NEW WAYS

RENOVATION AND EXTENSION OF BYSKOLEN, NAKSKOV

MA4-ARK11 - Louise Rasmussen - Master Thesis - May 2013 - Arkitektur & Design - Aalborg Universitet

ABSTRACT

This project aims to design an addition to an existing city school. The school is situated in Nakskov on Lolland, a periphery part of Denmark.

The goal is to provide a good learning environment with facilities adapted to the current ways of teaching within the given boundaries with a good indoor environment. Besides this, the focus will be on energy; optimizing the existing building to consume less energy and reaching 2020 building regulation energy demands for the addition

The focus will be on integrating the addition and the existing school to one unity. This will be done by having a common room that acts as an entrance, distribution room and a social room for everyone to meet. The integrating part will stand out architecturally from the existing building and the new classrooms to underline its function.

NEW WAYS - RENOVATION AND EXTENSION OF BYSKOLEN, NAKSKOV

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MOTIVATION

I chose a school renovation project for my master's thesis, because of its interesting history, social aspects and relevance. Renovation of buildings also has interesting aspects, such as cultural heritage and dilemmas of renovating or building new.

When I chose to take Byskolen in Nakskov as a project, it is because it represents a lot of challenges similar to other schools in other cities in periphery Denmark; because of a decrease in school children in the area, schools are put together and some close when doing this. Which schools should stay and which should go? Or should new ones be built and in that case, what should be done with the existing buildings?

I come from Lolland and have gone to two schools that were closed and we were moved to bigger and more centralized schools. I would like to give a contribution to a solution on how to make the best of a scenario of closing two schools and gathering the students on a third existing school – a scenario most in that situation would not prefer.

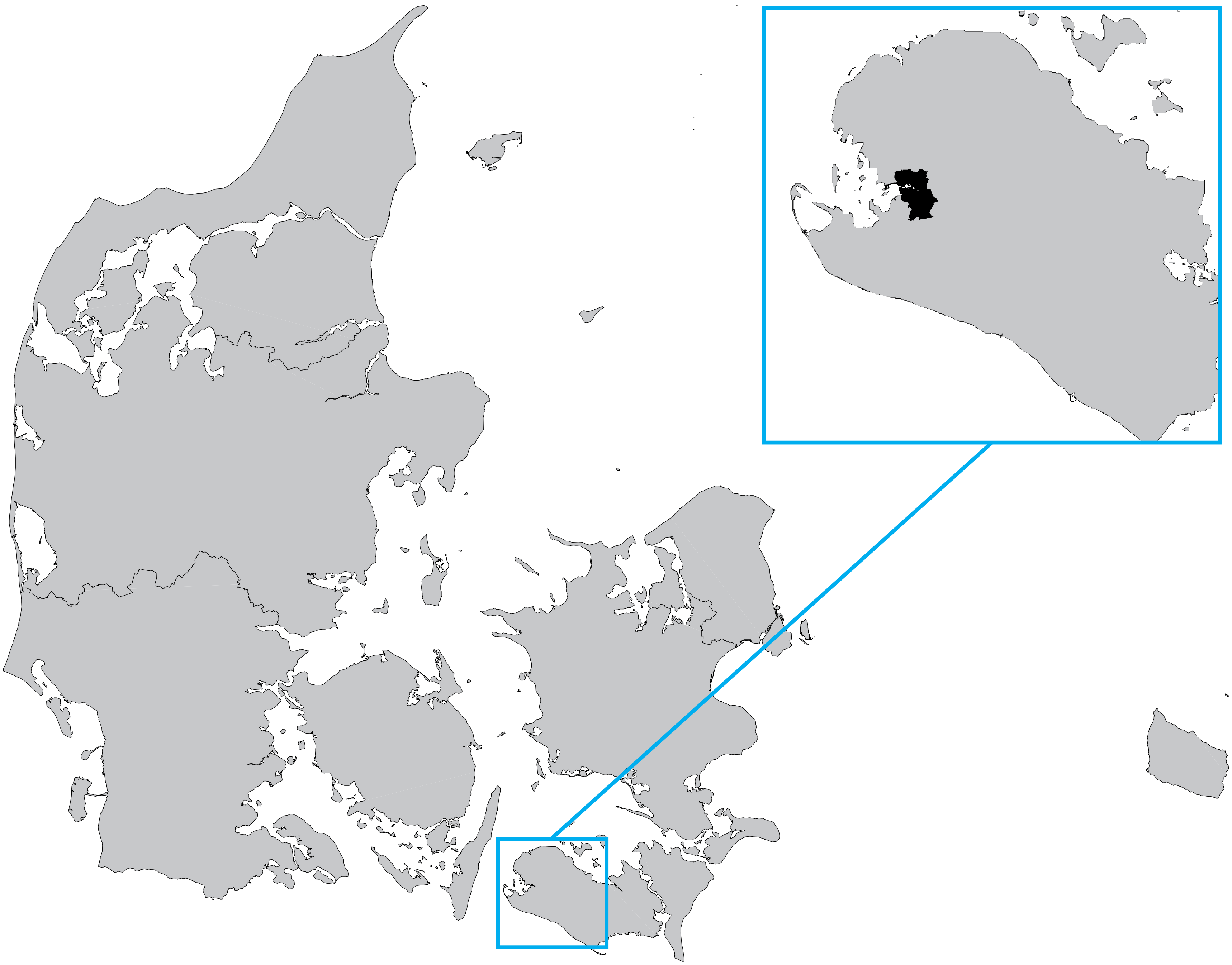


Fig. 01. Map of Denmark showing the location of Nakskov.

METHODS

IDP

Throughout the project, several methods will be used. The main method will be "Integrated Design Process" (IDP). The method has been developed for Architecture and Design students at Aalborg University to combine engineering and architecture and thereby develop more integrated projects. The method divides the project into phases: Problem / idea / motivation, analysis, sketching, synthesis and presentation, see figure 02. [Knudstrup, 2004]

For the method to work as intended, the process has to be iterative and not linear. The continuing evaluations and optimizations should result in a project of high quality.

PROBLEM / IDEA / MOTIVATION
In this phase the project and its problems are investigated to get a better understanding and a basis for making a solution. The project is defined in this phase.

ANALYSIS
In this phase the existing conditions are registered, user needs defined and academic research executed. Based on the analysis a vision is concluded, a room program defined and design parameters are found.

SKETCHING
The conclusions from the previous phase are developed further and ideas evolve into actual proposals, while taking into consideration both technical and aesthetic aspects. This is done by sketching, making physical models, doing calculations and evaluating continually to optimize the solutions.

SYNTHESIS
The design now finds its final form and is optimized into the most optimal integrated solution. The project is detailed and fulfilment of demands and wishes are documented.

PRESENTATION
The presentation is used to communicate the final design in plans, sections, elevations and visualizations. The solutions are documented and the aesthetic and technical qualities described.

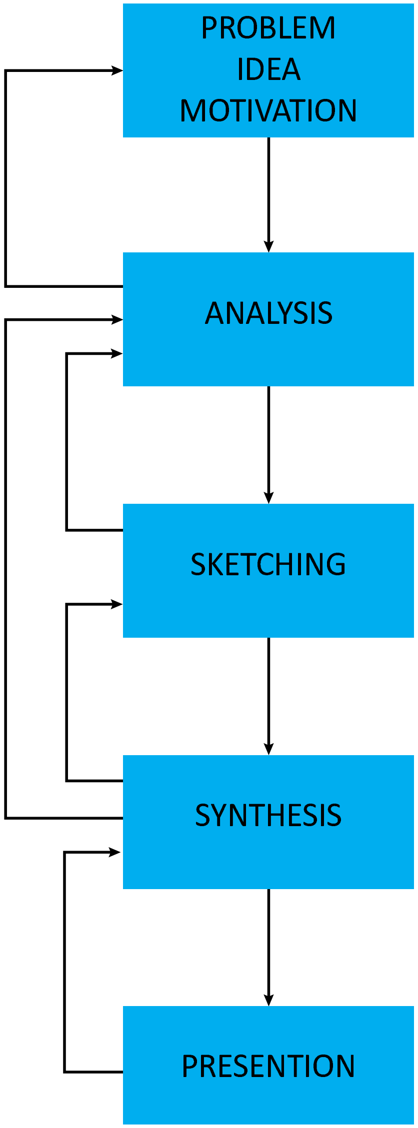


Fig. 02. Illustration of Integrated Design Process.

WORK METHODS

USER MEETING

In the beginning of the project, a meeting was arranged with the head of Byskolen in Nakskov to learn about the history of the school, the practices of the school and plans for the future. The main purpose of this meeting was to identify possible problems in the current situation and to find out what the schools' wishes for the future are.

The outcome of the meeting is to make basis for the further development of the project, as it is Byskolens' students and teachers who is going to be the users of the future building.

CONTEXT REGISTRATION

To get a better understanding of the project, the existing buildings and the functions are registered along with the surroundings of the site.

When analysing the context, two different methods are used:
Kevin Lynch's "The image of the city" [Lynch, 2002] is a empiric analytic method which maps the area with important physical element and Gordon Cullen's "Serial Vision" [Cullen, 1996] which is a phenomenological approach that presents the context in a way that makes it possible to relate to the site and experience it in a human way.

By making use of different methods, it is possible to get different perspectives of the site and thereby a better understanding.

CASE STUDIES

Case studies will be found throughout the project to give inspiration and as support in finding solutions. When having existing cases to relate to, it will be easier to argue pros and cons while visualizing. [Botin]

TOOLS

SKETCHING

Several kinds of sketching will take place and include hand- and computer sketching in programs according to the desired output. Sketching is a good tool to try out ideas and experiment during the project, but also as a way to communicate.

MODELS

Some parameters are easier to study in a physical model e.g. volume- and daylight studies, so to get a better understanding, physical models are build and investigations made from them.

SPREAD SHEETS

Simple calculations will be performed to estimate ventilation, indoor climate and energy consumption. Initial estimations can provide information to influence the design, both in terms of architectural and technical aspects.

BE10

BE10 will be used to make experiments in the initial design process and to document the energy consumption of the final design.

ECOTECT, VELUX DAYLIGHT VISUALIZER & GREEN BUILDING ZONE

These programs will be used in the sketching phase and in the final design to experiment with and document the daylight factor and –distribution.

BSIM

BSim will be used in the sketching and synthesis phase to evaluate the indoor climate of the building and investigate consequences of alterations. The program is an important tool to help secure and document a good and acceptable indoor environment in the building.

ANALYSIS

INTRO

Based on statistics for Lolland municipality a decrease in the number of children of school age (6 to 16 years) is expected, mostly because of fewer newcomers to the area. In the district of Fjordskolen a reduction of 24% (1528 to 1157) is expected in the period of 2011 to 2022. It is a general tendency for all districts of the area. [Befolkningsprognose]

The decrease has been going on for several years and as a result several public schools have been closed and centralized. This is certainly not benefitting for the smaller local communities, as it might make it harder and take longer for some to get to school, which could lead to families moving closer to the bigger cities where the schools are and thereby leaving outskirt areas deserted.

The schools are provided money per pupil and the decrease therefor affect the economy of the schools. In Fjordskolen the budget is in balance at a number of 21 pupils pr. class. A lower number gives less financial possibilities for e.g. field trips.

As a result of the decrease in pupils, more schools might close and if that happens Byskolen is the school most likely to take over Fjordskolens' students because of its' central location in close proximity to cultural- and educational institutions and infrastructural connections.

For Byskolen to receive more students, it has to expand and update some facilities. The project will therefor concern the addition of these functions with a focus on aesthetics, functionality and technical aspects.

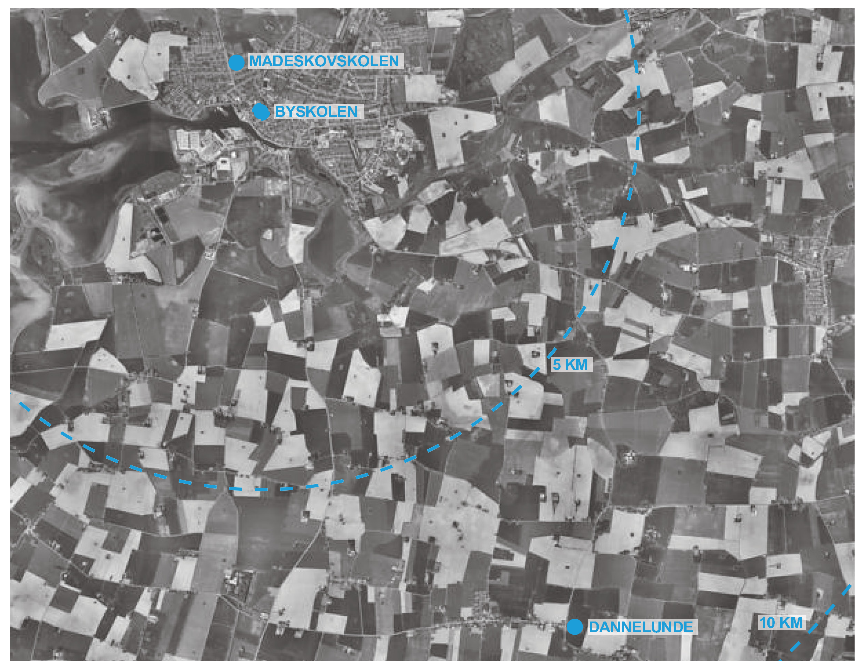


Fig. 03 Fjord skolen, 1:10.000

USER NEEDS

On the meeting with the head of Byskolen some wishes for the future was defined [Bjarne Miazva]:

As Byskolen already have many normal class rooms, therefor the focus should be on subject specific rooms which differ from the existing class rooms. These include physics, chemistry, biology, home economics, design and music.

The oldest pupils are allowed to go outside the schools' premises in recess, but in fact it is preferred for the students to stay at school grounds. In that respect it is a wish to have some facilities to interest the pupils and make them want to stay.

A media center is also a wish from the school. It should combine library and IT in one common area.

CONTEXT

The landscape on Lolland is very flat in general and especially on western Lolland where Nakskov is situated. To make more land for farming the wet land was dammed up long ago.

In Nakskov which is Lollands' larges city and first recorded in the 1200 century, old city walls also mark the landscape and this is relevant for Byskolen which is located on the border of the old northern mound where the fjord used to be. At the back of the school, a part of the old mound is still visible. The mound is listed and therefor it cannot be touched. This creates a natural boundary on the site, see fig. 11.

Behind Byskolen is the old public swimming pool. It is still in function, but only until the new one is built. The new public swimming arena is located between the local sports facility (NIC) and preschool. It is under construction and scheduled to finish in the end of 2013. [http://nic-sport.dk/ny-sv-mmehal.html/index.html]. When the new swimming pool opens, the traffic on Blegen to the school will be limited to delivery transport and the like and a transformation of the existing road, Elvej leading to the school is possible. The old swimming arena is in such a condition that is will be very expensive to renovate and it could therefor make room for new functions for Byskolen.

In close proximity is the city athletic facility (NIC), the future public swimming arena, the high school (NUC) and the public library, also easily accessed via Blegen, see fig. 4.

Train tracks used to lead to the harbor, which was very active with industry and a shipyard until the 1980's. The tracks leading to the harbor are no longer in use and end at the back of Byskolen, dividing the area between the old school building and the preschool. The remaining tracks are only in use when trains changes track, so noise from trains will not be a problem.

Easy access through the area is secured by a path and passage under the tracks at the end of Blegen. The street is therefore public and cannot be closed off to only serve the school.
Along Blegen a stone carver is located and at the end is Huset which houses concerts and other cultural events, see fig. 5.

The fire museum at the end of the site, close to the train tracks, could benefit from being moved to another place in the city, where access possibilities and more obvious exposure could promote the museum to tourists, fig. 5.

Next to the fire museum at the back of the school is the city water work, which is fenced and not to be touched, see fig. 5.

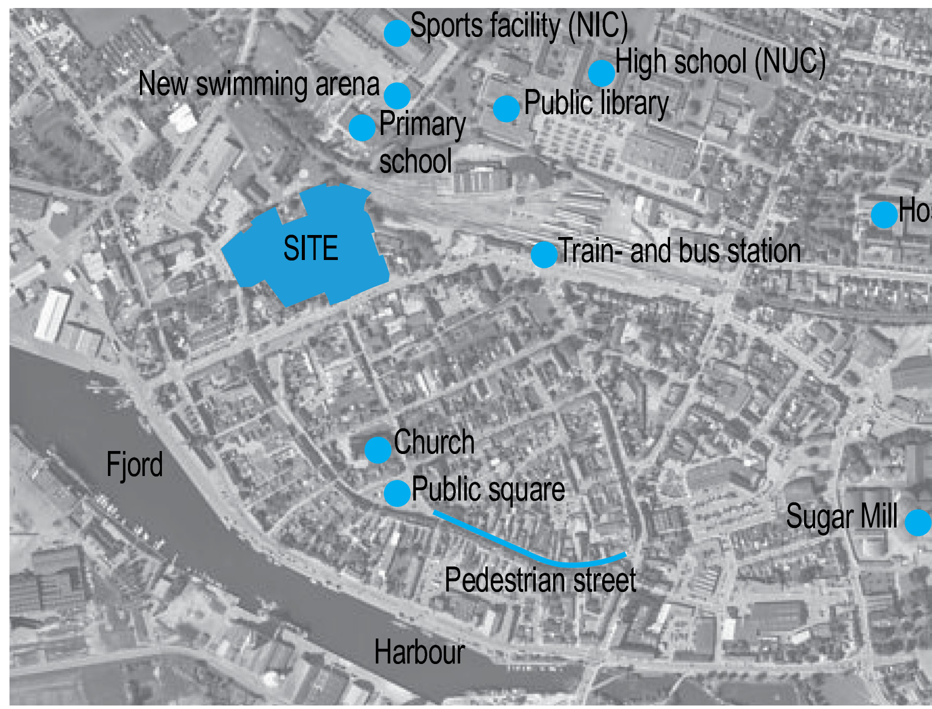


Fig. 04. Map showing functions near the site. Scale 1:5000

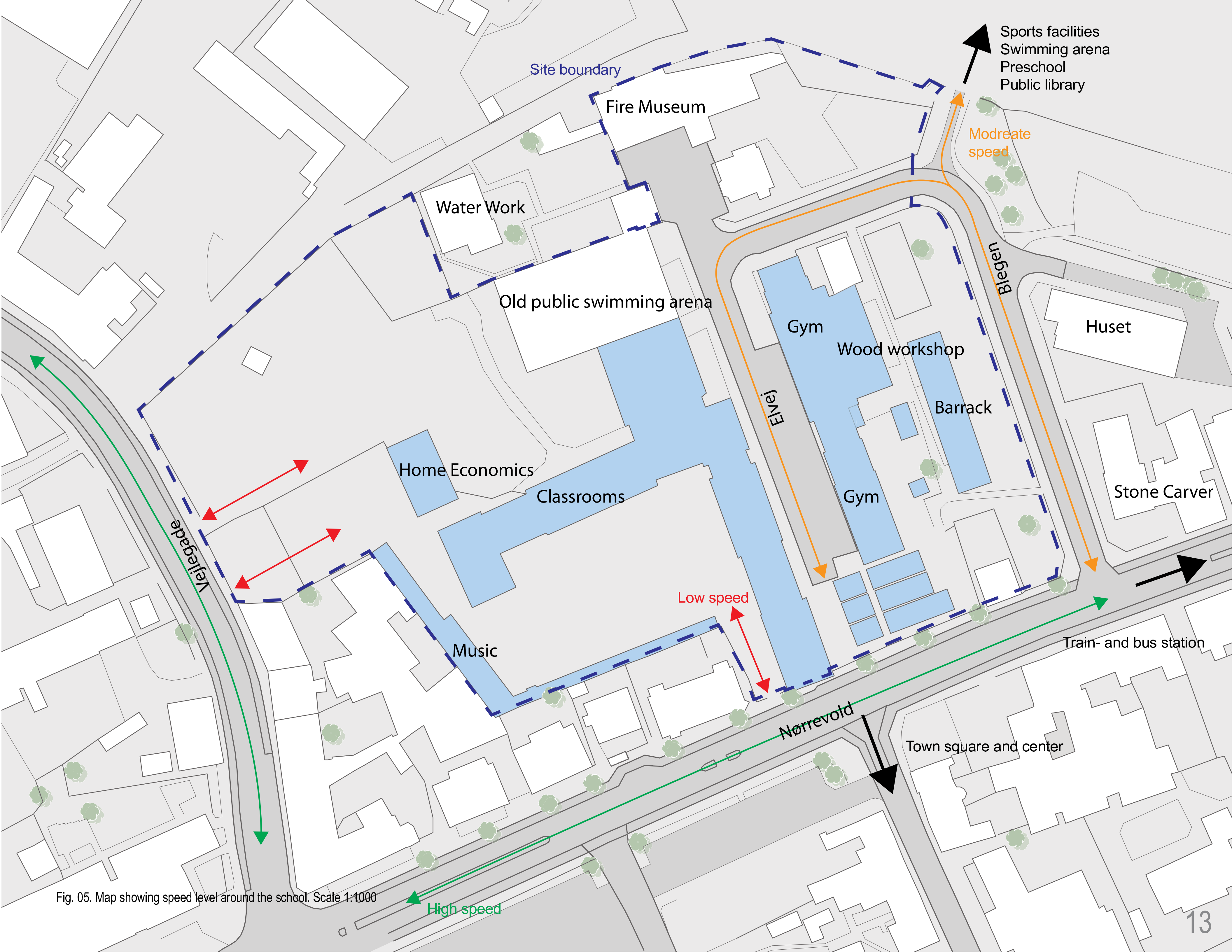


Fig. 05. Map showing speed level around the school. Scale 1:1000

SCHOOL TYPOLOGIES

By comparing three main school typologies dating back to 1850, it is possible to get an overview of the development that has happened till now, not just building- but also teaching wise.

The multi-story school is defined by traditional class teaching whereas most of the floor area is reserved for class rooms and little for common areas, mostly transit areas; hallways and stair cases. [Erhvervs- og Byggestyrelsen, 2010]
In this period the teacher was visibly superior, often seated higher than the pupils and the students mostly had to learn by heart, seated at desks.

The function divided school makes more use of the built area by utilizing some of the hallways for stay and not just transit. Though you'll find more common areas in the function divided school than in the multi-story school, most of the floor area is reserved for teaching purposes.
Along with traditional class teaching, project- and group work takes place in the function divided school. [Erhvervs- og Byggestyrelsen, 2010]

The room flexible school focuses more on project work than traditional class teaching. This has led to the inclusion of common rooms for stay and transit to also be used for project- or group work. This school type therefor has more floor area containing common rooms than class rooms. [Erhvervs- og Byggestyrelsen, 2010].

Byskolen is a typical multi story school, containing mostly traditional classrooms, large hallways and big central staircases. The development in the view on teaching has given way for the hallways to be used for project and group work, which is mostly seen in the room flexible typology. The functions have not been separated individually, except for the administration and the staff room, which has been placed on one level in one wing of the school.

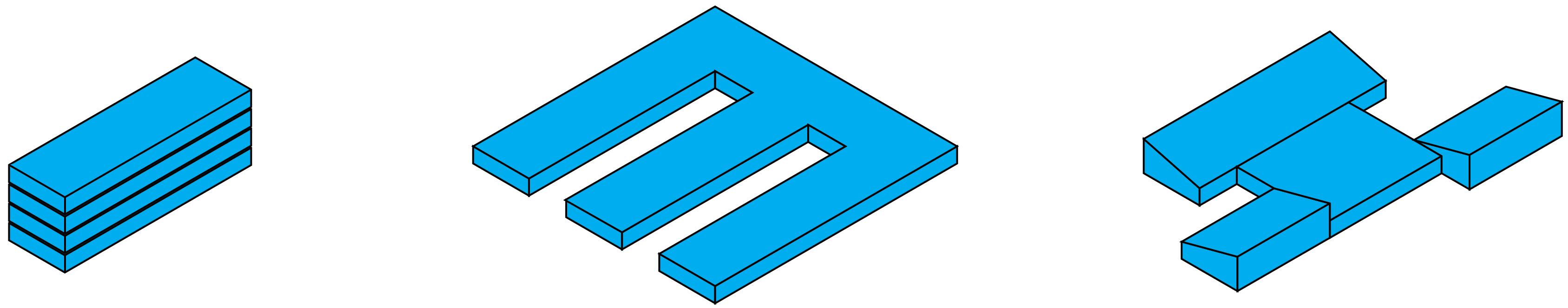
When considering the user wishes, it is mostly the qualities of the room flexible typology. In the project there will be drawn on elements from this typology, to fulfill the wishes for new teaching environments, with actual common rooms that can be used for project- and group work. However it is important to take into consideration how it can be integrated with the existing building.

Fig. 06a. Bird perspective of Byskolen.

Fig. 06b. Byskolen, entrance from Nørrevold.

Fig. 06c. Byskolen, atletic facility in foreground.

Fig. 06d. Byskolens' school yard.



Multi storey school	Function divided school	Room flexible school
PERIOD:		
1890 onward	1930 onward	1970 onward
TYPE:		
City school	Central- or wing school	Open plan school
LAYOUT:		
3-4 storeys Central main entrance Classrooms in one or two sides of corridors Small classrooms and a lot of area for stairs and corridors	Central- or wing school 1 storey Each wing contain one function; e.g. administration, classrooms or subject specific rooms Occupies great site area Large common areas	Open plan Moveable furniture to create different spacial experineces Differenciation in work; single-, group-, team-, or class work
OUTDOOR AREAS:		
Large areas with asphalt Additional bicycle sheds, sports facilities and pavillions	Large areas for sports and play	Areas surrounding the school buildings
LEARNING PRINCIPLES:		
The teacher is superior, raised above the pupils on a platform	Teacher and pupils are equal	Learning takes place as a collaboration between teacher and pupils

Fig. 07. School typologies

TEACHING

The ways of teaching have developed over time, but in many of the first editions of "Arkitekten", class teaching EQUALED teaching. This seems to be the dominating teaching form until the 70'ies, where a change is seen in the pedagogic ideal of teaching and group-, project- and individual work is seen as a supplement to traditional class teaching. The students are meant to learn through own experiences and teaching revolves around their learning. This sets certain demands to the class rooms in terms of equipment and layout, because the students participate more actively. [Rum, form og function]

Around 1970 the changes in pedagogic ideal begin to show in school architecture with the open plan schools and versions of flexibility accommodate the new ways and different teaching methods during the day. [Rum, form og function]

The home base classroom started out as being an economical solution to having several subjects taught without having specific classrooms for each subject. Along with the home base classroom came the home base teacher to conduct most of the teaching in the class. This, however, has changed over the years and now one teacher only teaches two or three subjects. [Klasselokalet er en forældet idé]

Because of the home base classroom, the teachers commute to the different classrooms, while the students spend most of the day in the same room, without having to leave it.

In a home base classroom you often find many visually disturbing elements not relating to the subjects being taught, and eliminating these disturbing elements could help improve the learning environment and the effect of the teaching.

In this project the vision is to not have home base classrooms, but subject specific for each subjects. This will make the students commute to the different subjects and meet other students along the way and move. If the pupils meet across class and year they will feel more united and hopefully take more care of each other.

Having to commute to classes can also help grow interest for what others do and learn as school work can be displayed in connection to the classroom.

Fig. 08a. Classroom 1949, Lynge Skole.

Fig. 06d. Contemporary learning situation scene.

It is impossible to predict the future of schools and teaching, but by looking at tendencies we can get an idea of the direction it is going.

A Danish analysis called “Modelprogram for Folkeskoler” studies these tendencies and will be used as a tool in the project.

Optimal learning conditions differ from person to person and adaptation to these are in focus. Class-, team- and individual teaching, physical activity and contemplation are different learning situations representing a normal school day in most schools.

The tendency in primary schools as mentioned above is larger commons rooms which can also be used for teaching. Zoning of these common areas can accommodate different needs for different activities.

A large variety of possibilities for teaching can accommodate these different learning styles and a couple of new schools, Ørestadens Gymnasium and Ørestadens Skole, have been visited and analyzed to get an understanding of the facilities providing the requested diversity in learning environments.

CASE STUDY - ØRESTADENS GYMNASIUM

Ørestadens Gymnasium by 3XN from 2007 is 12.000 m^2. The high school is the first in Denmark based on the visions from the 2005 high school reform; professionalism, organization and learning systems. [DACa]

The high school is designed based on the conviction that architecture generate conduct, and that open and flexible rooms allow for better interaction, which thereby facilitates a better learning and working environment.

Four boomerang shaped decks divide the building into four study zones; humanities, social studies, media and science, one on each level. A rotation of the decks creates a high central space, optimal for interdisciplinary connection. The levels are connected by a central staircase spiraling toward the roof terrace.

Three great columns make the overall load bearing construction, assisted by smaller columns placed more freely and not in a grid. The great columns contain secondary functions, stairs and technical shafts.

Other circular structures make flexible and temporary settings for varying group sizes.

The focus of the building is open rooms, scientific zones, niches for creativity and engagement and total access to cyber space.

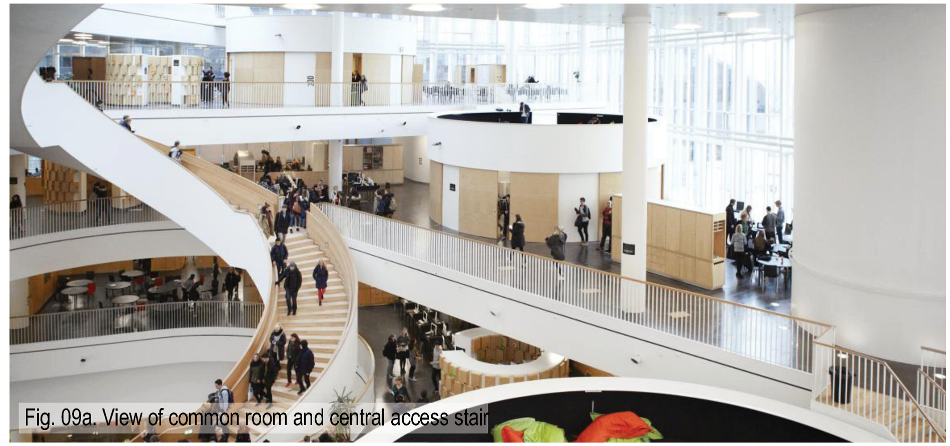


Fig. 09a. View of common room and central access stair

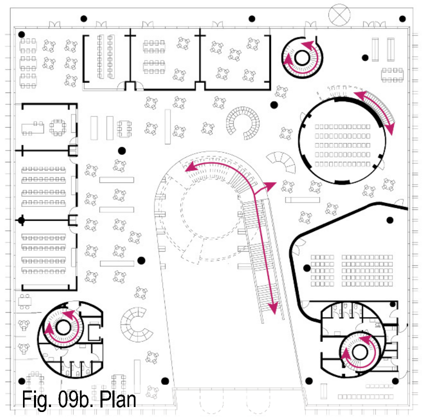


Fig. 09b. Plan

Fig. 09c. Common area in use

Fig. 09d. Open room organized for group lecture

CASE STUDY - ØRESTADENS SKOLE

KHR Architects have been inspired by the Tuscan middle age city, Barga with its' hanging gardens, bays and little piazzas. Because of the limited building site, outdoor areas in form of terraces have been created on the roofs of the eight story building. [Ørestad Skole]

The new school is open, flexible and provides differentiated possibilities of learning to adapt todays' school vision. Traditional classrooms have been replaced by multifunctional environments to accommodate future changes. A library open to the school and the public has been placed at ground level and is open 24-7. [DACb]

The school is a part of an experiment which focuses especially on aesthetic learning processes and the development of them, and virtual media, resulting in special attention on visual arts, drama, music and crafts work. The pupils are not put in classes according to age, but according to development. [Ørestad Skole]

On the interior, the focus have been on creating furniture, which can be moved around and built up, so the pupils can create environments, optimized for them. In general the interior decorating takes the point of departure in the individual, because all doesn't learn best in the same ways. [Arkitektforeningen]

The school has been chosen to set an example of climate focus; low energy consumption from choice of materials and sustainability in terms of energy consumption and CO_2 load. Photo voltaic panels on the roof, a wind mill and an herb garden and waste separation give a sustainable signal to the students and the world. [Ørestad Skole]

Some of the visions from Ørestadens' School will be incorporated in Byskolens' new facilities [Københavns Kommune]:

- Environments for healthy development in community with other students
- Living learning environments and inspiring physical environments supporting subject knowledge
- Different spaces to accommodate peace, absorption and corporation

Fig. 10a. Common room with facilities for individual contemplation

Fig. 10b. View into classroom

Fig. 10c. Room for contemplation in common access area

BYSKOLEN

Byskolen, the primary school was built in 1915 as well as the high school and gymnasium next to it. When the new high school (NUC) was built in 1979, the old building was added to the primary school. [Historisk Atlas, 2013] In 2009 a new preschool section was built for the youngest pupils (kinder garden – 2'nd grade)

Byskolen is a part of Fjordskolen, which is made up of three schools on western Lolland; Dannelunde in Dannemare in the south, Madeskovskolen in northern Nakskov and Byskolen in central Nakskov, see fig. 03.

The school contains mainly rectangular classrooms of approximately 48 m2, which makes a natural limit in the amount of pupils per class of 24. Each classroom have its' own smart board. The hallways can be used for group work to make room for a more varied way of working [Bjarne Mirzva]. Extensions have been built to house music and home economics classes along with a barrack which was previously used for after school care, but is now unused. The additional buildings have not been integrated architecturally and therefor stand out in terms of expression and use of materials, see e.g. fig 13.
Next to the school is the gym and in addition to this, the wood workshop.
The gym has three halls, but the size of them limits the possible activities and number of participants. Currently one class is divided; girls in one hall and boys in the other hall. In the interview with Bjarne Mirzva, this situation was discussed and the plan is for the preschool to use the schools' gym and the older students to use the athletic facilities (NIC).

10'th grade are located at NUC to focus on the transition from school to higher education and introduce the pupils to the possible educations and thereby help them find out which education to choose.

Fig. 11 . Access possibilities at Byskolen. Behind the school is a listed mound, which is fenced. Scale 1:1000

Fig. 12. Plans of Byskolen indicating hallways and stairs Scale 1:1250

Fig. 13a. Play area and home economics building

Fig. 13b. Elvej between school and gym

Fig. 10l. Dwellings demarkating the site of the school

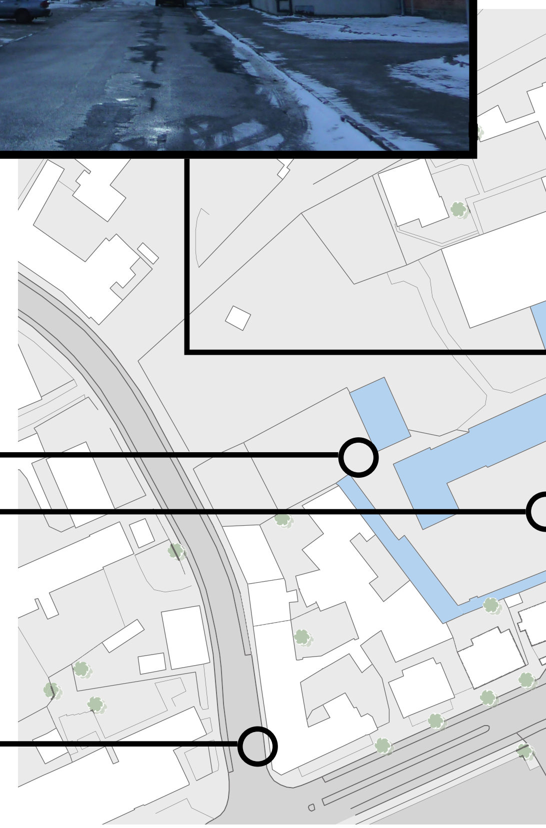


Fig. 13k. Existing school and school yard

Fig. 13j. Dwellings demarkating the site of the school

Fig. 13i. School entrance


Fig. 13 c. Pre school


Fig. 13 d. Public library.


Fig. 13e. Dwellings demarkating the site of the school

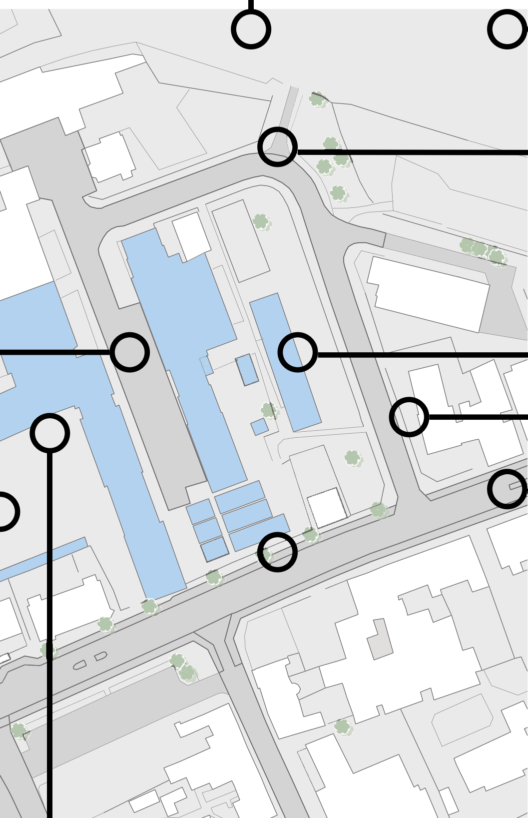



Fig. 13f Passage under train tracks


Fig. 13g. Existing barrack (unused)


Fig. 13h. Dwellings demarkating the site of the school

WIND

When considering the location and rotation of the building as well as the conditions of the outdoor facilities of the school, wind has to be taken into consideration. This is to provide optimal conditions for utilizing natural ventilation and providing protective outdoor environments with lee where the children can play. When utilizing natural ventilation, the wind direction is important to the occurrence of over- or under-pressure on the building.

The site shielded from the wind by the surrounding buildings, so to be able to facilitate wind induced natural ventilation it is crucial to analyse where to get sufficient pressure from the wind.
The site is also bordered by roads with traffic on two sides. Traffic can pollute the air so much that it cannot be used for ventilation, but it is estimated that the pollution level of the roads surrounding the site is so low, that the air can be used for ventilation purposes.

The wind rose describes wind directions and –speed throughout the year, in Nakskov the prevailing wind direction is south west [DMI, 2013].

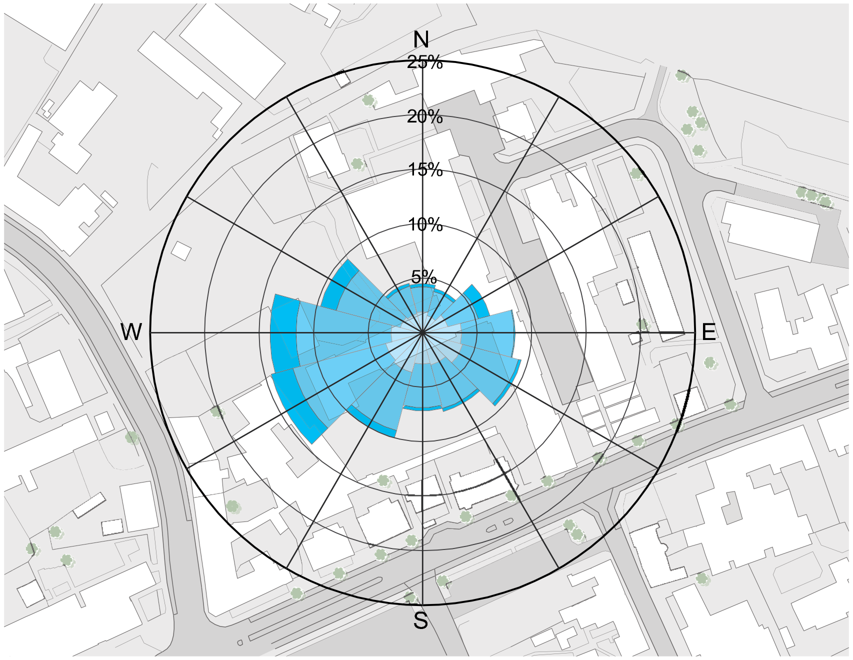


Fig. 14. Wind rose. Intensity and direction in Nakskov throughout the year.

VENTILATION

Ventilation can help secure a good indoor environment by providing fresh air, keeping the temperature, moisture content and the pollution level below the limit.
Ventilation can happen naturally, mechanically or as a combination of the two.

NATURAL VENTILATION

Outdoor air is supplied to the room by opening windows, doors, vents or air canals. Natural ventilation is facilitated by thermal buoyancy (caused by differences in density because of temperature or moisture content) or wind induced pressure, but the two can be combined.

MECHANICAL VENTILATION

Ventilators continually provide and exhaust or recirculate air. The system can regulate the temperature of the room, and with heat recovery, it is possible to preheat the incoming air with the outgoing, when the outside temperature is too low, so the air is warm enough to let in without creating unconformable draft.
There are two principles for mechanical ventilation; mixing and displacement.

MIXING

Reduction of air pollution by MIXING: The fresh air is let in the room at high speed at the occupant zone. The polluted air is exhausted by the ceiling or floor. This principle can be used for both cooling and heating.

DISPLACEMENT

The fresh air is let in by the floor which displaces the polluted air to the top of the room where it is exhausted. This principle can be used for cooling, though the effect is low. It requires large rooms with low pollution load to have full effect [Ventilationsteknik]

HYBRID VENTILATION

Because of the climatic conditions in Denmark natural ventilation is used when the outdoor temperature is above 11°C and when not or if the natural ventilation is too slow or too strong (draft is not desired in the building), mechanical ventilation can be used. This combination of natural and mechanical ventilation is called hybrid ventilation. The ventilation can change between the two or mechanical ventilation can support the natural ventilation when the natural forces can't ventilate sufficiently on its own.

The building regulations have minimum standards for ventilation; intake of outdoor air and exhaust in normal class rooms has to be 5 l/s pr. person and 0,35 l/s pr. m² floor, furthermore the CO_2 level cannot exceed 0,1% for longer periods BR10, 6.3.1.3, stk. 2 [BR10, 2010].

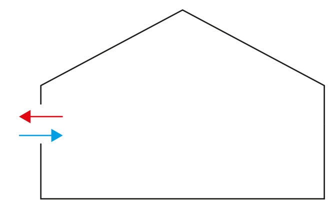


Fig. 15a. Single sided ventilation

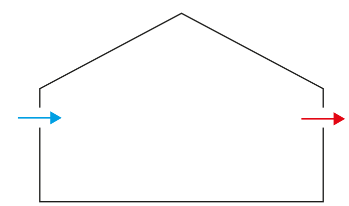


Fig. 15a. Cross ventilation

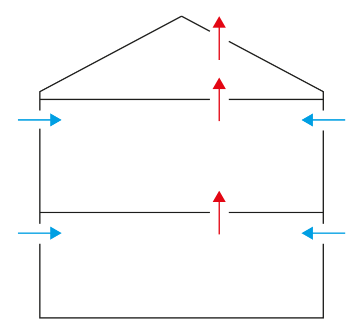


Fig. 15a. Thermal bouyancy

SUN

The sun is a very important parameter to consider as it has great influence on both out- and indoor climate. The sun will influence the design regarding the buildings' orientation, window placement and elements for solar shading. These factors have influence on providing sufficient daylight for different tasks and avoiding overheating.

The surrounding buildings and the existing school buildings cast shadows on the site and a shadow analysis provides information as to where the sun is most present, see fig. 16.

The sun diagram shows the path and height of the sun through the year, see fig 17.

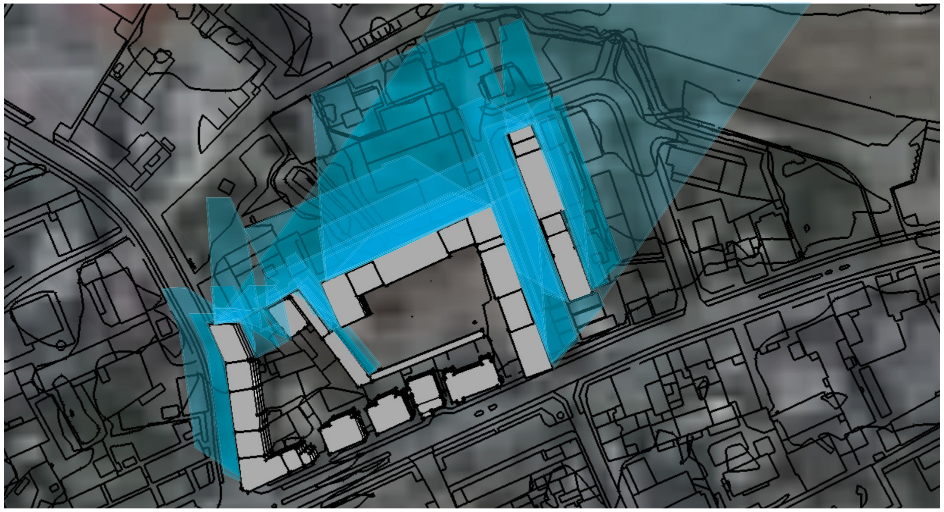


Fig. 16. Shadow study. Blue color indicates shadow extent.

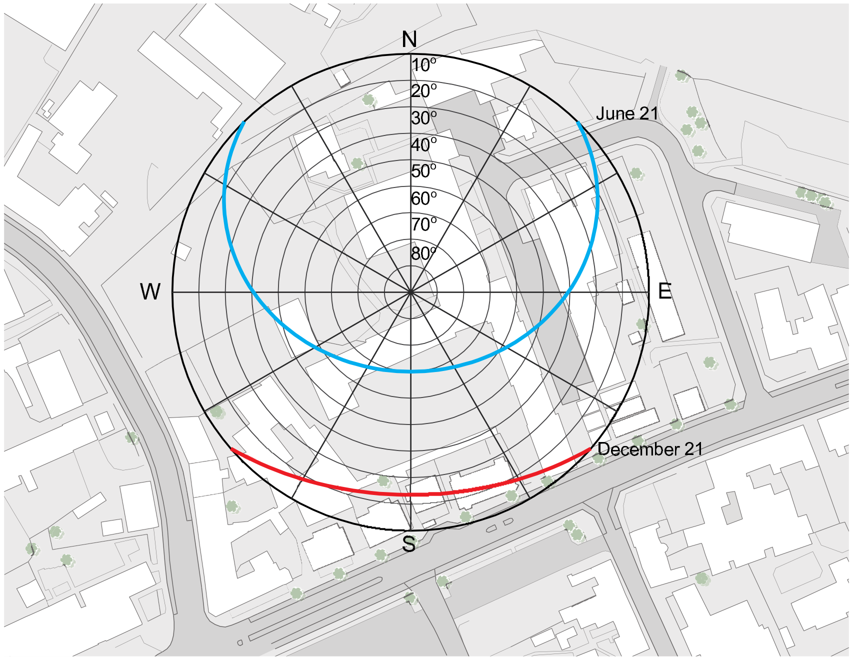


Fig. 17. Sun diagram. Sun angle at different times of the year.

DAYLIGHT

"*Research studies (Heschong Mahone Group) shows, that the students, who had most daylight access, in general developed 20% faster than the students, who had the least daylight access*" [Erhvervs- og Byggestyrelsen, 2010].

The daylight factor for 2020 schools has to be minimum 3% BR10, 7.2.5.1, stk. 7, that equals a lux-level of 300, see fig. 20 for daylight factor illustration. Since the rooms in this project will have different functions, the light conditions will be adjusted to the intended tasks for the most optimal working conditions, they can be seen in Room Program [DS 700].

Daylight can be provided in many ways, but because the people and equipment load is high in classrooms, it is important not to add to overheating with excessive glazed areas without solar shading. Therefor the glazed areas have to be balanced according to solar heat gain, heat loss and daylight factor.

Position of windows, size and the use of reflectants can help direct the light to where it is wanted.

Room/Activity	LUX level
Board, dark	500
Board, light	200
Toilets/cloakroom	100
Common access areas	50
Common rooms	200
Design	500
Home economics	200
Visual arts	200

Fig. 19. Lux-level demands for specific rooms, DS700

Fig. 18. Daylight inspiration.

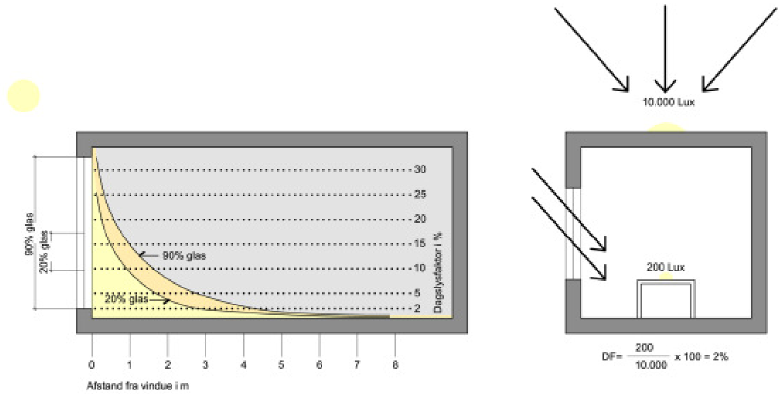


Fig. 20. Principle for daylight factor.

SUSTAINABILITY

The design of the building will focus on sustainability; lowering the energy consumption and CO_2 emissions. This can be done by reducing heating- and cooling demands and reducing the need for electricity.
There are passive and active approaches to sustainability:

PASSIVE METHODS:
By using constructions and elements of high U-value, as well as securing tight constructions without cold bridges, heat loss can be minimized. This on the other hand gives rise to higher ventilation demands and perhaps cooling to reduce overheating, to secure a good indoor environment.

Solar heat gain can minimize the energy consumption for heating in winter, but in summer when the insolation is at its highest, the demand for heating is also at its lowest and therefor the task is to provide shade from the sun to minimize the need for cooling.

Facilitating natural ventilation can help reduce the energy consumption for mechanical ventilation.

ACTIVE METHODS:
Photo voltaic panels (PV's) can produce electricity and solar panels can produce hot water from utilizing the suns' energy. Windmills are also an active way to produce electricity, by making use of the energy from the wind.

The task will be to find a balance between energy consumption and indoor climate by use of active and passive methods.

The aim is to design for building class 2020, which means a reduction by a third compared to the current energy frame (2010) of (71,3 + 1650/A) kWh/m² pr. year, A is the heated floor area, BR10, 7.2.2, stk. 1 [BR10, 2010].

Building class 2020 demands that the entire energy consumption for heating, cooling, ventilation, hot water and lightning pr. m² floor area doesn't exceed 25 kWh pr. year, BR10, 7.2.5.2, stk.1. [BR10, 2010]

INDOOR CLIMATE

A good indoor environment is crucial for the wellbeing and optimal learning conditions for students.
The building regulations have minimum standards for the indoor environment, but better conditions can be secured by increasing the demands.

The indoor climate is divided into different categories; thermal, atmospheric and acoustic:

THERMAL INDOOR CLIMATE
The temperature of a room is affected by the solar transmittance, the person- and appliances load and the degree of ventilation. The temperature must not exceed 26 ^{o}C for more than 25 hours a year BR10, 7.2.1, stk. 13, [BR10, 2010] but for working conditions to be optimal, The Danish Working Environment Service recommend a temperature of 20-22 ^{o}C [AT, 2013]

ATMOSFARIC INDOOR CLIMATE
The air is polluted from persons, appliances and materials. The building regulations demands that the pollution from CO_2 does not exceed 900 ppm when aiming for 2020 building class. BR10 7.2.5.1, stk.11 [BR10, 2010].

ACOUSTIC INDOOR ENVIRONMENT
Noise nuisances can come from inside the room, surroundings or ventilation. The building regulations set an upper limit for reverberation of ≤ 0,6 s for a normal classroom BR10, 6.4.3,stk. 3 [BR10, 2013].

To ensure good conditions for the pupils, it is the ambition to reach a class A indoor environment, which means a percentage of dissatisfied persons of 6 [DS/CEN/CR 1752]. Demands for specific rooms are described further in Room Program.

FLEXIBILITY

Flexibility is a word commonly used regarding several kinds of buildings, not least schools.
Since the future is unpredictable, we can't future-proof the school, but by making the building flexible we can make it easier to change the conditions. The structural system of the building plays a major role in this and by e.g. making the facades load bearing, the interior can be modelled freely, which also illustrate that "flexible" doesn't necessarily equal "mobile". [Oase #79]

Flexibility will be considered in this project as for example rooms which are possible to easily transform according to use. In this way a room can be used for several activities on a short or long term and not just in one configuration.
Because of the variety in use, areas have to be programmed to suit different purposes and to not disturb each other.

Common rooms are often used for project work and in recess. These different situations and activities, sometimes at the same time, make it a challenge to design the room and to accommodate needs in different situations; therefore a balance has to be found.
Some areas function most optimally with a fixed program and some with an open program. A differentiation in fixed and more mobile furniture could solve the dilemma. [Erhvervs- og Byggestyrelsen, 2010].
By dividing the room into smaller units or shielding off areas, quiet and intimate spaces can be defined. Furniture and differences in level can also be helpful in this respect.
It is also possible to divide the room vertically. This might further more make it easier to separate activities according to noise level. A small room or a room with low ceiling height also invites to quiet activities whereas larger rooms and high ceilings invite to activity and noise. [Erhvervs- og Byggestyrelsen, 2010].

Hallways can be difficult to make use of for work because of the activity level, which is why it could be helpful to screen rooms to exclude disturbing elements and create an intimate environment in the open common area. [Erhvervs- og Byggestyrelsen, 2010].

At Byskolen it is important to provide flexible facilities and common areas for the students to meet and interact across age and class, since the existing buildings doesn't provide that opportunity.

Fig. 21a. Flexible spaces

Fig. 21b. Flexible spaces

ROOM PROGRAM

The necessary amount of classrooms has been calculated based on the future amount of children and the minimum amount of lesson given by the The Ministry of Children and Education [UVM] and an occupation percentage of 75 to ensure flexibility [Modelprogram for Folkeskolen]. See fig. 22.

The room summary has been based on the current average; 95 students per level divided in 5 classes. With the expected decrease of 24 %, that number will be 73. The desired number of students per class is between 21 and 24 students, which gives 3-4 (3,5) classes on each level.

As previously mentioned, the intention is to not have home base classrooms, but only subject specific classrooms. To document that it is not more room consuming than the normal version, a simple calculation has been performed and the result is that the same amount of rooms are necessary in either version:

3,5 classes * 10 levels = 35 classrooms

Additional rooms:
1 Physics/chemistry
2 Music
2 Visual arts
1 Design
1 Home Economics
1 wood- and metal work

Total: 35 + 8 = 43 rooms

Subject	Recomended number of units (75% occupation)
Danish	13
English	4
German	2
Mathematics	7
Physics/Chemestry	1
Biology	1
Natural Science/technology	2
Geography	1
History	2
Social studies	1
Christian studies	2
Music	2
Visual arts	2
Design	1
Wood- and metalwork	1
Home economics	1
TOTAL	43

Fig. 22. Number of rooms required

By organizing the subjects in amount of rooms available in the existing school, some subjects do not fit in and they have to be provided in the addition. The subjects which do not fit in the existing school have been listed in the room program. They have been mentioned in the user wishes and have specific demands that have to be fulfilled for them to work and they also contain subjects which require more space for activities and equipment, which the existing school cannot provide without greater alterations to the building.

Subject	Number of units	M^2	Daylight factor	Equipment	Specific demands
Physics/Chemestry	1	90	2	Bunsen burners	Fume cupbords Local exhaustion Two exits
Music	2	90	2		
Visual Arts	2	90	2		High Ra-value
Design	1	90	5		
Home Economics	1	90	2	Stoves and ovens	High Ra-value

Fig. 23. Room program

VISION

A noticeable thing when analyzing the school is the fragmentation of buildings; home economics in a separate concrete building, music in a rebuilt toilet building, blue wooden barracks serving no purpose at the moment and a preschool department on the other side of the railway tracks.

These separated functions and the fact that the old buildings previously served as a high school (east wing) and primary school (west wing) and therefor has separate entrances and are separated until 2'nd level because of a passage gate, further divides the school.

The vision is to unify the school by gathering functions, optimize the building and add to it to fulfill the wishes previously mentioned from the school, giving a clear expression and proving one main entrance.
It is the vision to provide inspiring and motivating learning environments for the students with possibilities for working individually, in groups and in teams.

Common rooms will be inviting and dynamic and combine academic and social functions, and make room for gathering and different activities, ranging from play to contemplation.

Technically the vision is to optimize the existing building to lower its energy consumption, and to reach 2020 building regulation requirements for the new addition.

DELIMITATION

Economic aspects have not been included in the project as well as life cycle analysis as the focus on architecture and energy has had top priority.

The outdoor spaces are of great importance for the function of the school and wellbeing of the pupils. The outdoor areas however will not be a part of the design process, besides on a flow basis to make buildings and landscape work together.

PRESENTATION

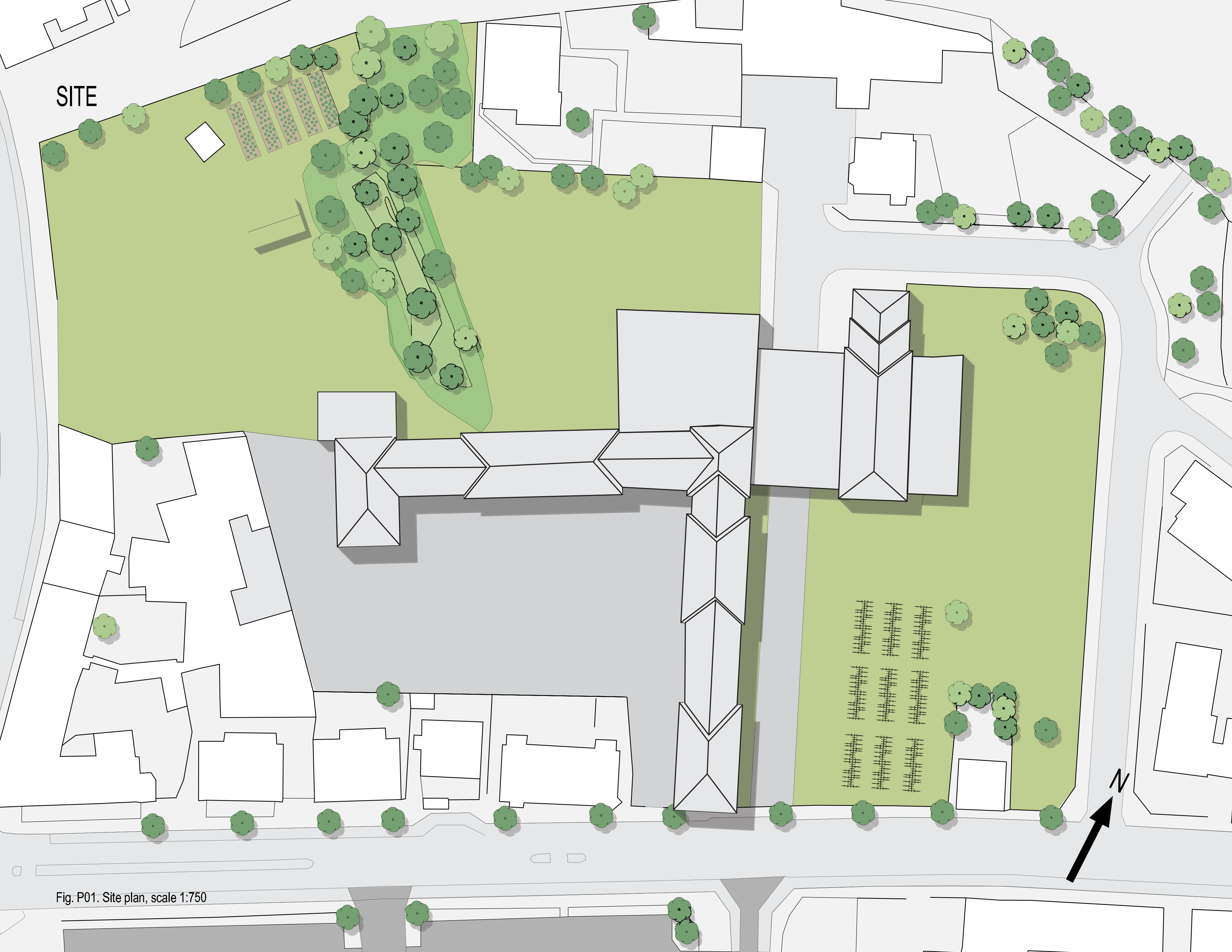


Fig. P01. Site plan, scale 1:750

LEVEL 0

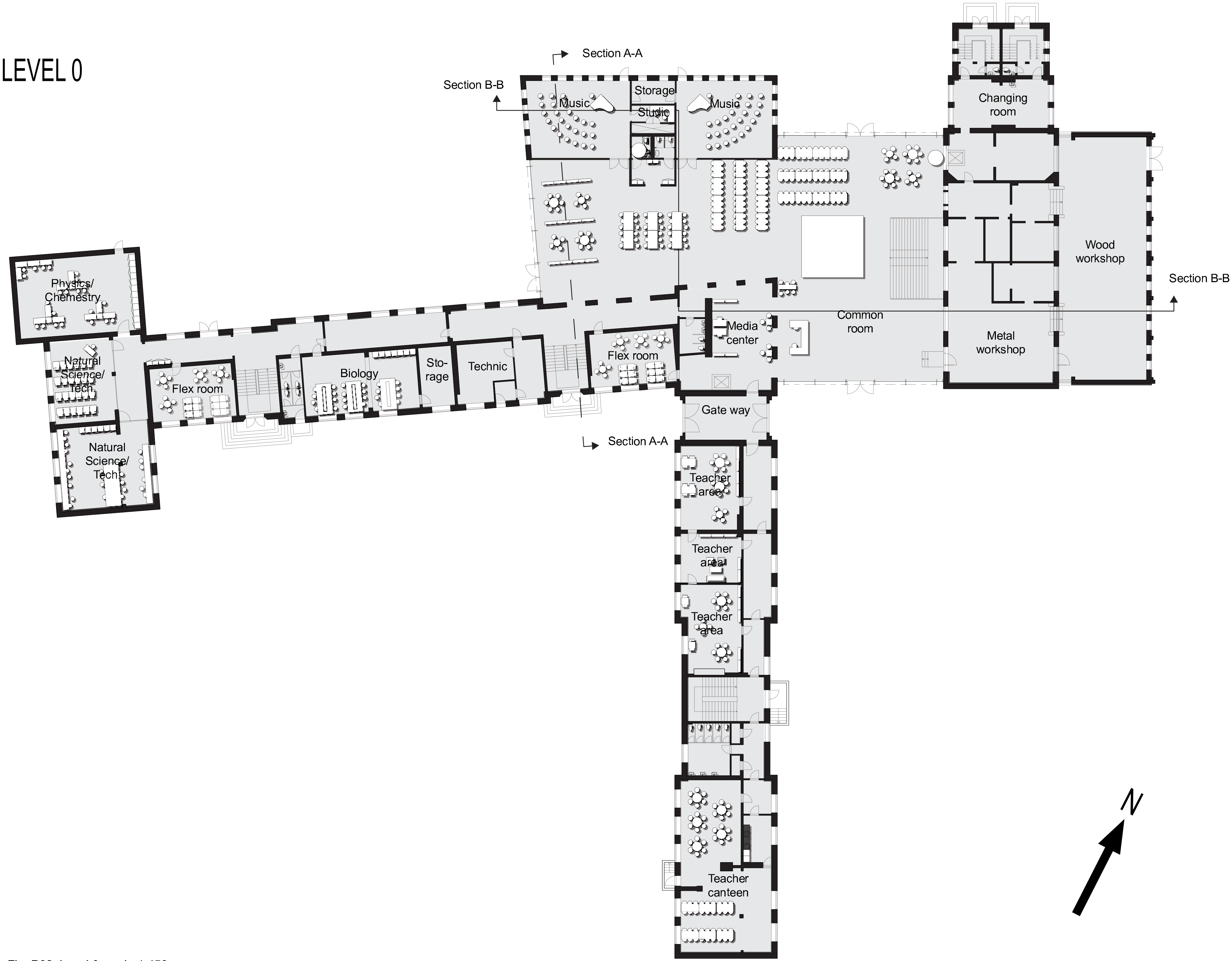


Fig. P02. Level 0, scale 1:450

LEVEL 1

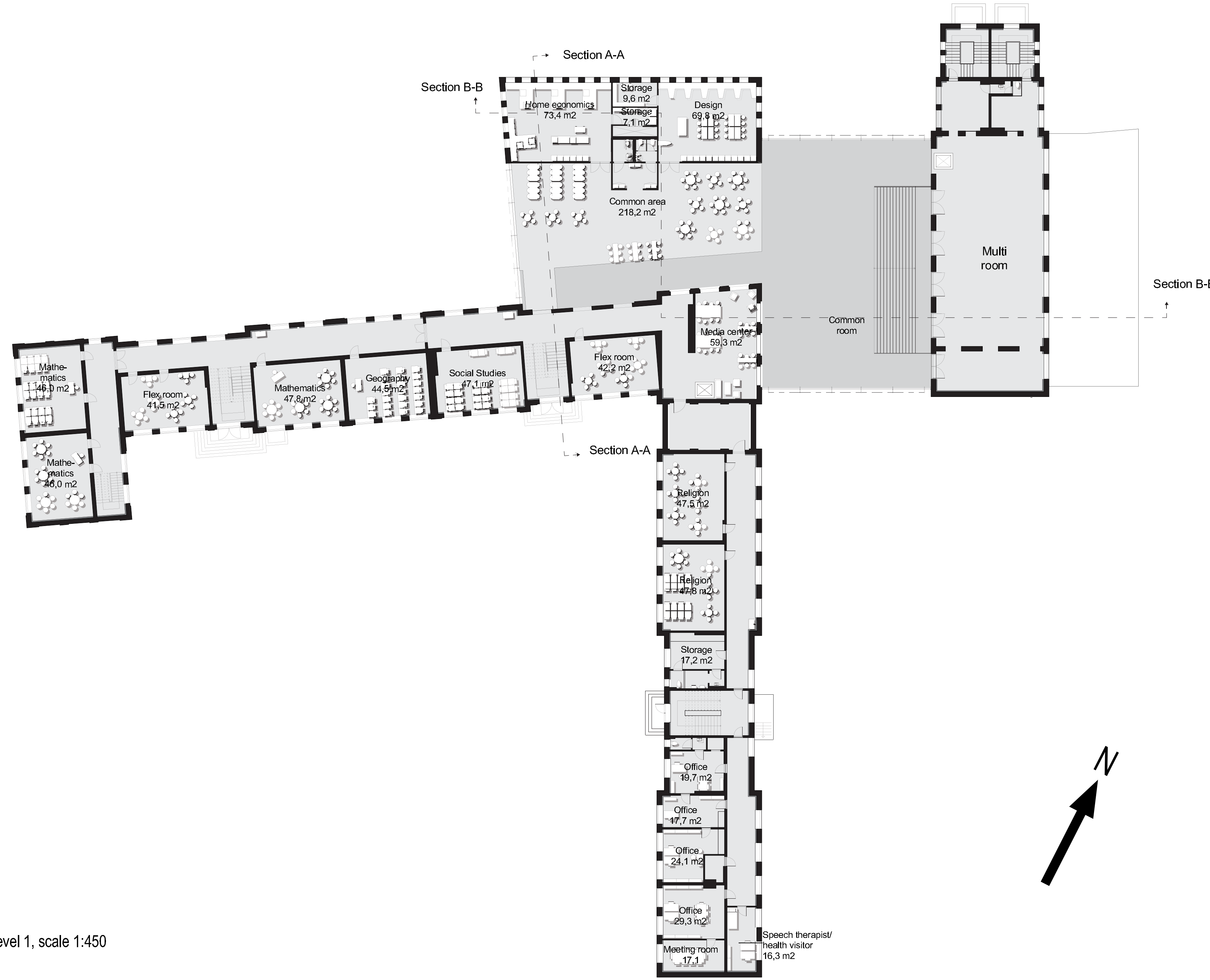


Fig. P03. Level 1, scale 1:450

LEVEL 2

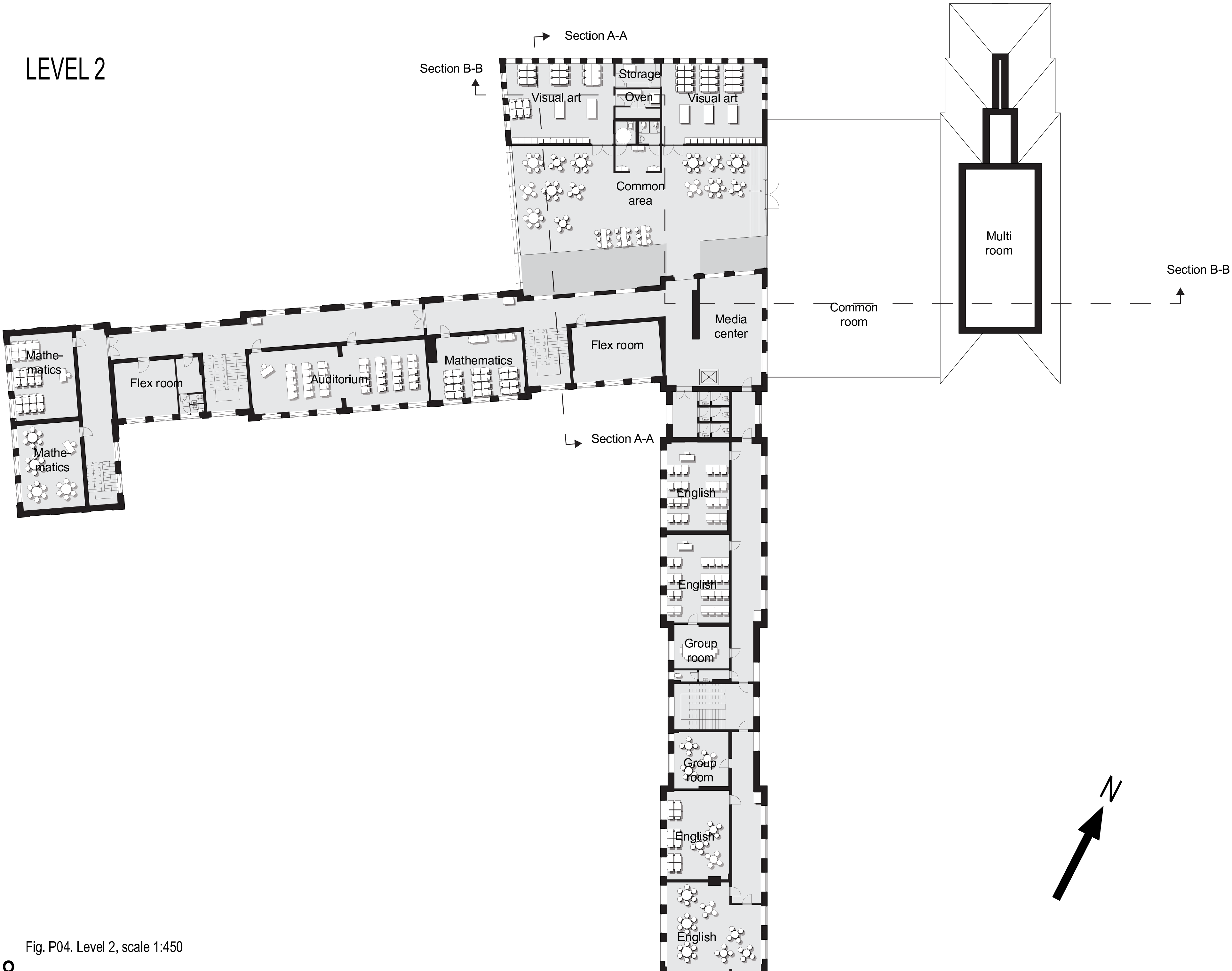


Fig. P04. Level 2, scale 1:450

LEVEL 3

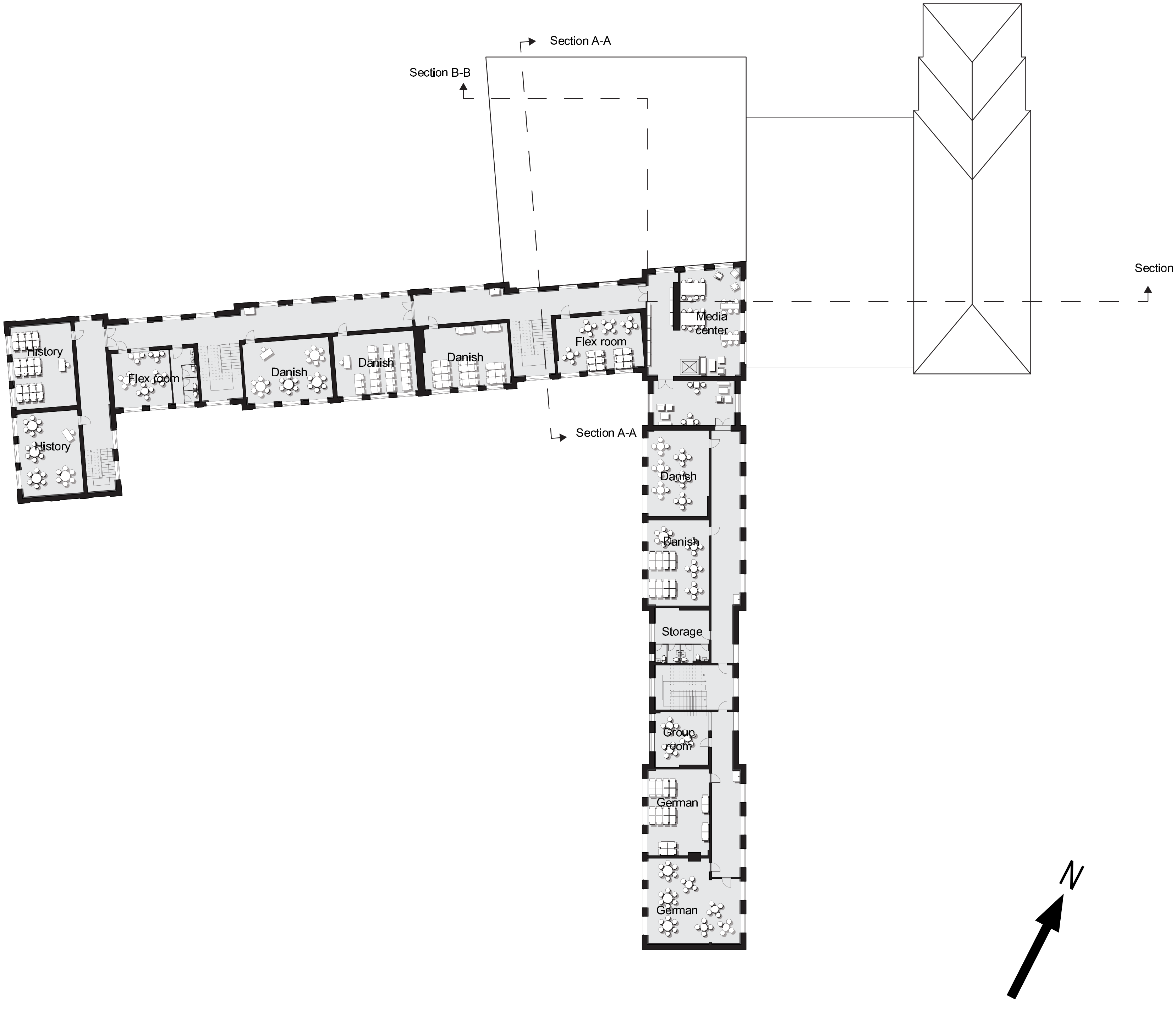


Fig. P05. Level 3, scale 1:450

LEVEL 4

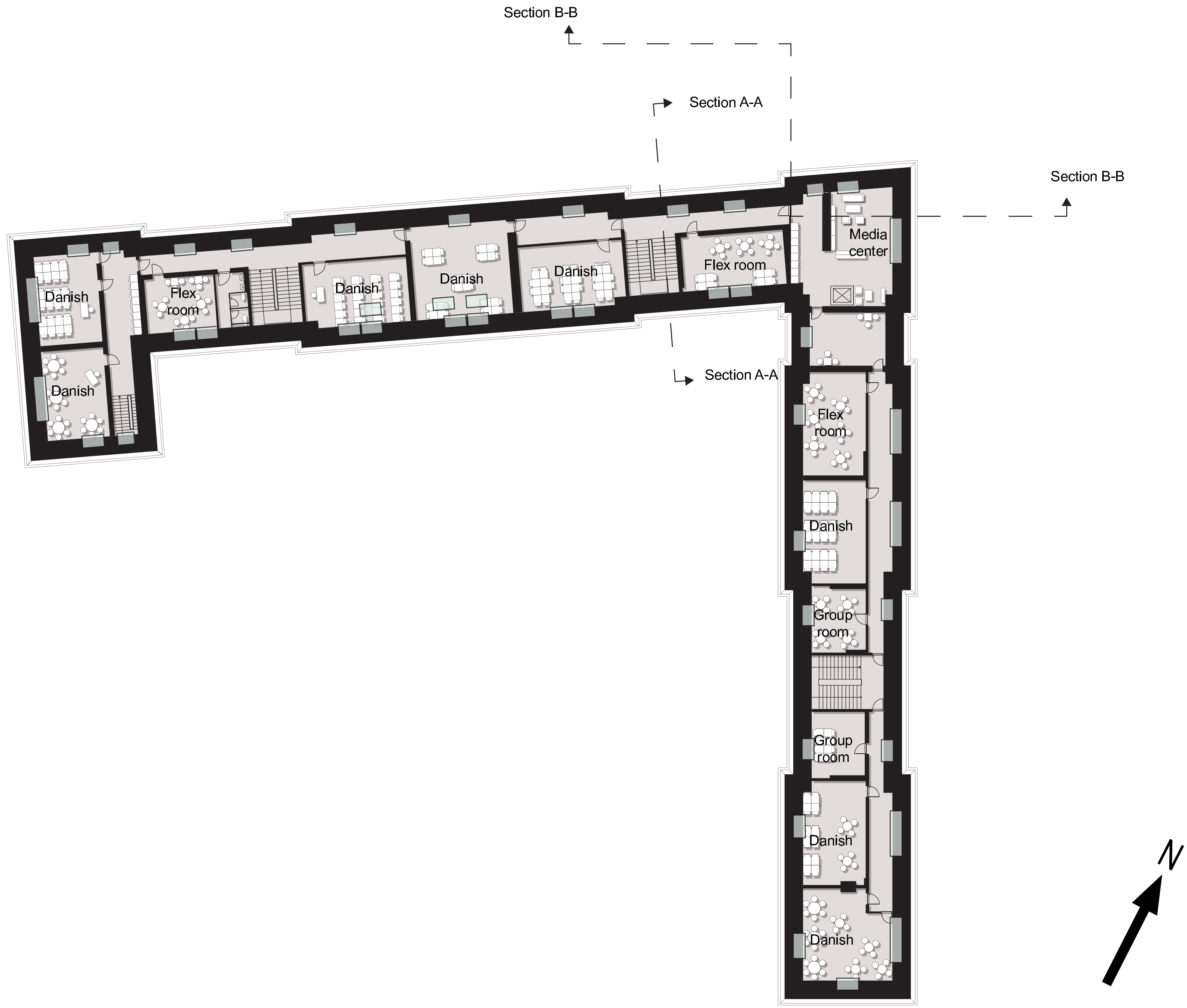


Fig. P06. Level 4, scale 1:450

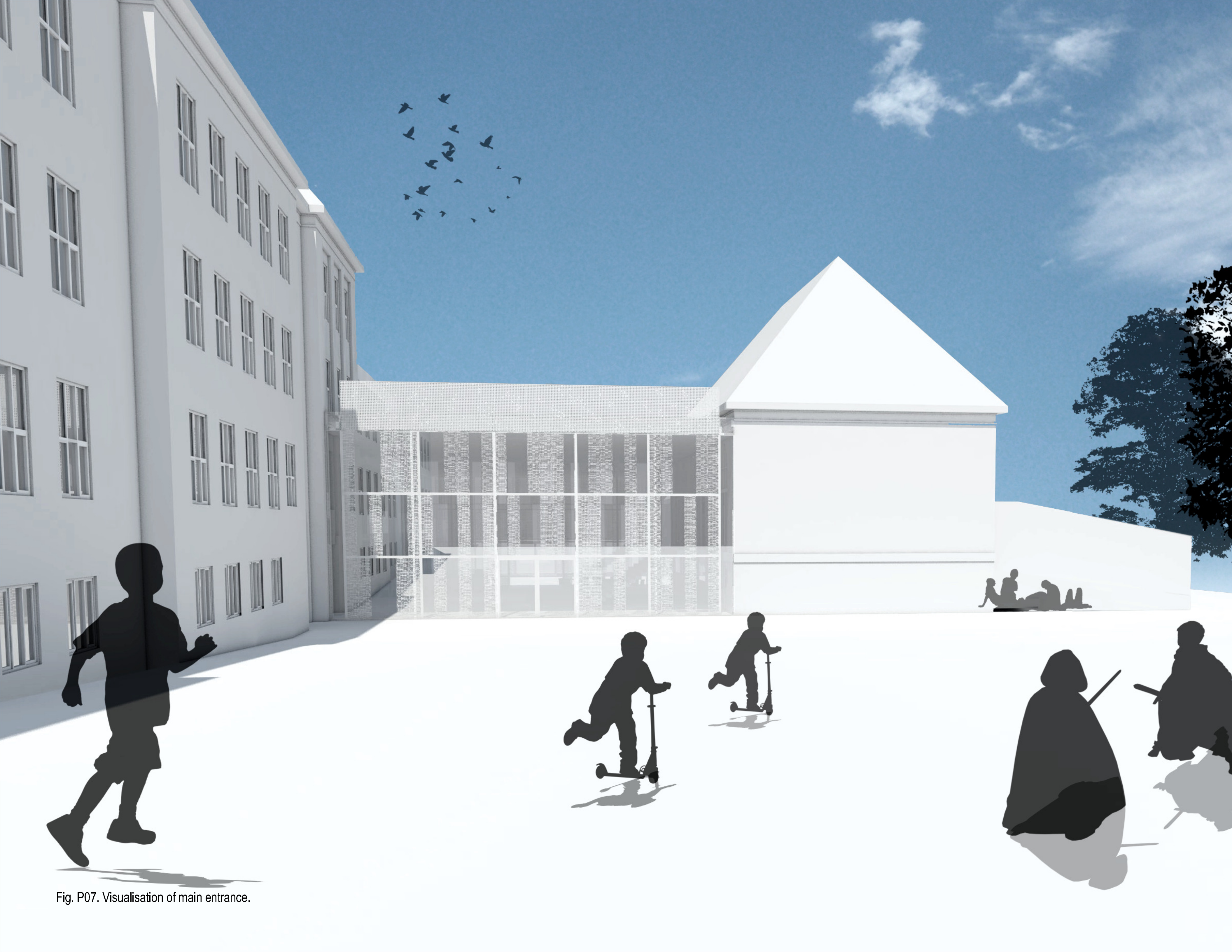


Fig. P07. Visualisation of main entrance.

SECTION A-A

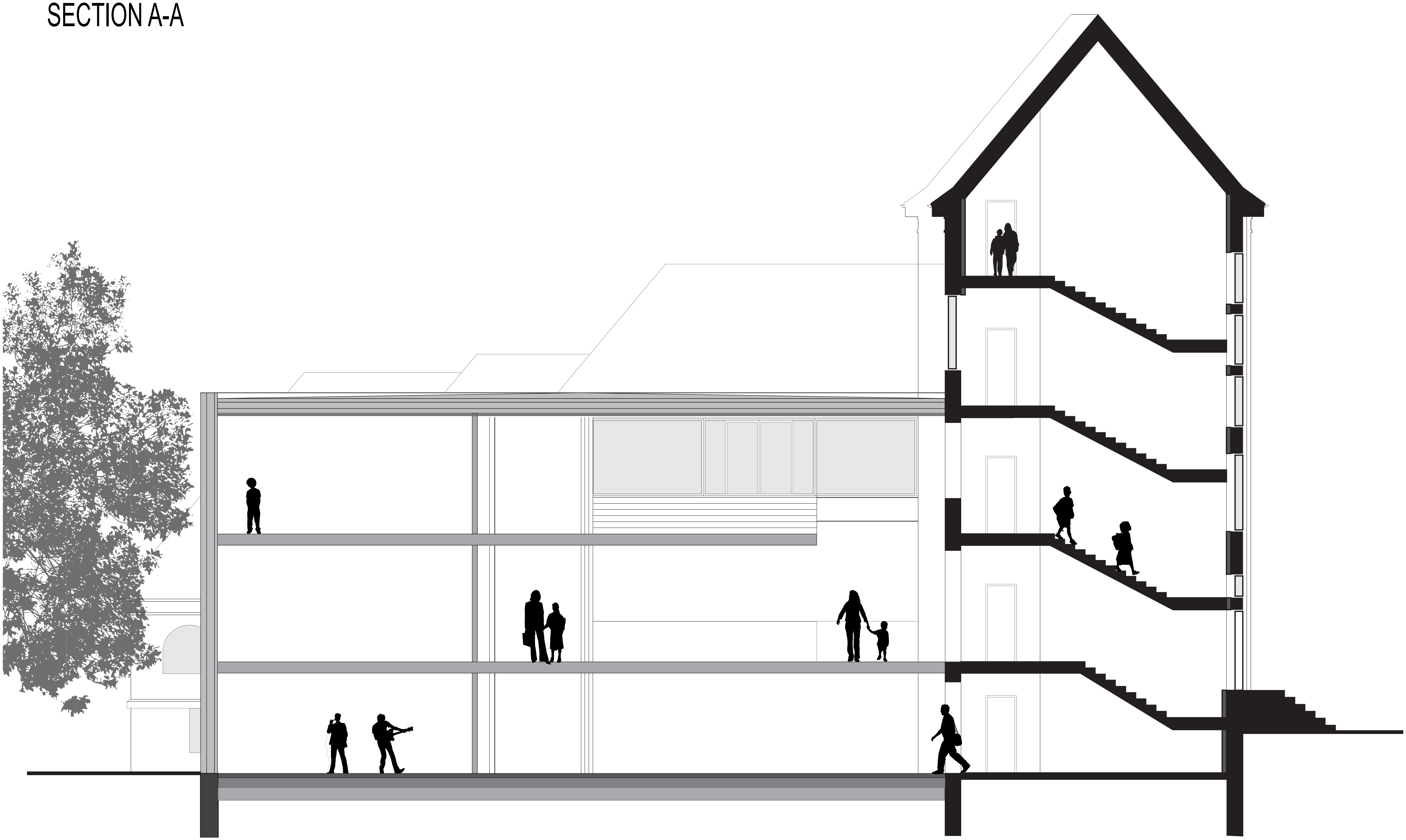


Fig. P08. Section A-A, Scale 1:150.

Fig. P09. Visualization of platforms connecting new and old building.

Fig. P10. Visualization of common room in atrium.

SECTION B-B

Fig. P11. Section B-B, scale 1:250

Fig. P12. North facade, scale 1:450

Fig. P13. South facade, scale 1:450

Fig. P14. East facade, scale 1:350

Fig. P15. West facade, scale 1:350

PROCES

When considering the assignment and analyzing the school typology and the way teaching methods have changed over time, the thought of building a new school have come to mind.

A new school would accommodate the new ways of teaching in an environment built especially fit for them and with a much lower energy consumption for operating. The materials of the existing building however contain a lot of embedded energy which have to be accounted for if the building was to be demolished.

Energy- and environmental analysis of renovation projects have proved the energy consumption and environmental impact of operation to be most significant, but the impact regarding production and disposal has to be taken into account as well. [Energi og miljøvurdering ved renovering]

Examples have proved the payback time for emission of CO_2 from demolition and new build instead of renovation to be 25 – 30 years. [Renovering eller nybyggeri]

Apart from these considerations, the school is in use, windows have been changed in 2009 and the roof is currently being changed, so the building has been maintained throughout its lifetime. Kultur Styrelsen also finds the school building worthy of preservation [Kulturarv 2]. The gym buildings next to the school are also mentioned, but only as possessing some architectural and cultural value [Kulturarv 3] and [Kulturarv 6].

Based on these considerations, an addition to the existing school to provide the needed facilities and optimize the learning environment, weighs higher than to build a new school. But to accommodate the previously mentioned teaching ways, an inspiring learning environment, to provide classrooms of a suitable size and to consolidate the existing school environment with the new, the interior will have to be modernized. In connection with this, re-insulation could reduce heating costs significantly and optimizing the heating and ventilation system could improve the indoor environment.

The school building has been rated as worth preserving.

During time, the school has had need for more room and to accommodate specific functions. This has resulted in scattered buildings of different appearance and quality.

The surrounding buildings have also been rated, but with different marks, see fig 25. [Kulturarv 2-8]

The preservation status is defined by a scale from 1 to 9, where 1 is the highest rate. The assessment is based on five different conditions; architectural value, culture-historical value, milieu, originality and state. The rating does not define what considerations to take if renovating, as this differs from building to building. [Kulturarv1]

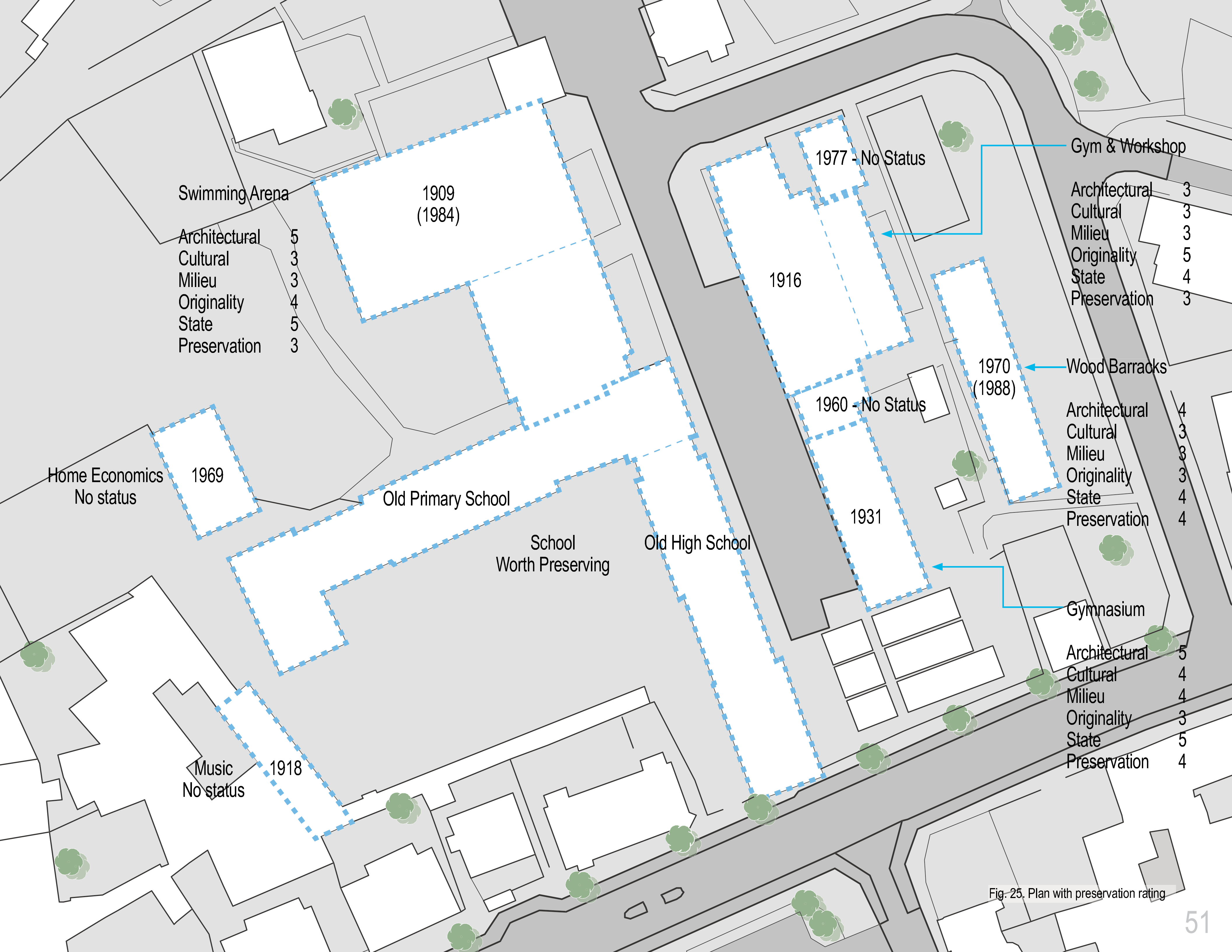


Fig. 25. Plan with preservation rating

ARCHITECTURE

The architecture of the school is New Classicism, which dominated from 1915 to 1930. Neo Classicism is inspired by the ideals of simplicity and harmony of antiquity. [Bygningskultur]

The building is characterized by order and axial symmetry; the windows proportions and placement have been matched to fit the level height, the plan has a strong geometrical form, the hipped roofs unifies the building structure and defines functions, and especially the entrances have monumental qualities as well as the clear definition of the base of the building and the window surroundings to some extent.

In front of the school are villas from the same period, but aside from them, the surroundings have a very varied character.

The character of the existing school will be preserved and respected. The intent is for the addition to visualize the new ways of teaching, the new view on teacher and student and the new way of building and architecture. This will be expressed in the façade and it will therefor differ in appearance from the existing building.

Fig. 25.Illustration of hipped roofs, characteristuc for new classicism

Fig. 25. Illsutraion of subtle ornamentation characteristic for new classicism

Fig. 25. Illustration of order and proportion characteristic for new classicism

GATHERING FUNCTIONS

Through the schools existence smaller buildings have been erected to accommodate an immediate need for room, without great expense. Some of the buildings no longer has any school function and only serves to decrease the architectural value of the school seen as a whole.

To unite the school, both architecturally and logistically, the vision is to replace the scattered functions with an addition linked directly to the existing school. This will also free outdoor areas for the children to use in recess and to use for educational purposes.

The buildings to be torn down are:

- Home economics as it is no longer in use and the pupils are taught at an other school
- Music as it is a wish from the school to have new rooms
- The blue barracks as they are not in use and does not relate architecturally to the school and to free outdoor area
- The gymnasium because it is not big enough for a whole class to have gym lessons together and they therefore are going to use the local sport facilities instead. It also does not relate as strongly to the school as the other gymnasium
- The connection between to two gym-buildings to ensure direct connection to outdoor area from the school yard and because its changing room func tion no longer has a purpose when the gymnasium is no longer there
- The old public swimming arena as it is in such a bad condition that a new one is being built

The intention is to unite school fully, which also include the preschool pupils, currently located on the other side of the railway tracks.

When commuting to all subjects, they would have to be assisted by teachers for them to feel safe in the beginning at least. Sister classes between young and old levels, can help the integration for everyone at the school.

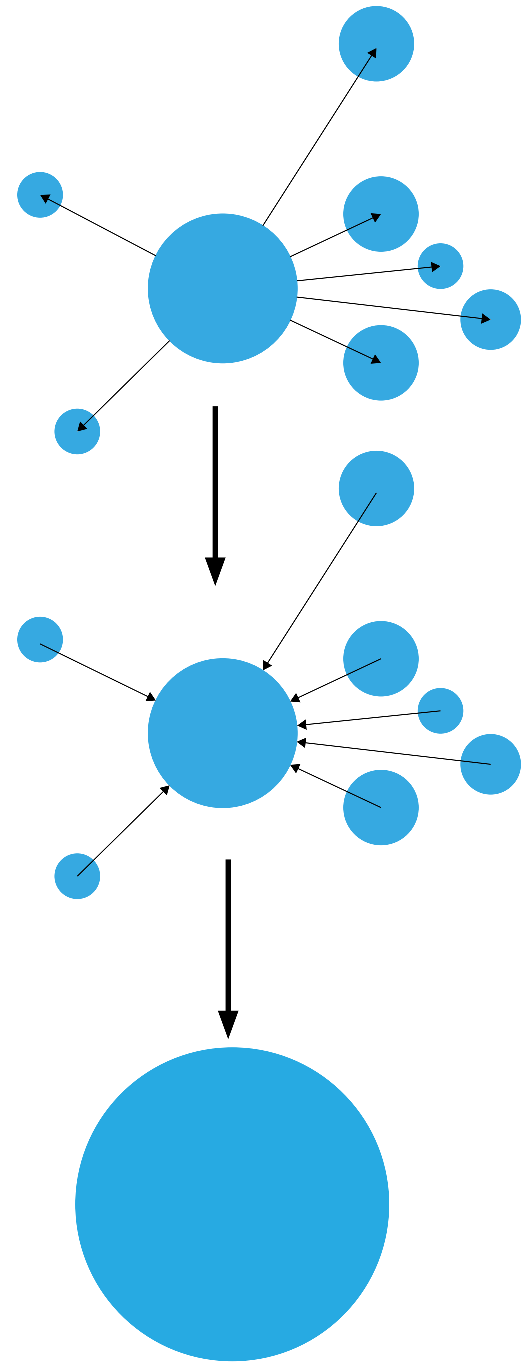


Fig. 26. Illustration of scattered functions, gathering functions and one unity.

ACCESSABILITY

Since one wing has served as high school and the other as elementary school, they each have their own entrance with the same appearance and. This means that when you approach the school, there is no main entrance and you don't know which entrance to choose if you have not been there before.

To connect the two wings and provide a main entrance, different possibilities have been explored:

- Making one of the existing entrances the main one

The entrance to the elementary school wing is in natural line of view when accessing the school yard, whereas the one to the former high school is to the side. Both entrances have stairs leading up to them and give access to staircases leading up and down the building. The accessibility is therefore not good for disabled people

- Making a new and clearly visible entrance

The differences in levels and the stairs at each entrance is a general problem for accessibility.

Currently an elevator serving all levels has been installed, hidden at the back of the school to not obstruct the architectural expression of the facades.

A small elevator has also been installed on the east façade to service level -1 and 0. This elevator is necessary as the PORT divides the two sections of the school until level 1 where there is access above the gateway. The elevator does nothing good architecturally for the façade.

Based on an old picture of the school, the intention is to reopen a path between the school building and the two gym buildings and make it the main entrance. The old gate to the school can still be used, but the reopened path will be the main entrance.

The passage gate will remain open to provide access from the old school yard to the new green area on the east side of the school along Blegen without having to go to the street.

Fig. 27. Previous entrance.

TERRAIN

To ensure the previously mentioned accessibility, the terrain has to be considered.

The terrain drops 2,5 m from the street to the back of the school, all the way along the east façade.

By lowering the terrain some around the passage gate, on the north side of the building and between the school and the gym, it is possible to provide access to both existing buildings.

By placing a gangway inside the passage gate, only one elevator is necessary to provide access to the whole existing school complex and it will therefore be possible to access the school without having to use stairs, given that an entrance to the east-wing is placed in that same level to avoid more stairs or elevators.

The gangway inside the passageway and the new entrance at level 0 makes it possible to discard the elevator on the eastern façade, which clears the façade and leaves it as intended.

Fig. 28a. Existing terrain and floor level (dashed line).

Fig. 28b. Future terrain in level with floor.

STRUCTURAL SYSTEM

When having found the overall concept, considerations to the structural system had to be made.

To allow an open space without pillars between the two existing buildings, beams or frames have been investigated:

The window openings in the school and the gym do not correspond either in height or width and beams will therefore not be possible to place without placing some irregularly to an opening.

Frames across the buildings will pose the same challenge regarding the openings as the beams, whereas frames lengthwise to the buildings leaves an open space and only has to take the openings into consideration height wise, as the windows are not of the same height or placed in the same level.

By choosing frames lengthwise to the building, they can help accentuate the direction of the room and the changes in the roof structure; glass - roof - glass.

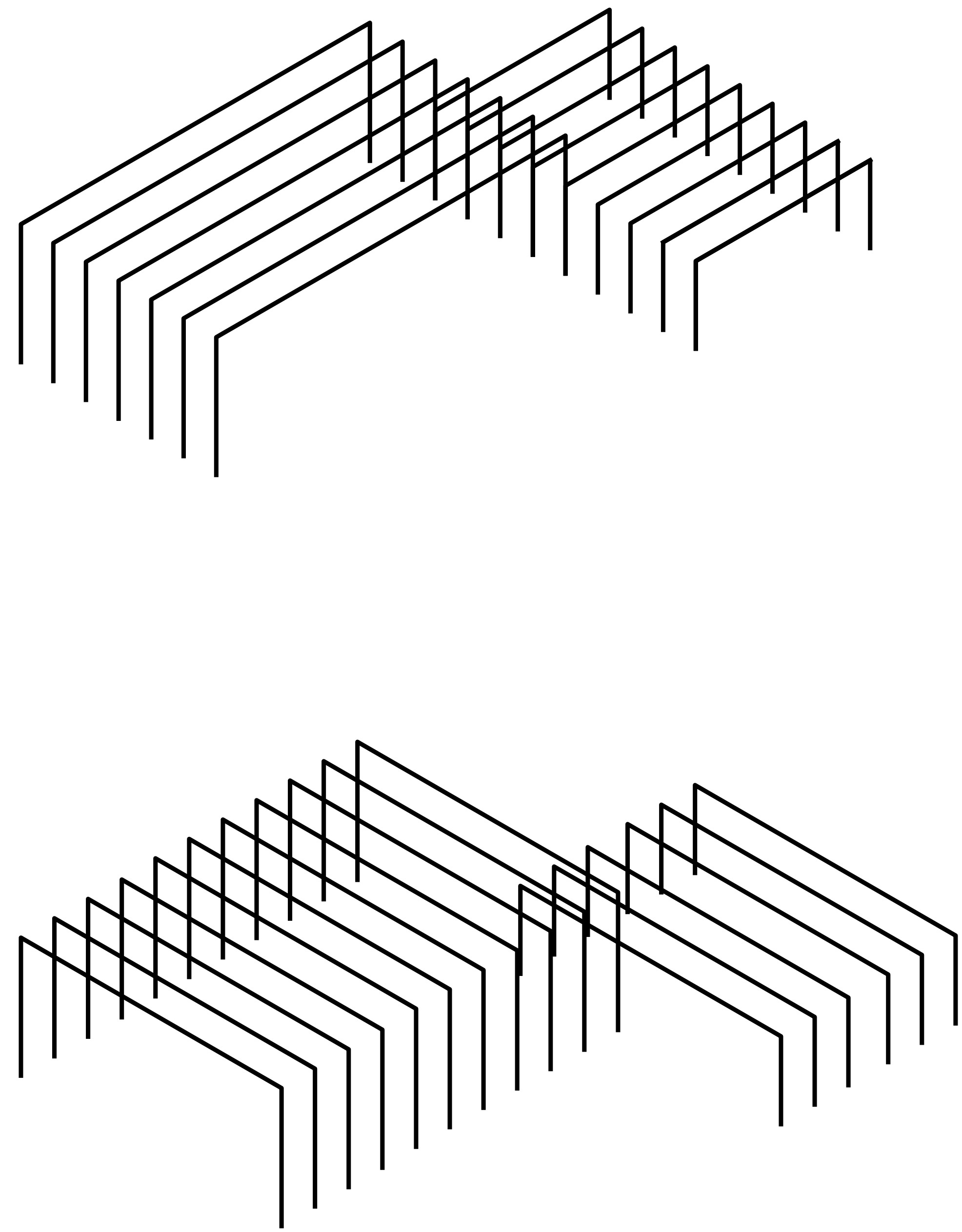


Fig. 29. Structural system

ORGANISATION

When changing the concept of the school from home base classrooms to subject specific classrooms, the organization of the school has to be considered.

When placing subjects of similar topic e.g. creative subjects as design and visual art in close proximity, they can benefit from each other and work across subjects in workshops and draw inspiration from each other.

This kind of organization has organized the classrooms throughout the school:

Level 0: Science subjects, Physics/chemistry, Natural science and technology and Biology in the west-wing and teacher area in the east wing

Level 1: Mathematics, Geography and Social Studies in the west-wing and Christian Studies and teacher area in the east wing

Level 2: Mathematics in the in the west-wing and English in the east wing

Level 3: History, Danish and German

Level 4: Danish

Throughout the school there are group rooms in smaller rooms and flex rooms in rooms that are a little too small for being used for class rooms. These rooms can be used for other activities than class teaching and herein lays the flexibility within the existing school building.

The corner room connecting the west- and the east wing functions as media center throughout the building. Here relevant books for the individual levels can be found. The media center also includes areas for contemplation and social activities as computer game corner, play area, reading couches and the like.

The new facilities have been separated from the existing building by an atrium to underline the difference from old to new. The atrium contains repos for more free class teaching and work in general. These areas also have computer stations for common use and will be used for common room in recess.

The atrium connects the existing school building, the additional new class rooms and the old gym and wood- and metal workshop.

The creative subjects; Music, Visual Art, Design and Home Economics have been placed in the new addition, as they benefit from being placed in close proximity to each other and they are more room demanding than other subjects and would therefore be hard to fit into the existing building, without having to expand room and thereby change the structure in the building which is both expensive and difficult.

See plans in Presentation section for visualization.

COMMON FUNCTIONS

The wish from the school is for a room where people can meet and gather – sometimes the whole school at the same time.

This room will be provided in the addition, connecting the existing school to the new classrooms and the gym, which will function as a multipurpose room.

Since the terrain will be regulated, the school and the addition will be on the same level. Direct access from one part of the united building to another is therefore possible and makes it more likely for the atrium to be used.

The old gym building has different levels from the school and access to these will happen by stair or elevator.

The corner room of the school will function as media center throughout the building and spread out from this corner. When placing the media center in the corner room, it is placed centrally and is easy to reach and find.

The elevator providing access throughout the building is also placed in the corner room for easy access to any level of the building

The atrium will function as canteen, teaching area, addition to the media center and as general common room.

Fig. 30a. Common area, A.P. Møllerskolen

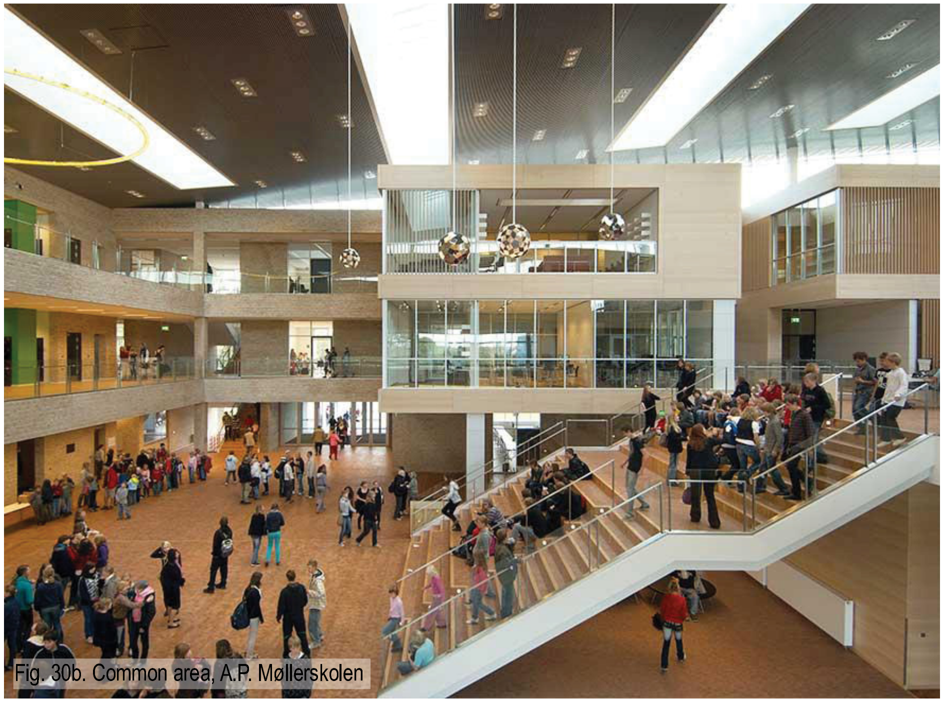


Fig. 30b. Common area, A.P. Møllerskolen

AFTER-INSULATION

The building has been listed as worth preserving because of its architectural and cultural value. This makes it hard to insulate the building externally without covering the valued existing façade and therefor it will be insulated inwards to improve the U-vale of the façade.

Internal insulation is less energy effective compared to external, because it leaves significant cold bridges e.g. at windows, decks and walls connected to the façade.

When insulating an existing wall internally, the dew point moves into the construction and it is therefore only recommended is special cases, such as when renovating listed buildings. The execution of the internal after insulation has to be done carefully to ensure the most optimal result.

Since the facade will be insulated internally, the thermal mass is reduced considerably, but the insulated wall will receive a minimal amount of direct sunlight and therefore the impact is minimal (see effects in Bsim simulations). The thermal mass after insulation is lowered from 160 Wh/K*m^2 (extra heavy construction) to 120 Wh/K*m^2 (medium heavy construction)

Fig. 31a. Illustration of covering up the existing facade when renovating, Kulturværftet in Helsingør

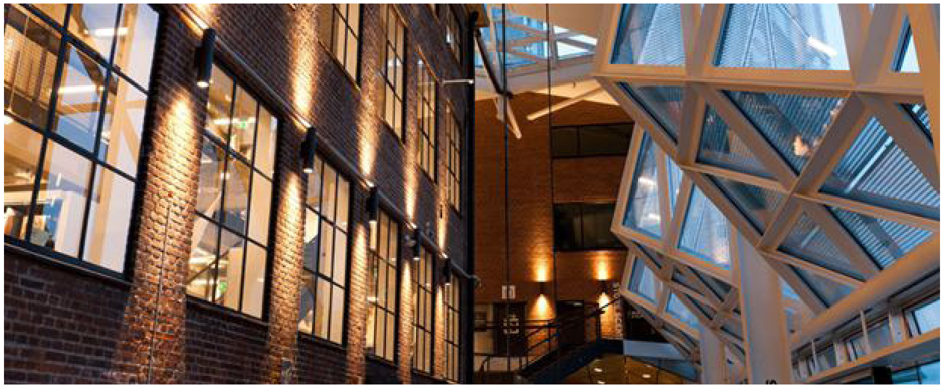


Fig. 31b. Illustration of covering up the existing facade when renovating, Kulturværftet in Helsingør

REUSE FACADE

Fig. 32a. New extension on side of facade.

Fig. 32b. Old facade as interior wall.

When extending the school, it has been important to integrate new with old, but keeping the characteristics of the old building, so its story still is can be read when adding a new skin.

Aside from the changed to the window holes, the façade will remain untouched.

In the school building, only window openings will be altered to have direct access to the extension. The window openings will therefor become door holes in level 0 and one window on level 1 and level 2, will also become door holes to provide access over gangways to the plateaus and classrooms in the addition. Regarding the rest of the windows, the windows will be removed to connect stronger to the atrium.

In the gym- and workshop building, some alterations have to be made to provide access. The arched windows facing the atrium will be converted into doors to integrated the multi room with the atrium, but with the possibility of closing the doors, if activities require it.

Where the existing façade will be covered with a new one, it is not necessary to insulate, which can save both time and money in the building process. The new façade will be the insulating one and has a significantly better U-value than the existing massive wall.

Fig. 32c. Opening up old window wholes to connect to other room.

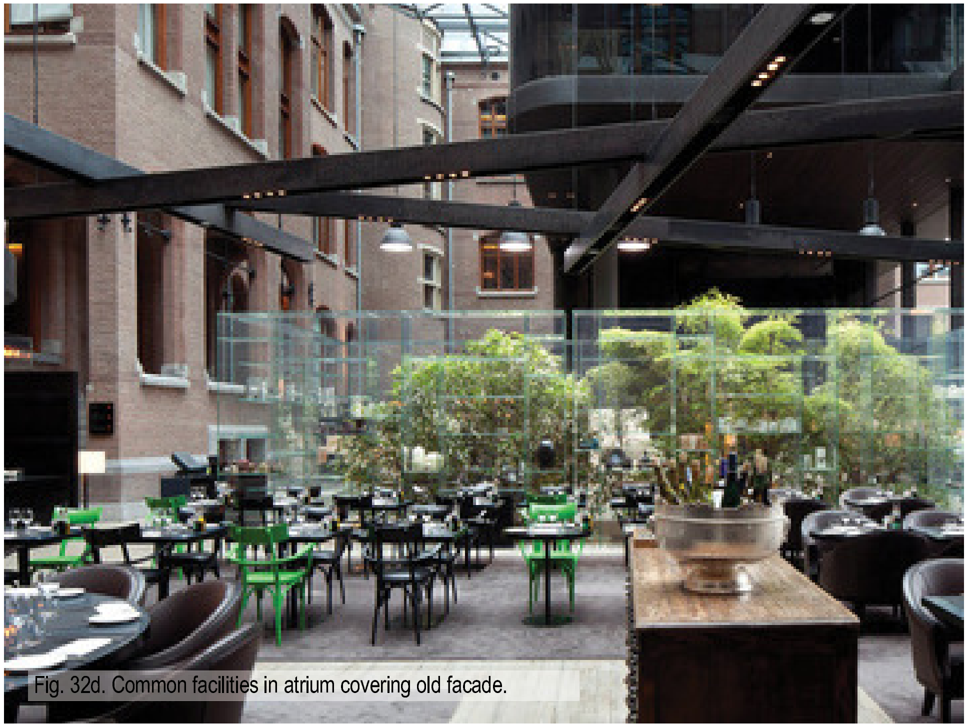


Fig. 32d. Common facilities in atrium covering old facade.

FACADE

The existing new classicistic building is characterized by relatively tall and slender building volumes, and openings and recesses have been placed regularly with a rhythm in the façade. The windows have been placed directly above each other, giving verticality to the façade.

When extending the school, the atrium is situated between the school- and the gym building, and the classrooms behind the school to the North.

Since the extension is lower and wider than the school building, some measures have to be taken to give verticality to the new façade as well and for it to relate to the existing façade.

Regarding material, the new building should stand out from the old one, but still relate to it. It is also important for the material to be durable in terms of maintenance to minimize the budget.

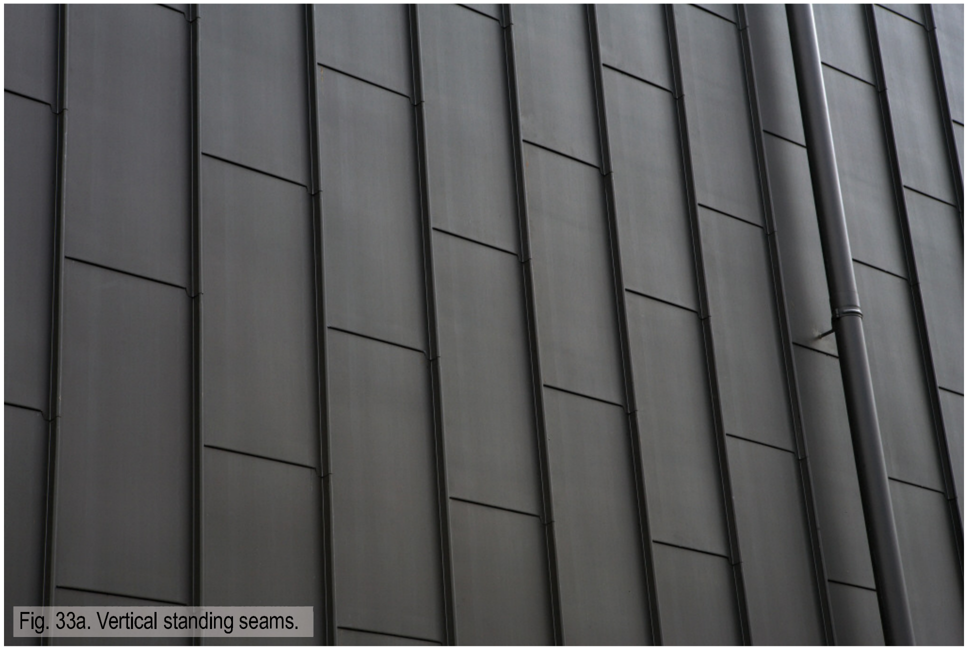


Fig. 33a. Vertical standing seams.

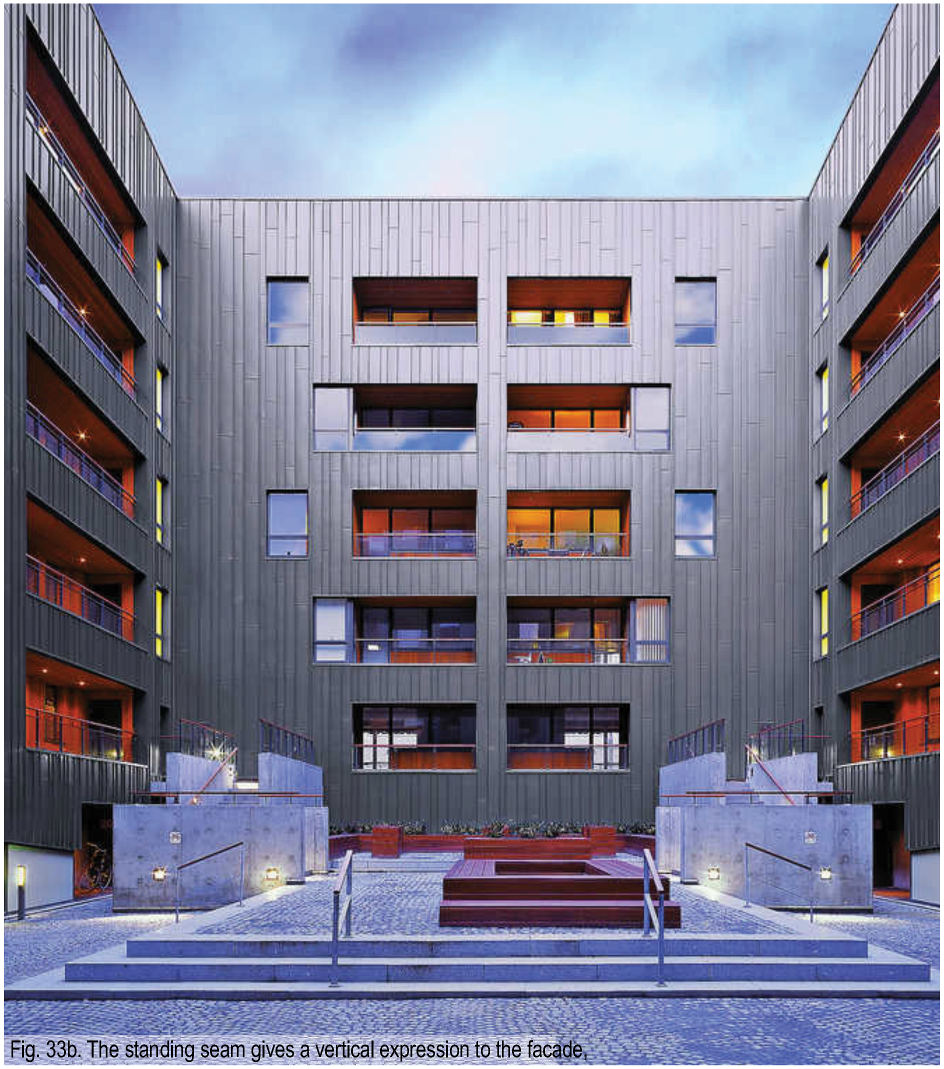


Fig. 33b. The standing seam gives a vertical expression to the facade,

It is chosen to use zinc cladding with shale colored patina. Standing seams can help emphasize a vertical direction to the façade.

The windows of the new classrooms will have a rhythm and verticality to them as well. Because the levels in the addition correspond to the ones in the school, the room height is quite high; 2,9 m. on level 0 and 3,3 m on level 1 and 2. On level 1 and 2, because of the larger room height, the windows have been divided into two – one tall window and a smaller one atop for ventilation purposes and to let light further into the room.

At ground level, there will be direct access to the outdoor from the two classrooms.


Fig. 33c. Correlation between materials.


Fig. 33d. Distinct seperation between old and new.

The atrium, filled in between the two existing buildings, is going to be the new entrance, distribution area and common room. The room will appear light and welcoming, but will stand out as a contrast to the existing buildings, also material wise.

The atrium will be a tall, deep and broad room, and since the intention is for the roof of the atrium to have a terrace, skylights is not a good solution.

It is chosen to have glass facades between the existing buildings and the new classrooms. Because of the height of the atrium (~7 m.) light will penetrate quite long into the room.

Slender profiles will give a light expression to the façade.

Large glazed areas, however, can also give problems with excessive heating and solar shading is necessary to prevent overheating and help ensure a good indoor environment. External shading is most effective, as it stops the radiation before it enters the room.

Vertical solar shading can provide a similar expression as the standing seams and is therefore chosen. By having moveable shading, divided throughout the façade, it is possible to move the shading according to the activity going on inside the room.

The solar shading will be the same material as the façade, but will be perforated to ensure daylight though the shading is on.

At the border of the glass facades, the façade has been left clear of any shading to accentuate the transition between old and new.


Fig. 34a. Distinct seperatin between old and new.


Fig. 34b. Glass facade with clear structure behind.


Fig. 35a. Moveable solar shading. System for solar shading.


Fig. 33a. Material expression of solar shading.

MATERIALS

The school in Denmark has developed from an institution reserved for the rich to a free right for everyone. When school was first made free and obligatory for children, health issues had high priority because of the many poor and dirty children suddenly going to school. To adapt to the health problems, the schools became very similar to hospitals. This sterility was maintained for many years and can also be seen at Byskolen with its white smooth surfaces on the walls.

Since then things have changed and these changes and the new views and contrasts can be reflected in the choice of materials in the addition to the school.

The vision of the addition is to bring in soft materials e.g. wood floors, gypsum walls because of acoustics and vertical wooden lamellas on some parts of the walls, both for acoustics but also to bring in a natural and warm element to enhance the homely feeling that has come to the school concept over time.

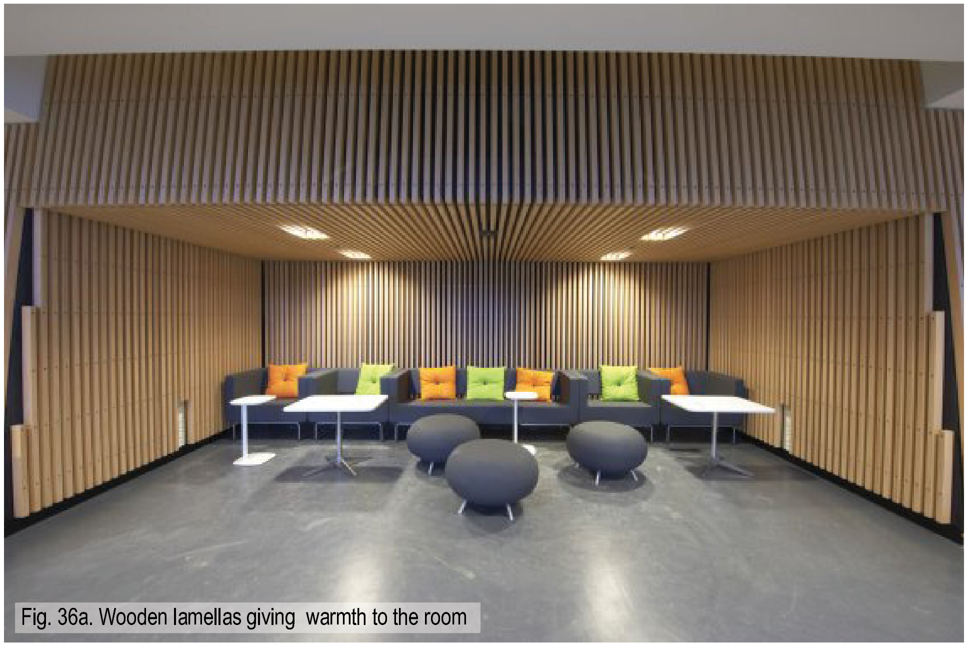


Fig. 36a. Wooden lamellas giving warmth to the room

Fig. 36a. Wooden lamellas emphasizing other function.

When visiting Ørestadens Gymnasium and Ørestadens Skole, see previous case studies, visibility and translucency was a recurring motif.

The intention is not opening up the classrooms as on e.g. fig. 37a, but to have glass doors to connect rooms and environments, and thereby foster curiosity for the different subjects. When the classrooms are not opened up so much, it is to prevent too much disturbance during lessons.

Fig. 37a. Ørestadens Skole, transparency to classrooms.

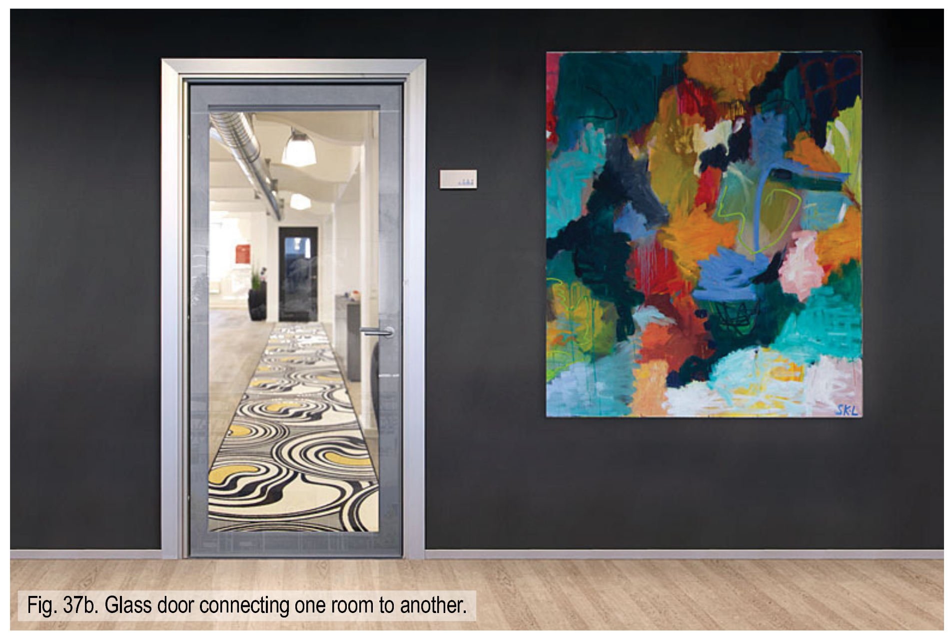


Fig. 37b. Glass door connecting one room to another.

A large staircase leads from the common room to the multi room in the old gym hall. The stair is to be seen as a piece of furniture as well as a functional object.

The staircase is placed centrally in the common room and can be used for sitting while gatherings take place. The staircase will be divided in a section for walking and a section for sitting, so it can still serve its function as stair when used for sitting. Stairs for sitting is higher than the ones for sitting, as it is more confortable.

The stair is an informal place to meet, and often an attractive place to stay.

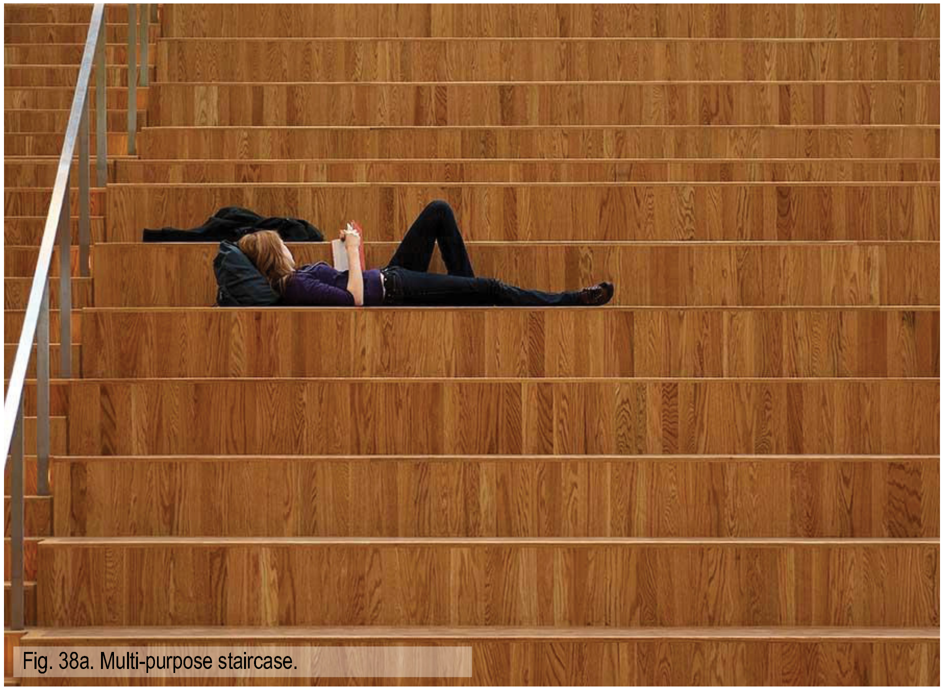


Fig. 38a. Multi-purpose staircase.

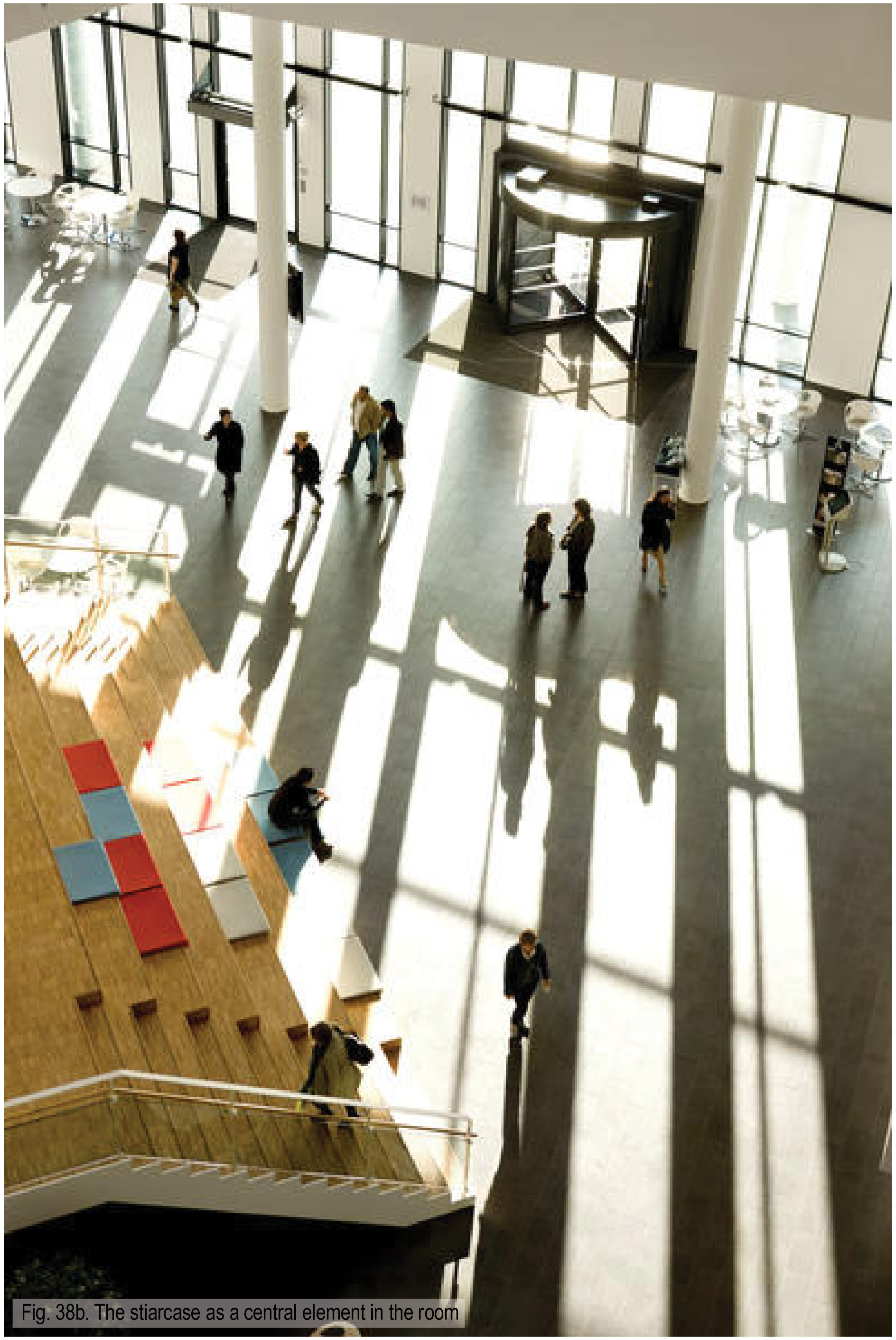


Fig. 38b. The stiarcase as a central element in the room

Some rooms in the existing school building are too small for class teaching, and will be used for individual-, group- or project work.

The "Flex Rooms" should be seen as informal places for school work or social relations. The furnishing will be different from the furniture in the classrooms, symbolizing the different function and the individual responsibility for learning, when sitting in a room without a teacher's constant supervision.

The atrium has been described as the big common room, but at the back toward the North, the existing school building and the addition with classrooms are connected by platforms.

These platforms can be used for teaching purposes, for canteen and general stay.

From the top platform, a stair leads to the roof terrace, which faces South and North and can be used for teaching purposes and stay when the weather allows it.

Fig. 39a. Flexible solution to a childrens library

Fig. 39b. Flexible room for individal work or social gathering

LIGHTING CONDITIONS

Daylight plays an important role in the human wellbeing therefor the aim should be to utilize daylight as the main light source, not only to decrease energy consumption, but also for the sake of the development of the eyesight and general wellbeing, as daylight helps strengthen children's sense of space, time and place. [Lyset i Skolen]

The eyesight is developed throughout the human lifetime and light conditions can help this development:

At the age of 0-7 years, the color vision is developed and good representation of colors is important to not slow this process down.

At the age of 7-12 depth vision is developed. In a school situation is important for the children to clearly recognize facial expressions in relation to body language. Indirect and diffuse lighting can obstruct this recognition as the facial expression is blurred.

The eyesight will be developed at 12-16. [Lyset i Skolen]

Conditions to help develop the eyesight:
Good representation of colors (high RA-value)
Contrast on boards and other objects
Sufficient light at work stations with a minimum of glare
Often a mix of direct and indirect light is best for school work

The challenge is to reach a sufficient daylight level while obtaining lighting conditions that support the many varied activities taking place within the same room, especially if the setting of the room is allowed to change.

From an examination of different schools in Denmark, the best daylight has been found in two schools with the simplest window configurations; normal side light from one side through windows in the façade, both with a glass area of 15% of the floor area. The modest room depth, less than 2 times the room height, light colors on window frames, window niches and all surfaces, help improve the lighting conditions.

By providing high placed daylight windows and lower view windows, often makes it easier to screen for specific conditions, provided that the windows have separate solar screens.

When designing class rooms, one should be aware that most children are right-handed and light coming from the left side of the room is therefore most suitable.

Artificial light can support the daylight and provide optimal working conditions when daylight is not sufficient. In this respect it is important to integrate the artificial light, both in respect to quality and energy economical operation.

Artificial light can be divided into zones within a room so that e.g. the zone closest to the windows can be turned off if it isn't needed.

Adjustable general lighting can create different light settings for different purposes.

Studies show that daylight sensors by the ceiling regulate the artificial light best, compared to sensors placed in the window. Studies also show the on older schools, it is possible to reach significantly better lighting conditions, with installed effects as low as 6-8 W/m^2, which is half of most existing lighting systems.

Presence detectors can help lower the energy consumption, but they should only be able to turn off the light. Turning on the light have to be done manually.

When lowering the energy consumption for lighting, other electricity consuming factors become relatively more significant and have to be taken into consideration as well e.g. old refrigerators in class rooms and the like. [Lyset i Skolen]

DAYLIGHT FACTOR INVESTIGATIONS

Daylight investigations have been executed in Velux Daylight Visualizer.

Daylight conditions in the classrooms are ok by the primary work stations and fulfills the 2020 building regulation demads of a daylight factor of 3 or more. However the conditions could benefit from light penetrating further into the room. It is possible to place windows on the East and West facades, but they do not improve the light conditions in the center of the building.

Because of the low daylight factor in the center for the building, a wardrobe leading to the toilet has been placed here. The wardrobe also divides the platform into two departments, which can be used individually or collectively for teaching purposes or stay.

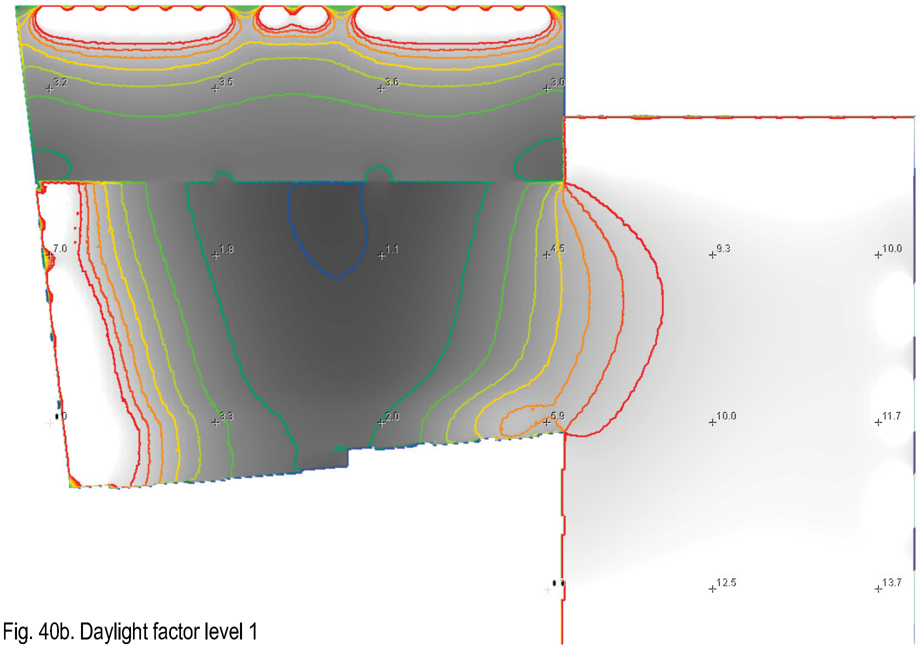
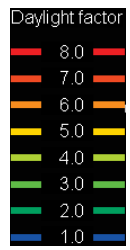


Fig. 40b. Daylight factor level 1



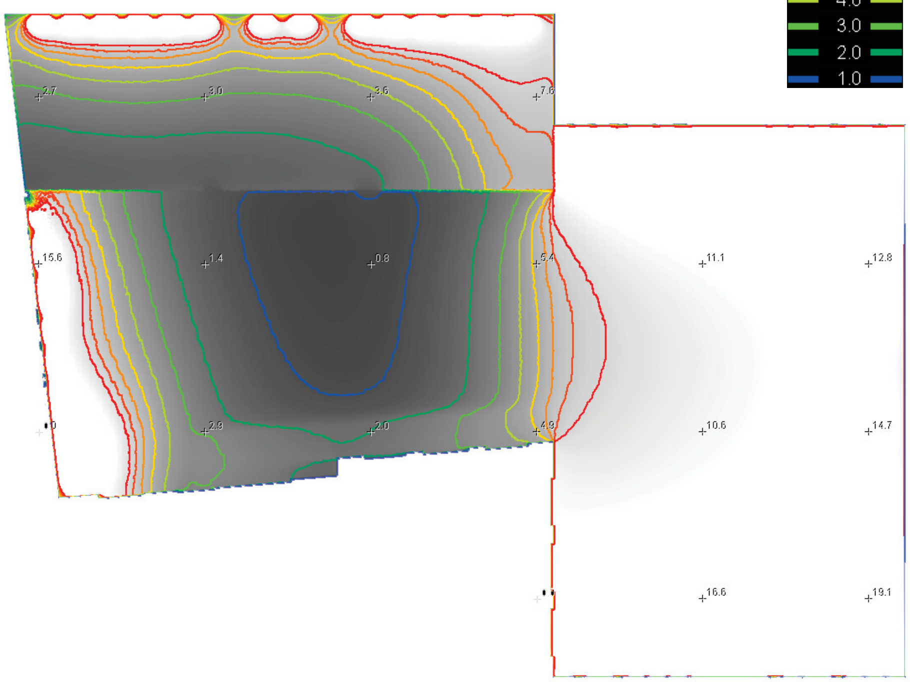


Fig. 40a. Daylight factor level 0

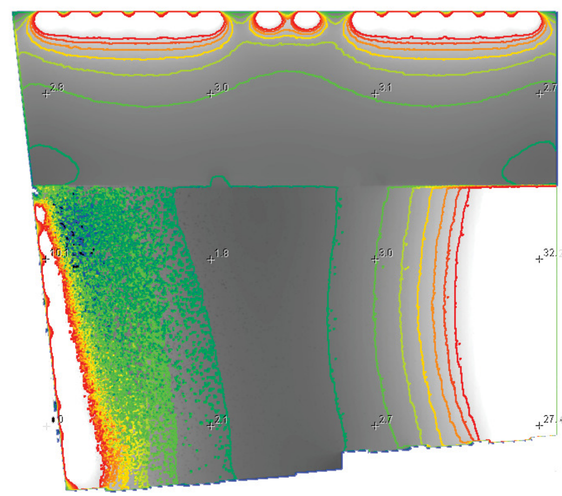


Fig. 40c. Daylight factor level 2

ROOF

The roof of the atrium is meant for stay and therefore has to have a flat surface.

When constructing especially flat roofs, it is important to have focus on damp to prevent mould.

The two common ways of constructing flat roof are to place the insulation on the internal (cold roof) or the external (warm roof) side of the construction.

The warm roof construction have mostly been used for larger buildings, but have lately also been used for small scale buildings. The reason for this is

- Better chance of conducting vapor barrier
- Lower risk of moisture damage from rising room moisture
- Tighter construction
- The load bearing structure does not expand or shrink as a result of not being exposed to large temperature differences

By placing the vapor barrier 1/3 inside the insulation, it will not be perforated as easily as if it was placed before the insulation. [Rockwool]

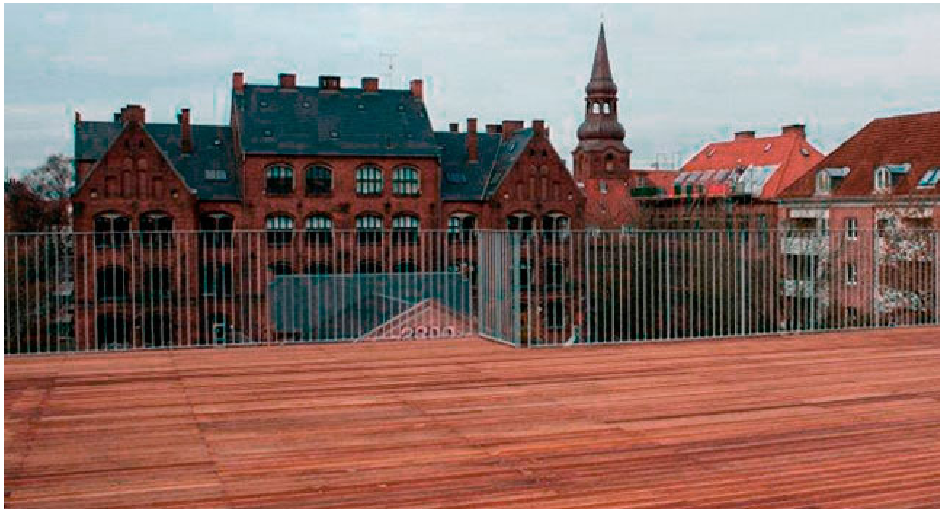


Fig. 41a. Roof terrace with wood flooring

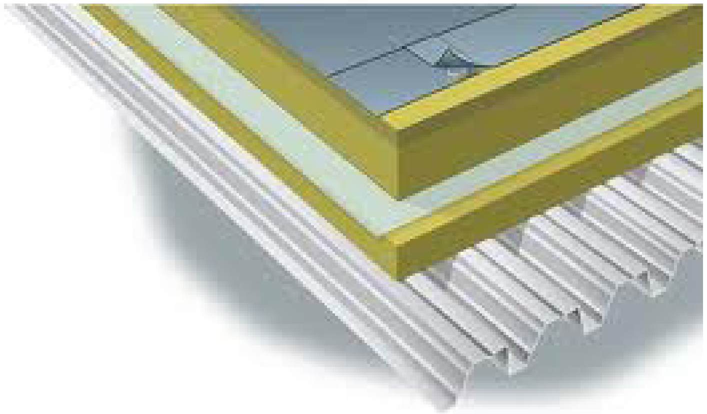


Fig. 41b. Roof construction principle, warm roof.

BE10

BE10 have been used to model the building and determine the energy consumption for later comparison.

BE10 determines the energy consumption in relation to the current building regulations (BR10).

The information applied in BE10 has been listed to give an overview, see next page.

Because of the different factors influencing the buildings performance, the calculation is divided into steps:

Point of origin: Existing building including gymnasium

Step 1: The surfaces that become internal when the new building is added are extracted from the calculation

Step 2: + 50 mm insulation and 120 Wh/Km^2 heat capacity

Step 3: + 100 mm insulation and 120 Wh/Km^2 heat capacity

Step 4: + 150 mm insulation and 120 Wh/Km^2 heat capacity

Step 5: + 100 mm insulation, 120 Wh/Km^2 heat capacity and light control

Step 6: + 100 mm insulation, 120 Wh/Km^2 heat capacity, light control and higher ventilation efficiency

Every step has been visualized with the information from BE10 and a diagram showing the distribution of energy consumption according to use.

The diagram shows the consumption in primary energy, which is the total energy consumption needed for producing one unit of energy. In the calculation of primary energy, extraction and transport of resources, conversion and transport of energy is included. [Fremtidens Fjernvarme]

The primary energy is different from energy form to energy form, as not all forms have the same environmental impact to produce [De store Bygningers Økologi]

Excessive heating is calculated as the equivalent electricity consumption for eliminating the over temperature with mechanical cooling. [BE10]

The factors for primary energy are:

	2010	2020
District heating	1	0,6
Electricity	2,5	1,8

The results of every step are analyzed and conclusions are made to see what influence the changes have.

GENERAL INFORMATION:
The school has a total area of 5046 m^2.

The building consists of three stories, a basement and a top story, all used for teaching.

The façade is massive brick wall, 470 mm in the basement and 410 mm above the basement.
The roof is clad with red tiles and currently being renewed.

The windows were renewed in 2009, with windows with the same expression as the original ones.

The classrooms have had decentral AirMaster wall ventilators installed and they are expected to ventilate according to CO_2 level.
Throughout the building ventilation chimneys are still functioning.

The facades and an internal wall constitute the load bearing structure.

INFORMATION FOR BE10

Use	Other
Heat capacity, existing	160 [Wh/Km^2]
Heat capacity, new/extra insulation	120 [Wh/Km^2]
Normal usage time	40 h/week
Start-End	8-16

HEAT TRANSMITTANCE

410 mm massive brick wall	1,2 [W/m^{2}K]
+50 mm internal insulation	0,46 [W/m^{2}K]
+100 mm internal insulation	0,29 [W/m^{2}K]
+150 mm internal insulation	0,21 [W/m^{2}K]
Brick wall workshop	0,25 [W/m^{2}K]
+100 mm external insulation	0,14 [W/m^{2}K]
Light wall workshop	0,3 [W/m^{2}K]
Light wall replaced with new	0,08 [W/m^{2}K]
Wall, new building	0,08 [W/m2K]
Roof	0,15 [W/m^{2}K]
Roof, new building	0,08 [W/m^{2}K]
Floor	0,28 [W/m^{2}K]
Floor, new building	0,08 [W/m^{2}K]
Windows and Doors	
Old doors and windows	Estimated
Renovated windows	Calculated on Rationel home page
Curtian wall, new building	1,0 [W/m^{2}K]
Sky light	1,0 [W/m^{2}K]
Linear Thermal Transmittance	
Brick wall - Foundation	0,7 [W/mK]
Brick wall - Window	0,34 [W/mK]
Workshop walls - foundation	0,24 [W/mK]

VENTILATION

Q_m winter	2,41 [l/s*m^2]
η vgv	0,65
Ti	18 [oC]
El-HC	0
q_n winter	0,3 [l/s*m^2]
$q_{i,n}$	0,43 [l/s*m^2]
SEL	0,6 [l/s*m^2]
$q_{m,s}$ summer	2,41 [l/s*m^2]
$q_{n,s}$ summer	1,2 [l/s*m^2]
$q_{m,n}$ night	0
$q_{n,n}$ night	0

INTERNAL HEAT SUPPLY

Persons	4 [W/m^2]
App.	6 [W/m^2]
App, night	0

LIGHTING

General, min	0 [W/m^2]
General, inst.	
Lighting	
DF	
Control	
Fo	
Work	
Other	
Standby	
Night	

HEAT DISTRIBUTION PL

Supply pipe	70^{o}C
Return Pipe	40^{o}C
Type of plant	Dual

DISTRICT HEATING PUMP

Type	A (always)
Number	2 (school and gym)
Pnom	2,7 [W]
Fp	0,6

DOMESTIC HOT WATER

Hot water consumption	100 [l/year*m^2]
Temperature	55^{o}C

HOT-WATER TANK

Number of tanks	2
Part of hot-water consumption	1
Tank volume	500 [l]
Supply temperature	70^{o}C
El. heating	No
Solar heat tank	-
Heat loss	0
Temp. Factor	0

CIRCULATION PUMP

Number	1
Effect	45 [W]
Reduction Factor	0,4

DISTRICT HEAT EXCHANGER

Nominal effect	16 [kW]
Heat loss	[W/K]
DHW heating through exchanger	Yes
Exchanger temp., min	0^{o}C
Temp. Factor	0
Automatics, stand-by	5 [W]

EXISTING BUILDING INCLUDING GYMNASIUM

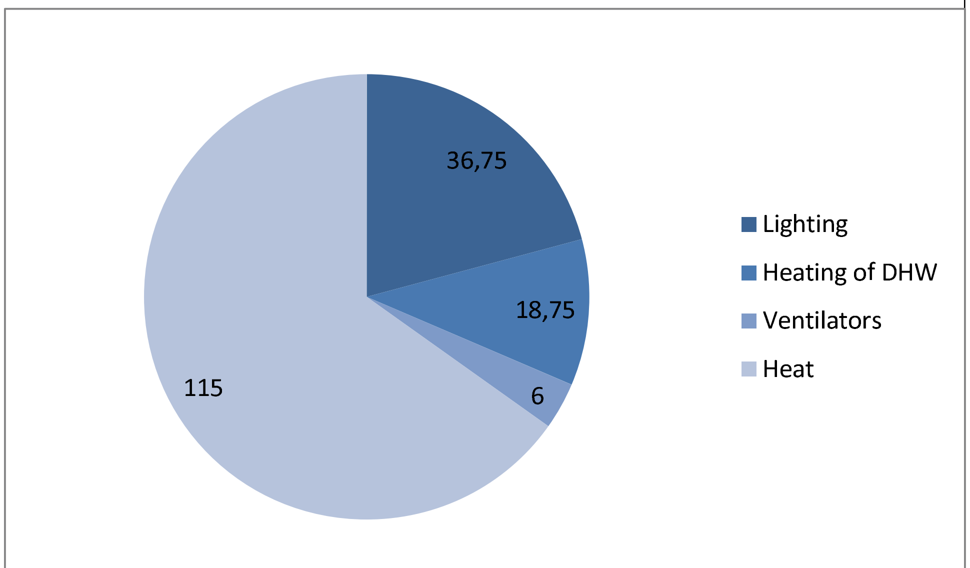


Fig. 42a. Primary energy diagram.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	176,4

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	153,4

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	113,2

Contribution to energy requirements		**Net requirements**	
Heat	115,0	Heat	115,0
El. for operation of building	24,6	El. for operation of building	9,7
Excessive in rooms	0,0	Excessive in rooms	0,0

Selected electricity requiremnets		**Heat loss from installations**	
Lighting	14,7	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,2
Heating of DHW	7,5		
Heat pump	0,0	**Output from special sources**	0,0
Ventilators	2,4	Solar heat	0,0
Pumps	0,0	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	34,6	Wind mills	

Fig. 42b. BE10 keynumbers.

EXISTING BUILDING EXCLUSIVE ADDITION

The facades and windows where the new building is added are removed from the BE10 model because the transmission loss no longer exist as the existing facade becomes an internal wall when the addition is built.

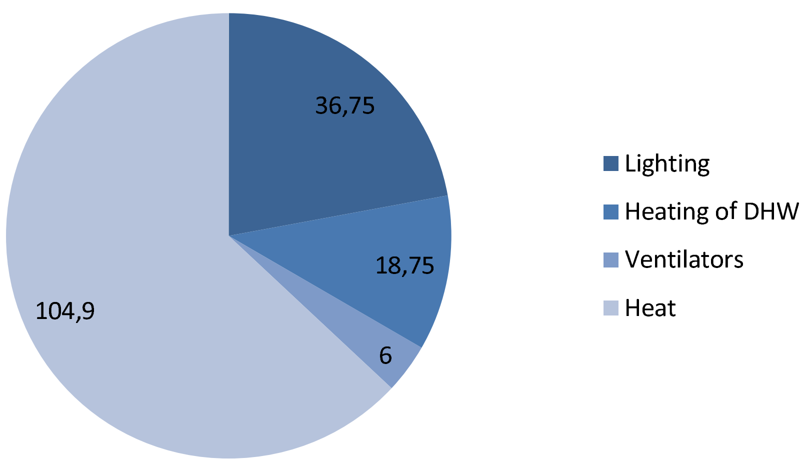


Fig. 43a. Primary energy diagram.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	166,3

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	145,3

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	107,1

Contribution to energy requirements		**Net requirements**	
Heat	104,9	Heat	104,9
El. for operation of building	24,6	El. for operation of building	9,7
Excessive in rooms	0,0	Excessive in rooms	0,0

Selected electricity requiremnets		**Heat loss from installations**	
Lighting	14,7	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,2
Heating of DHW	7,5		
Heat pump	0,0	**Output from special sources**	0,0
Ventilators	2,4	Solar heat	0,0
Pumps	0,0	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	34,6	Wind mills	0,0

Fig. 43b. BE10 keynumbers.

EXISTING BUILDING EXCLUSIVE ADDITION + 50 MM INSULATION

34,6 % reduction in heat requirement
Excessive temperature in rooms because of the decreas in heat capacity

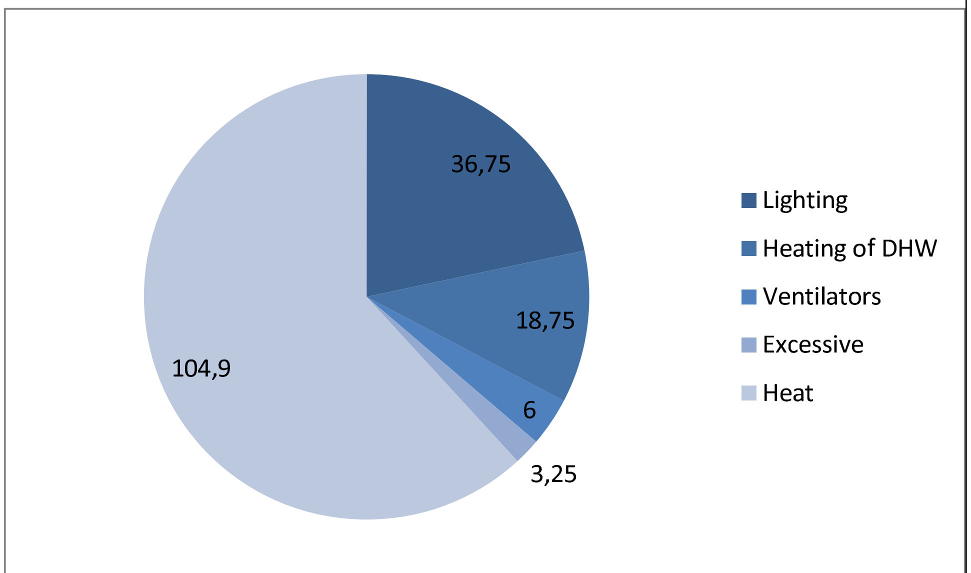


Fig. 44a. Primary energy diagram.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	131,3

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	117,6

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	86,7

Contribution to energy requirements		**Net requirements**	
Heat	68,6	Heat	68,3
El. for operation of building	24,6	El. for operation of building	9,7
Excessive in rooms	1,3	Excessive in rooms	0,0

Selected electricity requiremnets		**Heat loss from installations**	
Lighting	14,7	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,2
Heating of DHW	7,5		
Heat pump	0,0	**Output from special sources**	0,0
Ventilators	2,4	Solar heat	0,0
Pumps	0,0	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	34,6	Wind mills	

Fig. 44b. BE10 keynumbers.

EXISTING BUILDING EXCLUSIVE ADDITION + 100 MM INSULATION

43,2 % Reduction in in heat requirement
Excessive temperature in rooms because of reduction in heat capacity

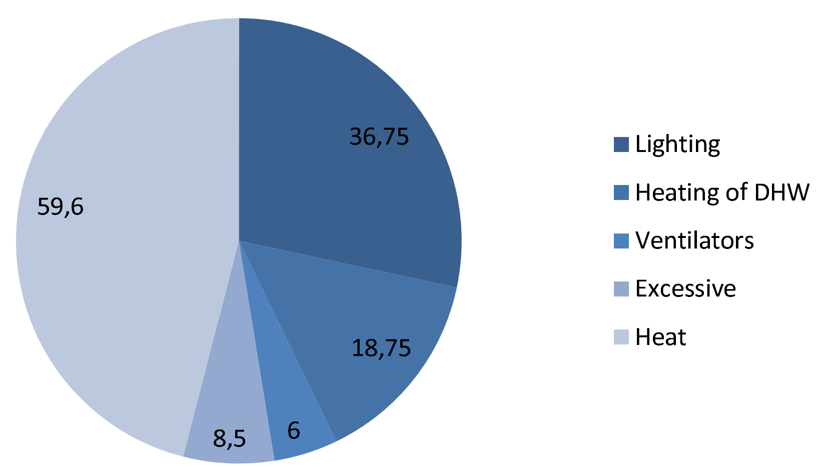


Fig. 45a. Primary energy diagram.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	124,4

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	112,5

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	83,4

Contribution to energy requirements		**Net requirements**	
Heat	59,6	Heat	59,6
El. for operation of building	24,6	El. for operation of building	0,0
Excessive in rooms	3,4	Excessive in rooms	

Selected electricity requiremnets		**Heat loss from installations**	
Lighting	14,7	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,2
Heating of DHW	7,5		
Heat pump	0,0	**Output from special sources**	0,0
Ventilators	2,4	Solar heat	0,0
Pumps	0,0	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	34,6	Wind mills	

Fig. 45b. BE10 keynumbers.

EXISTING BUILDING EXCLUSIVE ADDITION + 150 MM INSULATION

46,7 % Reduction in in heat requirement
Excessive temperature in rooms because of reduction in heat capacity

The investigation shows that the extra insulation decreases the requirement for heat significantly, but the requirements do not decrease proportionally to the extra insulation.

It is chosen to add 100 mm extra insulation to the existing massive brick walls to bring down the need for heating. This will make basis for the rest of the investigations.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	121,4

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	110,2

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	81,8

Contribution to energy requirements

Heat	55,9
El. for operation of building	24,6
Excessive in rooms	4,1

Net requirements

Heat	55,9
El. for operation of building	9,7
Excessive in rooms	0,0

Selected electricity requiremnets

Lighting	14,7
Heating of rooms	0,0
Heating of DHW	7,5
Heat pump	0,0
Ventilators	2,4
Pumps	0,0
Cooling	0,0
Total el. consumption	34,6

Heat loss from installations

Room heating	0,0
Domestic hot water	2,2

Output from special sources 0,0

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	

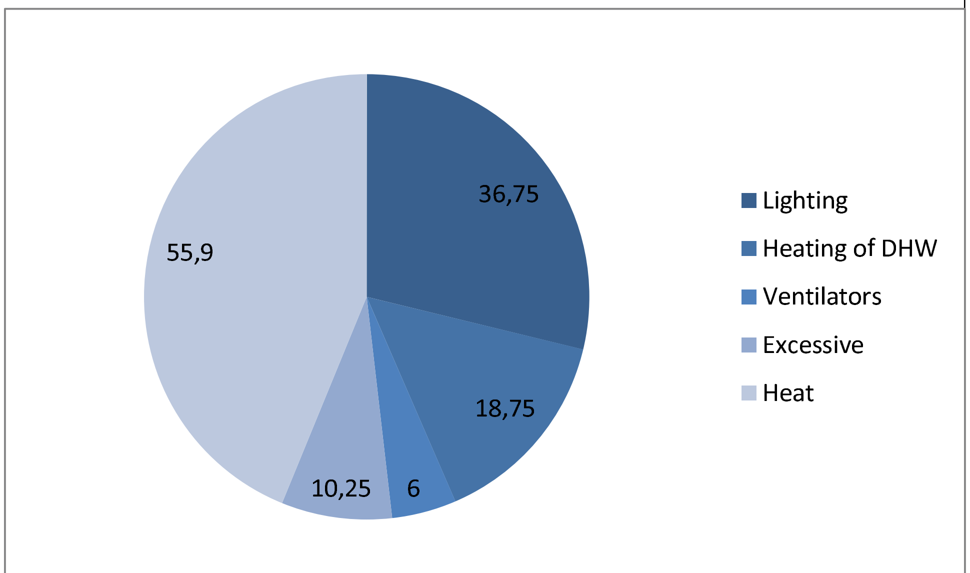


Fig. 46a. Primary energy diagram.

Fig. 46b. BE10 keynumbers.

EXISTING BUILDING EXCLUSIVE ADDITION + 100 MM INSULATION AND LIGHT CONTROL

Instead of the existing on/off light control, a flexible will help bring down the electricity consumption for lighting. The system can “switch the light on and off using manual input, daylight regulation and/or presence detection” [Philips] and thereby provide the optimal conditions.

Changing the light control from “none” to “always”

- Increases the need for heat because of the decrease in use of light
- Eliminates the excessive temperature in rooms because of the decrease in use of light

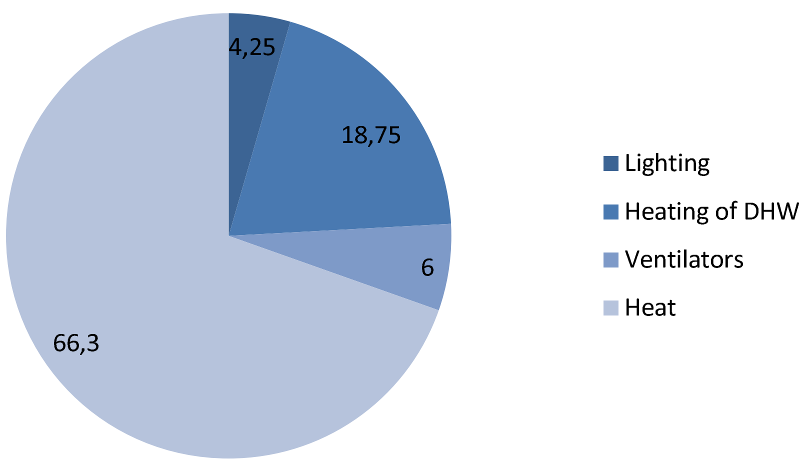


Fig. 47a. Primary energy diagram.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	95,2

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	82,0

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	60,6

Contribution to energy requirements		**Net requirements**	
Heat	66,3	Heat	66,3
El. for operation of building	11,6	El. for operation of building	9,7
Excessive in rooms	0,0	Excessive in rooms	0,0

Selected electricity requiremnets		**Heat loss from installations**	
Lighting	1,7	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,2
Heating of DHW	7,5		
Heat pump	0,0	**Output from special sources**	0,0
Ventilators	2,4	Solar heat	0,0
Pumps	0,0	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	21,6	Wind mills	

Fig. 47b. BE10 keynumbers.

EXISTING BUILDING EXCLUSIVE ADDITION + 100 MM INSULAON, LIGHT CONTROL AND VENTILATION EFFICIENCY

Changing the fans into some with a heat recovery of 85% instead of 65 %
Decreases the need for heat

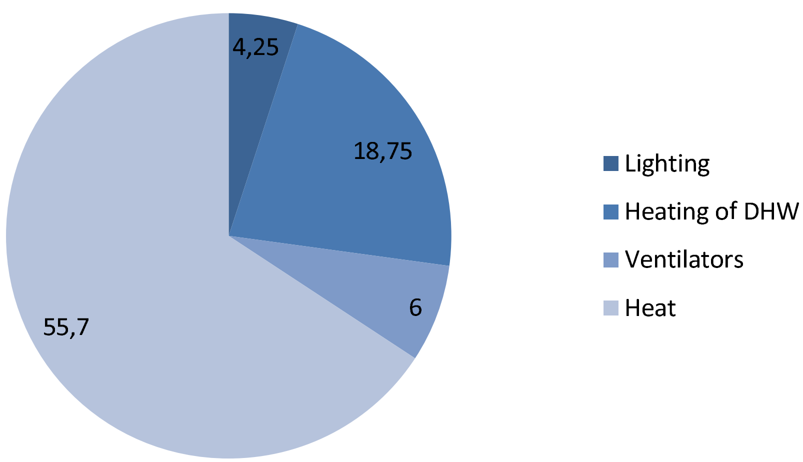


Fig. 48a. Primary energy diagram.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
71,6		71,6
Total energy requirement	0,0	84,7

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,2		41,2
Total energy requirement	0,0	73,5

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	54,3

Contribution to energy requirements		**Net requirements**	
Heat	55,7	Heat	55,7
El. for operation of building	11,6	El. for operation of building	9,7
Excessive in rooms	0,0	Excessive in rooms	0,0

Selected electricity requiremnets		**Heat loss from installations**	
Lighting	1,7	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,2
Heating of DHW	7,5		
Heat pump	0,0	**Output from special sources**	0,0
Ventilators	2,4	Solar heat	0,0
Pumps	0,0	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	21,6	Wind mills	0,0

Fig. 48b. BE10 keynumbers.

ADDITION

The new building reaches 2020 building regulation energy requirements.

KEY NUMBERS, KWH/M² YEAR

Energy frame Building 2010

Without supplement	Supplement for special conditions	Total energy frame
72,1		72,1
Total energy requirement	0,0	35,9

Energy frame Building 2015

Without supplement	Supplement for special conditions	Total energy frame
41,5		41,5
Total energy requirement	0,0	30,8

Energy frame Building 2020

Without supplement	Supplement for special conditions	Total energy frame
25,0		25,0
Total energy requirement	0,0	22,8

Contribution to energy requirements

Heat	25,4
El. for operation of building	4,2
Excessive in rooms	0,0

Net requirements

Heat	20,2
El. for operation of building	5,3
Excessive in rooms	0,0

Selected electricity requiremnets

Lighting	1,6
Heating of rooms	0,0
Heating of DHW	0,1
Heat pump	0,0
Ventilators	2,5
Pumps	0,1
Cooling	0,0
Total el. consumption	12,4

Heat loss from installations

Room heating	0,0
Domestic hot water	0,0

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

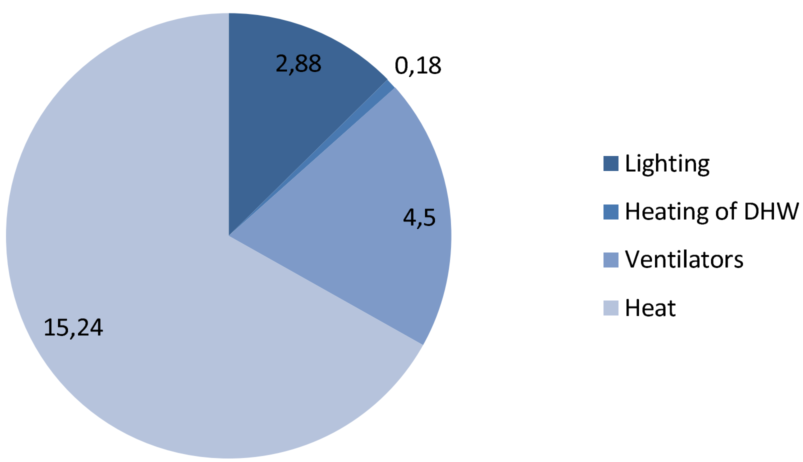


Fig. 49a. Primary energy diagram.

Fig. 49b. BE10 keynumbers.

BSIM

Building	Floor area [m²] 47	Ceiling height [m]	Volume [m³]				
People Load	Person Load [Pers] 27	Time [Weekdays] Mon - Fri	Time [Hours] 8 - 15	Schedule [%] 100	People Activity [Met] 1,3	Pollution CO_2 [l/h] 19	Heat Generation [W] 0,035
Infiltration	Basic Air Change [/h] 0,7	Time [Weekdays] Mon - Sun	Time [Hours] 1 - 24	Schedule [%] 100	Basic Airchange [l/s] 110,8	Basic Air Change [m³/h] 628	Basic Air Change [/h] 4,6
Heating	Max. power [kW] 40	Summer temperature [Celsius] 22	Winter temperature [Celsius] 22	Summer Time [Months] June, July, August, Sep.	Winter Time [Months] J, F, M, A, M, O, N, D	Time [Weekdays] Mon - Fri	Time [Hours] 8-15
Ventilation	Ventilation [m³/s] 0,111 Summer Te1 [Celsius] Winter Te1 [Celsius]	Heat recovery [%] 0,78 Summer Te1 [Celsius] -12 Winter Te1 [Celsius] -12	Heat coil [kW] 2 Summer Tinl1 [Celsius] 24,5 Winter Tinl1 [Celsius] 18	Summer Time [Months] June, July, August, Sep. Summer Te2 [Celsius] 20 Winter Te2 [Celsius] 21	Winter Time [Months] J, F, M, A, S, O, N, D Summer Tinl2 [Celsius] 24 Winter Tinl2 [Celsius] 21	Time [Weekdays] Mon - Fri	Time [Hours] 8-15
Lighting	Light level [lux] 200	Task Light [kW] 0,05	General Light [kW] 0,5	Switch [Control] On / Off	Time [Weekdays] Mon - Fri	Time [Hours] 8-15	

Fig. 49b. BE10 keynumbers.

ENERGY CONSUMPTION FOR HEATING, 1'ST OF JANUARY

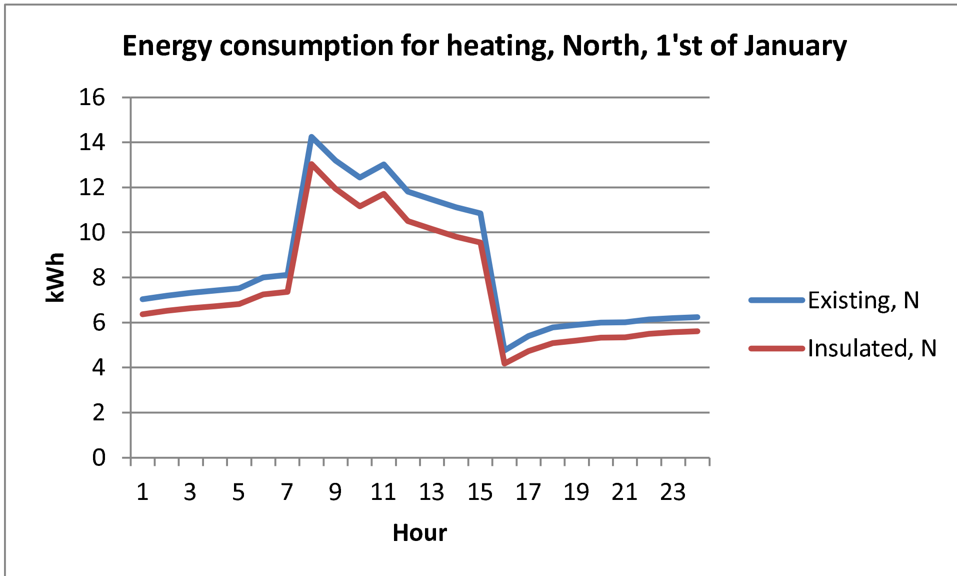


Fig. 50a. Energy consumption for heating, North, 1'st of January

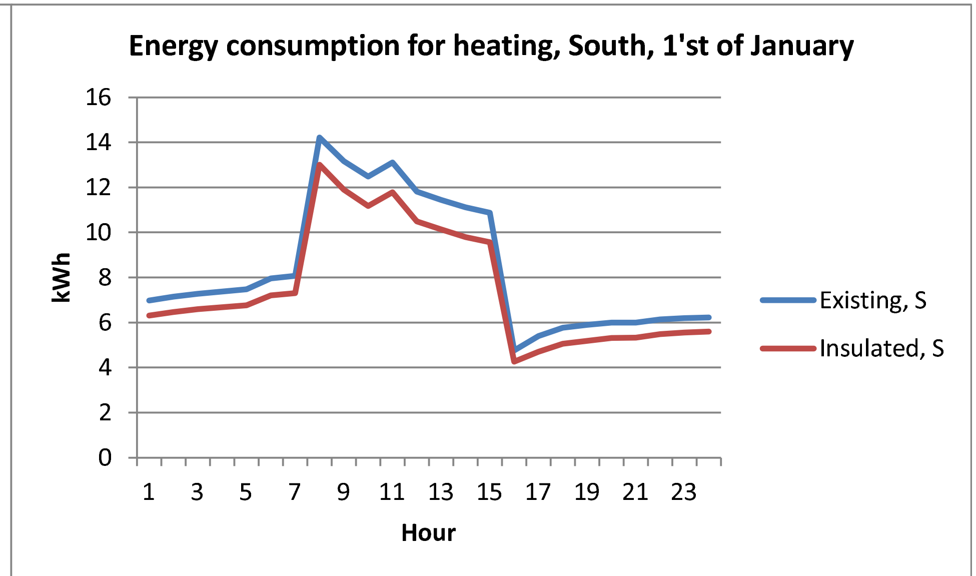


Fig. 50b. Energy consumption for heating, South, 1'st of January

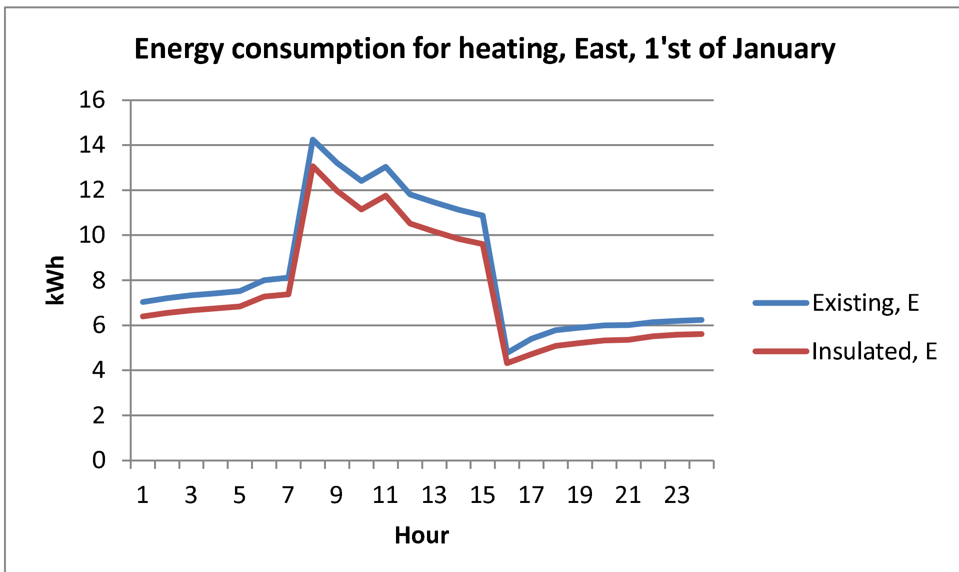


Fig. 50c. Energy consumption for heating, East, 1'st of January

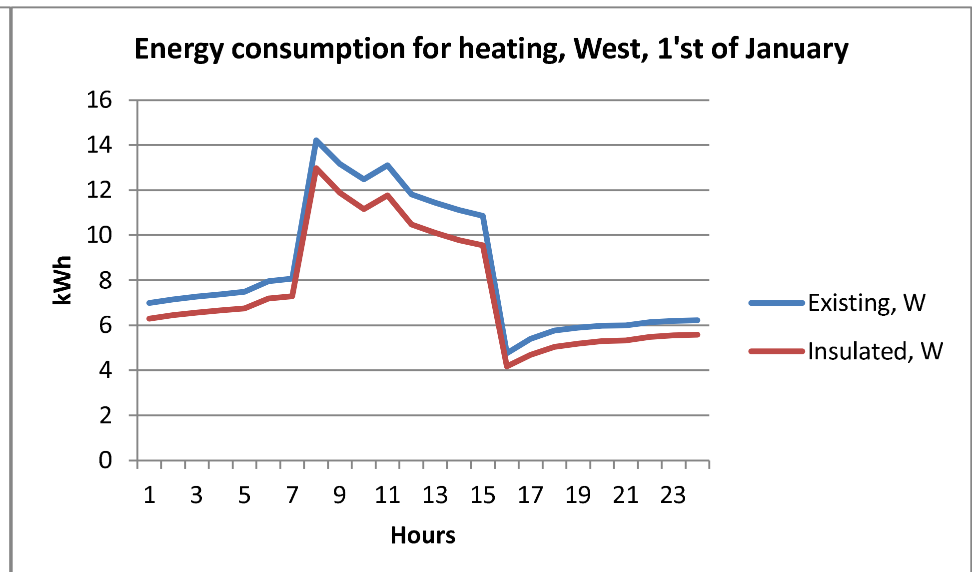


Fig. 50d. Energy consumption for heating, West, 1'st of January

ENERGY CONSUMPTION FOR HEATING, 2'ND OF SEPTEMBER

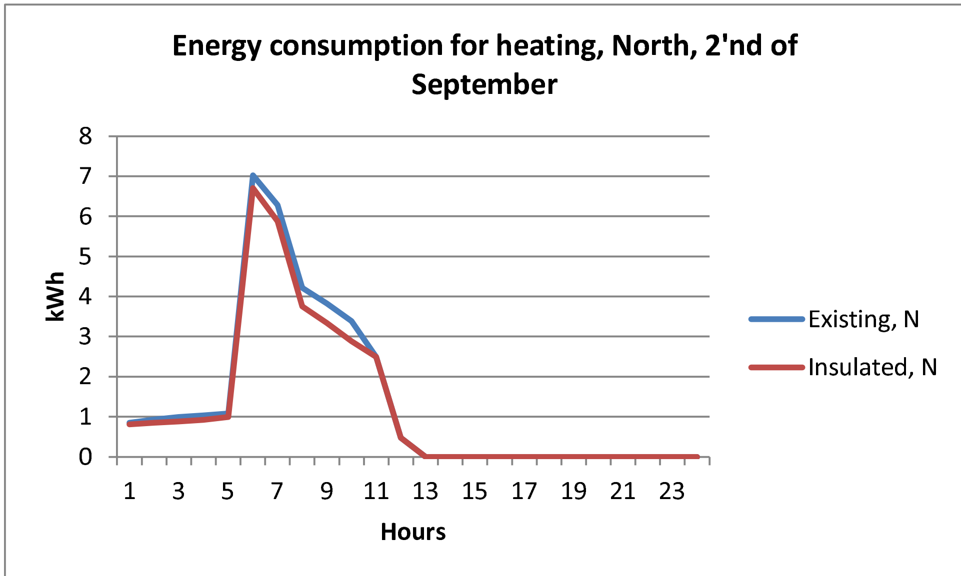


Fig. 51a. Energy consumption for heating, North, 2'nd of September

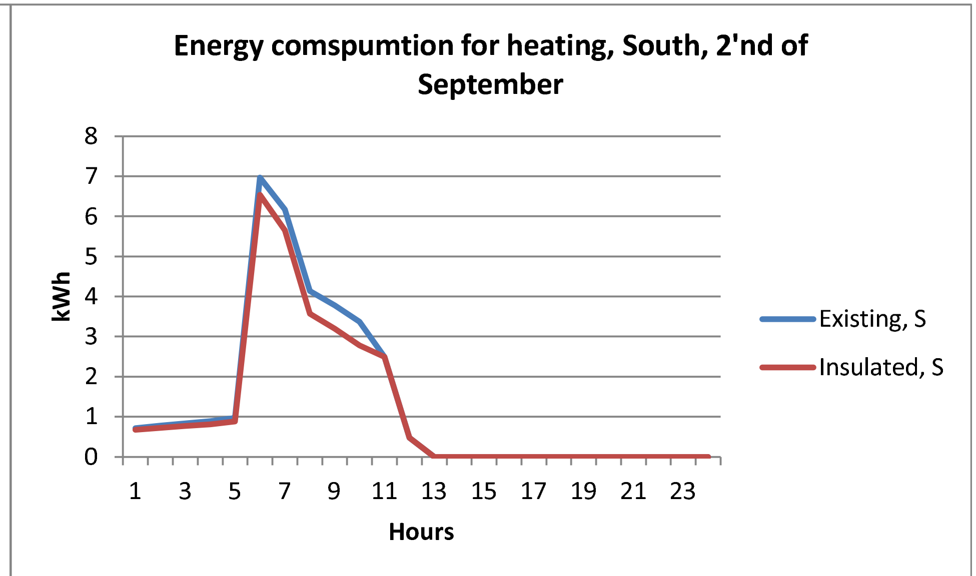


Fig. 51b. Energy consumption for heating, South, 2'nd of September

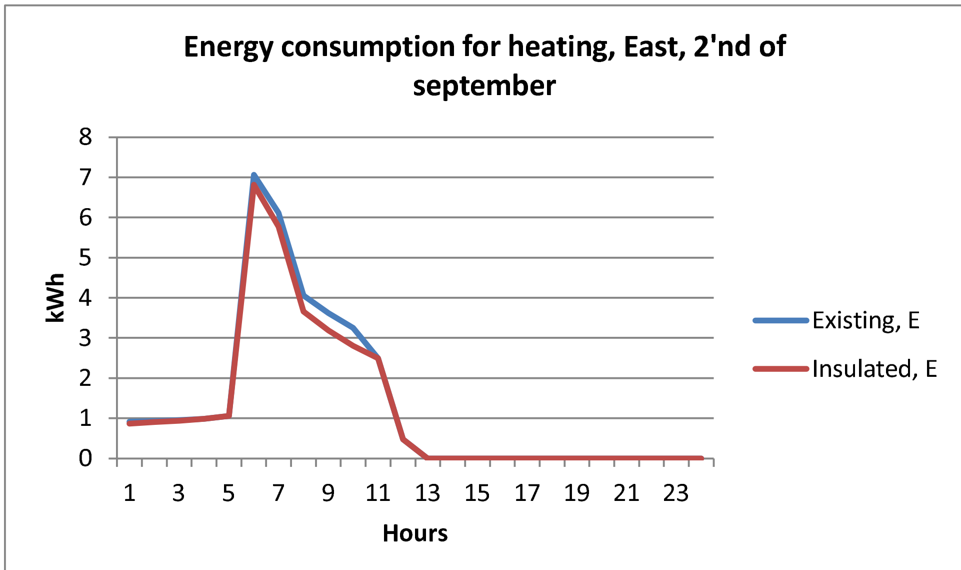


Fig. 51c. Energy consumption for heating, East, 2'nd of September

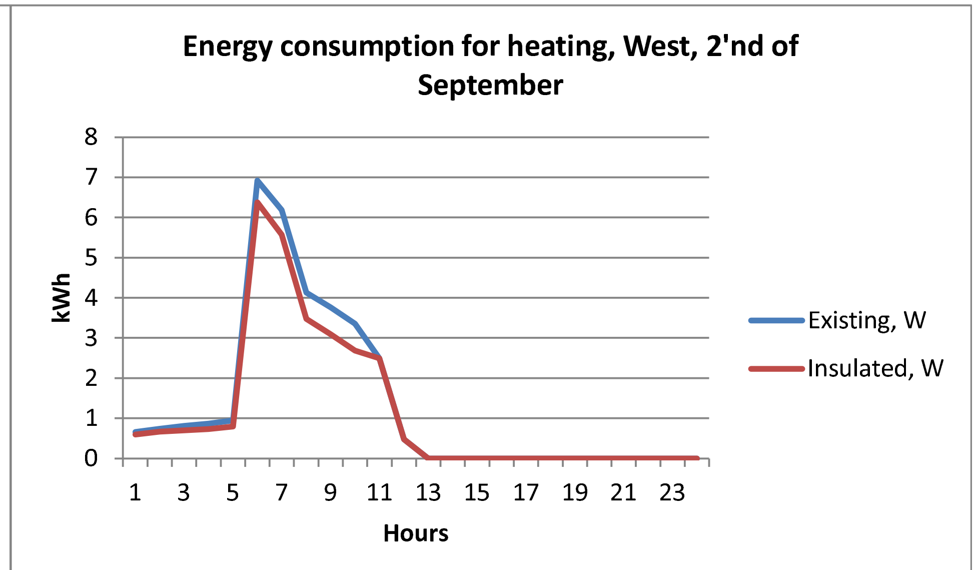


Fig. 51d. Energy consumption for heating, West, 2'nd of september

SURFACE TEMPERATURE, 1'ST OF JANUARY

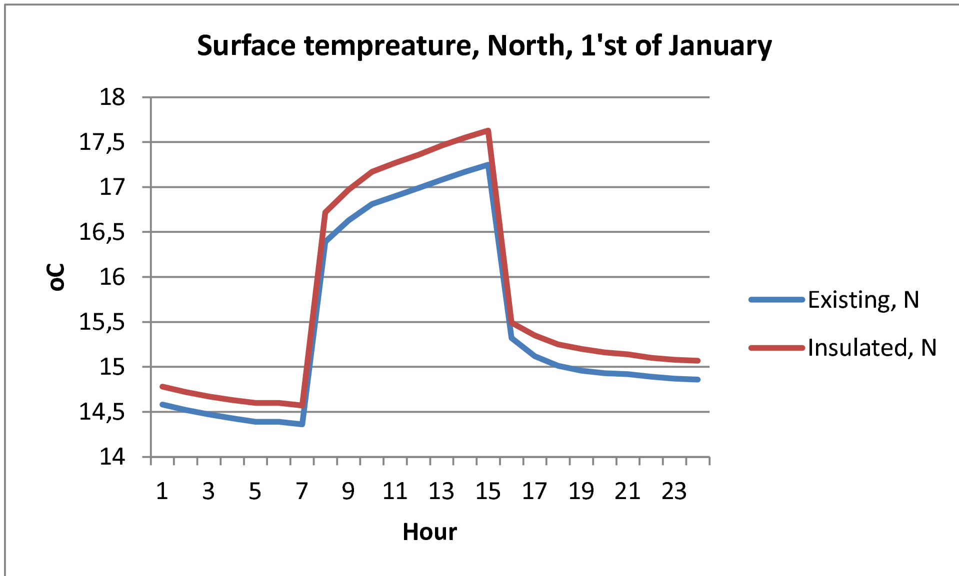


Fig. 52a. Surface temperature, North, 1'st of January

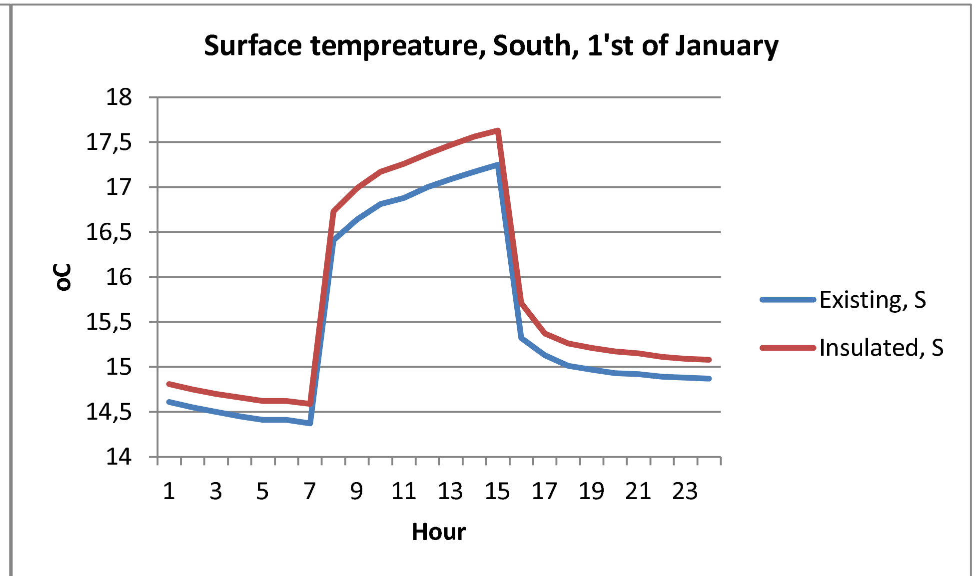


Fig. 52 b. Surface temperature, South, 1'st of January

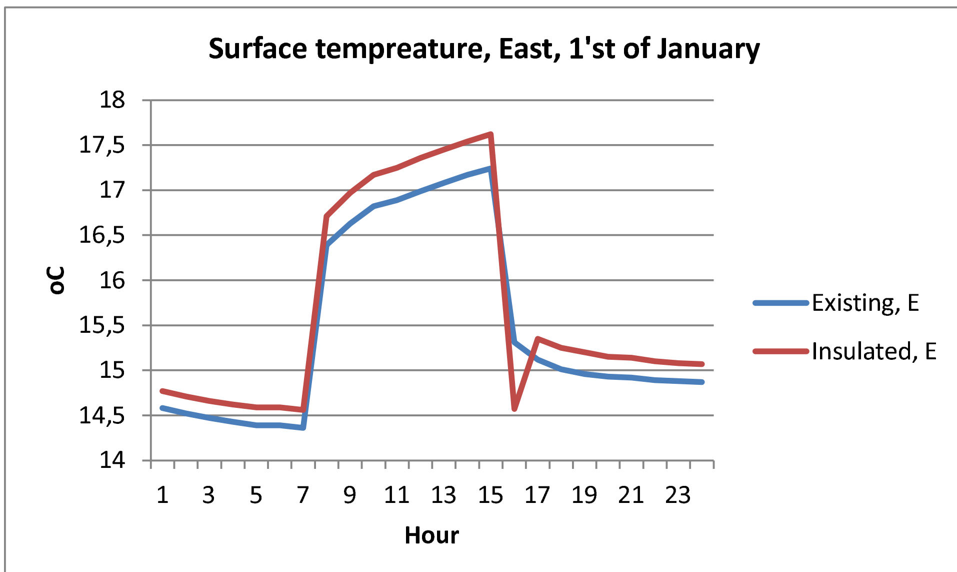


Fig. 52c. Surface temperature, East, 1'st of January

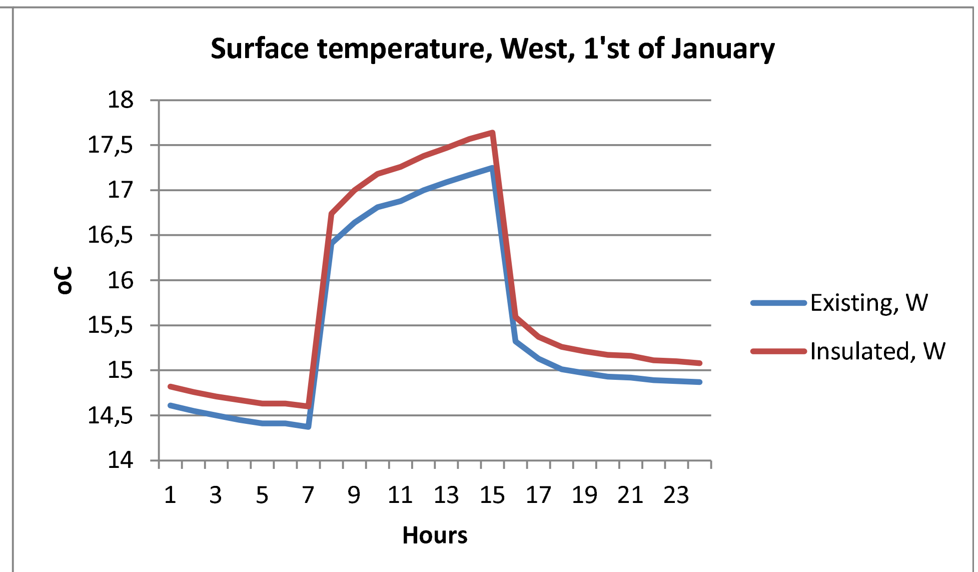


Fig. 52d. Surface temperature, West, 1'st of January

SURFACE TEMPERATURE, 2'ND OF SEPTEMBER

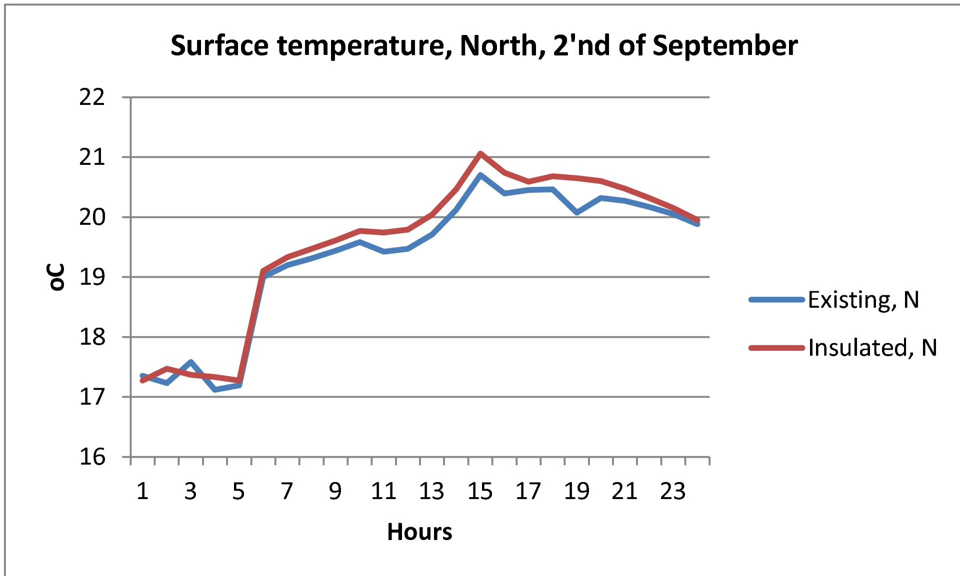


Fig. 53a. Surface temperature, North, 2'nd of September

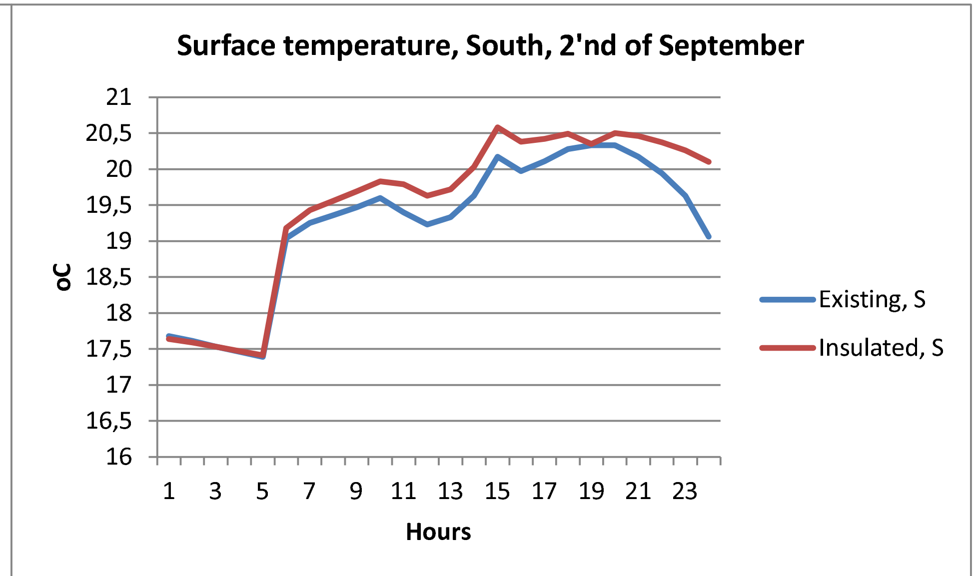


Fig. 53b. Surface temperature, South, 2'nd of September

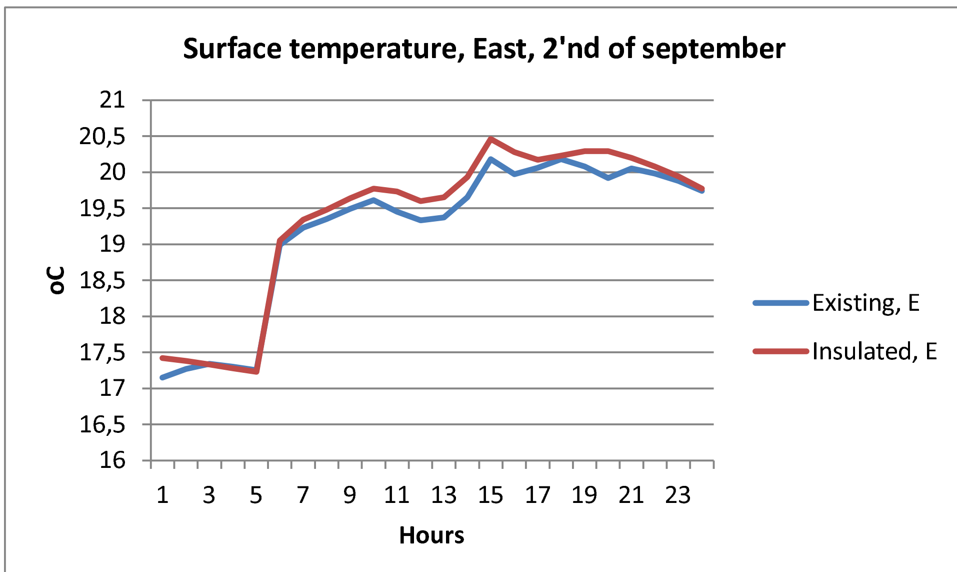


Fig. 53c. Surface temperature, East, 2'nd of September

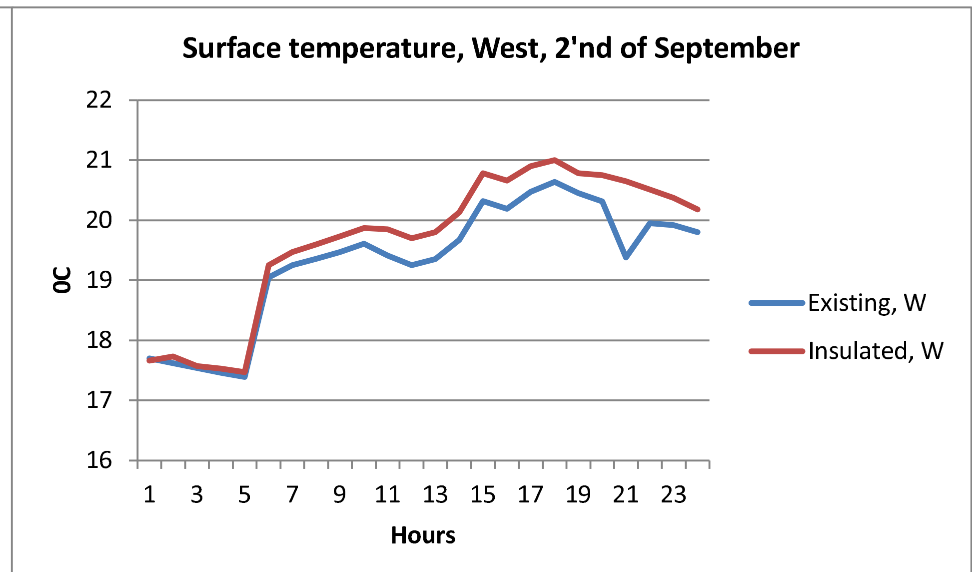


Fig. 53d. Surface temperature, West, 2'nd of september

YEARLY

After having run the analysis for a winter month and a summer month for North, South, East and West, the West-model has been used for further investigations, as West was the direction with the larges differences in values.

The yearly diagrams show a lower energy demand after the façade has been insulated. It is most significant in the winter months. As a result of the low outdoor temperature, the heating demand is higher to accommodate an ideal indoor temperature.

The temperature rises in summertime, but is almost equal in wintertime. This is a result of the lower heat accumulation value after having insulated internally. The existing façade can accumulate heat during the day and release it during the night and thereby even out the temperature. The insulated wall cannot accumulate heat as well and as a result the temperature increases.

The surface temperature has been investigated to see what influence internal insulation has. The heating is not turned off after school hours to ensure that the surface temperature is not cold when students and teachers meet in the morning. If the surfaces are cold, they radiate cold and then the room will not be comfortable to be in even though the air might be warm.

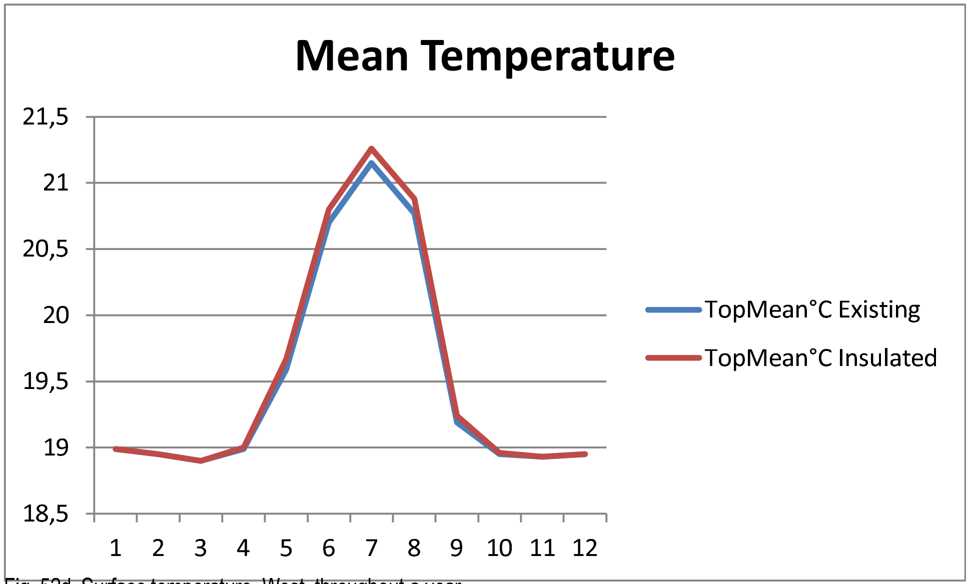


Fig. 52d. Surface temperature, West, throughout a year

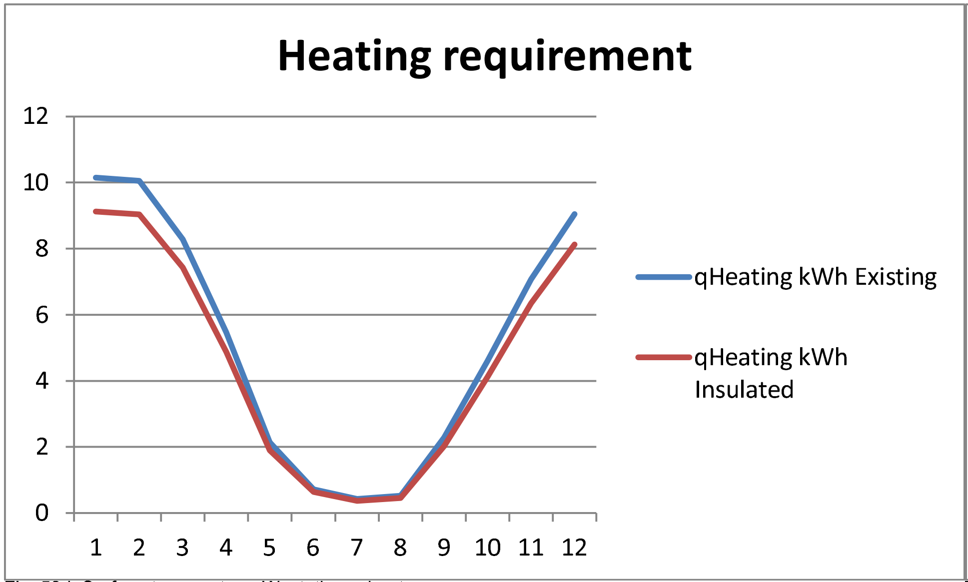


Fig. 52d. Surface temperature, West, throughout a year

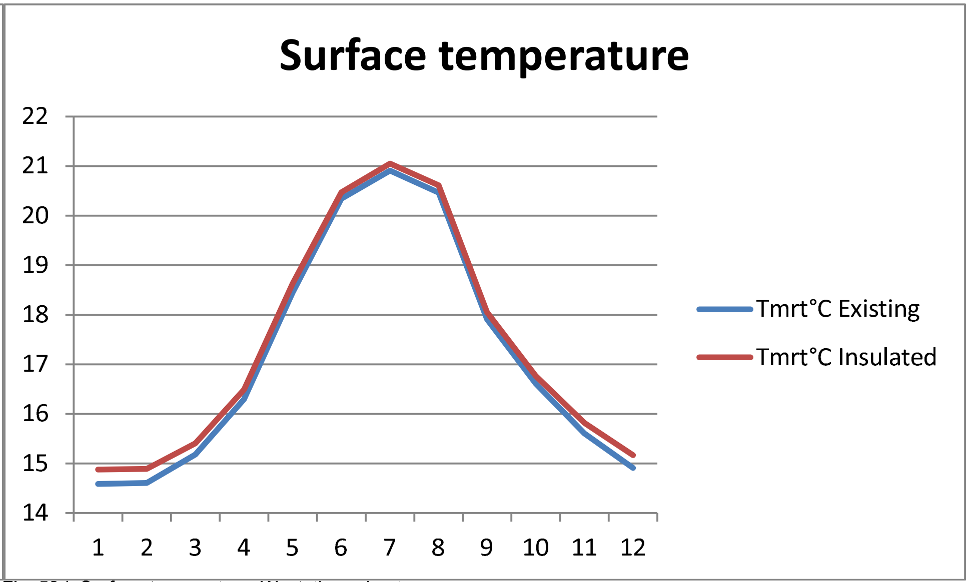


Fig. 52d. Surface temperature, West, throughout a year

CONCLUSION

The result of this project is a united school, both physically and architecturally.

The requests from the school have been fulfilled, reusing some of the existing school buildings and adding new.

New ways of teaching and buildings supporting this have been explored, and the vision of differentiated learning possibilities incorporated in the project. This has been done by having flexible spaces in rooms too small for class teaching and on platforms in the new atrium. These spaces ensure options besides the normal classroom.

The organization of the school has been based on trying to create a synergy effect from subjects relating to each other working together.

Much focus has been put on creating a community on the school for the students. This has been done by suggesting not having home based classes, but subject specific rooms the students have to commute to. In this way the students will have greater possibility for meeting across class and levels.

With the atrium providing a natural space for gatherings, the chance for meeting is even greater. Here the students can have lunch, play, work or relax. The same applies for the media center, located in the corner room of the existing school. Here it will be possible to play computer games, read books or relax.

The technical aspect was to renovate the school to lower the energy consumption and provide a good indoor environment.

Because of the already installed Airmaster ventilators in the classrooms, combined with the infiltration from the ventilation chimneys, the indoor climate rates just above class B (660ppm) with its maximum CO_2 concentration of 699ppm.

The goal for the extension was to reach 2020 building regulation energy requirements, which was accomplished. By applying solar cells, the energy consumption could be decreased even more.

Aesthetically the vision was to create an addition that related to the existing building, but would stand out from it. This has been done by interpreting elements from the existing façade and incorporating them in the new. Material wise, a metal cladding with a patina has been chosen. It stands out, without differing too much, and the detailing of the new façade, can relate to the old one, but interpreted

The wish to create a united design seems accomplished. The new and old relate and unite, both externally and internally. Possibilities for differentiated learning have accommodated along with good possibilities for meeting.

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Fig 32d. Atrium covering façade, http://www.iqnn.nl/uploads/tx_rkextttnewsdb/Conservatorium_Hotel_-_brasserie.jpg, 19.05.2013

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Fig. 33c. Risskov Skole, picture by Mattias Dorph

Fig. 33d. http://pinterest.com/pin/363876844862643719/, 19.05.2013

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Fig. 40a. Daylight factor visualization, level 0, own illustration

Fig. 40c. Daylight factor visualization, level 1, own illustration

Fig. 40c. Daylight factor visualization, level 2, own illustration

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Fig. 42-49a. Primary energy diagram, own illustration

Fig. 42-49b.Keynumbers from BE10, own illustration

Fig. 50a-52d. Own illustration