 148-150. Daylight factor

WINDOW TOP HEIGHT

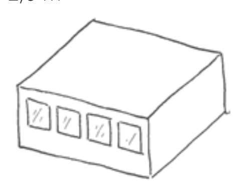
2,0 m



2,3 m



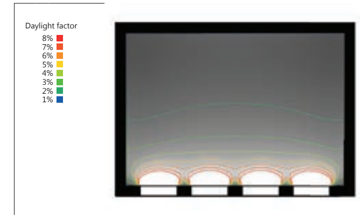
2,6 m



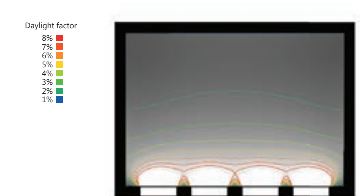
Ill. 151-153. Window top height

AVERAGE DAYLIGHT FACTOR

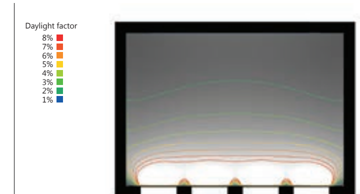
3,0 %



3,6 %



4,1 %



Ill. 154-156. Daylight factor

TECHNICAL STUDIES

INDOOR CLIMATE

ACOUSTIC EXPERIENCES

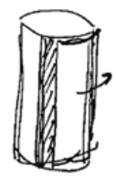
Good room acoustics are important for students to be able to concentrate while working and to hear and understand what is being said during classes.

Acoustics is also an essential subject for the city of Struer as well as this project, *Lydens By Skole*. It is therefore considered how different acoustic experiences can be created using different materials. The small rooms can be used to play, relax or study alone or in small groups. The circular shape of the rooms focuses the sound towards the centre of the room, opposite to a convex shape, which would have scattered the sound.

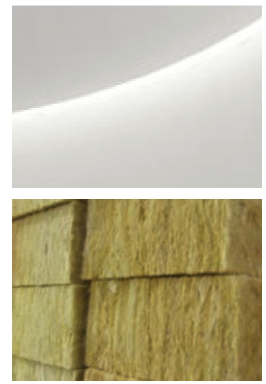
The first principle is the isolated room, where one is able to escape from the surroundings for a short while. The other principles consist of a reflecting, an absorbing, and a diffusing interior surface, which will create three different experiences of the rooms.

An estimate of the reverberation time is calculated with Sabine's Formula. The formula is developed for rectangular rooms, but the calculation illustrates how the different materials can affect the acoustics of the room, see appendix 8.

ISOLATING



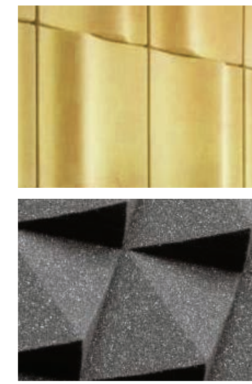
Material: Isolating wall
Sound insulation: R_w 65 dB



Ill. 157-159. Isolating

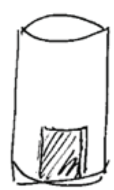
ABSORBING

Material: Acoustic foam
Reverberation time: 0,08



Ill. 163-165. Absorbing

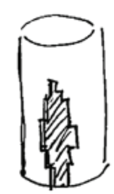
REFLECTING



Material: Concrete
Reverberation time: 4,00

Ill. 160-162. Reflecting

DIFFUSING



Material: Wood panels
Reverberation time: 0,20

Ill. 166-168. Diffusing

TECHNICAL STUDIES
ENERGY & INDOOR CLIMATE

SIMULATION TOOLS

Be10 is a monthly calculation tool estimating the total energy requirements for a building on a yearly average, including energy for heating, ventilation, cooling and domestic hot water. The calculations are based on general information of the building; building envelope, ventilation strategy, internal heat supply, and renewable energy sources, see appendix 5 for further explanations. Initial Be10 calculations show a total energy requirement on 38,6 kWh/m², which is unacceptable compared to the limits for 2020 of 25 kWh/m² per year for a public building. The calculations could be improved by solar shading and hybrid ventilation, to remove excessive heat in rooms and decrease the total energy requirement.

BSim is an hourly calculation tool showing more detailed results of the indoor climate. The program is controlled by several systems and includes information of the building envelope, windows and solar shading, which all influence the temperature and quality of thermal comfort. The temperature and CO_2 concentration is compared with different categories to evaluate the quality of the indoor climate. This means that the temperature must not exceed 100 hours > 26 degrees and 25 hours > 27 degrees [DS474, 1993]. Further explanation and results can be found in appendix 4.

BE10

ENERGY FRAME BUILDINGS 2020

Total energy requirement:	38,6 kWh/m²

CONTRIBUTION TO ENERGY REQUIREMENT

Heat:	30,8 kWh/m²
El. for operation of building:	8,1 kWh/m²
Excessive in rooms:	5,6 kWh/m²

BSIM

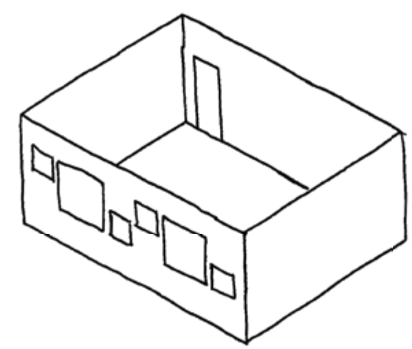
TEMPERATURE CLASSIFICATION

Hours above 26 degrees > 76

Hours above 27 degrees > 46

CO_2 CONCENTRATION

Category A++	47 %
Category A+	53 %



Ill. 169. BSim model for a classroom

SUMMARY DESIGN PROCESS

The design process initiated with volume studies considering the scale of the city with high open typologies to the North and low open typologies to the South. The building must relate to contextual lines to form pathways and entrances for the building. Studies are performed, testing movement in outdoor spaces externally and internally of the building, suggesting a courtyard for more private outdoor settings. Movement is also considered to be expressed architecturally within dynamic forms or with continuing elements.

Room studies include visibility and spatial possibilities of achieving different learning environments. This accounts for gathering in classrooms, contemplation in group rooms and debate in common rooms. The building must present itself as a cultural institution, including a public zone with a café, library and labs orientated around an atrium. Conceptual focus of sound and movement is further emphasized in music labs and a large multi hall.

Technical studies explores potentials of natural ventilation to avoid excessive heat and keep the CO_2 concentration low. Good daylight conditions are also important for an effective learning environment. Furthermore, initial simulations of energy and indoor climate in Be10 and BSim define too much excessive heat, which could be improved by solar shading and ventilation systems.

DETAILING

This section includes detailing of the building facade, windows, solar shading and materials - all in the light of architectural and sustainable objectives. Design solutions are evaluated within technical parameters including calculations of energy consumption and estimation of the quality of indoor climate. This method is used to compare results of solar shading and ventilation. Finally, few active strategies are introduced to fully reach the goal of zero energy building.

Ill. 170. Blocks

FACADE

EXTERIOR EXPRESSION

SOUND AND MOVEMENT

The facade should express the two essential themes of the project; sound and movement. Ways of doing this are tested with the use of facade cladding, lamellas, and windows to create a sense of rhythm and patterns that continue round the building, ill. 176. Especially the vertical lamellas create a rhythm in the facade and a changing appearance as one moves around the facade and sees it from different angles and in a different light.

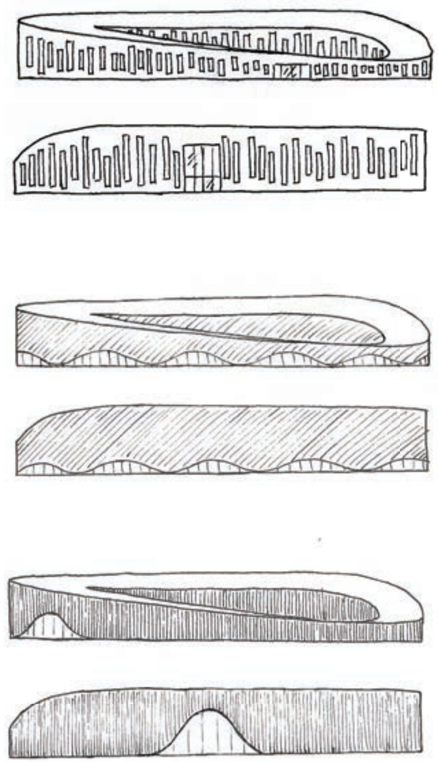
The different entrances of the building should be visible from a distance, where the main entrance should be more significant and transparent than the others, ill. 177. This can be done by lifting the building or the facade above the entrances, or creating larger window areas.

Different shapes of windows are tested to see the appearance, both on the facade and inside a classroom, ill. 178. The square windows would work well on the facade to create a pattern on the three different levels, but also functionally inside the classroom with windows at different heights for different purposes.

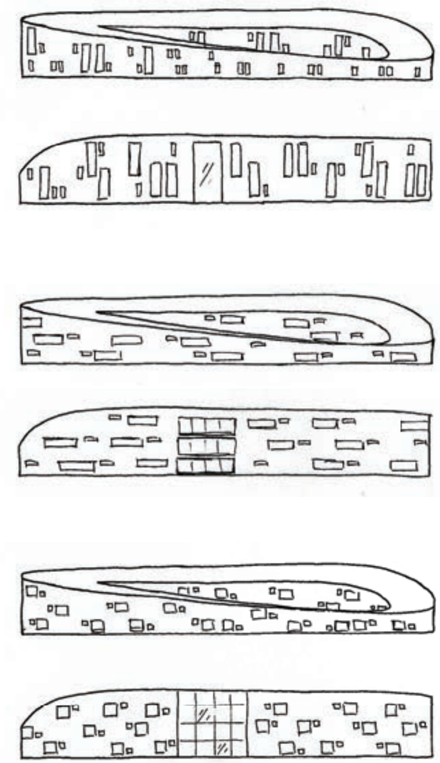




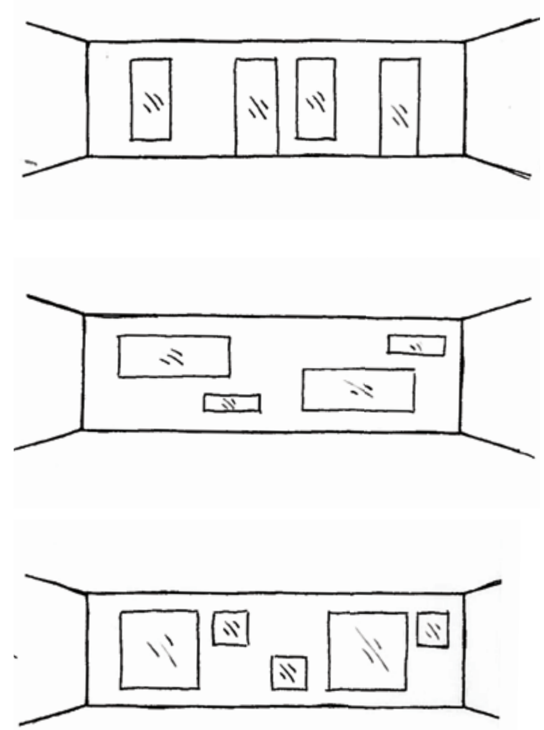
Ill. 171-175. References of facades



Ill. 176. Exterior



Ill. 177. Facade windows



Ill. 178. Classroom windows

FACADE
WOOD TYPES

Wooden lamellas will be used as cladding on the entire facade to create a sense of rhythm and a more dynamic appearance. Different types of wood are considered in relation to sustainability and the appearance of the building.

Pine is one of the most common types of wood in Denmark, and it is used a lot in the building industry, but it needs a treatment to avoid rot and infections. Pressure treatments are a common way of making the wood more durable. However, the treatment involves chemicals, which can be problematic for the environment and in contact with children [Miljøstyrelsen, 2015].

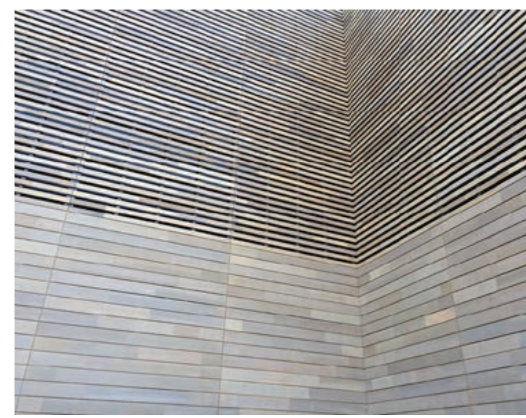
An alternative is Siberian larch, which is slow growing and more durable because of its large part of heartwood. Larch is sensitive to mould and should also be treated, for example with linseed oil, which is a natural product.

Western red cedar grows mostly in North America, but is also used in Europe because of its durability and minimal maintenance. Cedar has its own anti-fungal and anti-bacterial substance called thujaplicins, which means it can last for many years without any treatments. It has a warm brown colour, which turns silver grey with time unless it is treated. Western red cedar is the choice of wood for the project based on all of its properties.

Ill. 179. Pine wood

Ill. 181. Western red cedar

Ill. 180. Siberian larch



Ill. 182. Western red cedar (weathered)

FACADE

DAYLIGHT

WINDOW PATTERN

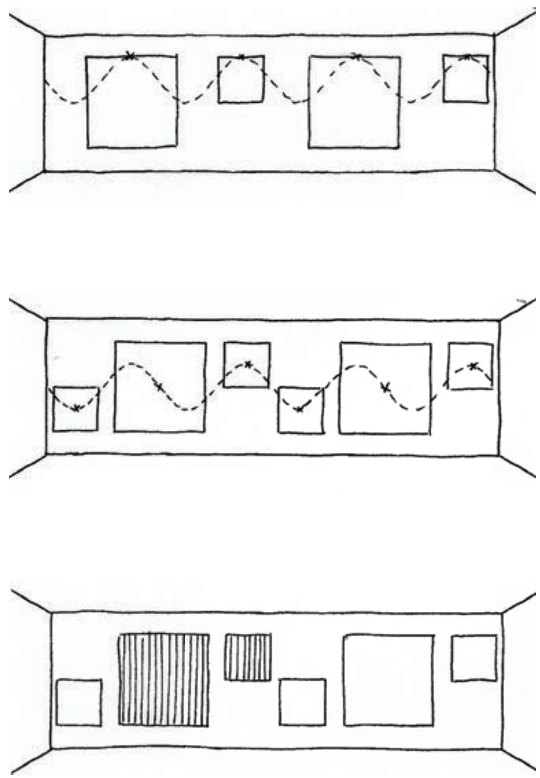
In order to create a continuing pattern with the windows, ideas of placing them along a sine wave are tested. A sine wave relates to the physical terms of sound, with amplitude and frequency defining the size of the curve.

Large windows and small windows at different heights serve different purposes. High windows are good for daylight and natural ventilation. Low windows can be used to obtain visual contact in a sitting position, and large windows give an overall view to the outside, ill. 183.

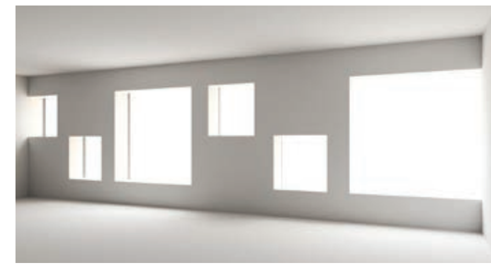
SOLAR SHADING

It is also tested how wooden lamellas, which in this case function as a permanent type of solar shading, will affect the experience of the interior as well as the daylight factor in the room.

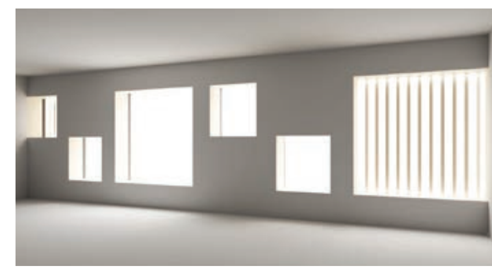
The lamellas reduces the daylight factor considerably. If the windows had been removed instead, the daylight factor would have resulted in 2,2%, which would be too low, ill. 184-186. The lamellas makes it possible to reach the goal of an average daylight factor of 3% in the classroom, while shielding from a part of the direct radiation from the sun.



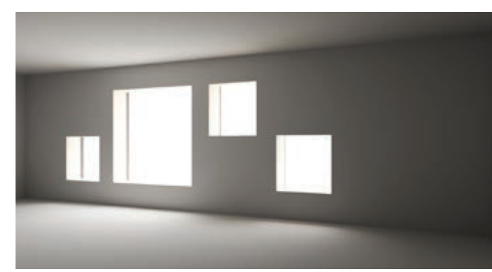
Ill. 183. Window sketches



Ill. 184. Daylight without lamellas - Average daylight factor: 3,7%



Ill. 185. Daylight without lamellas - Average daylight factor: 3,1%

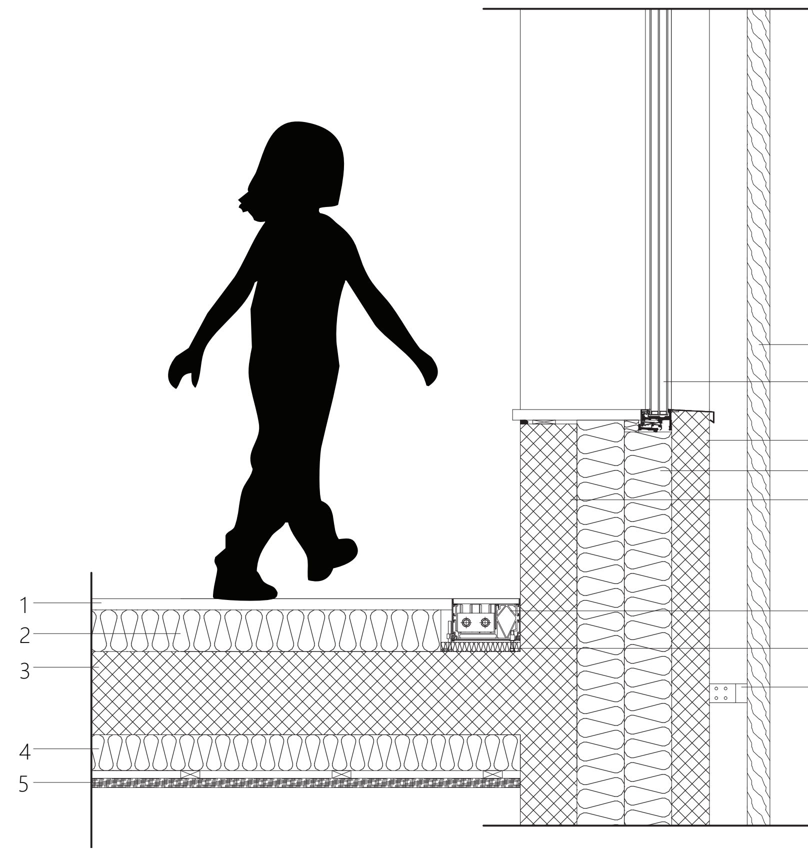


Ill. 186. Daylight without lamellas - Average daylight factor: 2,2%

FACADE
DETAIL

A detail of the exterior wall in classrooms illustrates the window's position in the wall, creating a place to sit, ill. 187. The windows are placed near the exterior surface, forming a deep frame of wood suggesting the place to be inhabited. Outside the window, lamellas function as solar shading and create a secure and protected atmosphere. The thick building envelope, with 250 mm insulation, is a strategy of decreasing the energy consumption of the building by passive initiatives. Shear walls of concrete form the construction of the exterior walls, supporting concrete slabs perpendicular to the wall. For further explanation of the building construction see appendix 1.

1) 30 mm concrete floor
2) 110 mm insulation
3) 220 mm concrete slab
4) 95 mm insulation
5) 25 mm troldtekt
6) 60 mm wooden lamella
7) Window with 3-layer glazing
8) 100 mm concrete facade
9) 250 mm insulation
10) 150 mm concrete wall
11) 180 x 110 mm convector
12) 25 mm insulation
13) Steel mounting



Ill. 187. Detail of exterior wall in classroom, 1:20

FACADE

ENERGY BALANCE

HEAT GAIN

For low energy buildings, it is possible to cover a large part of the heating requirement with heat obtained from the sun. However, the heat gain must be balanced to prevent the indoor temperature from rising too much during warm periods. This was the case with the first energy calculation in Be10, which showed an energy consumption of 5,6 kWh/m^2 per year just to remove excessive heat in rooms.

Besides an aesthetic purpose, the lamellas on the facades also have the potential to function as solar shading, and decrease the heat gain from the sun. A new simulation in Be10 shows that excessive heat in rooms has been lowered with lamellas as a shading factor in front of the windows. The results also show that while the heat gain has been lowered, the heating requirement is slightly higher.

Similarly, the BSim results show a slightly decreased amount of temperatures above 26 and 27 degrees compared to previous results without lamellas. However, the amount of hours are still insufficient according to the regulations. In addition, the CO_2 concentration is slightly higher with lamellas than without, as the lamellas potentially interrupt the driving wind forces.

BE10

ENERGY FRAME BUILDINGS 2020

Total energy requirement:	37,0 kWh/m^2

CONTRIBUTION TO ENERGY REQUIREMENT

Heat:	33,5 kWh/m^2
El. for operation of building:	8,1 kWh/m^2
Excessive in rooms:	2,3 kWh/m^2

BSIM

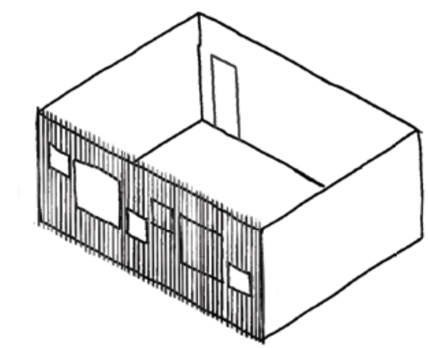
TEMPERATURE CLASSIFICATION

Hours above 26 degrees > 67

Hours above 27 degrees > 36

CO_2 CONCENTRATION

Category A++	46 %
Category A+	54 %



Ill. 188. BSim with lamellas

VENTILATION STRATEGY

HYBRID VENTILATION

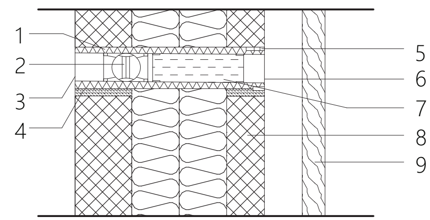
SEASONS

Natural ventilation is preferable during the summer, as the ventilation is driven by free energy. However, natural ventilation is often a problem during winter, because of the large heat losses it entails. For this reason, mechanical ventilation with heat recovery is often a more suitable choice during winter months to save heat and avoid draught from cold air.

FUTUREVENT

FutureVent is a hybrid ventilation system developed especially for school classrooms [WindowMaster, 2015]. This solution is single sided ventilation with window openings, which are used to ventilate during the summer season supplemented by mechanical ventilation, if the natural airflow is not sufficient. This ensures a steady airflow regardless of weather conditions.

The system consists of micro-ventilation units, which provide a basic airflow during the winter season with up to 86% heat recovery, ill. 189-191. The system must have a minimum of two units in each room that change between intake and exhaust transferring heat from the outgoing to the incoming air.

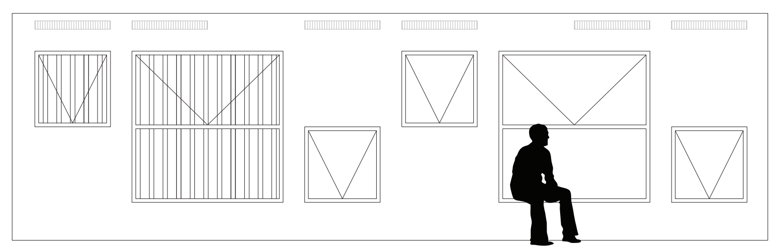


1) Cassette
2) Fan
3) Internal screen
4) Mortar
5) Elastic joint
6) External screen
7) Regenerator
8) 500 mm external wall
9) 60 mm wooden lamella

Ill 189. Detail of ventilation system in wall, 1:20

	Air flow		SEL	Heat recovery	Watt
Unit	l/s	m³/h	J/m3	%	W
2 MV8 Triple	124,8	449,3	271	86	32,6
2 MV8 Single	41,6	149,8	271	86	10,9

Table 190. Data from manufacturer



Ill. 191. Exterior wall in classrooms, 1:100

VENTILATION STRATEGY

HYBRID VENTILATION

ENERGY & INDOOR CLIMATE

With the use of a mechanical ventilation system with heat recovery during the winter season, the heating requirement for the building has been greatly reduced according to the results from Be10. Moreover, the possibility of using the system to increase the ventilation rate on warm days has now removed the excessive heat in rooms.

In BSim, the mechanical ventilation system has decreased the amount of hours above 26 and 27 degrees to acceptable values, which is 100 hours above 26 degrees and 25 hours above 27 degrees. In addition, the CO_2 concentration is improved by 11 % in category A++ compared to previous results without the ventilation system. As shown in appendix 4, the temperatures in the classroom has reached a more steady value throughout the day, which results in a more comfortable indoor climate. A more even temperature in the classroom has potentials of influencing the students' ability to focus, creating a more efficient learning environment.

BE10

ENERGY FRAME BUILDINGS 2020

Total energy requirement:	20,8 kWh/m^2

CONTRIBUTION TO ENERGY REQUIREMENT

Heat:	9,5 kWh/m^2
El. for operation of building:	8,4 kWh/m^2
Excessive in rooms:	0,0 kWh/m^2

BSIM

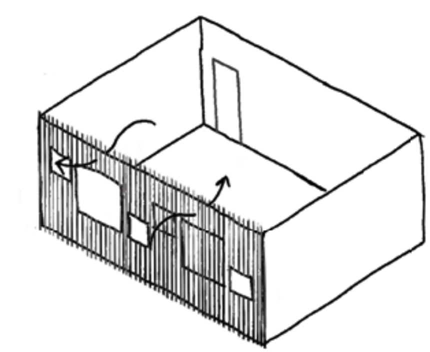
TEMPERATURE CLASSIFICATION

Hours above 26 degrees > 37

Hours above 27 degrees > 23

CO_2 CONCENTRATION

Category A++	57 %
Category A+	43 %



Ill. 192. BSim with hybrid ventilation

ACOUSTICS
ZONES

ACOUSTIC EXPERIENCES

Acoustics have great influence on how different rooms are perceived, and must be adapted to the different functions of the building.

The first acoustic experience is the atrium, ill. 193, a large open area with lively and resounding acoustics, which emphasizes the life of the school environment.

Common spaces are meant for play, conversation or group work and need a low reverberation time to keep the noise level down, ill. 194. The reverberation time in classrooms should be low, but adjustable according to teaching methods, ill. 195.

The active environment in the multi hall allows for a higher reverberation time, which is also suitable when used for concerts, ill. 196. The music room is divided into two rooms, ill. 197, one for acoustic music with a reverberation time between 0,8-1,1, and a room for amplified music with a reverberation time less than 0,6 s [Energistyrelsen, 2013].

Other 'acoustic experiences' are placed at different spots in the building as circular rooms covered with different materials on the inside as described earlier, ill. 198.

Reverberation time: 1,6 - 2,0 s

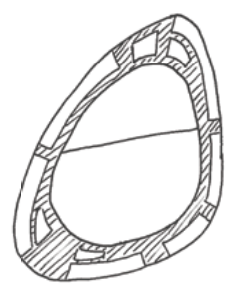
Ill. 193. Zone 1 - The Atrium

Reverberation time: < 0,6 s

Ill. 195. Zone 3 - Teaching

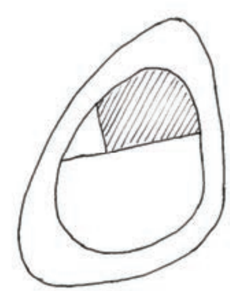
Reverberation time: 0,6 - 1,1 s

Ill. 197. Zone 5 - Music room



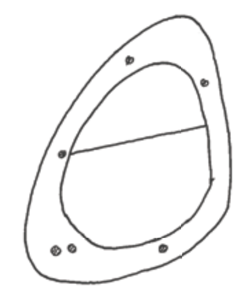
Reverberation time: 0,4 - 0,9 s

Ill. 194. Zone 2 - Common space



Reverberation time: < 1,6 s

Ill. 196. Zone 4 - Multi hall



Reverberation time: 0,1 - 4,0 s

Ill. 198. Zone 6 - Acoustic experiences

ACOUSTICS

CLASSROOM

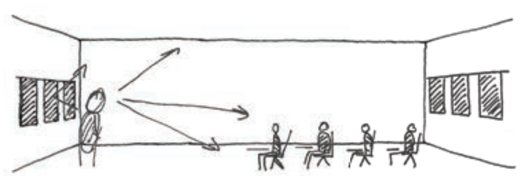
REVERBERATION TIME

The reverberation time in the classroom has been calculated with Sabine's Formula, which indicates how the volume, the surface area and the properties of materials affect the reverberation in a room, see appendix 8. The classroom consists of both hard surfaces as concrete and softer surfaces of wood. With an acoustic material on the ceiling, it is possible to reach the required reverberation time beneath 0,6 s.

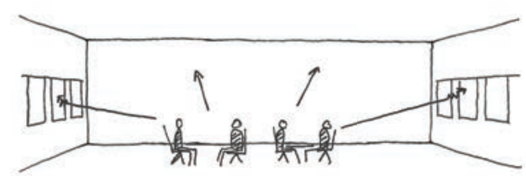
Two of the walls inside the classrooms will be installed with a flexible board system, which can be used for blackboards, whiteboards, or soft display boards. These can also be used to turn around and create different acoustic situations. In teacher-to-student teaching, the hard boards can be used as reflection, so that more of the sound reaches students sitting in the back of the room, ill. 200. Another situation is group work, where several conversations occur on the same time. Here, the sound should be absorbed to keep the noise level down, ill. 201.

		Freq.	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
SURFACE	MATERIAL	Area (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)
CEILING	Troldtekt 25 mm + 40 mm insulation	70	0,59	41,3	0,97	67,9	0,94	65,8	0,88	61,6	0,85	59,5	0,98	68,6
FLOOR	Concrete, polished	70	0,01	0,7	0,01	0,7	0,02	1,4	0,02	1,4	0,02	1,4	0,03	2,1
WALL	Concrete, painted	18	0,1	1,8	0,05	0,9	0,06	1,08	0,07	1,26	0,09	1,62	0,08	1,44
	Wood (furniture wall)	30	0,28	8,4	0,22	6,6	0,17	5,1	0,09	2,7	0,1	3	0,11	3,3
	Plasterboard	42	0,14	5,88	0,16	6,72	0,08	3,36	0,06	2,52	0,02	0,84	0,06	2,52
WINDOW	Insulating glass	12	0,1	1,2	0,07	0,84	0,05	0,6	0,05	0,6	0,02	0,24	0,02	0,24
TOTAL ABSORPTION AREA A				59,28		83,66		77,34		70,08		66,6		78,2
REVERBERATION TIME T				0,57		0,40		0,44		0,48		0,51		0,43

Table 199. Classroom reverberation time



Ill. 200. Reflecting surfaces for teaching



Ill. 201. Absorbing surfaces group work

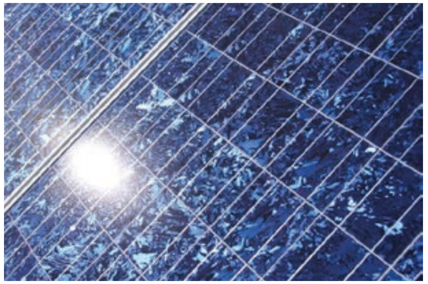
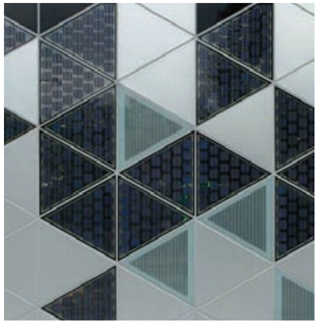
ZERO ENERGY
ACTIVE STRATEGY

PHOTOVOLTAICS

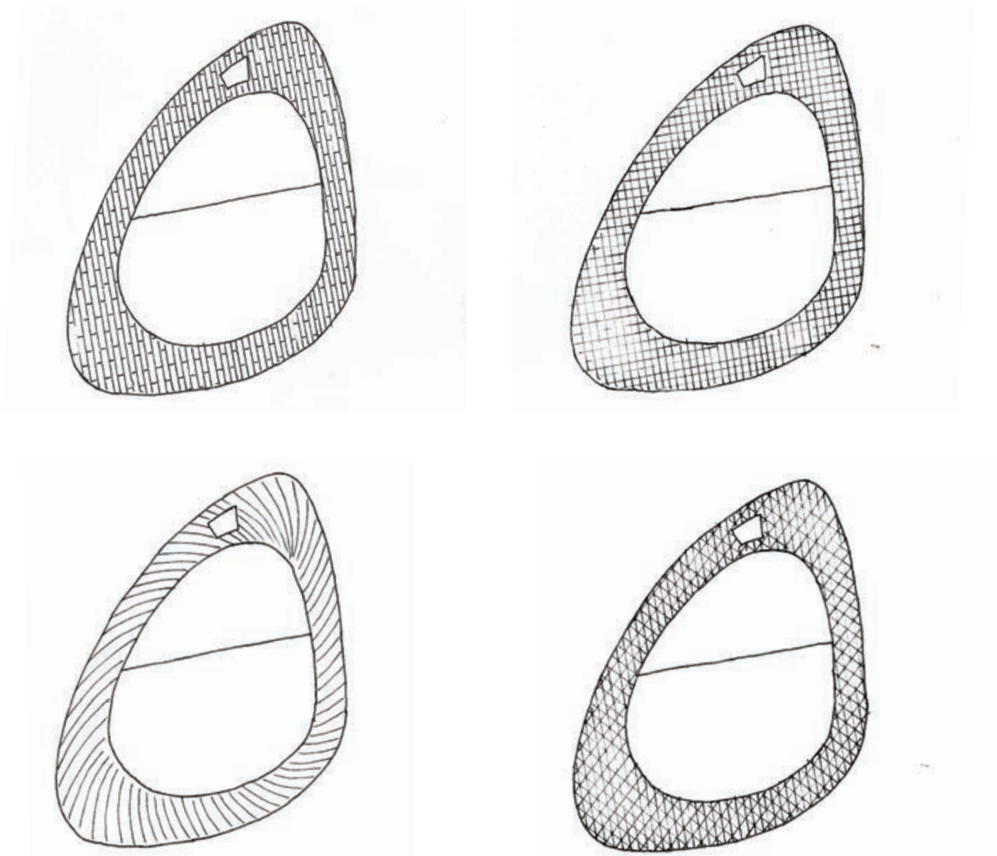
In order to reach zero energy and cover the energy consumption of the building with energy from renewable sources, photovoltaic panels are installed on the building. To avoid shadows, and to take advantages of the sloping roof towards South, the PV should be installed on the roof. To create a coherent appearance of the overall building, it is chosen to integrate PV panels on the whole roof surface, which will then replace another roof material.

Comparing the architectural expression of the different types of PV panels, monocrystalline has an even appearance with black or dark blue panels. Polycrystalline panels has a more lively and glistening appearance available in a range of colours. This type of panel is less efficient than monocrystalline, but more efficient than thin film. A calculation of the needed area, for each type of panel, can be found in appendix 6, showing sufficient results when using polycrystalline panels. This type is therefore chosen for its aesthetic and technical potentials. Different shapes of panels are considered, with the conclusion that triangular panels are easiest to adjust to the shape and the curvature of the roof, ill. 206. This shape also corresponds to the structural appearance of polycrystalline panels.



Ill. 202-205. References of PV panels



Ill. 206. Shapes of PV panels

BE10

ENERGY FRAME BUILDINGS 2020

Total energy requirement:	-26,5 kWh/m^2

CONTRIBUTION TO ENERGY REQUIREMENT

Heat:	9,5 kWh/m^2
El. for operation of building:	8,4 kWh/m^2
Excessive in rooms:	0,0 kWh/m^2

OUTPUT FROM SPECIAL SOURCES

Solar cells:	26,3 kWh/m^2

SUMMARY DETAILING

The detailing includes considerations of the facade expression relating to two of the essential themes of the project, sound and movement. The facade aims to express a sense of rhythm, which is created by lamellas having a changing appearance moving along the building. In relation to this, windows are placed on a sine wave forming a pattern and emphasizing sound as a conceptual objective. Few windows have lamellas in front, performing as solar shading and reducing excessive heat shown in BSim and Be10. In order to appear inviting and functionally convincing, studies explore how to create visible entrances on the facade.

The lamellas must be sustainable within durability and maintenance. Western red cedar last for many years without any treatment, and changes colour from warm brown to silver grey, emphasizing climatic consequences and the honesty of raw materials.

To fully reach the goals of a comfortable indoor climate, mechanical ventilation is introduced. This hybrid system supplements window openings for fresh air during summers, and uses heat recovery during winters to minimize heat loss. As a result of the system, the building fulfils the energy frame for 2020, and the indoor climate corresponds to Danish regulations. Lastly, PV panels are introduced as the roof material reaching zero energy.

PRESENTATION

In this section the final design will be presented, showing the results of several design decisions solving functional, technical and aesthetic parameters. The presentation visualize architecture from a student's perspective, having room to gather, contemplate and play. These spaces are provided both in- and outside, suggesting multiple possibilities of energetic activities.

The section is finalized with a conclusion and reflection, summarizing important aspects in the project.

Ill. 207. Playing music

LYDENS BY SKOLE

MASTERPLAN

Lydens By Skole illustrates a project proposal of a public school in Struer. The project has a conceptual focus of sound and movement, relating to goals of the municipality and the new Danish public school reform. A dynamic form creates inspiring settings for students and teachers, functioning as a learning environment and a working facility. Contextual lines and infrastructural paths forms several entrances and encourage sustainable transportation to and from school, including bicyclists, pedestrians, and public transportation. Parking is provided for staff and citizens using the school.

Ill. 208. Masterplan, 1:2000

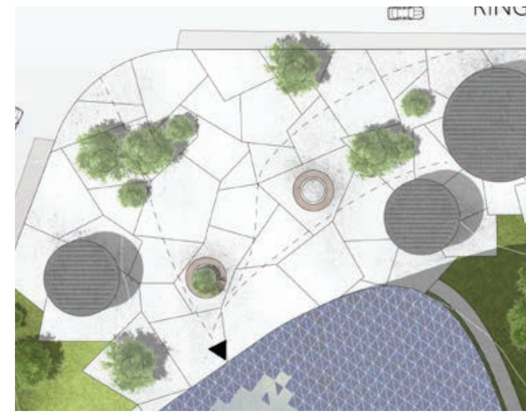

LYDENS BY SKOLE

Ill. 209. Main entrance

ARRIVING TO SCHOOL

MAIN ENTRANCE

When arriving to the school from the city of Struer an iconic form appears in the surroundings. The building unfolds a public node, suggesting a place to sit and rest, a place to skate or hang out. From the public place a dynamic entrance of glass allows views inside the building, while creating an inviting atmosphere for the user. Looking down the building facade, a window rhythm is noticeable, emphasizing the conceptual focus of sound and movement. A dynamic architectural expression is created by wooden lamellas, including technical perspectives of solar shading. This furthermore relates to a functional perspective of ensuring private indoor settings for the students.



Ill. 210. Masterplan zoom in, 1:1000

FUNCTIONAL PERSPECTIVE

PLAN

The floor plans reflect a functional perspective of ensuring well designed plan solutions for students, teachers and citizens using the building. When arriving to the building from the city, a public atrium appears inviting and welcoming, while distributing classrooms and labs in several levels according to student zones. In close relation to the atrium, music labs and a multi hall are located, reflecting the conceptual objective of sound and movement.

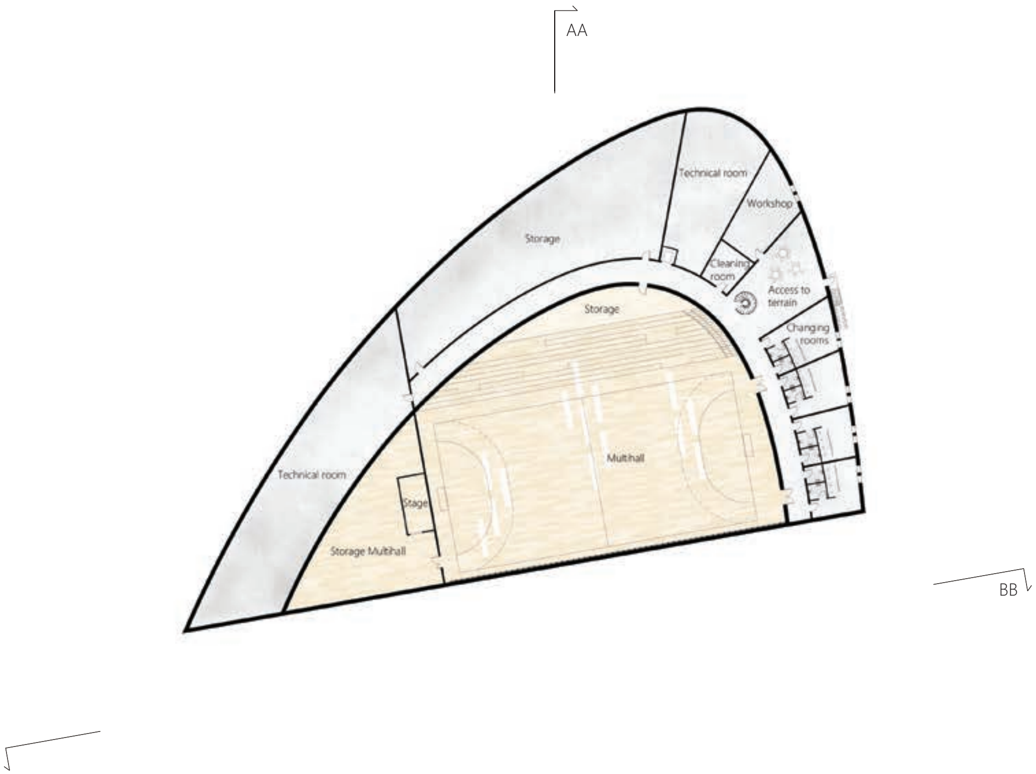
The floor plans illustrate a differentiation between public and private, having labs near the atrium usable for the citizens after school or in weekends. The labs reflect the different directions of the school suggested by the municipality, with creative, aesthetic and music labs on the ground floor plan. Science and technology labs are located on the first floor plan and language labs are placed on the second floor to be used by students or evening language classes.

This leaves the classrooms in the more private zone of the building, for a more secure and intimate atmosphere. The youngest students are placed on the ground floor, from where the students grow up in the building as they become older.

Ill. 211. Ground floor plan, 1:1000

Ill. 212. First floor plan, 1:1000

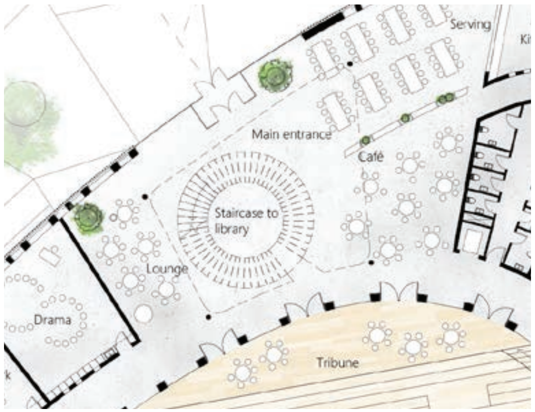
Ill. 213. Second floor plan, 1:1000



Ill. 214. Basement plan, 1:1000

A SCHOOL FOR THE CITY

ATRIUM



Ill. 215. Plan zoom in, 1:500

When arriving through the main entrance from North, a multifunctional space enlightens the user, with a high atrium surrounding a circular staircase. A roof window lights up the room and casts shadow on the floor from the triangular PV panels. This emphasizes sustainability as an architectural perspective. The atrium includes a public café, library and allows access to music labs, multi hall and classrooms. Views down the dynamic hallways invites the user to inhabit the building and move along the space, which is a result of the circular shape. Goals of the municipality are reflected in this public space, forming an extrovert school in Struer, which is available for citizens after school hours and in weekends.

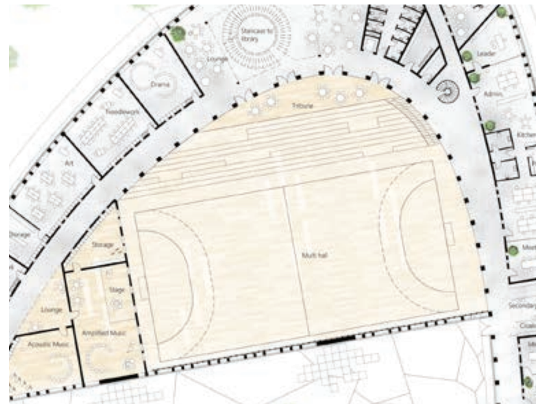
Ill. 216. Atrium

MOVEMENT AND EXERCISE

MULTI HALL

From the atrium, access is provided to the multi hall through several glass doors, creating visual and physical connections. From here, a large staircase connects the two levels, functioning as a plateau for the audience and a staircase down. Students, teachers, and citizens can use the multi hall for sport, concerts and other common activities. In one end, windows encourage views into the music lab, and a movable stage further enhance this connection. This stage could be used for school concerts, drama plays or other common activities. A climbing wall and ropes contributes with additional activities in the hall.

Windows from the courtyard provide daylight and visibility across levels for the curious students playing outside. The structural system with glue-lam beams forms an interesting ceiling, which is enlightened by roof windows between the beams. From these windows, students can look down to the multi hall from the roof terrace, enhancing visual contact between levels. From the multi hall, connections are created to changing rooms and storage in the basement.



Ill. 217. Plan zoom in, 1:500


STAGE
SPORT

Ill. 219. Acoustic music lab

Ill. 220. Amplified music lab

SOUND AS A TOOL FOR LEARNING

MUSIC LAB

In relation to the objective of sound as a conceptual focus in *Lydens By Skole*, an area of music have been detailed in the project. The music labs include a lounge area in connection to the hallway, from where you may enter two different acoustic spaces. These spaces have different acoustic performances for acoustic instruments and amplified music, which are to be used by the students and the public after school hours. The architectural expression of each space aims to emphasize its acoustic properties, one room being more reflective, the other more absorbing for amplified music. From the largest music lab, a moveable stage provides access to the multi hall and storage in the basement.

Ill. 221. Plan zoom in, 1:500

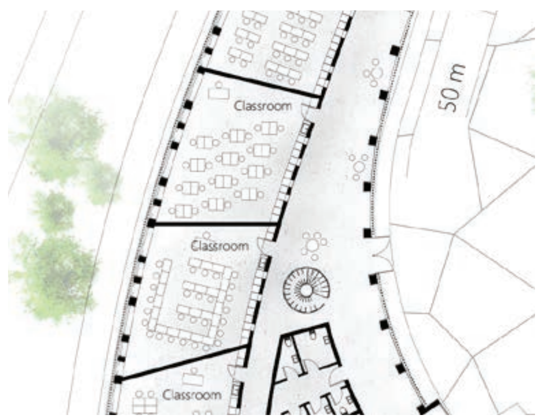

HOW ARE YOU?
WHAT'S YOUR NAME?
A B C
ENGLISH 1.B

Ill. 222. Classroom

AN INSPIRING LEARNING ENVIRONMENT

CLASSROOM

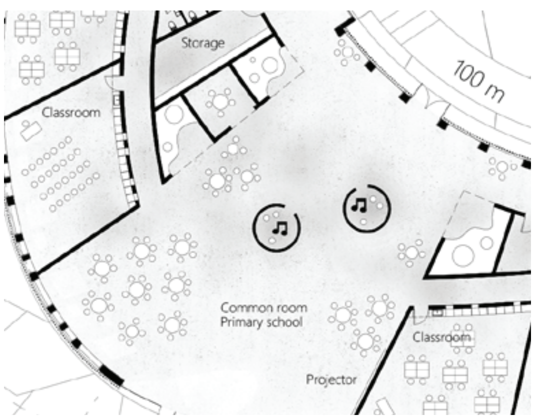
A theoretical approach of creating learning environments for gathering, contemplation and debate forms the scenes for the intimate learning spaces. The classrooms have good daylight conditions with large deep window openings, forming a place to sit, read a book and retreat. Furnishing of the classrooms have multiple possibilities as shown on the floor plans. A furniture wall provides storage inside the classroom and enclose small window openings creating views to the hallway. Through these windows, homemade art could be exhibited for people walking on the hallway.



Ill. 223. Plan zoom in, 1:500

COOPERATION AND INDIVIDUALITY
COMMON ROOM

The common rooms host several activities, a place to read a book alone or in groups with other students. It's a place for students to meet within their age zone, to play and hang out with friends. From this space students walk down the hallway to their classroom, including additional space for individual contemplation. Several acoustic experiences are placed along the common spaces to awake curiosity for sound. Students can escape into these spaces, read a book quietly or discover the sound experience of different materials. From the common room access is provided to the private courtyard, emphasizing a near transition from in- and outdoor spaces.



Ill. 224. Plan zoom in, 1:500

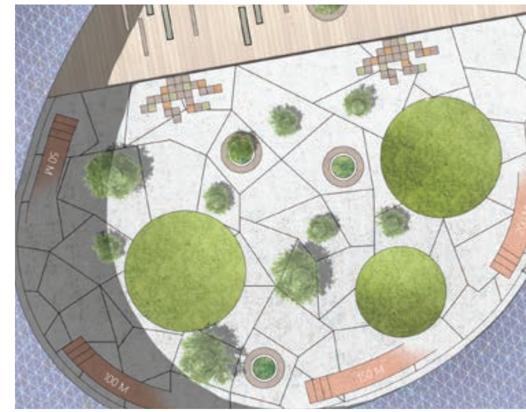
Ill. 225. Hallway

Ill. 226. Courtyard

TIME FOR A BREAK

COURTYARD

During breaks, students can escape to the courtyard, providing private outdoor settings for the younger students. Above the multi hall, a large roof terrace forms similar settings for the older students, in this way the age zones of students are physically separated but with visual connections. The courtyard includes several play zones, greenery, a running track and places to sit. The space has an atmosphere of a traditional school yard, protected by the building walls and is inspiring in its multiple activities. A climbing wall encourages the students to form connections between the two zones, but only for the ones who are brave.



Ill. 227. Masterplan zoom in, 1:1000

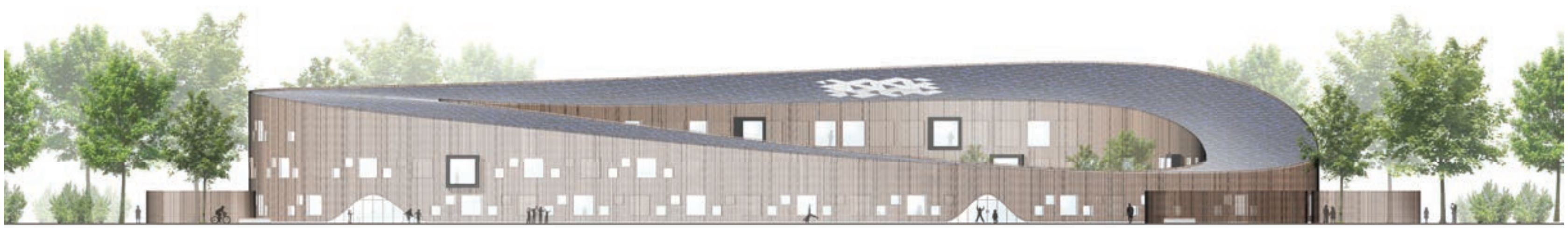
Ill. 228. Masterplan zoom in, 1:2000

LEARNING THROUGH NATURE
URBAN GARDEN

To the South, a large nature zone is located, with high growing grass, a pond, pavilion, and an urban garden. These activities aim to emphasize sensuous learning methods, which can easily be used in lessons or by the students in their spare time. From this view the building raises towards North, enlightening the architectural focus of integrated sustainable initiatives. Polycrystalline PV panels shine on the dynamic roof, producing electricity for the building while functioning as the roof material. In this way the students' awareness of sustainability and global warming are strengthened.

Ill. 229. Urban garden

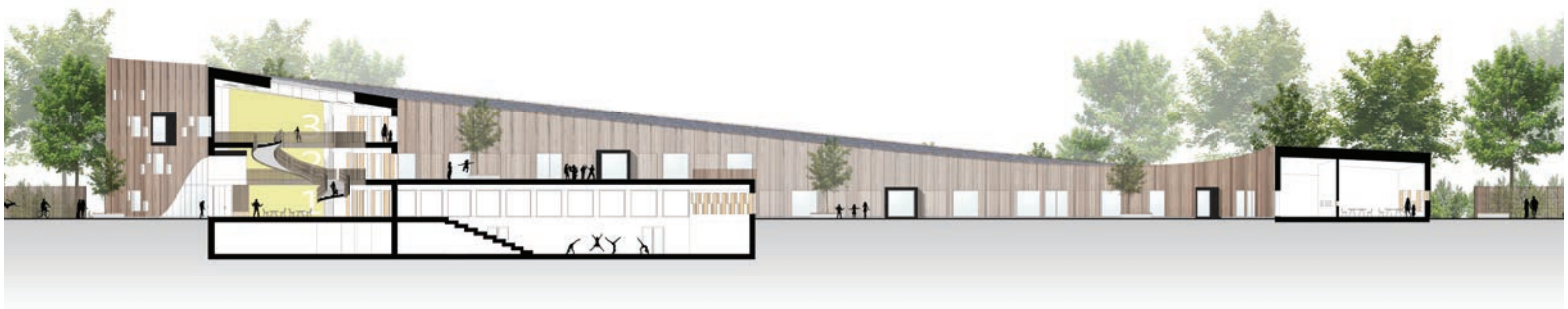
Ill. 230. Northern Elevation, 1:600



Ill. 231. Southern Elevation, 1:600

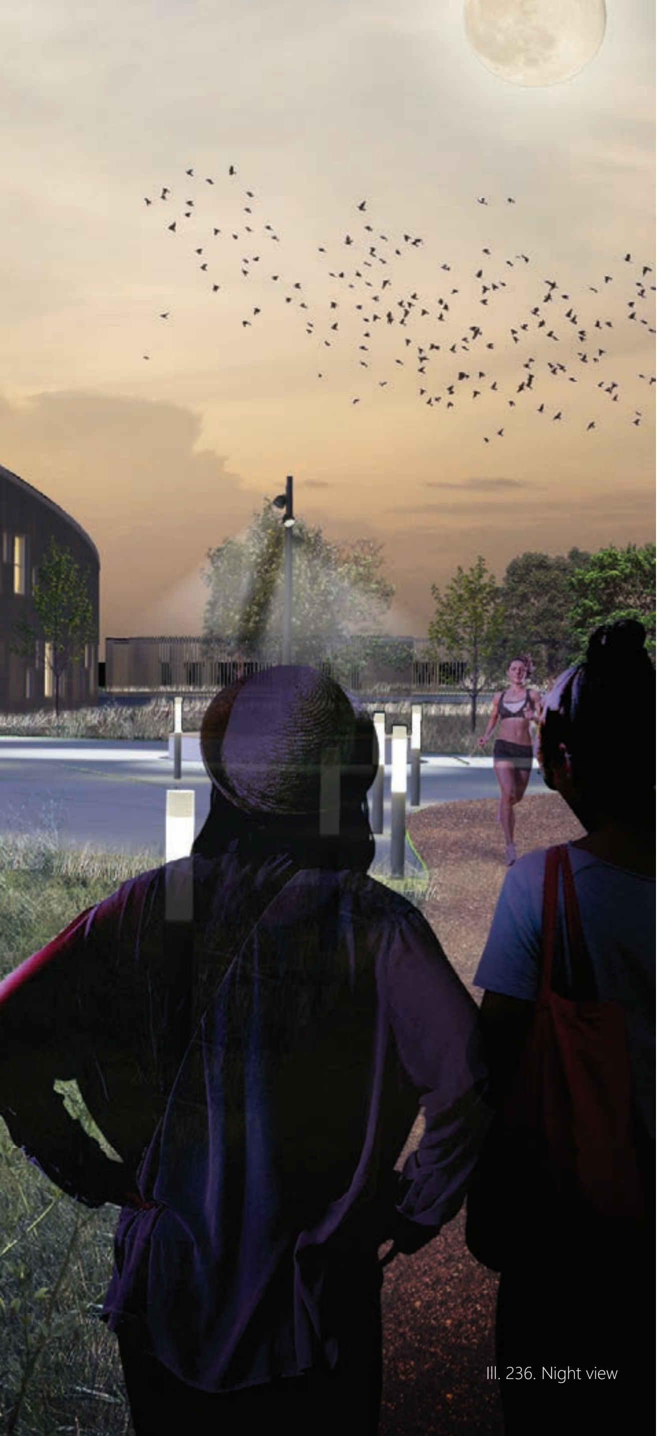
Ill. 232. Eastern Elevation, 1:600

Ill. 233. Western Elevation, 1:600



Ill. 234. Section AA, 1:600

Ill. 235. Section BB, 1:600

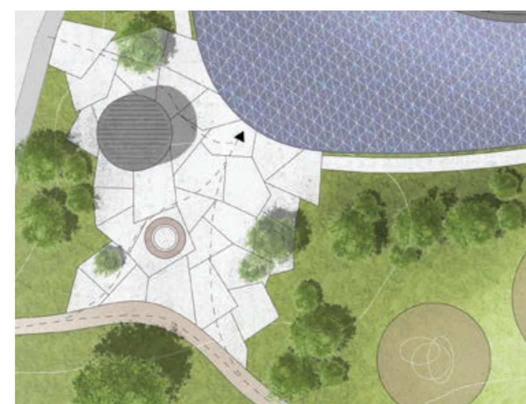


Ill. 236. Night view

A CULTURAL INSTITUTION

LYDENS BY SKOLE

Walking by the building by night, the dynamic window rhythm appears behind the lamellas and the architectural identity of sound and movement elicits. *Lydens By Skole* is a school for the city, focusing on sound and movement, while considering sustainable methods and social reflections of the new Danish public school reform. The building is a part of a strategy of placing Struer on the national map, enlightening the city as an acoustic pioneer. Most importantly the school is a building for the city, a place generations unites as a community.



Ill. 237. Masterplan zoom in, 1:1000

CONCLUSION

LYDENS BY SKOLE

The project *Lydens By Skole* deals with the design and development of a Danish public school located in Struer. A school, that should not only function as an educational institution, but also a cultural institution that gathers the local community. With sound as a central theme, the school should become an icon for the city of Struer. Another perspective of the project is the new Danish public school reform, which is a national objective of improving all public schools to international standards. The reform considers the individual student, and aims for an active learning environments with longer school days and a wider range of activities. The school should be ahead of current tendencies within environmental sustainability in public schools, with an excellent indoor climate and a low energy demand, counterbalanced by renewable energy produced on site.

The building have been designed with considerations of nearby typologies, meeting the scale of the city with the low single-family houses to the South, rising towards the centre of the city and the larger apartment blocks Northwest from the site. While the circular shape of the building stands out in the area, it has been adjusted to the site with the entrances orientated towards existing roads and pathways. The dynamic glass entrances emphasize an inviting appearance, and welcome the citizens inside the building. The functional organization is orientated around a public zone with library and café, access to labs and sport facilities for after school activities. This zone becomes a common place where citizens, students and teachers meet. The theme sound has been integrated in the design with great room acoustics, music labs in a central position, and different acoustic experiences around the building. Sound has also been translated into an architectural expression through a dynamic and organic form of the building, rhythm as a repetitive element in the form of lamellas, and quadratic windows as a continuing pattern placed like pearls on a curve.

The new Danish public school reform has been considered in various ways, but mainly with focus on movement. The multi hall is placed in the centre of the building, with visibility and direct access through the main entrance and atrium, as well as direct views from the music lab, courtyard and roof terrace. There are also plenty of possibilities for movement and various activities in the outdoor spaces surrounding the building, which in its own circular shape suggests a sense of movement and continuity. The school is organized in a public area with labs, café and library, common for all students and other interested citizens, while a more private area with classrooms, group rooms and niches on the hallway, create a place for the students to gather, debate and contemplate. The vertical organization of the school levels creates secure surroundings for the students, which can be customized or personalized by the different age groups. Because of the longer school hours and preparation time during school, each teacher has their own desk and work space on the same floor as the age group of students they are associated with. The staff area also has small lounges and a large dining area, where all employees can gather.

It is not only the visual and functional surroundings that create good settings for learning. A good indoor climate is equally important. Atmospheric and thermal comfort is ensured with a hybrid ventilation system, which guarantees that rooms are well ventilated all year. Besides the aesthetic purpose of the lamellas, it also functions as a permanent form of solar shading, which decrease the excessive temperatures in rooms, while allowing good daylight conditions.

Calculations show that the design fulfils the government's requirements for building class 2020. The low energy consumption of the building, will be compensated by renewable energy from solar cells. The PV panels form the dynamic roof of the building and emphasize the sustainable focus in the project.

REFLECTION
SUSTAINABLE LEARNING

Designing a school building is a comprehensive process that involves considerations of many different themes. How do we make the school specific for its location? What constitutes a great learning environment? And what is important when designing a school for today's society, in relation to academic developments and sustainability?

The integrated design process has been the basis for the course of the project and a mean to ensure that all important parameters are considered throughout the process. However, due to the limited time line for the project, it can be a challenge to accomplish all the initial objectives and intentions.

In connection with the project *Lydens By Skole*, the goal was to create an iconic building reflecting the city's status as the *City of Sound*. The building should also be more than a public school in the traditional sense, but invite, and be usable to other citizens. The atrium, café and library, create a well-defined public zone, with direct access to the multi hall, which, besides sports events, can also host gatherings and concerts in connection with the music lab and stage. The remaining labs, which are meant for evening classes and other activities, are visually connected to the public zone with small windows in the interior walls. However, this connection could have been stronger if the labs were a more central part of the public zone, or if it was possible to open up and merge the labs with the corridor and atrium, making them more flexible and easy to exhibit for special events.

The new Danish public school reform has been a large part of the motivation behind the project. One of the problems with the reform is, that many current schools are not equipped for the changes it involves. One thing is room for the teachers' preparation time, another is space and equipment, both inside and outside for exercise and movement. This is something that has been implemented in *Lydens By Skole*, together with different learning environments, which can support different activities. The classroom is the students' base, their familiar surroundings, which can be personalized and displayed through the furniture wall. The hallway offer room for casual meetings while larger common rooms are spaces for gatherings and debate. The group rooms, and niches along the hallway, are places to contemplate and to concentrate on the individual task alone or in groups. Focus on the individual student, and different ways to learn, has to some extent been implemented in the project, but this is a subject that could be explored further, both within the indoor and outdoor spaces of the school facility.

The design of buildings is really a multidisciplinary task, and the integrated design process is about combining knowledge from both architectural and engineering faculties. By introducing technical considerations early in the process, an overview of the possibilities and limitations for the project has made it possible to design a 'whole building' without large compromises concerning either the aesthetics, the functional or technical aspects of the design.

During the project, sustainability has mainly been discussed in relation to indoor climate, low energy consumption and the production of renewable energy. One may ask if these technical considerations are enough for a building to be fully sustainable. Does the building provide quality to the users in other aspects than technically and functionally? Looking at Vitruvian virtues of architecture a consisting interrelation between Utilitas, Firmitas and Venustas is necessary to perceive a perfection of form. From this perspective a sustainable building must, besides technical and functional aspects, include high architectural quality and a relation to its context to be fully sustainable. It must provide something extraordinary to the daily life of the users, and by doing so, a building becomes greatly successful.

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Ill. 32. *Site opportunity and school district*. Own illustration

Ill. 33 – 39. *Østre Skole*. Own illustration

Ill. 40 – 45. *Context mapping*. Own illustration

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Ill. 65. *Scale of the city.* Own illustration

Ill. 66. *Zoning.* Own illustration

Ill. 67 - 75. *Ideation.* Own illustration

Ill. 76 - 78. *Comparison.* Own illustration

Ill. 79. *New model.* Own illustration

Ill. 80 - 81. *Sun and shadow*. Own illustration

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Ill. 127. *Classroom*. Own Illustration

Ill. 128-130. *Natural ventilation*. Own Illustration

Table. 131-133. *Ventilation principles*. Own Illustration

Ill. 134-138. *Thermal comfort*. Own Illustration

Ill. 139-156. *Daylight*. Own Illustration

Ill. 157. *Isolating*. Own Illustration

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Ill. 183-186. *Daylight*. Own Illustration

Ill. 187. *Detail of exterior wall*. Own Illustration

Ill. 188. *BSim with lamellas*. Own Illustration

Ill. 189. *Detail of ventilation system in wall*. Own Illustration

Ill. 190. *Data from manufacturer*. Available at: https://windowmaster.adobeconnect.com/7zvu1yy/?launcher=false&fcsContent=true&pbMode=normal [Accessed 30.03.15]

Ill. 191. *Exterior wall in classrooms*. Own Illustration

Ill. 192. *BSim with hybrid ventilation*. Own Illustration

Ill. 193-198. *Acoustic experiences*. Energistyrelsen, 2013. *Vejledning om lydbestemmelser i Bygningsreglement 2010 (akustisk indeklima)*. Denmark

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Ill. 206 *Shapes of PV panels.* Own illustration

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Ill. 208 - 237. *Presentation.* Own illustration

Ill. 238. *Looking back.* Available at: http://hdwallpapers.cat/grass_child_flowers_girl_splendor_nature_hd-wallpaper-1766566/ [Accessed 14.05.15]

Table 239. *Building elements*, Own illustration

Ill. 240. *Detail multi hall*. Own illustration

Tables 241 - 242. *Area Schedule & parking.* Own illustration

Ill. 243 *Screenshot from spreasheet.* Own illustration

Ill. 244. *Bsim model.* Own illustration

Table 245. *Classifications*, DS3033, 2011. *Friviligklassificering af indeklimaets kvalitet i boliger, skoler, daginstitutioner og kontorer.* Copenhagen, Denmark.

Ill. 246 - 255. *BSIM*. Own illustration

Ill. 256. *Roof Division.* Own illustration

Table 257. *Energy production from PV.* Own illustration

Table 258. *Escape routes and emergency exits.* Statens Byggeforskningsinstitut, 2014. SBi 230 - Anvisning om Bygningsreglement 2010. Copenhagen SV, Denmark

Table 259. *Escape routes for common areas.* Energistyrelsen, 2012. Eksempelsamling om brandsikring af byggeri. Copenhagen K, Denmark

Ill. 260. *Fire Plan.* Own illustration

Tables 261 - 263. *Reverberation time with Sabine's formula.* Own Illustration

APPENDIX

The appendix includes technical calculations and results from BSim, natural ventilation sheets, acoustic considerations, calculations of different PV panels, area schedules and fire plans. All of these results have been considered in the design process and used to supplement design decisions.

Interviews, spreadsheets, BSim and Be10 files can be found on the attached USB.

Ill. 238. Looking back

APPENDIX 1
CONSTRUCTION

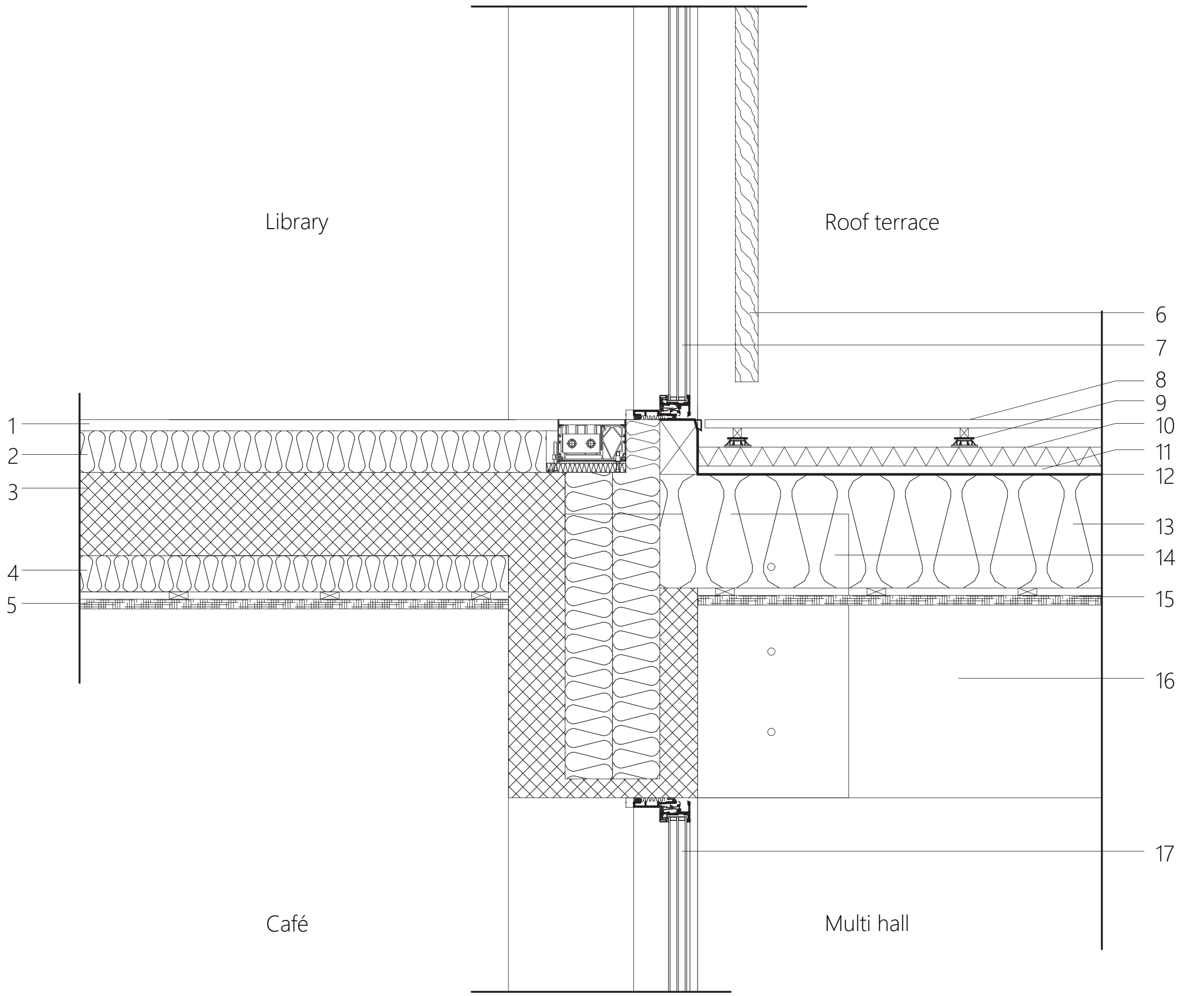
The construction of the building is mainly designed with concrete elements. Slabs are supported by columns, which follow the exterior wall facing the courtyard and the inner circle following the classrooms. The slabs furthermore rest on shear walls following the exterior wall facing the road. The circular shape of the building and the internal zones stabilize the construction.

Some of the structural elements are described on the table, ill. 239, defining a low u-value as a result of thick building elements. This data is used later in BSim to define building elements of the simulation model.

As a contrast to the concrete, a wooden ceiling construction is implemented in the multi hall, ill. 240. This construction allows a thinner slab, and solves the connection between atrium, multi hall and the roof terrace, which all should have appropriate ceiling heights and an aligned connection from library to terrace.

BUILDING ELEMENTS	U-VALUE [W/M²K]	MATERIALS
660 MM EXTERNAL WALL	0,11	150 mm reinforced concrete
		250 mm rockwool insulation
		100 mm reinforced concrete
		100 mm joists
		60 mm lamellas
230 MM INTERNAL WALL	0,28	25 mm plasterboard
		45 mm rockwool insulation
		90 mm airspace
		45 mm rockwool insulation
		25 mm plasterboard
1000 MM FLOOR	0,08	30 mm concrete floor
		130 mm rockwool insulation
		300 mm polystyrene
		300 mm leca
		240 mm sand
500 MM CEILING	0,14	25 mm troldtekt
		20 mm airspace
		95 mm rockwool insulation
		220 mm reinforced concrete
		110 mm rockwool insulation
		30 mm concrete floor

Table 239. Building elements



1) 30 mm concrete floor
2) 110 mm insulation
3) 220 mm concrete slab
4) 95 mm insulation
5) 25 mm troldtekt
6) 60 mm wooden lamella
7) Window with 3-layer glazing
8) 22 mm planks
9) Chocks with joists
10) 50 mm polystyrene with slope 1:40
11) 22 mm OSB
12) Bitumen roofing membrane
13) 300 mm insulation
14) Steel joint
15) 25 mm troldtekt
16) 855x210 mm gluelam beam
17) Window with 3-layer glazing

Ill. 240. Detail of multi hall, 1:20

APPENDIX 2
AREA SCHEDULE & PARKING

FLOOR	NET AREA m^2	GROSS AREA m^2
Basement	3144	3598
0. floor	4299	4920
1. floor	3059	3501
2. floor	2491	2851
Total	12994	14870

Table 241. Floor areas

ROOM	NET AREA (m^2)	GROSS AREA (m^2)
Café	439	502
Library	616	705
Multi hall	1294	1481
Classrooms	2191	2507
Labs	1198	1371
Staff	1141	1306
Common area	3708	4243
Kitchen	81	93
Toilets & changing room	514	588
Storage	538	616
Storage basement	574	657
Technical room	698	799
Total	12994	14870

Table 242. Room areas

AREA SCHEDULES

The area schedules describes the net- and gross area of the floor plans and the different room types. In total, a gross area of 14.870 m^2 is created, which is averagely higher than the estimated minimum defined in the program. The area furthermore reflects a focus on common rooms, classrooms and staff, providing space for lessons and preparation.

CAR PARKING

The standard number of parking spaces in public schools is estimated to 1 parking space for every 2 employees in the school facility [Aalborg Kommune, 2015]. With 64 employees the number of parking spaces should be at least 32. With a few extra spaces for visitors and disabled parking, the school facility is designed with 40 parking lots.

BICYCLE PARKING

The norm for bicycle parking in schools is 1 for every 2 students. With approximately 800 students, this equals 400 spaces for bicycle parking, which are established in sheds close to the different entrances of the building.

APPENDIX 3

NATURAL VENTILATION

NEEDED AIR FLOW IN A CLASSROOM

Basic air flow:

Area: 70 m^2
0,35 l/s per m^2
3 l/s per child (28 students)
5 l/s per adult (2 teachers)

0,35 l/s • 70 m^2 + 3 l/s • 28 + 5 l/s • 2 = 118,5 l/s

118,5 l/s / 70 m^2 = 1,7 l/s per m^2

Needed air flow on a warm day:

The needed air flow rate on a warm summer day is found by calculating the 24-hour average temperature. With a maximum average temperature of 25° the needed air change rate is 3,82 h^{-1} or air flow rate: 223 l/s

The spreadsheet, ill. 243, used for calculating the 24-hour average can be found on the attached USB.

CALCULATED AIR FLOW

The natural ventilation through the openings in a classroom is calculated with the spreadsheet below, which can also be found on the attached USB. The calculation is depended on weather data and the size and placement of the openings.

Following data has been used for the calculation:

Pressure coefficients, 90 degree West [SBi 202, 2002, p.69]
Windward: 0,2
Leeward: -0,25
Roof: -0,4

Mean outdoor temperature for July [SBi 202, 2002, p.31]
16,1 °C

Maximum indoor temperature [DSEN 15251, 2007]
26 °C

Mean wind velocity [SBi 202, 2002, p.33]
4,4 m/s

Wind factor V_h [SBi 202, 2002, p.35]
Suburban areas: k: 0,35 and α: 0,25

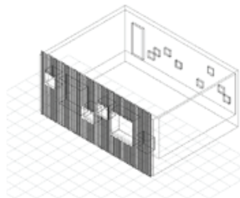
$V_h = k \cdot h^{\alpha} = 0,35 \cdot 10^{0,25} = 0,62$

Pressure Coefficient		**Windfactor**	0,62	**Pwind**	4,7 pa
Windward	0,2	**Vmeteo**	4,4 m/s	**Pmin**	-1,9 pa
Leeward	-0,25	**Vref**	2,728 m/s	**Pmax**	0,9 pa
roof	-0,4				
Location of neutral plan	2,2 m	**Buildingvol.**	m3		
Outdoor temperature	16,1 C	**Volume**	m3/section/floor		
Zone temperature	26 C				
Discharge coefficient	0,7	**Internal pressure**	pa 0,93		0,93
Air density	1,25 kg/m3				

	Area m2	Eff. Area m2	Height m	Thermal Buoyancy pa	AFR (thermal) m3/s	Pres Coefficient	Wind pressure pa	AFR Wind) m3/s	Wind pressure pa	AFR total m3/s
1. floor	1	0,700	2	0,102	0,28	0,2	0,000	0,000	0,000	0,282
1. floor	1	0,700	2,5	-0,102	-0,28	0,2	0,000	0,000	0,000	-0,282
				Massebalance	0,00		Massebalance	0,00		0,00

Ill. 243. Screenshot from spreadsheet

APPENDIX 4
BSIM


Ill. 244. BSIm model

THERMAL ZONES

BSim is an hourly calculation tool used to estimate the quality of the indoor climate. This program is more detailed than Be10 and shows extreme results within temperatures and indoor air quality.

The building is divided into thermal zones according to the functional purpose of the room. In this model, the classroom is simulated alone, with similar thermal zones above and around it, with exception for the external wall and floor facing outdoor.

A site specifies the location of the model, which influence the outdoor temperatures and solar radiation, effecting the simulations. The classroom is orientated straight South for the most critical solar heat gain.

BUILDING ELEMENTS

The model includes a database with information of the building elements and their respective u-value, see appendix 1. The building elements are inspired by guidelines in Rockwool *Den Lille Lune*, determining construction elements and thickness of insulation [Rockwool A/S, 2013].

SYSTEMS

The systems are defined for each thermal zone, including data for heat loss and heat gain. These data aim to create realistic settings for technical and person use of the classroom. Heat loss accounts for infiltration, venting and ventilation during summer months. Heat gain accounts for heating, people, equipment and ventilation during winter months with heat recovery.

In the systems, the summer months are regulated from March to November, focusing on extending the period of natural ventilation. Natural ventilation is regulated by a temperature on 23 degrees, whereupon the users expect to open the windows. Furthermore, mechanical ventilation is installed with 6 FutureVent controlled by a VAV system on 3 levels, ventilating maximum 0,223 m^3/s. This system is suppose to run mainly during winter months with heat recovery, and supplements natural ventilation during the summer period when necessary. This especially accounts for afternoons, 12.30-15.00, where the thermal comfort is heavily exposed.

The system is controlled by a user schedule determining 28 students and 2 teachers in the classroom. In weekdays there is 100 % occupancy from 8.00-12.00 and 12.30-15.00. The public is considered using the room for language school or other activities in the afternoon 15.00-20.00, in weekends and holidays 10.00-18.00 with 50 % occupancy.

SIMULATIONS

A voluntary classification of the quality for the indoor climate in schools is used as guideline for the simulations. Category A equals the demands stated in the building regulations. A+ is the good indoor climate rapidity better than the building regulations. A++ is the excellent indoor climate with a graduate thermal comfort and possibilities for manual control [DS3033, 2011]. The project strives for minimum A+ classification.

CATEGORY	A++	A+	A	B	C
SUMMER [°C]	23,5-25,5	23-26	23-26	22-27	-
WINTER [°C]	20,5-23,5	20,5-23,5	20-24	19,5-24,5	-

CATEGORY	A++	A+	A	B	C
CO_2 [PPM]	800	1000	1200	1500	>1500

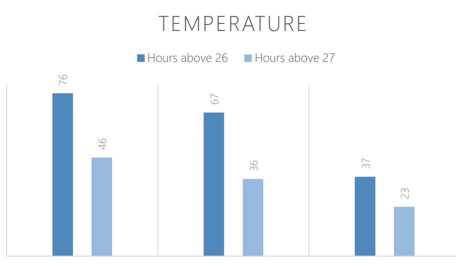
CATEGORY	A++	A+	A	B	C
DAYLIGHT [%]	>5	>3	>2	>1	>1

Table 245. Classifications [DS3033, 2011]

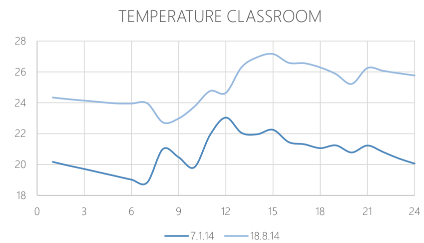
Thermal comfort is influenced by temperatures, shadows, windows, solar shading and emissions from equipment and lighting. A maximum of 100 hours above

26 degrees and 25 hours above 27 degrees is accepted [DS474, 1993]. As seen in the ill. 246, the hours above 26 and 27 degrees decrease as lamellas and mechanical ventilation is added to the model. A daily simulation, ill. 247-249, shows the temperature inside the classroom on a winter and summer day, showing the result of lamellas and mechanical ventilation. Also, as shown on the diagrams, ill. 250-252, the temperature classification is averagely good with mainly A++ classification, showing temperatures for every hour an entire year. Few improvements occur when including lamellas and by installing mechanical ventilation.

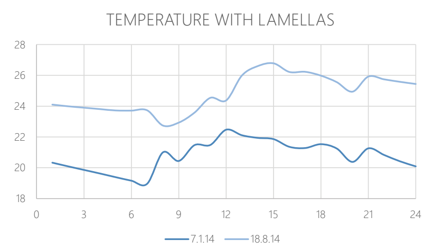
Atmospheric comfort concerns air, CO_2 concentration, odour, humidity and the occupants' experience of the indoor air quality. The diagrams, ill. 253-255, shows CO_2 concentrations in category A++ and A+, improving slightly with mechanical ventilation.



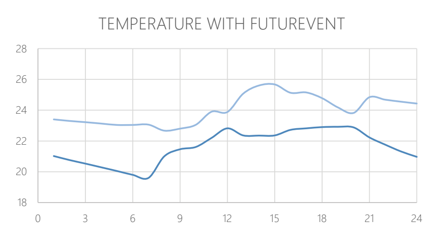
Ill. 246. Temperature comparison



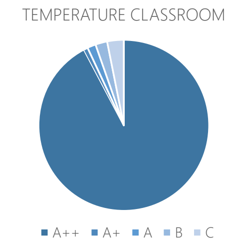
Ill. 247. Temperature classroom



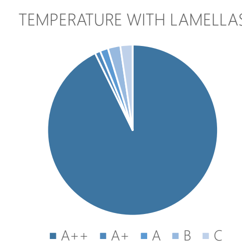
Ill. 248. Temperature with lamellas



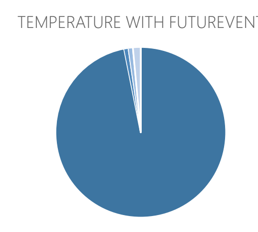
Ill. 249. Temperature with FutureVent



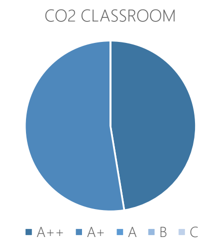
Ill. 250. Temperature classroom



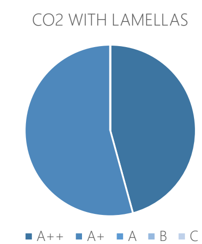
Ill. 251. Temperature with lamellas



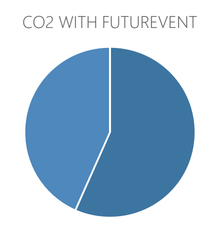
Ill. 252. Temperature with FutureVent



Ill. 253. CO_2 classroom



Ill. 254. CO_2 with lamellas



Ill. 255. CO_2 with FutureVent

APPENDIX 5

BE10

Be10 is a software used for estimating a building design's energy consumption and to document that it complies with the energy requirement of the building regulations.

One of the most important factors is the building envelope, which should be tight and well insulated to prevent unnecessary heat loss. Another important factor is the windows, which besides daylight also provides heat. The heat gain through windows should be balanced carefully, since excessive temperatures tends to be a problem in low energy buildings. Especially in buildings as schools, where a large amount of people and equipment also contributes to the heat gain.

In Be10 excessive heat is removed with electric cooling which has a negative impact on the total energy frame. Be10 calculates with primary energy, where electricity is an expensive source of energy with a primary energy factor on 1,8 compared to 0,6 for district heating in according to the energy frame *Buildings 2020* [Bygningsreglementet, 2014].

Different properties of the windows have been tested during the process to find a balance between daylight, heat gain, and shading with the use of lamellas.

The chosen ventilation strategy with natural ventilation during summer, and decentralised mechanical ventilation with heat recovery during winter, ensures a low heat loss as well as low electricity consumption for running the ventilation.

In non-residential buildings, lighting is a substantial part of the contribution to the energy frame. The building has been divided into different zones with different needs for lighting or different hours of use. The electrical lighting depends on the amount of daylight in the different zones and is automatically controlled.

The energy production of solar cells makes the building a zero energy building. The shape and curvature of the roof means that some areas of solar cells are more efficient than others. For the calculation in the program the roof have been simplified and the pv panels divided into eight different areas with different orientations and slopes.

All in- and outputs from the program can be found on the attached USB.

ENERGY FRAME BUILDINGS 2020	
Total energy requirement:	-26,5 kWh/m²
CONTRIBUTION TO ENERGY REQUIREMENT	
Heat:	9,5 kWh/m²
El. for operation of building:	8,4 kWh/m²
Excessive in rooms:	0,0 kWh/m²
SELECTED ELECTRICITY REQUIREMENTS	
Lighting:	7,9 kWh/m²
Heating of rooms:	0,0 kWh/m²
Heating of DHW:	0,0 kWh/m²
Heat pump:	0,0 kWh/m²
Ventilators:	0,5 kWh/m²
Pumps:	0,0 kWh/m²
Cooling:	0,0 kWh/m²
Total el. consumption:	27,5 kWh/m²
OUTPUT FROM SPECIAL SOURCES	
Solar heat:	0,0 kWh/m²
Heat pump:	0,0 kWh/m²
Solar cells:	26,3 kWh/m²
Wind mills:	0,0 kWh/m²

APPENDIX 6

PV CALCULATIONS

In order to calculate how much energy that can be produced with PV panels on the roof, the roof is divided into eight different areas with estimated orientation and angle. The possible production is tested with the three different types of photovoltaics: monocrystalline, polycrystalline, and thin film.

According to the results from Be10, the building consumes 9,5 kWh/m² for heating and 8,4 kWh/m² on electricity, which adds up to 17,9 kWh/m². With an area of 13539 m² the yearly energy demand is 242348 kWh, not accounting for the primary energy factors.

The formula and data used for calculating the energy production can be found on the USB (PVdimensioneringsguide-nomogram).

Production = C • D • E = kWh

C: performance

C = A • B / 100

A: area of modules

B: module efficiency

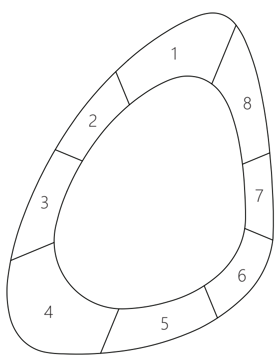
D: system factor

E: radiation

PV panels integrated in the building have a slightly lower productivity than free standing modules, and the system factor is set to 0,7. The varying factor between the different types of PV is the module efficiency.

Monocrystalline: 15
Polycrystalline: 12
Thin film: 6

The production of the polycrystalline panels corresponds best to the energy demand of the building, table 257.



Ill. 256. Roof division

ZONE	ORIENTATION	SLOPE°	AREA (m²)	RADIATION kWh/m²	PRODUCTION (kWh)		
					Monocrystalline	Polycrystalline	Thin film
1	South	12	645	1097	74294	59435	29718
2	South East	12	317	1067	35515	28412	14206
3	East - South East	8	398	1017	42500	34000	17000
4	South East	6	965	999	101224	80979	40489
5	East	4	536	999	56224	44979	22489
6	South	2	386	999	40489	32392	16196
7	South - South West	6	301	999	31573	25259	12629
8	South West	10	571	1062	63672	50938	25469
Total			4119	8239	445492	356394	178197

Table 257. Energy production from PV

APPENDIX 7

FIRE STRATEGY

This section takes it point of departure in the Danish States Building Institute standards for fire regulations [Energistyrelsen, 2012].

The building is categorized within functions and escape strategies in case of fire. Parts of the building follow category 2 for educational spaces with classrooms and labs for less than 50 persons. The atrium, multi hall and common rooms follow category 3 for restaurants, concert halls and meeting rooms for more than 50 persons. In both of these categories the users don´t necessarily know the building, but are able to bring themselves into a safe space in case of fire [SBi230, 2014].

FIRE SECTIONS

The building is divided into several fire sections according to zones in the building. These zones consist of classrooms, labs and staff, from where there is access to common facilities. The fire sections aim to ensure evacuation of the specific zone, before the fire extents to other zones in the building.

ESCAPE ROUTES

In case of fire, the users must be able to move to a secure area and have at least one escape route and one emergency exit, directly to terrain or to another fire section. The following table describes number of escape routes and emergency exits according to area and number of persons [SBi230, 2014].

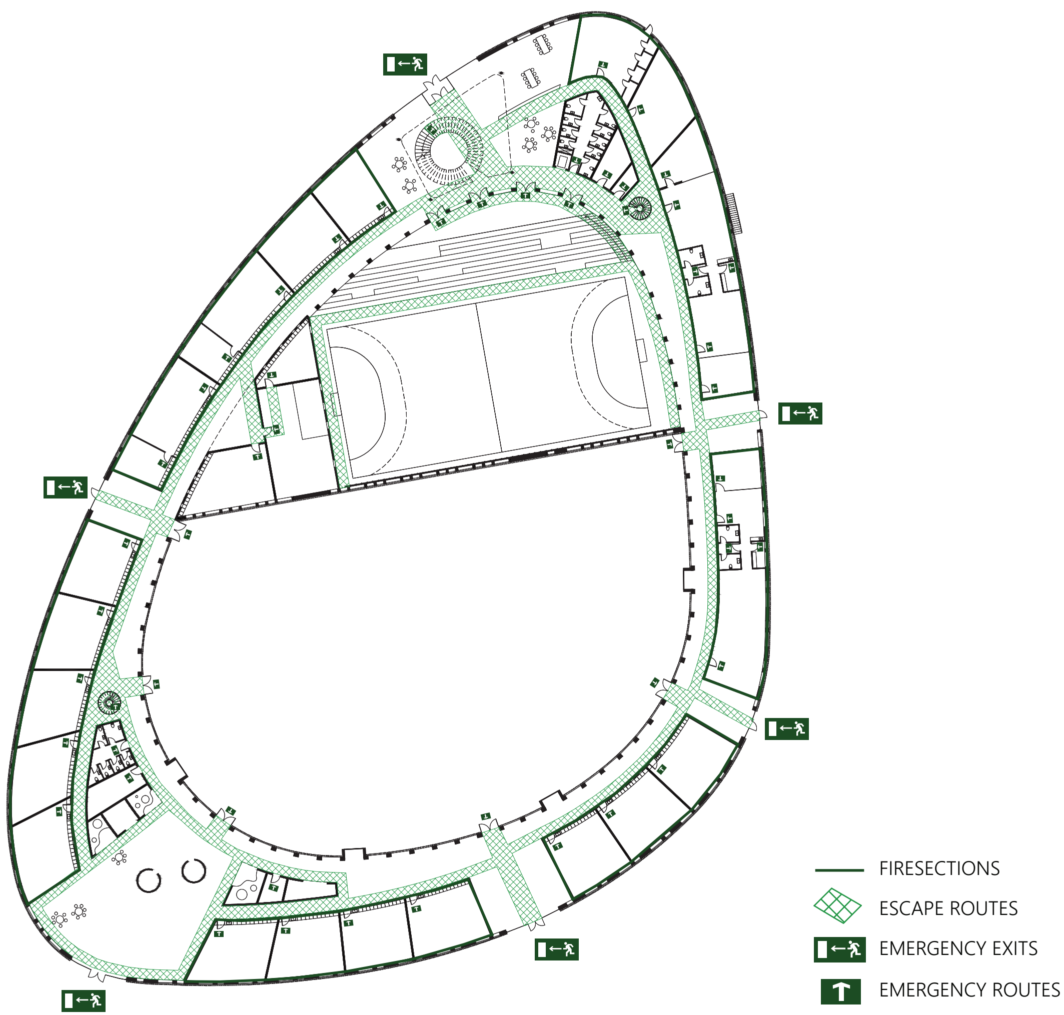
AREA	PERSONS	NUMBER OF ESCAPE ROUTES	EMERGENCY EXITS
< 150 M^2	< 50	1	Yes
> 150 M^2	< 50	2	Yes
> 150 M^2	> 50	Min. 2 independent routes	No

Table 258. Escape routes and emergency exits [SBi230, 2014]

The multi hall has a capacity of more than 800 persons, if all students and staff are gathered in the room. According to following table, the multi hall must have minimum 6 independent doors to escape routes and 3 independent escape routes [Energistyrelsen, 2012]. The table also accounts for other common spaces with a higher capacity.

PERSONS	DOOR [CM]	TOTAL WIDTH OF DOORS [CM]	NUMBER OF INDEPENDENT DOORS TO ESCAPE ROUTES	NUMBER OF INDEPENDENT ESCAPE ROUTES
150-349	120	150-349	3	2
350-549	120	350-549	4	2
550-749	120	550-749	5	3
750-949	120	750-949	6	3
950-1149	120	950-1149	7	4

Table 259. Escape routes for common areas [Energistyrelsen, 2012]



Ill. 260. Fire plan, 1:500

APPENDIX 8

REVERBERATION TIME

Reverberation time is a measurement for how much time it takes for sound to die out. More precisely, it is the time it takes for a sound level to drop by 60 dB [sengpielaudio, 2015]. The calculations of reverberation time in rooms have been based on Sabine's formula:

$RT_{60} = 0{,}161 \cdot V / A$

$A = \Sigma\, \alpha \cdot S$

RT: reverberation time in seconds
V: volume in m^3
A: Equivalent absorption area in m^2
α: absorption coefficient
S: absorption area in m^2

Even though the formula is developed for rectangular rooms, the calculation can still give an estimate of the reverberation time in circular rooms and illustrate the acoustic behaviour of the different materials. Table 261-263 show the calculated reverberation times for the small acoustic rooms, where both walls, floor and ceiling are the same material.

	Freq.		125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz
MATERIAL	Area	α	A (m2)	α	A (m2)	α	A (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)
CONCRETE, SMOOTH	16	0,01	0,16	0,01	0,16	0,01	0,16	0,02	0,32	0,02	0,32	0,02	0,32
REVERBERATION TIME RT			5,33		5,33		5,33		2,66		2,66		2,66
AVERAGE RT													4,00

	Freq.		125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz
MATERIAL	Area	α	A (m2)	α	A (m2)	α	A (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)
WOOD PANELS	16	0,33	5,28	0,70	11,2	0,45	7,20	0,23	3,68	0,15	2,40	0,23	3,68
REVERBERATION TIME RT			0,16		0,08		0,12		0,23		0,36		0,23
AVERAGE RT													0,20

	Freq.		125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz
MATERIAL	Area	α	A (m2)	α	A (m2)	α	A (m^2)	α	A (m^2)	α	A (m^2)	α	A (m^2)
ACOUSTIC FOAM	16	0,32	5,12	0,68	10,88	0,92	14,72	0,96	15,36	1,00	16,0	1,00	16,0
REVERBERATION TIME RT			0,17		0,08		0,06		0,06		0,05		0,05
AVERAGE RT													0,08

Tables 261-263. Reverberation time with Sabine's formula