NOTES

ABSTRACT

This report presents the process and final design of a continuation school situated at the west coast of Northern Jutland. With the theme of sustainability and green roofs as a design driver the aim has been to create a learning environment in balance with recreation and maturity fitting for the teenage pupils living away from home. Drawing from research on healing architecture and its affect on concentration and calmness of the mind the approach has been to maximise views to nature and ensuring high levels of daylight. As the landscape near the coast is rough and dramatic adapting to this has been a guiding factor in the overall planning of the school. The results is a complex integrated into nature with a humble yet sharp expression.

UNDER MOOR

Daniel Bröchner Christensen
Mikkel Rafn Chemnitz
Masterthesis 2018

UNDER MOOR

A new Danish continuation school

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MIKKEL RAFN CHEMNITZ
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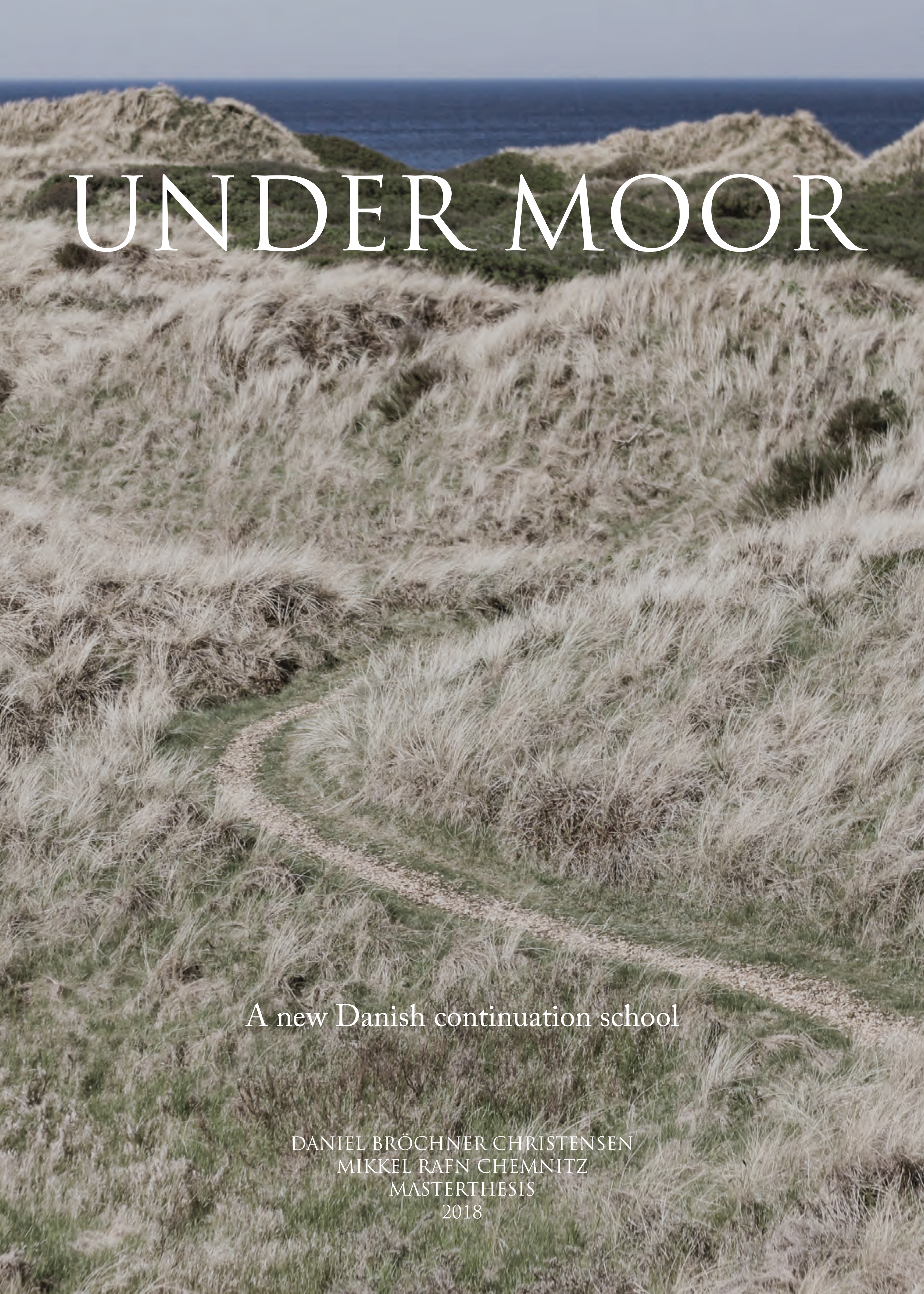

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READING GUIDE

The report will start of with an introduction where the motivation behind the whole thesis is presented together with the chosen theme of a continuation school. From here the different approaches to the theme of healing architecture and designing in a dramatic landscape will be explained together with the chosen research references that constitutes the base of the project.

Following the introduction, the methodology will frame the projects academic approach within the field of an integrated design process. The theme of sustainability is elaborated using ideas and theories of tectonic.

The project site will be presented in with analyses that focusses on the architectural context, the climatic conditions and the topography and nature surrounding it. This leads to the program analysis where a case study of Ingstrup Continuation is presented to establish a preliminary user group and function program. To establish an understanding of the traditions in Nordic architecture this is analysed. An analysis of green roofs focusing on thermal, biological and sustainable properties follow. Ending the analysis is a case study if the Danish summerhouse, theories on colour and the product of Inventilate. The Analysis is concluded in the vision and backed by the design parameters and -principles.

Following the program the process of the project will be presented, starting with different architectural references which is group into different focus point of which was found relevant for the project. The program and the reference project then lead to a design phase, the ideation, where the knowledge and investigation was combined to produce a range of different design iterations and a final concept. Ending the process are considerations regarding materiality. As a conclusion the room program is presented in tables with a focus on both architectural as well as engineering aspects. This is formalized through a conceptual connectivity.

Lastly the finished project will be presented, which is the result of the combination of the previous phase which has be combined into a finished building. First and foremost, the design of the entire complex is presented in plan and elevation, and then further elaborated through touch downs on specific functions of the school. The Techne part will dig deeper into the actual realization of the project with respects to construction, indoor environment, daylight and fire. This is concluded with a description of the applied tools throughout the project.

The epilogue concludes the project and reflect upon choices during the process as well as start of a further discussion of the project. Lastly features the list of literature followed by the list of illustrations. Referencing will be done by the AUB Harvard standard of 2010.

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PROGRAM

PROCESS

PRESENTATION

EPILOGUE

MOTIVATION

The motivation for this master thesis was to explore architecture in a human context of young people as this was previously not featured in any project at Architecture & Design. The continuation school as a theme was chosen above the public school, kindergartens or alike due to the more complex room program. The fact that continuation schools feature overnight stay was also an interesting aspect, as the use of the architecture would be every hour of the day. This would also mean emphasis not only on architecture that drives academic growth but also something that would have an impact on the personal development of youngsters.

There have been many studies on the effect of proper indoor environment in connection with educational architecture, and despite the positive outcome these aspects are not necessarily connected to the aesthetics of a space. In the approach to designing a school and spaces for learning it seems obvious to study correlations between the human brain and architecture. Neuroarchitecture is a new branch from the healing architecture exploring the stress architecture can influence humans.
There seems to be more to architecture than merely the visible aesthetics: acoustics, tactility, scent and even taste affect the human perception - this must account for the perception of architecture as well. Therefore, creating architecture – especially architecture that is used both day and night – which activates more than the visual sense should be explored.

From the research on healing architecture correlations between views – especially to nature – and restorative or de-stressing effects. Furthermore, an overall contact with nature directly or indirectly appears to have a positive influence on humans in

"STUDY NATURE, LOVE NATURE, STAY CLOSE TO NATURE. IT WILL NEVER FAIL YOU. "

Frank Lloyd Wright (Wright)

different stages of life. Working with an interesting and inspiring landscape as the setting will, therefore, be another element in a pursuit towards a holistic piece of architecture.

The western coast of Jutland has a unique character that is as enticing as it is treacherous, inspiring and life-affirming yet unwelcoming. The powerful and noisy waves combined with intense winds. The soft sand with sharp lyme grass. The warm sun and the cold water. The west coast is if anything a place of contrasts. The project site should be near this setting with the challenge of working with the elements and obtain a strong impression in the architecture and its interplay with the landscape.

Program

INTRODUCTION

The introduction will provide a guide into the thematic fields which sets the foundation for the project. With a brief description of the Danish Continuation school and its history as an institution in the Danish educational sector, this sets the topic for this thesis. Following this, the potential embedded in architecture regarding spaces for learning are discussed taking the scientific field of healing architecture into consideration. Where the healing architecture focusses on the restorative effect, the measuring parameters are often focussed on stress and hormone levels, which can be linked to an equal importance regarding learning spaces. From the studies of healing architecture, the influence of a view out to nature is further analysed in the context of learning and every-day stress. The chapter is finalised with the prospect of an ensuing description of the west coast in North Jutland and its appeal regarding this project.

Illustration 1 Rubjerg Knude lighthouse

THE DANISH CONTINUATION SCHOOL

The Danish continuation school take their inspiration from the folk high school as conceived by N.F.S Grundtvig, with the first opening in 1851 in Ryslinge, Fyn. In 1871 several continuation schools were founded as boarding schools near the newly established border between Denmark and Germany following the war of 1864. During this early period, the boundary between continuation school and folk high school is somewhat vague but eventually settled at the age of 18. (Efterskoleforeningen, 2015)

In 1930 the first law continuation schools in Denmark is adopted and has been adjusted ten times to its present state.

During the 1960's the Danish continuation schools suffer from declining intakes of pupils which eventually leads to major changes in the setup as final exams and a more regulated curriculum is introduced. With this revolution, the continuation schools start to grow drastically from the 1970's until the new millennium, where governmental subsidies make the continuation school economically available for the majority.

Today there are approximately 250 continuation schools in Denmark with more than 27.000 students distributed on three class levels (the Danish 8th, 9th and 10th grade). There are many different schools distributed in the whole of Denmark, with many different focusses and pedagogical foundations that being sport, music or religion etc. The common feature is the full-day school and student living at the school as seen with boarding schools. (Undervisningsministeriet, 2017)

The Danish continuation schools are founded on a high level of societal awareness and community

Illustration 2 Beach community

feeling with a vision of developing responsible and involved citizens. The full-day program and overnight lodging is in its own a driving force for establishing a close community with students being inter-involved 24/7. Another important part of the continuation school character is the close relationship with the teachers at all time opposed to the old fashion hierarchy and one-way communication of the past. (Efterskoleforeningen, 2012)

Being very liberal in their setup the continuation schools also structure their whole pedagogic around freedom with responsibility which leads to self-sufficient and independent students. In general, this human quality is in today's competition state very desired as there is an almost frantic search for robust and responsible well-educated labour in the western world. However, as this attribute is also more unmeasurable opposed to for example mathematic logic it is also very overlooked when discussing the future educational system and schools in present Denmark – a competition state. Not surprisingly the union of continuation schools in Denmark sees this tutoring of the "whole person" with focus on both academic as well as democratic teaching as positive and essential. In this context is also worth noticing the recent reform of the public school into a more full-day inspired program and with more emphasis on alternative learning. (Efterskoleforeningen, 2012) (Marianne Jelved om efterskolens bidrag. 2016)

ABOVE

The life and experience on a continuation school is more than anything about community and bonding with people in unique and astonishing situations.

FROM HEALING TO EDUCATIONAL ARCHITECTURE

The modern continuation school features many facilities and offers a wide range of elective courses, with a focus on a lot more than purely old-fashioned curriculum as the public school. As mentioned though the continuation schools still must fulfil the academic learning and liberal education equal to any public school. Therefore, modern and well-designed classrooms must be essential to realise the potential of the pupils. Research has already been conducted that suggest a clear correlation between a stressful physical environment and overall lessened learning potential as well as psychological challenges in pupils behaviour. (Strauss, Cody et al. 2011)

Regarding the design of educational architecture, a starting point can be to examine the research and results from the science of healing architecture. Within this theme, there is an approach of stress, a somewhat psychological condition, to be correlated to the healing of the body. Stress can be caused by physical as well as psychological influences, thus making it very a very relevant but also difficult factor for analysing a built environment. Stress also has both physical and psychological effects on humans, but in general, stress causes changes in metabolism and hormones resulting in a so-called 'fight or flight' mode where all unnecessary functions of body shuts down. (Malkin 1992)

In a long-term view stress hinders the body's ability to heal which is otherwise impelled by the natural drug endorphins. There should of course not be any need for pain-alleviation or healing at a continuation school, but as stress and stress hormones are one of the used indicators for the healing properties of hospital architecture, the conducted research is suitable for educational architecture as well. First of all, since stress, as stated, has an implication with pupils and adults

"WE SHAPE OUR BUILDINGS; THEREAFTER THEY SHAPE US."

Winston Churchill (Churchill 1943)

ability to learn and remember, it is an important marker for designing a suitable educational environment. (Beggs, Jennifer 2015)

Furthermore, the ability to learn and remember also seems to be connected another hormone, which again is affected by a stressed body and mind, cortisol. Research into the interconnectivity between cortisol and learning abilities concludes a clear correspondence for young adults. Cortisol is also one of the main markers – together with heart rates - in a research investigating the physical response to a stressed situation in different architectural settings. The conclusion is an increase in cortisol level, and heart rates for a closed setting opposed to an open, where a possible escape is apparent for the test subjects. (Dinse et al. 2017 63-67, Fich et al. 2014 91-97)

The cycle seems to be somewhat complete in terms of how architecture can affect humans and who as a result will experience a change in stress levels and as a direct consequence will have lessened abilities to remember and learn. However, the experiments and the conducted research is somewhat single-sided as only a few variables are changed regarding the Fich et al. Setup, which is also done under very staged circumstances. The reason is, of course, to control the experiment an focus on one factor in order to make a clear conclusion regarding its effect.

Staged experiments are one thing and the actual reality and context is something else, and there is also much more to a proper classroom than openness and a view to the outside. Again with the starting point from healing architecture research a large scale investigation in the United Kingdom has given way to a systematic design brief. The

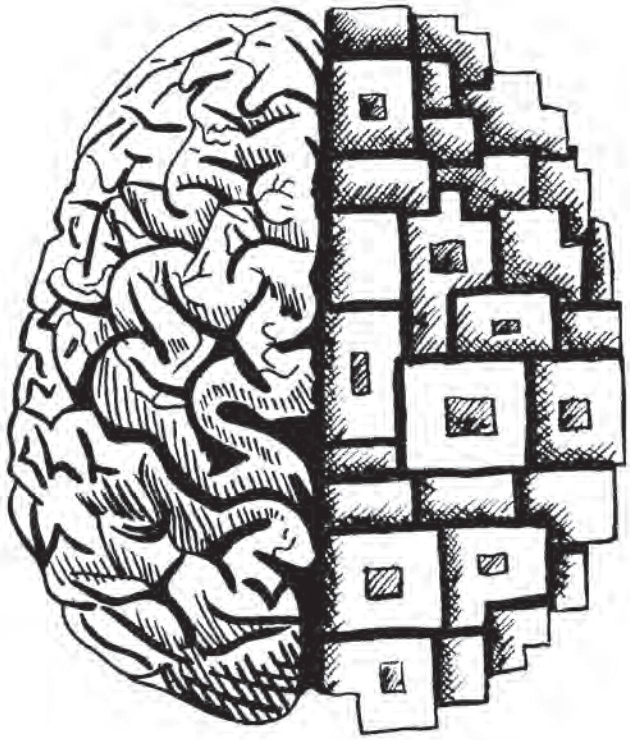


Illustration 3 Architecture and the effects on the mind

study differs from previous by collecting the many individual explorations on causes in physical environments that affect learning abilities. With 18 different design parameters clustered in three groups; Naturalness, Individualisation and level of stimulation all explored in different schools in the UK. the study is an empirical investigation in the actual context of the public school. The large scale of the study together with schools of different economic and social status evenly distributed in the country limits but does not eliminate possible factors such as teacher performance or general behaviour and approach the school system. (Barrett et al. 2015 118-133)

The results of this research are because of its coverage and systemic very suitable as a design guide for modern educational settings, and the main characteristics that support learning can be found in the figure. The full results can be found in appendix divided into the 18 design parameters and with comments on the individual support in the findings. As most of the results do not relate directly to the plan solution of a classroom, but more generic characteristics that can be suitable for learning in general the results are also more translatable to a Danish context and the context of the continuation schools that to some degree must be expected to differ from British public schools.

The results of the different researches and studies suggest that the classroom and in general learning environments of the future must have a light atmosphere with as much natural light as possible without it causing issues with glare. A direct architectural influence will be not only the ratio between window and floor area, but also the shape of rooms: A narrow long room with windows at the end will have a very differently experienced (natural) lighting with more glare opposed to a more evenly shaped room with a better distribution

Design principle	Design parameter	Good classroom features
Naturalness	Light	Classroom towards the east and west can receive abundant daylight and have a low risk of glare. Oversize glazing has to be avoided especially when the room is towards the sun's path for most of year. Also, more electrical lighting with higher quality can provide a better visual environment.
	Temperature	The classroom receives little sun heat or has adequate external shading devices. Also, radiator with a thermostat in each room gives pupils more opportunities to adapt themselves to the thermal environment.
	Air Quality	Large room volume with big window opening size at different heights can provide ventilation options for varying conditions.
Individualism	Ownership	Classroom that has distinct design characteristics; personalized display and high quality chairs and desks are more likely to provide a sense of ownership.
	Flexibility	Larger, simpler areas for older children, but more varied plan shapes for younger pupils. Easy access to attached breakout space and widened corridor for pupils' storage. Well-defined learning zones that facilitate age-appropriate learning options, plus a big wall area for display.
Stimulation	Complexity	The room layout, ceiling and display can catch the pupils' attention but in balance with a degree of order without cluttered and noisy feelings.
	Colour	White walls with a feature wall (highlighting with vivid and or light colour) produces a good level of timulation. Bright colour on furniture and display are introduced as accents to the overall environment.

Illustration 4 Overview of the results by Barret et al.

of light and smaller contrast between light and dark areas. (Logadóttir et al. 2016)

In relation to this, shading of windows can be necessary to avoid extreme fluctuations in temperature which again should be individually controllable according to the use of rooms. For a continuation school, these will also be expected to be used on more odd times of the day meaning that climatic properties must be flexible and adaptable. Directly connected to temperature is the air quality that must be sustained at sufficient levels, where the Danish building regulation can be a suitable reference, for temperatures. But here it is worth noting that research also suggests that optimal temperatures and air qualities are different from the threshold values in the directions. (Barrett et al. 2015 118-133)

Personal characteristics of classrooms such as different zones or at least adjacent areas together with display options support a more personal ownership amongst pupils. Ownership and zones of different assets lead to better concentration whereas display options improve the sense of pride and motivation that again leads to improved learning and eager to learn. To avoid too much or too little visible distraction rooms must have an adequate complexity, a balance between storage and de-cluttering and interesting aesthetics. The use of bright colours should be done delicately as smaller areas, or as furniture, where it will result in a positive stimulus whereas fully painted walls, should besides white be kept more frail colours. (Barrett et al. 2015 118-133)

ABOVE
Table showing the main characteristics of good classrooms that according to the Barret, Davies et al. study supports improvements of pupils learning.

A VIEW TO NATURE

As the daily schedule at a continuation school is much more far-stretched than the average public school with homework study until six o'clock and elective courses after dinner. Therefore each indoor space must be designed to be open, warm and pleasant throughout the day. An important part of this is the access to daylight, but merely daylight is not all. To have daylight is to have openings to the outside, and therefore a possible view to the outside that can also have a positive effect on the well-being of inhabitants. (Ingstrup Efterskole 2018)

There is a clear relation between a view to natural scenes and the restorative effects of human physique, and this has been known for more than thirty years. Being set in a natural environment any effect of a view would be beneficial according to the findings of Roger s. Ulrich. Therefore there is a strong potential in the effect of any view, though this is given the restorative effects. (Ulrich 1984)

As mentioned the restoration and healing of human physiology are linked to a stress body and mind. To further elaborate what a view can do to the mind it is relevant to look into the difference between having and not having a view. When stressed out the human body shuts down less important functions and the mind focusses on fight or flight. In any stressed situation, the mind searches for a possible flight and if a such does not exist the level of stress will increase. A view hinders stress and leads to a higher level of concentration, as well as better presentation performance and is therefore desired in any room where concentration is needed. (Fich et al. 2014)

Illustration 5 A peek out to nature

Being a sports and music continuation school the benefits of views from different rooms might be even more numerous. Though concentration is a part of sport and training and in order to obtain full, potential there might be more to it. The tranquillity of nature offers a possible restorative and stimulating effect that could be compared to physical gains of training. Looking into a more qualitative research it seems that even though training can benefit as a procrastination, different settings have an effect on just how well a person can empty their mind. In the context of a continuation school, it must be expected that many of the pupils will have unresolved issues that need attention. To cope with this in the every day any jog or sporting exercise should help ease their minds and therefore any view can help to facilitate a calm mind of a young person. (Olafsdottir et al. 2017 358-365)

A view out on nature can surely have a positive effect on a person's state of mind in the context of a restorative situation. Research also suggests that the same goes for conditions of more mental stress being tests or interviews as well as dealing with personal problems. With an underlying base of a correlation between views to nature and the stress hormone cortisol and an equal between the latter and learning capabilities a view out to nature, therefore, be argued to have a positive effect in a learning environment. (Dinse et al. 2017 63-67)

ABOVE

Looking at nature has a tranquil effect the physical and mental well-being of humans. The articulation of a view can be varying to accomedate the need for privacy or shading as this modern summer house with small openings in the large sliding doors.

THE WEST COAST

The history of the Danes at the northern west coast begins around 5000 BC with the first settlers of ancient times arriving at these hostile locations. As with many encounters between humans and nature, they would affect each other and things would be flipped upside down. At the point of the settlers arrival, Denmark was characterized by raging forests, which gave way as material for the first small communities in the shape of building material for small coverings and boats as well as providing firewood so that food could now be cooked – this was the first small (r)evolution.

The harvesting of the forests and grassing of animals eventually meant a dilution of the rich vegetation and as a result, the sand of the beaches started to wander. About 500 years ago it was evident that the lack of flora and forest was a serious threat to the communities along the west coast. However, there was little success until the 1800's where, under national guidance, the many plantations and wild grass were rooted.

With the sand under control soon after a new concern finds its way into the minds of the people on the west coast. As the world is now starting to globalise with commerce and trading between countries, and the choice of transport is now big ships with precious cargo, oppose to the settlers original small fishing boats. Many trades are done between the inhabitants near the west coast and Norway. However, the increased size of ships also means that more and more life and cargo are lost at sea in the waves, with the wretchedness (in Danish; Jammer) giving name to Jammerbugten (directly translated; the bay of wretchedness).

Along the coast, the characteristic rescue stations with two flags on the gable doors are set up during the 1850's. With trading and commerce

Fyld mere salt på
Fyld mere malt i
Sæt mere strøm til
Fyld flere drømme i mig

Blæs mig igennem som et mælkebøttefnug
Der kæmper for at få lov til at gi' slip
Blæs mig til grunden som en udestue
Der aldrig sku' ha' været ført op

Vesterhav kom nu og blæs mig igang
Hjertestarter

Simon Kvamm (Kvamm, 2012)

slowly centralising in the major market towns the 1900's brings a new context to the west coast. The first to conquer the west coast with a new state of mind is the many Danish artists and painters who utilised the special lighting and the breath-taking landscape. Soon after, with help from a new vacation law, the common Danes follow first residing in hotels or small cabins, but after WWII and with the economic growth most of Denmark's vacation homes were built between 1950 and 1970. Today not much has changed as the rough ocean, the wild nature and the special light still attracts not only the Danes, as soon as there is a glimpse of sun, but also many foreign tourist flocks to the west coast bringing all the life back into the many small towns that have stood still during the cold winter. The history and the life on the west coast have very much been on the premises of nature and still is.

Not far from the project site you find the tourist attractions of Rubjerg Knude and -Church and the old cemetery of the Mårup church. What makes these site so special is their very evident depiction of the forces at stake in this region: Moulded thousand of years ago the coast rises dramatically to 60 meters height above sea level, and with this rise, a clear-cut seems to appear depicting history, showing rudiments and different minerals layered in time. On average the coast here moves east at one meter per year, and though the coastline is not elevated at the project site, the rest of the drama is still apparent. Open out to the North Sea there is little protection against the wind coming from the west. This means that it hits with its full force, resulting in for instance flight of sand. So how come so many people flock to the coast in the summer, and how come so many choose to construct a vacation home here? (Skov 2009)

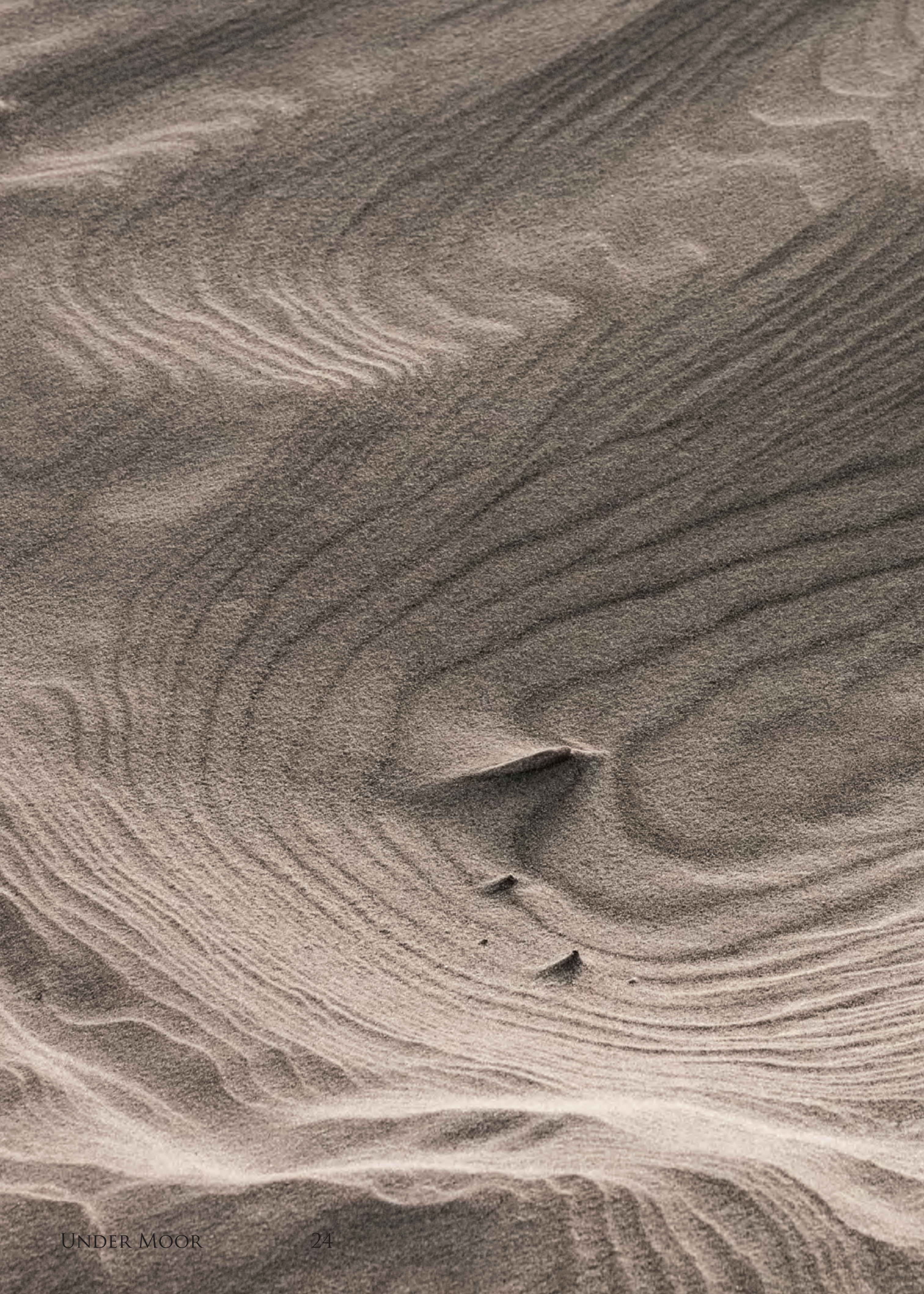
Illustration 6 Houses in Lønstrup

There is something about the light, which attracted artists, and there are beaches, but all of it is very inaccessible oppose to many other places. The sand may very well be the softest found in Denmark, but all around you find lyme grass characterised by very sharp edges on the leaves. Any relaxing swim should be supervised as the waves can be treacherous and as a child, you are told to respect the ocean. By Danish standards a very hostile environment, but also worth it due to its beauty. Perhaps it is that hostility that attracts so many because you feel more alive at the west coast. You are constantly reminded by the forces of nature, what it can do and therefore also feel a sort of gratitude for everything done by mankind, that makes it possible to live. The trees are crooked and skewed, some even broken or fallen over, and most other flora has evolved to endure the lack of nutrition in the soil such as the lyme grass or heather. (Bjerg, Halberg 2002)

The colours are very subtle in a way as brown and purple from the heathers are the only deviations in an otherwise delicate yellow-green canvas by the lyme grass, sand and pine trees. The dunes shape the landscape into dynamic three-dimensional waves and at the steepest points, nothing grows on them demonstration the patterns by sand flight due to the wind. This is so far from the agricultural planes inland Denmark has to offer and their moderate gradients. Anywhere in the plantation forests, you are never really alone as the sound of the wind and the waves are always present. With no big rivers or waterfalls in Denmark the waves on the west coast – oppose to the rest of the country – this is the only place where the potential of energy stored in water is both visible and audible. The west coast is where nature in Denmark is more alive than any other place. (Bröchner, Chemnitz 2018)

To be at the west coast is to survive, and to survive is to be alive.

Illustration 7 Where the sea meets land



METHODOLOGY

Rooted in the institution of Architecture & Design the methodology starts off with the Integrated Design Process. With the theme of sustainability as the overall thesis-theme, the IDP is adapted to this discipline resulting in a more complex scope of focus. The approach to sustainability as a natural element inherent in the theories of tectonics follows and should be seen as the primary approach to the theme of sustainability, where nature is major part together with social sustainability in the shape of community.

Illustration 8 Sand erosion

INTEGRATED SUSTAINABLE DESIGN PROCES

The methodical approach will in outline follow the Integrated Design Process – the core of the academic programme at Architecture & Design. The method focusses on the interplay between engineering and classic architectural discipline's featured in modern complex building designs. Through the integration of cross-disciplinary knowledge and with the use of actual problems and site the design process is driven forward toward a concrete architectural proposal of high complexity. Complexity will be achieved through various hermeneutic circular processes of analysing, sketching and designing from a previous perceptual understanding in order to reach a higher level from each exposition. (Knudstrup 2005)

In addition to the Architectural and engineering discipline rooted in the education, the whole aspect of sustainability will operate as a third academic element with its own respective components. At the same time, the theme of sustainability will through the integrated design process be intertwined with the architectural and engineering aspects. Sustainability is in general terms a very wide topic ranging from environmental to economic or social aspects. (Knudstrup, Bejder 2014)

The methodology in this thesis follows the process of the IDP with the first phase consisting of different analyses in order to obtain an understanding of the site and context together with the theme of educational architecture, neuroarchitecture and the multi-sensory architecture. Through research papers, mapping and phenomenological investigations this base of the project will drive the design forward with respects to all three elements of architecture, engineering and sustainability. To further clarify the design process the themes

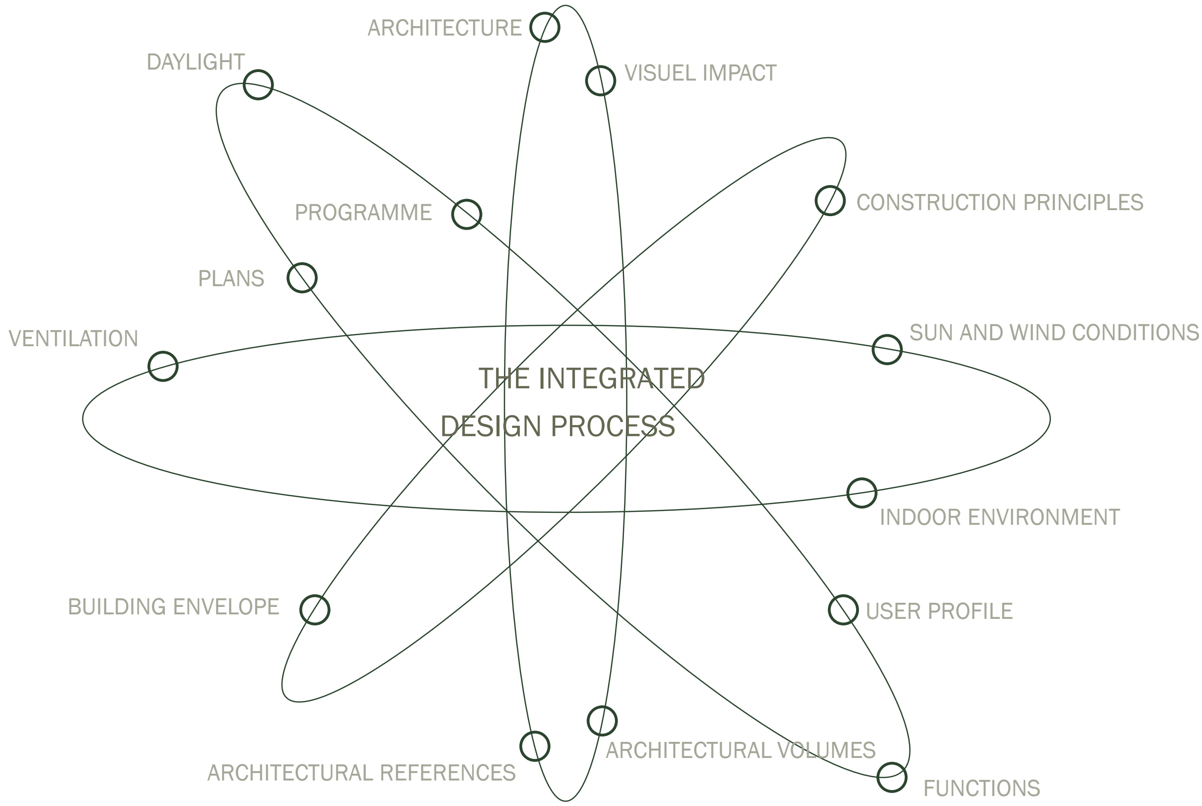


Illustration 9 Essential design parameters in IDP

ABOVE

Reproduction of the diagram originating from the Integrated Design Proces, by Mary-Ann Knudstrup. The diagram shows the vast number of design parameters that inflict a modern sustaianble piece of architecture and their interrelation in the proces. The model takes consideration to the many needed technical aspects of modern architecture that if not considered early in a design process may have a negative influence later on.

”Man has no place, and therefore he goes back into himself because nature is no longer internalized as instinctive knowledge. [...] We have created a correction, a revelation of a dream, and with the dream comes passion.”

Sverre Fehn 1980 (Fjeld 2009)

of Tectonic sustainability, Nordic architectural tradition and colour theory will be incorporated. Working with different case studies will link the project to the present reality where the theory will encounter actual practice. (Knudstrup 2005)

From the analysis phase, the individual results will be processed towards design principles and design criteria's which respectively features architectural, engineering, or sustainable aspects. In the sketching phase, the elements will further on be combined thus integrating the design into interdisciplinary principles and demands for the architecture. During this phase, many different implements will be exercised ranging from pure analogue to solely digital and varying combinations.

Synthesising the design in the next phase the different more generic principles will be elaborated into a final design of a high complexity. Through this process, further characteristics and qualities might turn up. From here the final design will arise and be detailed.

The final phase, the presentation is the communication of the final design where different media will ensure a clear yet variated and interesting exposition.

FOLLOWING PAGE
The Integrated Design proces, shown as a simplified diagram corresponding to the described phases . The process features many steps back and forth each with a higher level of knowledge as a driver and result.

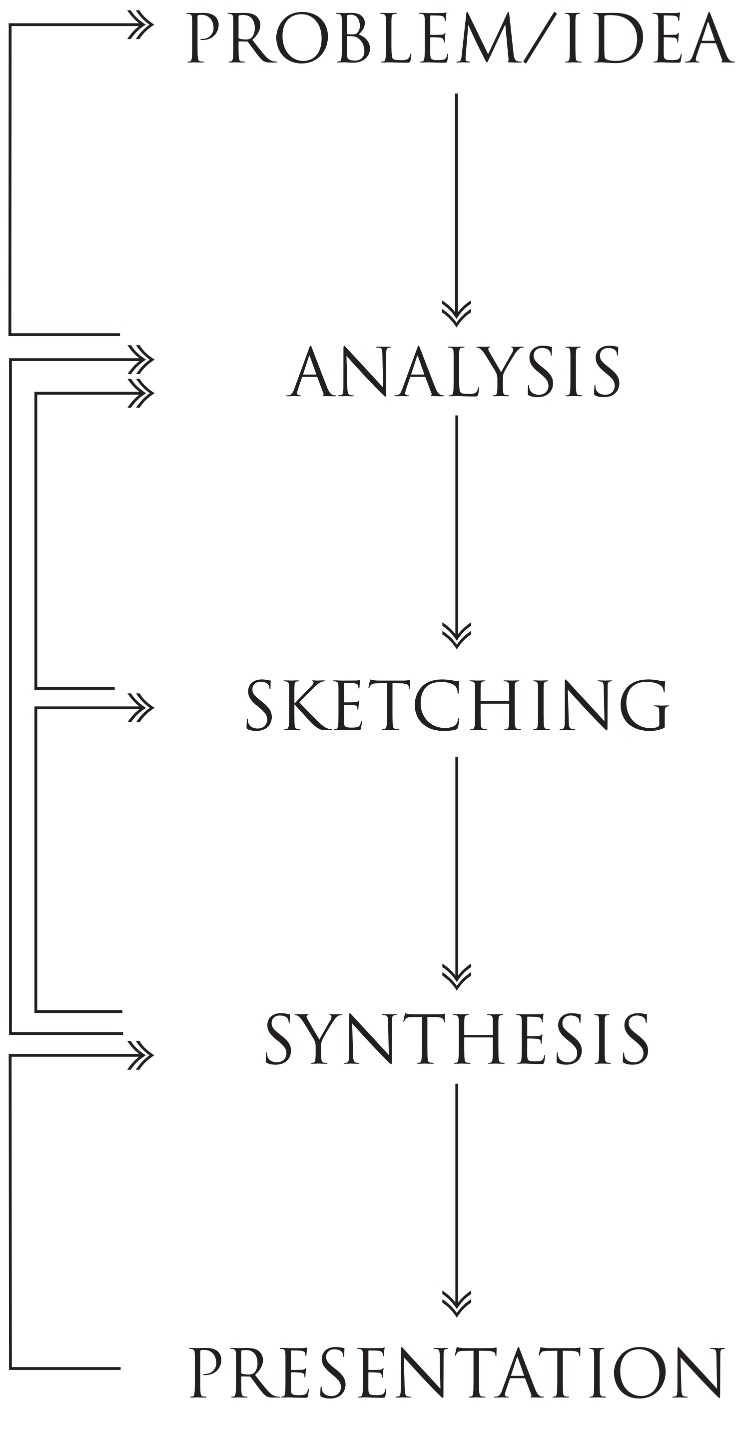


Illustration 10 The Integrated Design Process

TECTONIC SUSTAINABLITY

To say exactly when architecture began, will first of all be a question of a definition of what makes something architecture and perhaps more important what conditions does not make-up architecture. Furthermore, there is an inherent quest in archaeology to state the point in time where the modern human begins its evolution – the point where we as a race stopped being an advanced animal or ape and became a modern man. Several finds have in recent years together with better technology shifted this line and the conception of how homo sapiens evolved and populated earth. (Hannestad 2018, Thorsen 2011, Ritzau 2017) Semper who states:

“Only the potter’s art can with some justification perhaps claim to be as ancient as the craft of carpet weaving.” (Semper 1851)

The weaving of different materials with respects to availability, climate, natural surroundings and social relations creates not only a covering and a protection but also a statement of a sort as the interplay of the human touch and the altering of elements transitions it from natural to fabricated or to put it bluntly; unnatural. But the woven carpet also created something else: the architectonic division of spaces. (Gottfried Semper 1851)

However, Semper also put an emphasis on the settlement with the preparation of the fire for cooking as an important point in the history of man and the history of architecture. Around the fire, humans have always gathered to get warm, to be safe, to tell stories and to form new alliances. But the fire also provided a media for something else: Cooking. It is still unclear when humans – and which ancestral race – started to cook food but studies show that animals prefer cooked food

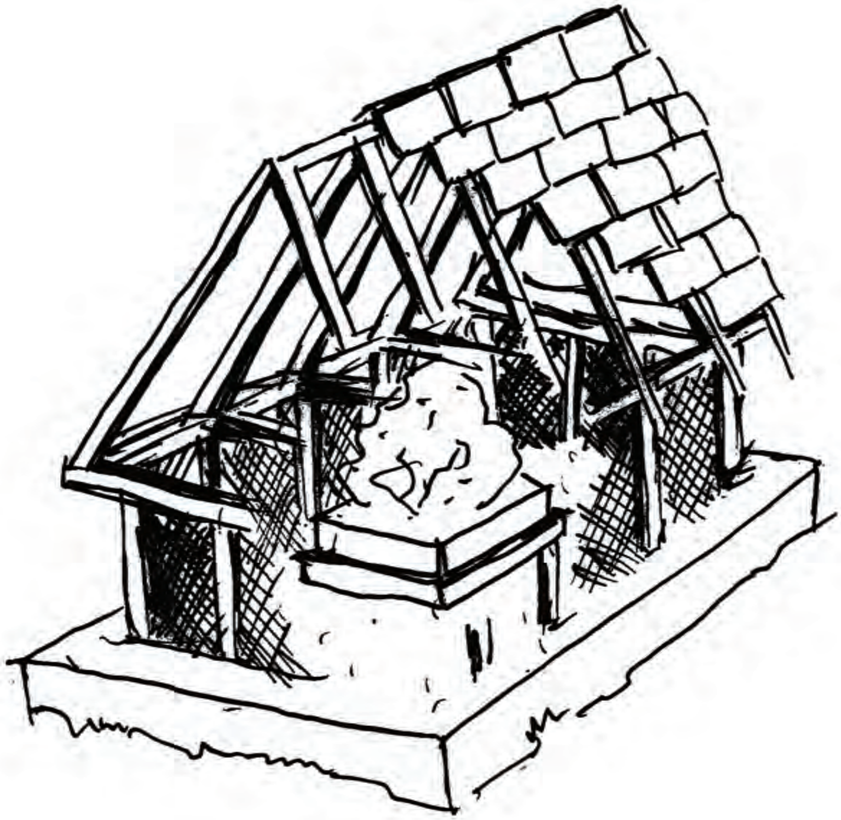


Illustration 11 Four elements of architecture

over raw. At the same time studies in evolution proves that animals – humans included – adapt and evolve according to their diet and not the other way around. (Wrangham 2009)

According to primatologist Richard Wrangham, the transition from ape-like animals to the first human race is the adaptation of a cooked diet and with it the control of fire and tools to utilize the methods. This fits with Semper's view on the central fire, the hearth and his argument that humans have strived to protect this. With the adaptation of a cooked diet, humans generate much more energy from digestion than animals on a raw diet, and with less energy spent on digestion. This is according to Wrangham one of the major stimuli that led to the drastic development of our much larger brain. Therefore the control and protection of fire is essential to the survival of humans.

"If we lost our ability to have a fire, we would all die" (Wrangham 2016)

In this perspective, the protection of the hearth is perhaps more important than the protection of the humans themselves. In the first part of The Four Elements of Architecture Semper also sets the hearth as the base for the other three elements as protective parties. This notes that architecture is the mean to keep nature away in order to survive.

Today – thousands of years later into evolution – not much has changed as buildings still sit atop a base on earth with walls and a roof to protect the central hearth – the kitchen. Materials have evolved and new ones have found their way, but the principle remains the same. One of the more apparent changes and one with a very significant impact on the way architecture is used and where modern architecture moves away from Semper's

PREVIOUS
Sketch of concept of Sempers fours elements of architecture: The central hearth on the earthwork base, enclosed by the weaved walls, and covered by the roof

OPPOSITE
Entrance to sporting hall at Rødhus Klit.
Example of nature as a central part of architectural design, as a dune is built ontop of the hall making it seem like a entity with its surronding.

four elements is the radiator or underfloor heating. With this invention, humans were suddenly detached from the central hearth as the source of warmth, and for some time even the cooking of food was decentralized only to be reinvented today as the modern open plan kitchen/dining/living room.

It is however still the heat source and the ability to contain this that makes up the principle of architecture and for a long time the evolution of the hearth in terms of its heating capabilities – even decentralized – that made architecture more and more comfortable. Since the 1970's, in Denmark or other northern countries, the shielding qualities of the three protective elements, the roof, the wall, and the groundwork have evolved into what is seen today as more sustainable. A terminology has evolved with important words such as low energy, solar or passive heat from an idea that buildings to a greater extent should supply their own energy. Better insulation and a more tight building envelope have led to the hearth previously being the most important part of architecture, the starting point of it all, the very reason, to begin with, to become almost inconsequential. (Williamson, R. 2003)
Another implicant of the sustainable evolution was the shift away from the suitable building which protected inhabitants to an increased focus on a building that would protect the environment:

"At a certain point, however - very recently in historical terms - we started worrying less about what nature can do to us, and more about what we have done to nature. This marks the transition from the predominance of external risk to that of manufactured risk." (Giddens 1999)

The energy-efficient building is to some extent a natural solution to this as with lower energy needs, less stress would be on the earth's natural resources. Does this then mean that sustainable architecture is not tectonic? It is a bold question and one that would require a thesis of its own, but the absence of an actual hearth results in the need of a substitution if given the conception that the hearth is the start of architecture. With the need to cook and a place to get warm out of the question

Illustration 12 Rødhus Klit sports hall

and forming of alliances deemed as something from a different society, the only activity from the Semperian use of the hearth is the storytelling.

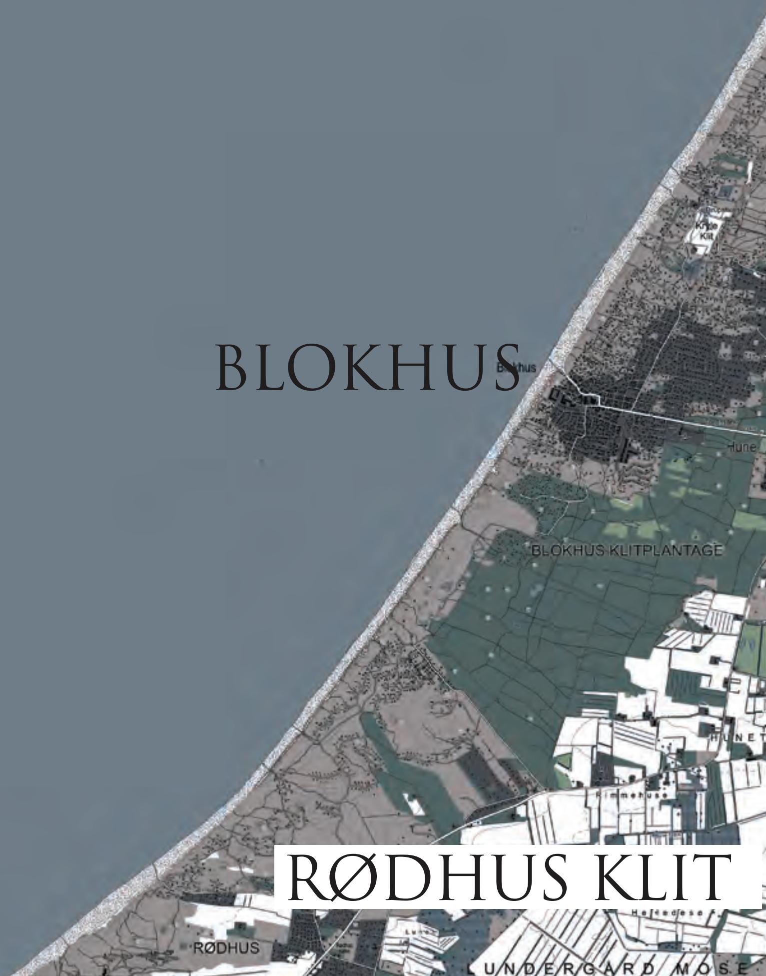
With so many initiatives integrated into the present-day building regulations in Denmark, the quest for more energy efficient buildings becomes a quest of decimals. There is little invention left on insulation materials and glazing which leads to new design practices: A new way of thinking and using walls and glazing and the adaptation of modern technologies such as solar cells or solar heating. The integrated design process combines with a focus on low or zero energy buildings supply a much complicated and intricate concept – all with the aspiration to harm nature as little as possible. (Knudstrup, Bejder 2014)

Nature is a fragile entity as it needs just the right balance of elements in order to sustain, in the same way, a fire is a fragile thing that needs certain conditions to maintain. Nature, however, is also a strong force that can tear apart any society being human or animal, and cause death and destruction along its way, and so is fire a force not be taken lightly as it also possesses the power of calamity.

Perhaps the tectonic idea by Semper with the hearth as the central part of architecture should be seen in a new light. As architecture is more and more concerned with keeping nature safe – partly because the protection of humans is so inherited – nature should take the place of the hearth, as the starting point - at least in a metaphorical manner. Maybe the tectonic sustainability is the protection of nature from man and not mans shelter from nature. After all, nature is and has always been the actual base all architecture is set upon.

PROJECT SITE

To present and introduce the chosen project site a map of the far context shows the nearest towns. A brief introduction to the weather conditions provides a quick overview. Following with a more graphic approach, mapping is used as a tool to present important contextual elements such as roads, buildings, different elements in the landscape and topography. As a final part, the very unilateral architecture enclosing the site is presented.



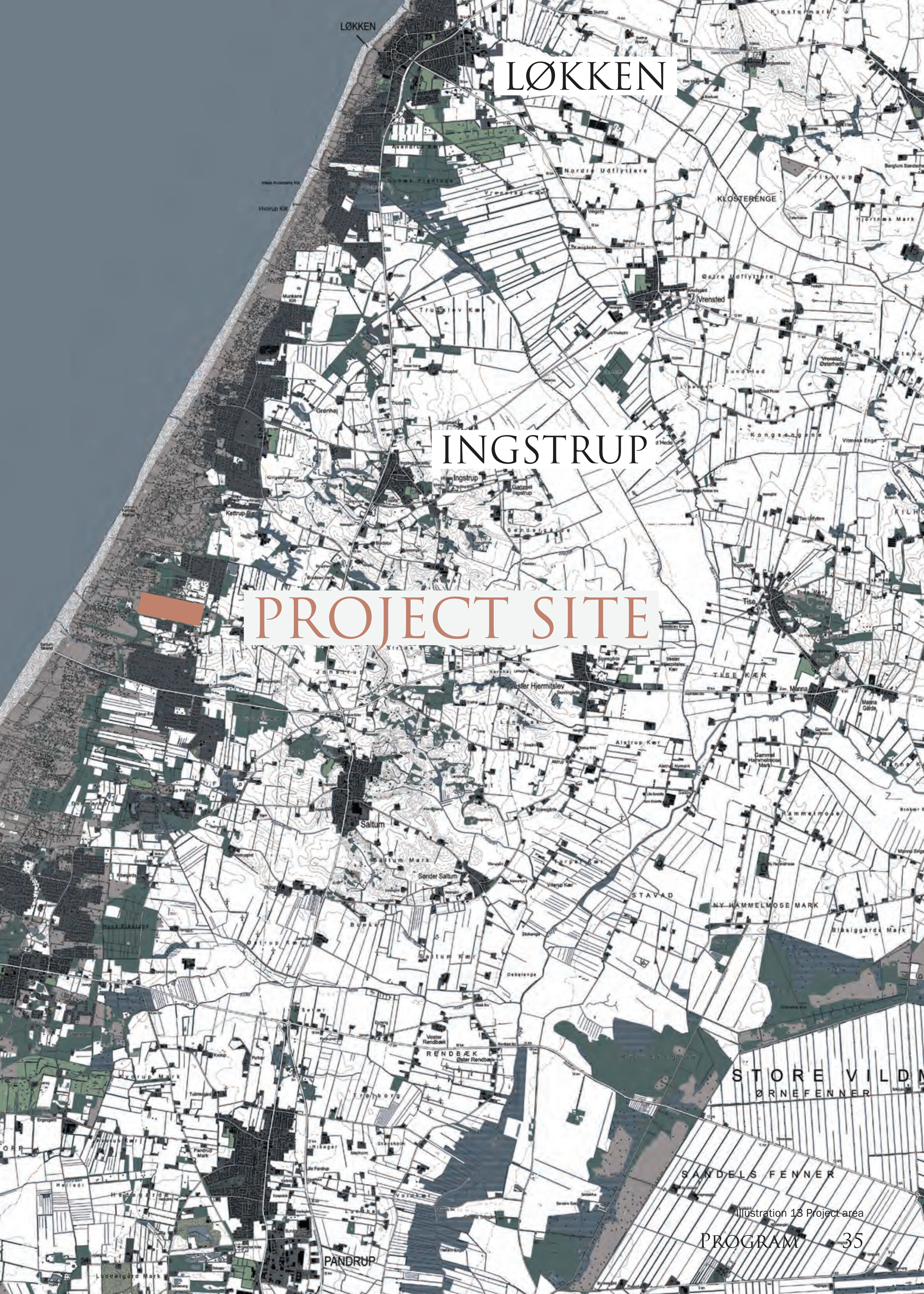


Illustration 13 Project area

SITE ANALYSIS

RIGHT
Mapping showing the extend 2,5 meter height curves roads and path as well as buildings.
The project will be an infill amongst many smal vacation homes and therefore theres is a real challenge in adapting to this sparsly built up context.

With almost no houses west of the site, and a small slope towards the coastline there is the dramatic opportunity to capture views of the ocean.

All nearby roads are small gravel-paved and this is a concern regarding access to the site in the future.

As there a no major roads near the site and traffic to vacation homes must be expected to be primarily during summer holiday and weekends the project site should be somewhat quiet during the week and should the other way around not affect the vacation homes.

Illustration 14 Project area roads, houses, topography

Illustration 15 Project site, and extend of forrest in the area

ABOVE

Mapping showing (in dark green) the extend of forest regions of major national importance.

The project site is situated around several small forest enclaves as well as having some on the actual project site

To a edegree the forests west and south of the site will result in some shading of the sun.

Illustration 16 Project site, and extend of moor in the area

ABOVE

Mapping showing (in dark green) the extend of moor and their extend from the coastline. Most of the project site is charachteried by a major part being moor with its rough tecture in the landscape as a result.

NEXT PAGE

Topographic map showing 0,5 meter height curves and section markers. Dramatic dunes surround the project site with a few small forrest giving a diverse and interesting view in all direction. Worth noticing is also the flat terrain on the east side of the project site.

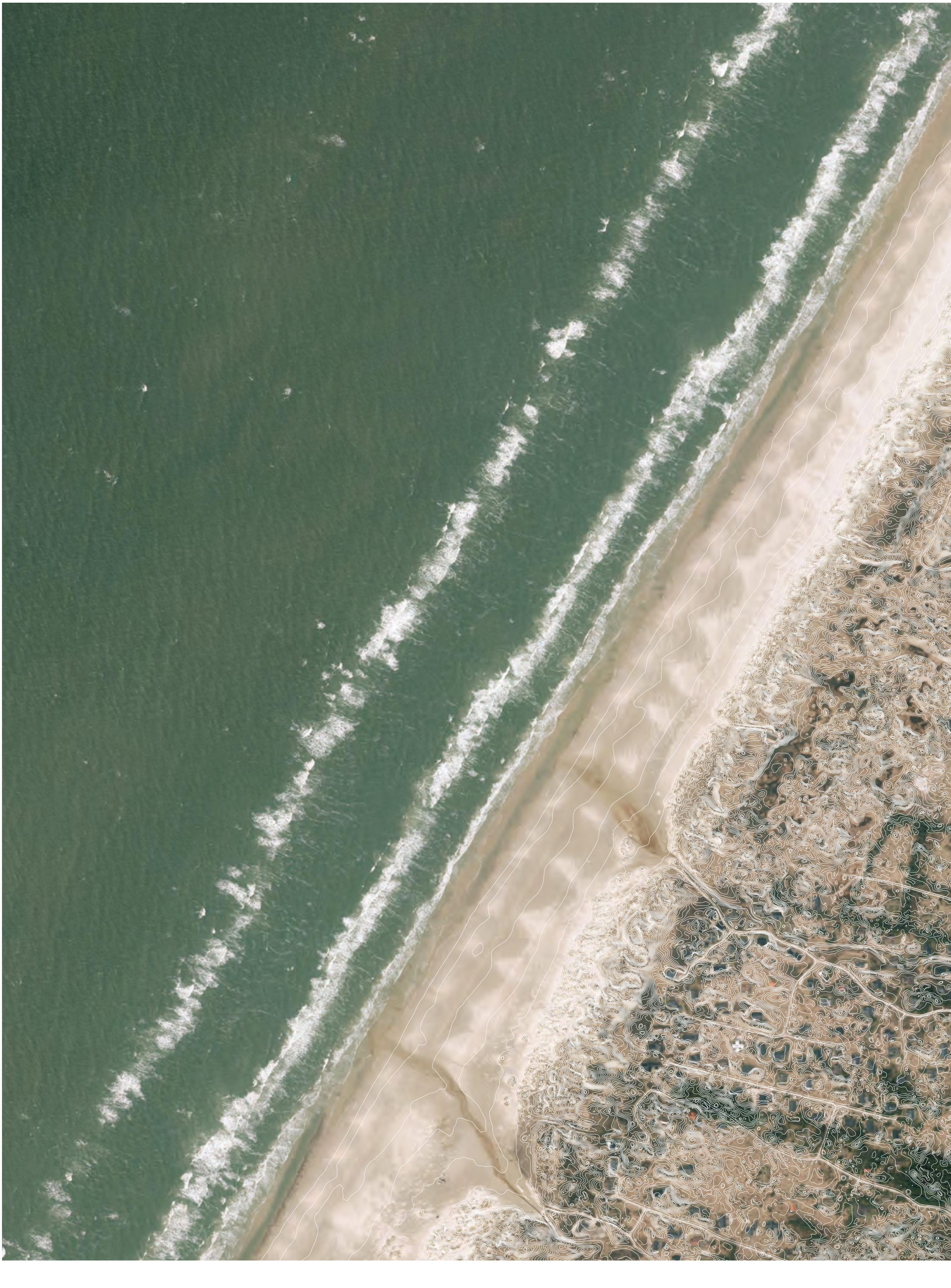


Illustration 17 Project site topography

SITE ELEVATION

Illustration 18 Site topographic section AA

MOOR

FOREST

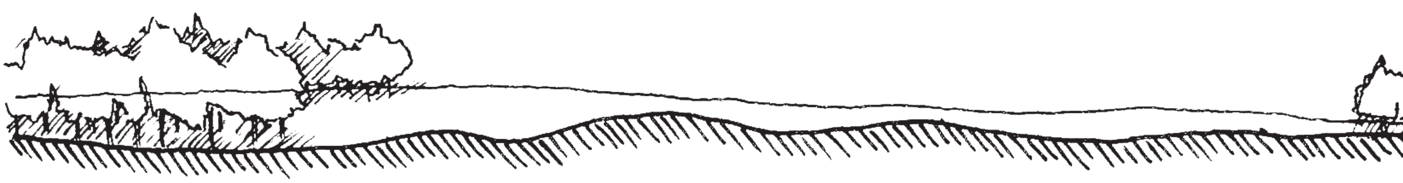
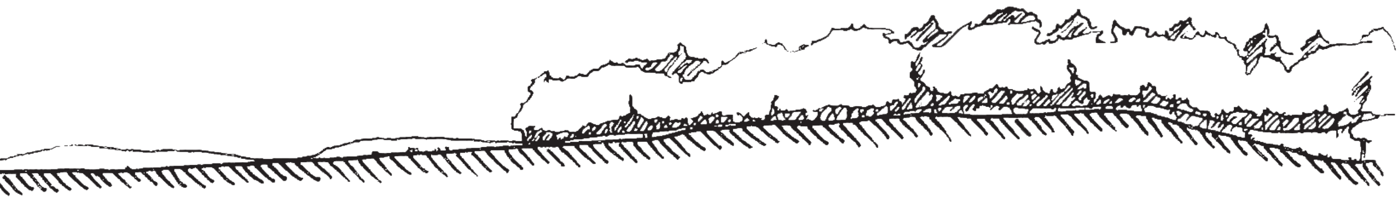


Illustration 19 Site topographic section BB

MOOR



MOOR ACCESS ROAD

FOREST

ELEVATION AA

Section from East to West of the project site. The East is dominated by the steep dunes in a semi-cirkle. Further the site has a vague slope towards the west and the ocean.

ELEVATION BB

Section from North to South of the project site. The landscape features a vague slope towards south with a small enclave of trees but otherwise low moor vegetation.

CLIMATE

In general, the area is characterised by strong western winds however these are mostly present during the summer and late winter, whereas the spring and fall are typified by more evenly distributed winds. The outdoor areas will mostly be used during spring and fall, as most of the summer, the school is closed. Considerations regarding sheltering outside areas must, therefore, accommodate winds from all directions. As the strongest winds are during the hottest period of the year this could be a driving force for natural ventilation. (Hoffmann 2015, DMI 1990, Cappelen, Jørgensen 1999)

Rain is most present during fall and winter with most rainy days where winds at the same time are multi-directional and any sheltering must, therefore, cope with this situation.

The hottest months of the year are June, July and August where the summer holiday is also present, and therefore most of the buildings will empty and unused.

The climate data has been retrieved from a report by the Danish metrological institute. The closest and most relevant measuring station is from Kandestederne approx. 30 kilometres from the project site. Situated at a bay and close to the west coast this is somewhat relatable to the conditions near Blokhus and Løkken. As an additional reference, the measuring station of Åholm, which is placed further into the countryside, has also been analysed. The conclusion was that there was little difference between the measured wind speeds, with more wind from the west in the case of Kandestederne, as would be expected.

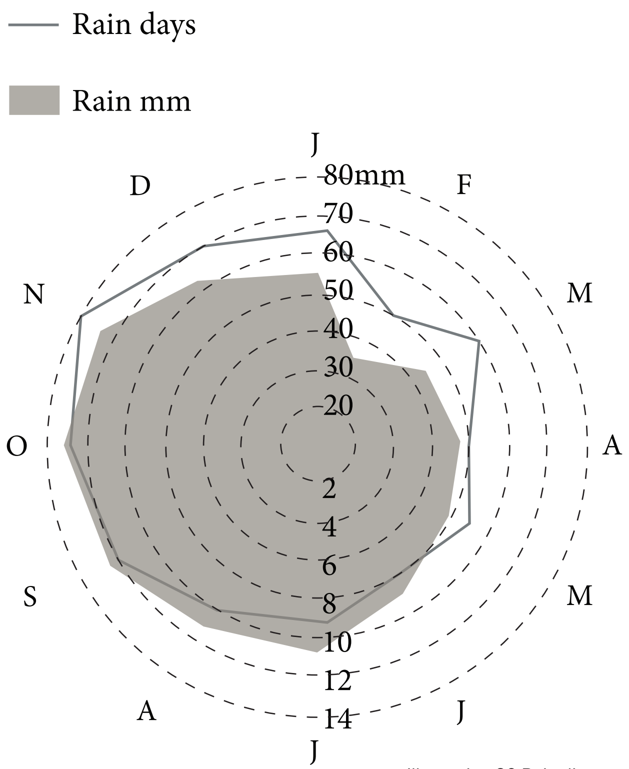


Illustration 20 Rain diagram

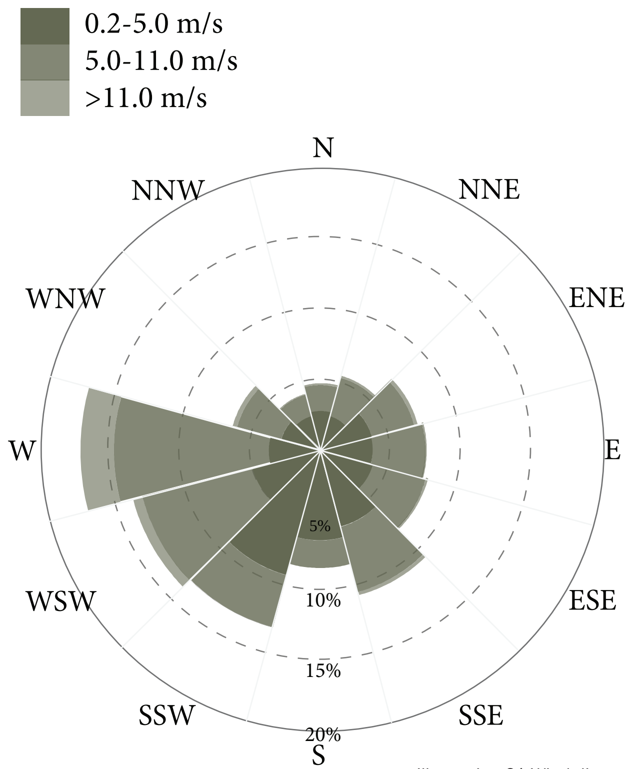


Illustration 21 Wind diagram

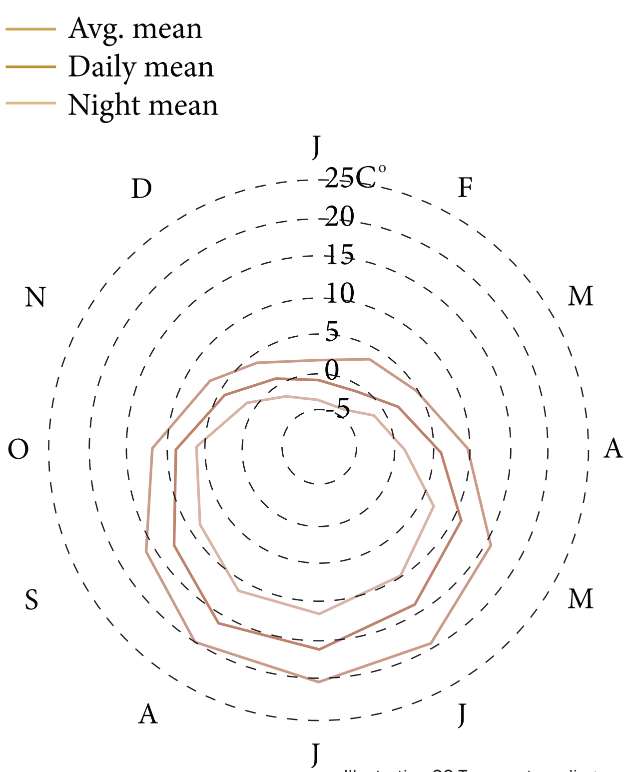


Illustration 22 Temperature diagram

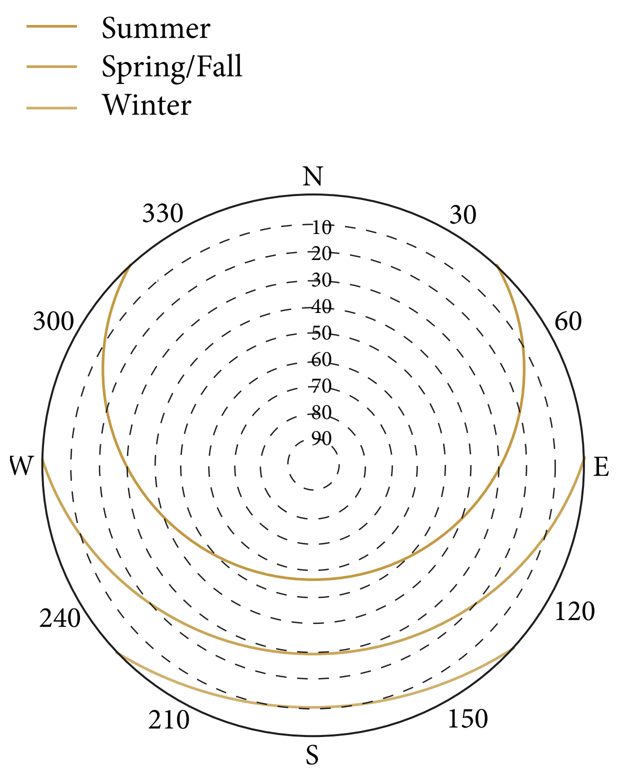


Illustration 23 Sun diagram

ARCHITECTURAL

CONTEXT

The architectural context of the project site is very much defined by the history of the nearest town of Blokhus and Løkken as holiday destinations. Apart from a few old farmhouses of whitewashed brick and red tile roofs, the area is characterised by the classic Danish vacation home typography.

This is settled in the district plan from 1953 by Saltum-Hune municipality. Pitched roofs should have an angle of either 20-30 degrees or between 45 and 55 degrees, where these should be covered with either thatched, tile or fiber-cement slates. Most houses are light wood constructions with wood cladding, that by the district plan should be either white or black or earthly colours, though some light ocean blue are found. The point where wall and roof meet should not be more than three meters above terrain. (Saltum-Hune kommune 1951)

As most of the vacation homes are fitted with the lower 20-30 degree roof and these are grass roof they very much blend into the landscape and placed into it instead of on top.

The context surrounding the project is barely visible with their earthly colours and living roofs. The geometry is simple and crisp but scattered with a more organic pattern breaking up the unity. To gain a wider understanding of this context the classic Danish summerhouse is deducted as a case study in the following analysis chapter.

RIGHT BELOW
Houses at Rødhus Klit holiday center. The modernist aestatics are set into the landscape with the dunes and lyme grass reaching the small houses. .

RIGHT ABOVE
Traditional Danish summer house with a light wood construction painted black and a self-sustaining green roof.

Illustration 24 Rødhus Klit holiday homes

Illustration 25 Danish Summerhouses near project site

ANALYSIS

Designing any piece of architecture in Scandinavia is taking part in a rich and valuable history and so the traditions in Nordic architecture is analysed within the fields of Danish tradition, innovation and light. To get a more comprehendible understanding of the continuation school as a user group the Ingstrup continuation school analysed through a case study. As the architectural context is almost entirely summerhouses the traditional Danish summerhouse is studied as another case. With the theme of sustainability green roofs are analysed with a focus on the potential within these. As architecture is perceived by more than the sense of sight the aspect of multi-sensory is touched upon together with colour theory as an inspiration. A new technology of hybrid ventilation is presented as this can benefit the overall design process. Concluding the analysis, the vision describes the trajectory of the design together with design principles and design parameters.

NORDIC TRADITION

The Norwegian architect Karl Otto Ellefsen gives his take on the definition of the northern architecture tradition;

"Det dreier seg om en arkitektur som I grunnsyn forholder seg til landskapet, som I beste fall behandler volumer, åpninger og flater I forhold til steds- og tidsvariabelt nordisk lys og bruker naturmaterialer." (Lund, 2008, p 298)

Karl Otto Ellefsen expresses that, the northern traditions are based on the adaptation of architecture and tendencies, and making this correlate to the landscape, and by creating the building in such a way that the ever-changing northern light is thought into the design as well as the use of local materials.

The combination of materials and the craftsmanship in how the buildings etc are made has also been a great part of the northern traditions.

Kay Fisker's and C.F. Møller's, Aarhus University is a good example of Karl Otto Ellefsen's take on northern architecture tradition. The large university complex which was design in 1933 and consist of several buildings which lays in a hilly terrain in central Aarhus. Instead of working against the terrain, the buildings follow the hilly terrain and thereby giving the whole complex a natural and flowing appearance. All the buildings are made of the same yellow brick and thereby giving the complex a uniform look. (Sommer 2014)

Illustration 26 Aarhus University

During the 20th century, a lot of the Danish architects also made furniture and other everyday objects. The term Danish Design rose from the chairs and lamps which saw the light of the day in this period and was synonymous with great craftmanship Architects such as Arne Jacobsen, Hans J. Wegner and Kay Fisker all contributed to the term Danish Design with their simplistic designs, where quality and design was the focus. (Lund, 2008).

ABOVE
Aarhus Unviersity by Kay Fisker and C.F. Møller. This classic of danish regionalism features simpel geometric paterns found in every piece of modernist architecture, but is still lined with traditional danish bricks and a pitched tile roof. Another chracteristic of Aarhus University is its position in the sloping landscape, a speciality of Kay Fisker and C.F. Møller.

TRADITION & INNOVATION

During the 20th new tendencies was adopted by the Nordic architects and made it to fit the harsher climate of the north as well as combining the ideas with the Danish tradition. Architects such as Arne Jacobsen, Jørn Utzon and Alvar Aalto, who created a picture of region, where the tendencies of the functionalism had survived by adapting it to the local tendencies of moderation of details, the sense of materials and the details (Lund, 2008).

Jørn Utzon would work from existing knowledge and building traditions which he would experience on his study trips to the Mediterranean and Mexico. He would look towards nature as a medium for inspiration and innovation as well as the local building tendencies. These tendencies and inspirations which he would encounter would be taken back home and placed in a northern context. The Kingo Houses which was constructed in Helsingør, Denmark, is one of those examples.

When Jørn Utzon travelled to the countries around the Mediterranean, he would experience cities that even though that they had a large variation in building sizes and shapes, they could all be considered as a whole, due to the similar use of materials. This principle of creating a whole by using the same material was brought back and became the Kingo Houses. The Kingo Houses was also based on Alvar Aalto's metaphor about the cherry blossom. (Sommer 2014)

"If you consider a bunch of cherry blossoms on a tree, you will see that each flower has a placement depending on the sun and the other cherry blossoms. Each flower is different from the others because of its location, yet they belong to the same family." - Jørn Utzon

Illustration 27 Kingo Houses

Så, når vi i dag beunder de solide, almindelige boligbyggerier, som Fisker & co. byggede i 1930'erne og 40'erne og 50'erne (hvor markedskværnen også kørte), så er dét, vi hylder, egentlig bare, hvad der kommer ud af at se sig tilbage, inden man tordner fremad."

(Kathrine Lotz)

ABOVE

The Kingo Houses by Jørn Utzon.

The inspiration from warmer climates is evident in the dry landscaping and the bars in front of windows, that bare resemblance to the mediterranean.

The sinlge family homes are positioned to allow the utmost view from every house. Utzon often worked with geometrically strong units arranged in an organic pattern.

THE DANISH TRADITION

During the 20th century, a lot of architectural tendencies rolled across western architecture. The Danish architects of that time had an ability to take in all these architectural tendencies and then combining them with the values and traditions of the Danish architecture. (Lund, 2008).

Nils-Ole Lund describes the traditions of Danish architecture, as an institution with a given tradition. This tradition is made up of a common set of values which the parties of the institution have agreed upon. In this institution, the parties show more consideration to the internal opinions from the other parties within the institution than from external opinions

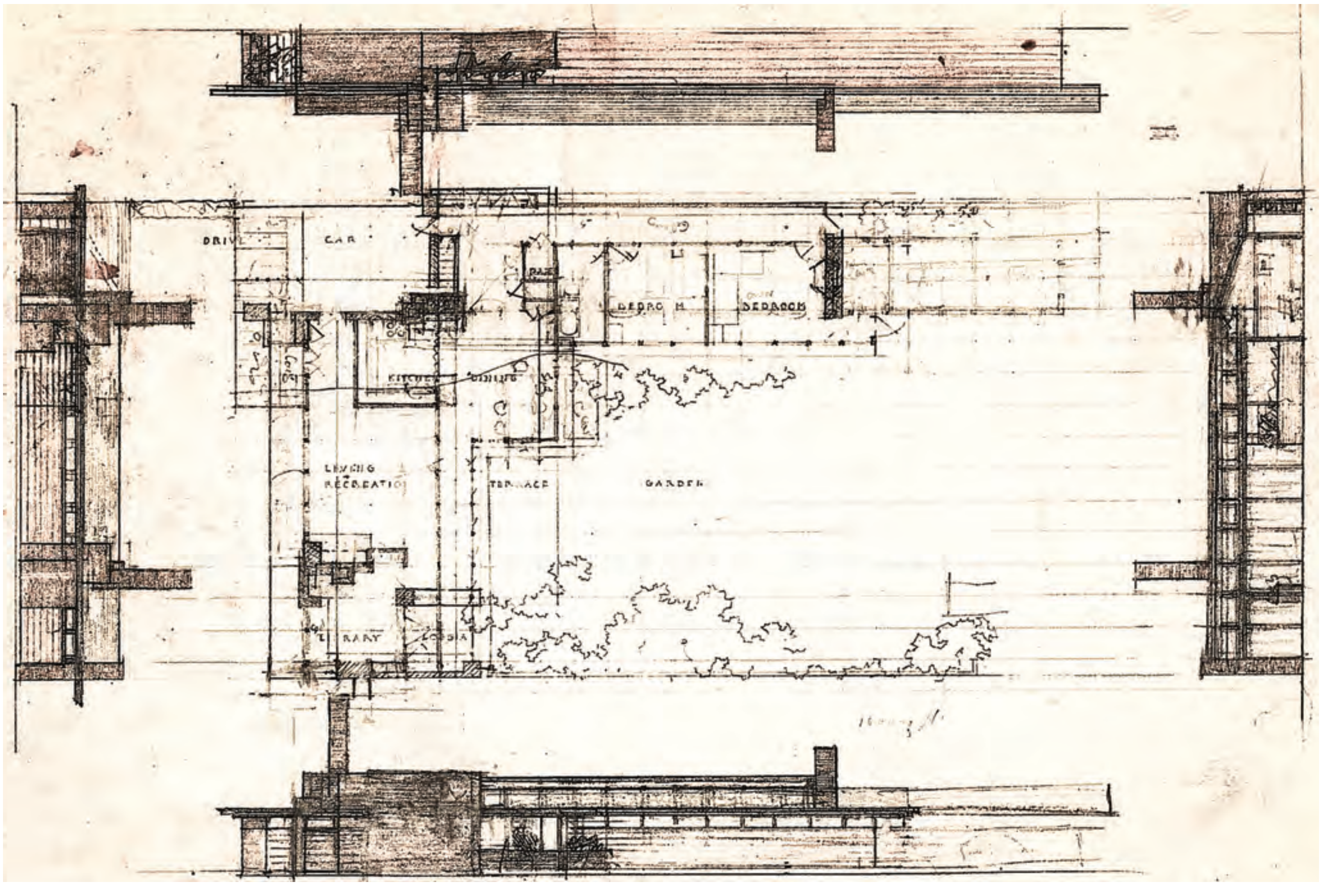


Illustration 28 Plan and facade of Robert Lusk House

The institution is not closed society. Other parties of the Danish building industry could affect the institution. The institution would undergo changes throughout time, as new developments and technology would emerge.

These values which make up the traditions and thereby the institution would only be changed slowly in a close dialogue between the different parties of the institution when a new tendency in architecture would emerge. The new impulses and tendencies from other countries would be broken down and only what the institution would find fitting for the common values, would be integrated into the Danish architectural traditions. By doing this the architects of that time was able to take the international tendencies, and by a few careful changes, make it Danish.

An example was the Danish single-family houses changed during the years after WWII, where the international inspiration from America. The houses got a more open floor plan, where displaced walls help dictate the rooms. The sloped roofs were replaced by flat roofs and new ways of construction, using columns gave way for large panoramic windows. The house would be centred around a large fireplace and the materials used would have a more raw and natural appearance.

ABOVE
Plan and facades of Robert Lusk House by Frank Lloyd Wright.
Being the first the series of Usonian houses though never built, the ideas and principles where adapted to the Herbert Jacobs house. Similarities to danish post-war homes are seen in the open plan, with a kitchen/dining space, the moderate bedrooms and the concept of the L-shape creating a tranquile courtyard.

THE NORDIC LIGHT

The cold northern light has always been an element in the northern architecture tendencies. The northern light compared to the light farther south, has a cooler and more diffuse character due to the harsher weather up north. The sun is most of the time blocked out by a cloudy cover, yet in the course of short time, the sun can shine through the clouds and bathe the earth in warm sunshine. (Lund, 2008).

Over the course of the year, the amount of sunlight changes a lot from summer to winter as well as the angle of which the sun hits the earth differs from summer to winter. In the summer the sun rises in the early morning and descends in the late evening where in the winter the sun is only up in a short period of time. In the summer the sun is situated high in the sky whereas in the winter the sun sits very low in the sky.

Because of the way the sun and weather behave, the architects have worked on solutions to be able to pull in as much sunlight as possible in dark and cold winter and at the same time, block out or shade of the sunlight in the summer, to prevent overheating of buildings.

ABOVE OPPOSITE
The Nordic Pavilion by Sverre Fehn for the Venice Architecture Bienale of 1962.
Uniting all the nordic countries under one roof the pavilion still stands today as a piece of almost inverted architectural gesture of the north: With only two structural walls, a bright stone floor and an open roof in concrete the pavilion translates the warm light and atmosphere of the mediterranean into the cold diffuse equal of the norht.

Illustration 29 Nordic Pavilion 1962

CASE STUDY: INGSTRUP EFTERSKOLE

With no previous experience with the theme of continuation schools, that be personal or professional, this subject will be processed from scratch. The first step was to find a Danish continuation school that would be interested in having an association with this project, but some criteria had to meet, where others were simply an added bonus: The case school should be situated in or near an interesting landscape that would pose a certain potential of sensuality and serenity – a landscape that will affect anyone within. Furthermore, the chosen continuation school should have an adequate size and a differentiated program that would match a master thesis project, especially in terms of the range of main subjects and therefore different function typologies.

The number one priority to work with was Ingstrup Efterskole, in Northern Jutland. Positioned close to the northern west coast of Denmark there was a real expectation regarding its context and how this could be adapted to the project. With approx. 10.000 sqm. of the built-up area the size of Ingstrup Efterskole seemed to fit the profile.

The first contact was set up by a telephone call which surprisingly unveiled that Ingstrup Efterskole is currently undergoing major changes in terms of both their administrative structure and their physical situation: During 2018 a new headmaster will be appointed who have big plans for the future of the school. A part of this is a long-term renovation, and possible extensions, of the school, where two architecture firms are already involved with tendering different propositions. Therefore Ingstrup Efterskole already have some priorities of facilities as well as demands and wishes. (Rasmussen 2018)

The next step was to set up a meeting and a tour of the school to gain a broader understanding of the physical conditions at present, to get an

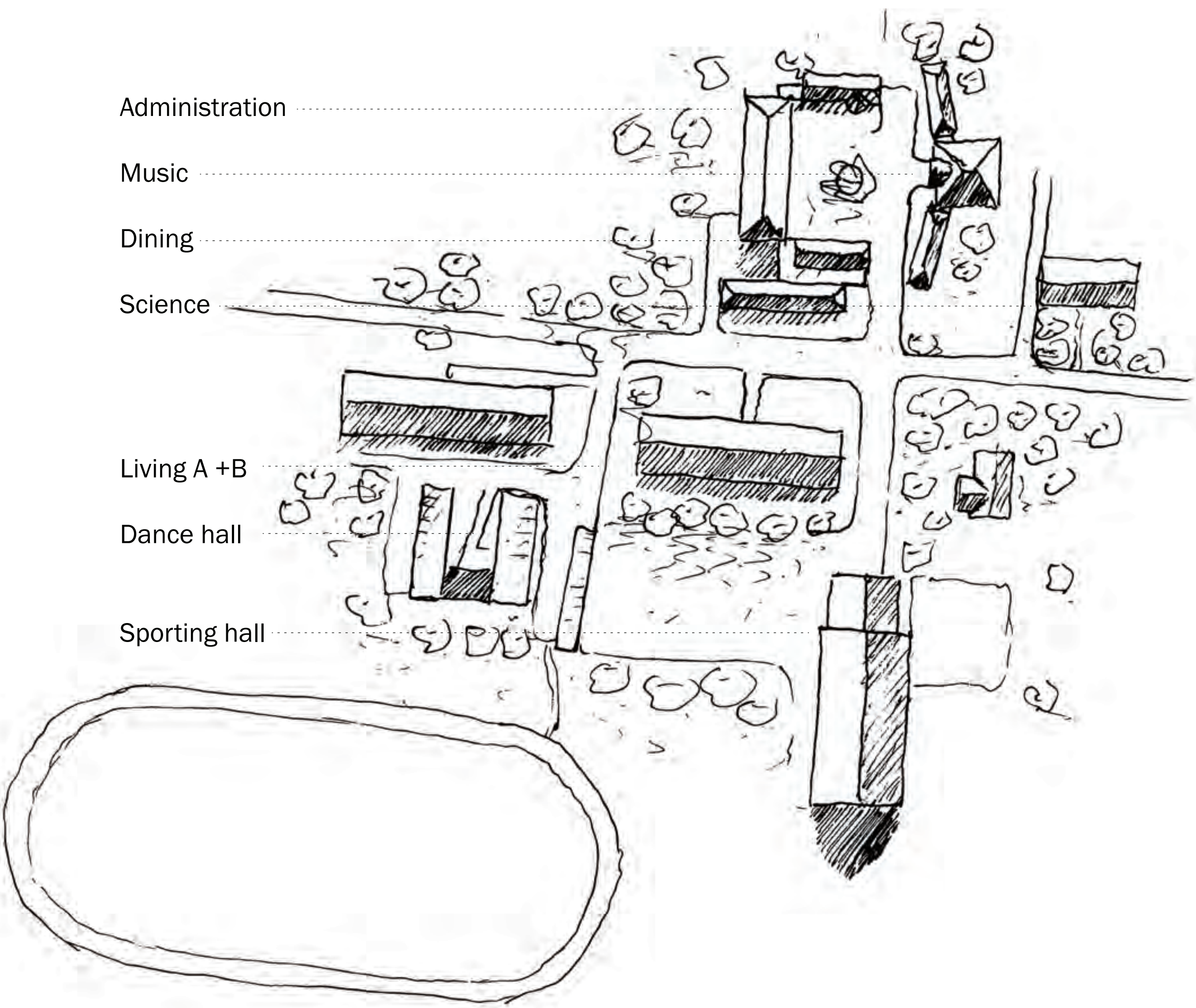


Illustration 30 Ingstrup Efterskole present layout

Illustration 31 Ingstrup Efterskole common room

insight into the plans for the future remodelling of the school and last but not least to gain a closer understanding of that special setting that is the continuation school.

As part of the common Danish school regulations the continuation schools must fulfil the curriculum and general education of the public school, and therefore any offers such as music or sport must be in addition to this. In addition to this, the evolution of the school sector poses a new way of thinking academic pedagogic with student involvement and multilogue during classes. (Efterskoleloven. 2017)

At Ingstrup Efterskole the very horizontal hierarchy is evident in both the physical setting and use of the different buildings as well as the interaction with teachers and how this is strengthened: Throughout the school students use every considerable space for either leisure or studying and many spaces are reserved interactions between students and/or teachers. The teacher's lounge is in its self a glass box open to everybody and with the door ajar at all times. Being away from home the students will naturally be subjective to situations where a parental figure is needed and where teachers must step up. During the tour, this special bond became apparent as the superintendent was called by a student for a private conversation with emphasis on the fact that it had to be the superintendent. (Rasmussen 2018)

To start up and develop the relations between the students of a year and to foster communities there are three major levels present at Ingstrup Efterskole: The close consisting of the roommates in the dorm room differing between two and four students – of the same sex. These are then grouped

Illustration 32 Ingstrup Efterskole dining area

into approximately ten students comprising of the so-called contact group. And then there is the whole school as the large community. Between these communities, others will obviously be established during a year, but will also differ. In the two living areas, the dorms are mixed with every second being a boys room and a girls room, and so forth. This was intentional from a pedagogic reasoning in order to balance out and avoid cliques or wind up situations. (Ingstrup Efterskole 2018)

The many different courses provide different functions each with their own focus in terms of both architectural as well as technical measures. With the modern school focusing on multilog learning, student involvement and project work, the classic one-way classroom should be challenged as a physical setting for learning. With the need of teachers being nearby their close relation with students as well as a need for open access the retreat to a closed teachers room is not viable.

The overall growth of a student at a continuation school comes down to much more than a well-designed classroom: There is a need of private space as well as spaces for the different communities and interactions between both students and teachers. Used day and night the spaces need to functional connected supporting the daily routines as well as keeping up the needed level of control in order to maintain a healthy interrelationship between everyone. (Rasmussen 2018)

ABOVE

Pictures from the common space and dining area as currently seen at Ingstrup continuation school.Overall the school is well-maintained, but has a limited sense of homely community and architectural distinction

GREEN ROOFS

With the established context of summer houses with a majority constructed with a heavy green roof of the natural inherent turf, the use of a green roof as a design parameter seem apparent. With most of the summer houses nearby having a traditional build-up turf layered roof and local planning laws in comparable neighbourhoods stating a required green roof this component must be further evaluated to establish a clear conception of its probabilities.

First of all the green roof have through Nordic history been a part of architecture as an easily accessible covering of a house. This has especially been seen in the northernmost parts of Scandinavia and the Nordic region characterised by the roughest weather. The high density that would not fly away in the wind together with an easy going material is, therefore, a natural choice for simple societies. Today green roofs are again found throughout architecture in Scandinavia and in Denmark, but with a very different set-up, best described by the general classification of green roofs: Extensive, semi-intensive and intensive. (Siguroardórttir 2012)

The extensive green roof is characterised by a low cost and likewise maintenance. This is ensured by a selection of plant species with little variation and with a high tolerance to draught as well as the capability to be not only established but self-generative even in thin layers of soil. Usually, extensive green roofs are fitted with plants from the family of sedum, that has these mentioned characteristics. The low cost comes from not only the self-generation meaning no maintenance in this regard, but also the overall biology of sedum, that does not need trimming or cutting during a year. Without the need for a rich and deep layer of soil, the sedum also keeps construction cost down

Illustration 33 Extensive green roof at Vestre FJordpark

Illustration 34 Intensive green roof at Moesgaard Museum

	Extensive	Semiintensive	Intensive
Weight at maximum water capacity	50 - 150 kg m^{-2}	120 - 350 kg m^{-2}	>350 kg m^{-2}
Subtrate layer thickness	6 - 20 cm	10 - 25 cm	>25 cm
Plant typologies	Succulent, herbaceous, and grasses	Herbaceous, grasses and shrubs	Grasses, shrubs, and trees
Slope	<100 %	<20 %	<5 %
Irrigation	Never or periodically	Periodically	Regular
Maintenance	Low	Moderate	High
Costs	Low	Middle	High
Use	Only accessible for maintenance	Pedestrian areas but with a moderate use	Pedestrian/ recreation areas

Illustration 35 Main typologies and features of green roofs

as there is little need for the excess dimension of structural parts to cope with the heavier roof. This is also the reason why the extensive sedum roof is popular in the case of a retrofitting of green roofing on an existing building as there would not be a need for a more structural base. However, the sedum and the whole construction of the extensive green roof is delicate and thus is not durable as an accessible part of a building. (Pérez, Perini 2018)

The intensive green roofs are often referred to as rooftop gardens as they have thick layers of soil supporting a richer and more varied palette of plant species. Solely the option of working with different height in plants opens up for a more morphically design that can almost equal that of a regular garden. The possibility of having many different plant species with more diverse needs obviously means a higher degree of maintenance needed. The layers of soil pack up to a heavier roof resulting in the need for a stronger structure underneath, making the intensive roof unsuited for renovation or retrofitting, though there are cases of achieving this such as the High Line in New York – which for the record is a renovation railroad and not a building. A sub-category of the intensive green roof is the semi-intensive green roof that covers much of the same characteristics as the intensive one but also has some equalities with the extensive. Where both the intensive and the semi-intensive green roof allows for public access, the semi-intensive features pathways or pavement in order to keep disturbance of flora to a minimum. The intensive green roof has a more sturdy range of plants that can cope with direct contact with humans. As with the case of The High Line the semi-intensive roof allows for public access due to the characteristic of having pavement, furniture or otherwise elements that interact with humans. On the other hand, the

Danish Museum of Moesgaard has an intensive roof with a covering of grass species allowing for direct public access on the entire roof throughout the year. (Pérez, Perini 2018, Friends of the High Line 2000)

In recent years green roofs have been subject of a wide variety of research, with one key element being the thermal properties of a green roof in respect to both the cooling factor on its own but also a deducted U-value to be used in energy performance calculations. With the focus in today's society on lowering CO2 emissions and energy consumption, the buildings sector has not been under the radar as major part of the annual energy consumption on earth comes from either the construction of or running buildings. This dilemma has mostly been sought resolved by an increase in thickness and performance of insulation layers. (D'orazio et al. 2012 439-451, Berardi et al. 2014 411-428, Saadatian 2013 155-168, Pérez, Perini 2018)

In Denmark where renowned Rockwool have gained a prominent position on the production of building insulation. With the modern-day techniques of ensuring an airtight construction, low energy windows and thick layers of Rockwool the problem facing engineers and architects is no longer keeping a building warm. On the contrary overheating is a dominant situation to be avoided when designing new buildings in On the contrary overheating is a serious situation to be avoided when designing new buildings in Denmark, where the regulations state how many annual hours are allowed with excessive temperatures. The short-term solution has been to avoid too large glazings (towards south) and incorporate huge and advanced mechanical ventilation systems. The direct effect from this is the architecture of a low value where space in the building (and on the budget) is used for ventilation aggregates and ducts or a limited design with little freedom and a decrease in the overall glazed area resulting in low daylight factor and views to the outside.

Effect	Method	Influencing parameter
Shade	Solar irradiation interception provided by different plant species	Density of the foliage (leaf area index (LAI))
Cooling	Evapotranspiration from the plants and subtrates	Density of the foliage (LAI)
		Type of plant (transpiration coefficient)
		Climate conditions (dry/wet)
		Subtrate moisture content
		Windspeed
Insulation	Insulation capacity of the different green roof layers: plants, air, subtrates, geotextile felts, drainage layer, etc.	Density of foliage (LAI)
		Subtrate thickness and composition
Wind barrier	Wind effect modification by plants	Density of the foliage (LAI)
		Windspeed

Illustration 36 Main paramters and effects related to thermal performance of green roofs

PREVIOUS PAGE
The great varity between different types of green roofs allows for more freedom during the design process as the build-up can be adapted. However as the scheme reveals a change in typology will have a great influence of any project especially regarding economy, maintenance and construction.

ABOVE LEFT
Many paramters influence the thermal performance of a green roof and this adds complexity to a buildings energy ballance making the capacity difficult to implement.

ABOVE RIGHT
A green roofs helps retain and detain rain water resulting in less flooding of drainage systems on and under ground.

Looking into just a few studies of green roofs with a focus on thermal performance and/or U-value and it becomes clear that there might be alternative solutions. However, the U-value of a green roof is a delicate and complex entity as it in opposition to conventional building materials does not have a static thermal resistance. Several factors affect the performance of a green roof weather the case of the extensive, intensive or semi-intensive one. First of all the base for the roof – the soil layer – can have many different compositions which by them self will have different thermal performances. To further elaborate this the thickness variation between extensive and intensive roofs will have an impact, not on the resistance of the layer of soil, but the final roof construction from inside to outside. Alone this matter should be taken into account when designing and choosing a green roof solution.

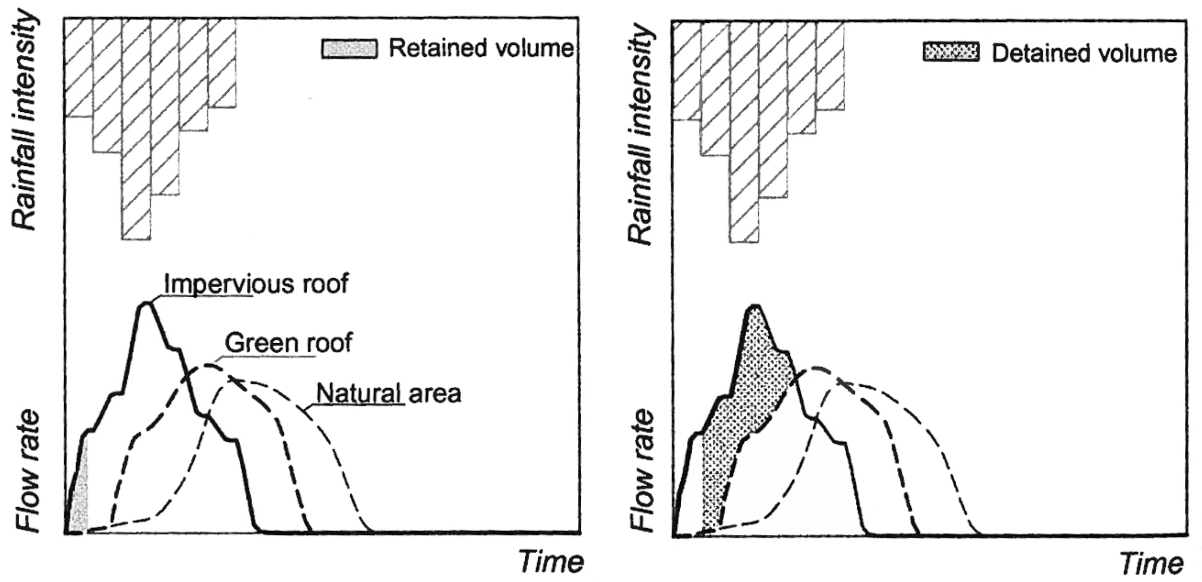


Illustration 37 Hydrolig response of green roofs

Digging deeper into the soil layer then the thermal resistance changes during the course of a year as the moisture level will fluctuate. As water has a different thermal resistance than mere soil the whole growing medium is a dynamic composite material with a changing performance. As for instance, the Danish energy-model of BE18 is a static simulation tool used to confirm the energy performance of a building there is a clear conflict regarding the implementation of a green roof as part of the energy performance calculations. In general, the research that has been studied focusses on finding the general average and mean U-values of a green roof. However, as the U-value changes alone by the annual moisture level – where different temperatures cause different levels of evaporation – a globally consistent value is inherently impossible. The U-value for any green roof must be revised according to local climatic conditions. With the evaporation, the roof further cools down a building as heat is drawn from the construction of the roof and the inside. With its inherently thicker layer of soil, the semi-intensive and especially the intensive green roofs have potential to outperform the extensive ones. A thicker layer of soil means more thermal resistance in itself, but with more soil, the roof can also hold more water to be evaporated and thus drawing heat from the construction.

The plants themselves – the visual conception of a green roof – also adds to the thermal properties of a green roof, but also are of some variation. The largest impact the choice of plant species have a green roof is the Leaf Area Index (LAI), an integer describing the number of leaves on any plant. A higher LAI means a larger area of the roof consisting of plant material, which results

Acronym	Address/ Location	Description of the Research Site	Established/ Research, Since	Av. Number of Vascular Plants/Year	Remarkables
PLU	Berlin - Inner City, 4th story	Extensive, 10 subroofs, sloped, roofs, about 900 m2, 10 cm growing media,	1985/ since 1986	41, seeded and planted species together	No maintenance, annual observation since the beginning
Ufa	Berlin - Inner City, 2nd story	Extensive, nearly flat, more than 3000 m2, 10 cm growing media	1985/ since 1992	93, wide range of seeded species	Irrigation in the first years (1985 - 1991), use of seed from the some attractive alpine vascular plants.
HS 2	Neubrandenburg, suburban, 4th story	Extensive, flat, about 1000 m2, 9 cm, 3 types of growing media	1998/ since 1999	28 seeded and planted species together	Seeded and spontaneous establishing on three different growing mediums, annual observation, and continual climate observation
HS 3	Neubrandenburg, suburban, 4th story	Extensive, flat, about 1000 m2, 10 cm, 2 types of growing media, turf mats, and seed	2001/ since 2001	55, small selection in the turf mats	Annual observation of plant development in relation to growing media, type of establishing, growing media, and run off measurements
Tom	Tornesch, Suburban, 3rd story	Semi-intensive, flat, 330 m2, 12 and 18 cm, planted	1999 and 2015		92 species planted in 1999: no maintenance since 2002, a lot of dead biomass since that time

Illustration 38 Scheme of evaluated green roofs

in a higher degree of shading meaning that less energy from the sun will reach the soil layer and transmitted into the underlying construction and the building itself. As plant to some degree varies during the course of a year this can also lead to fluctuations in the thermal performance. Furthermore different plants grow at different speeds which can cause problems early on in a buildings lifetime with overheating before the plants reach a desirable LAI. However, fast-growing plant can, on the other hand, impact the need for maintenance if these needs to pruned often or even replaced. Regarding the LAI and the connection to the type of roof, there is again a clear difference between the intensive types of roof and the extensive. As the latter can almost exclusively support the sedum species these a limited in their LAI as the plant them self-are small whereas the intensive roofs can have thick shrubs and small trees with a much higher LAI.

Another major climatic concern apart from the rise in global temperature due to CO2 emissions etc. is heavier and more frequent storms and flooding. Denmark has in recent years undergone this change in weather resulting in a focus on rainwater handling and drainage. In this case, the green roofs are a possible solution as they have properties in containing large amounts of water that would otherwise transfer down drain pipes and into severs causing flooding of these and ultimately basements. As mentioned the soil layer can have different moisture levels due to evaporation, and in reverse, the soil layer can also accumulate water that in time will either slowly drip away, but much of it will also be consumed by the plants. In the case of rainwater retention, the thickness of the soil layer with respects to the drainage part of this is the central element of which divergence is found between different green roof constructions. As with the case of evaporative properties, the

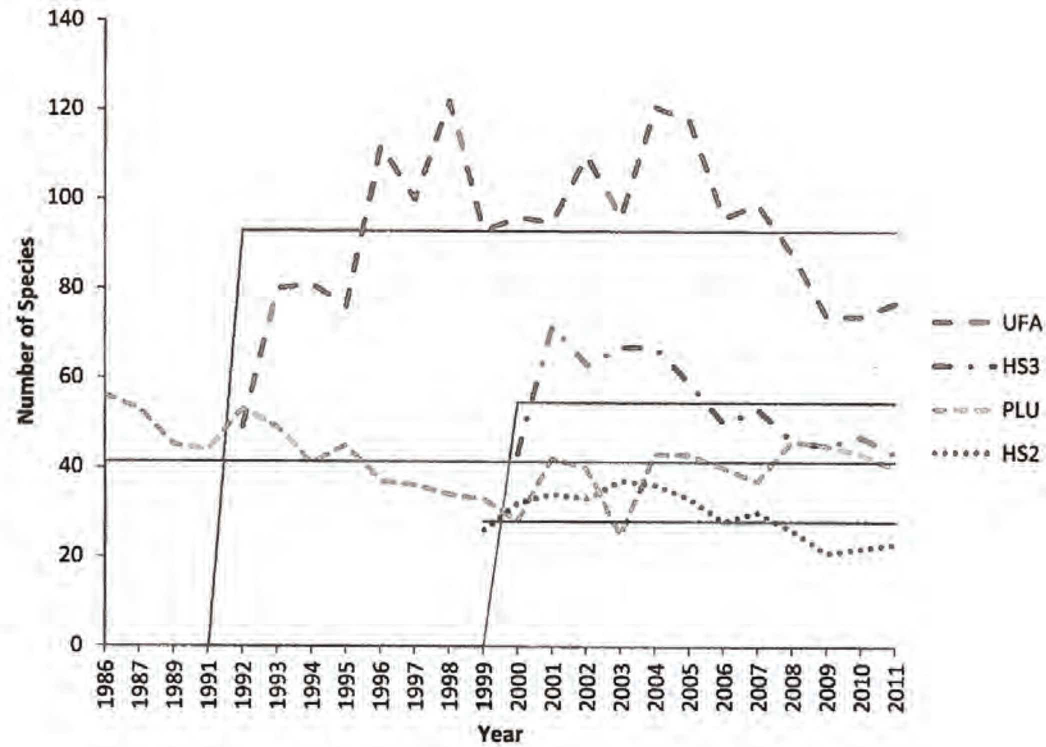


Illustration 39 Evaluation of plant diversity on green roofs

thicker soil layers does add up to a more effective stormwater retention, with measured results of up to 80 percent.

Another global risk soaring above are issues of threatened biodiversity and massive extinction of species. In this case and with a focus on the (positive) impact a green roof can have, the mass extinction is not publicly interesting animals such as rhinos or orangutans, but more insects and birds. With the urbanisation of cities and industrialisation of land into agriculture, many plant and small animal species are threatened as their natural habitats are either destroyed, outmatched or through professional breeding altered to hinder certain qualities. By utilizing the growing media of a green roof with the right palette of plant species there is a possibility to change this otherwise unfortunate evolvement. The naturally right sort of plants will have the potential to attract birds and insects that either live in or of this. If a sort of ramp or otherwise direct attachment to the ground the green roof could perhaps even foster the life of small land bases animals such as mice or wild hares. With the greater variety of plant species supported by the intensive and semi-intensive green roofs together with their inherent hardy biology their worth as habitats for biodiversity exceeds that of the extensive sedum roofs both in terms of flora as well as fauna. Furthermore, the intensive green roofs offer the opportunity of a more strategically palette of plant species that could support certain desired species to locally enhance their diversity. (Hansen et al. 2011, Pérez, Perini 2018)

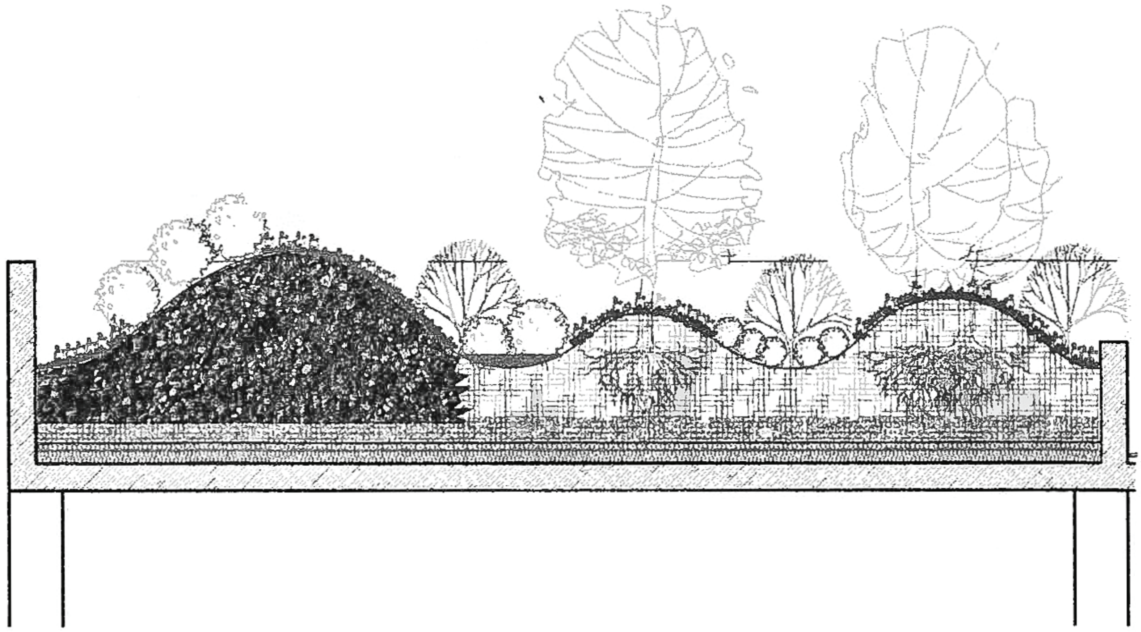


Illustration 40 High diversity build up principle

A green roof offers many positive approaches to building more sustainable as the green roof as a concept is graspable in most regions and transferable to local species and biology. With performative qualities of insulation, heat transfers and limitations of heat fluctuations a green roof can be a dynamic and mutable part of a modern building helping to ensure a better and more stable indoor environment. However, this inconsistency in thermal performance according to local climatic conditions hinders a wider use of the knowledge already gained by researchers limiting the integration of green roofs in architecture today. Thicker and more effective green roofs, the intensive and semi-intensive offers a better thermal performance than the extensive, but with the counter-argument of a higher establishing and running costs together with the need for a sturdier construction. As a fraction of local ecosystems, green roofs adapt to changes by not only accumulating heat but also retain stormwater limiting the need for drainage on and underground at a building. With different plant species comes greater floral biodiversity and the potential of a following higher fauna diversity as well. In regards to these qualities that are inherent in green roofs, it is worth noticing a general tendency of the more expensive and complex intensive roofs to outperform the extensive.

PREVIOUS PAGE

The graph shows the development in species count by yrealy measurements on selected german green roof studies. Worth noticing is the connection between maintenance, height of construction and tyopology where the Torn project (semi-intensive) with 82 species on average outperforms the extensive apart from the UFA project.

RIGHT

The High Line in New York is a mix between intensive and semi-intensive green urban typology. With less focus on thermal and hydration properties the High Line has a wide variety of plant species thus adding a much needed biodiversity in the city. By the use of paving and integrated furniture this green space also functions as a facilitator for community and gathering.

Illustration 41 The High Line, New York

CASE STUDY: CLASSIC DANISH SUMMER HOUSE

Scattered into the landscape around the project site are various vacation homes or summer houses. Giving this very unilateral architectural context the school will need to either adapt to this or take on a contradicting aesthetics. An adaptive architectural point of view will take a stand in the constructive base of the summerhouses, their proportions, and materials. To work with contrast the school will need to stand out from the summerhouses apart from the obviously larger size. Materials and contact with nature should be differentiated. To get a further understanding of this context in order to have a clear conception on how to approach it, the summer houses must be analysed. With the many equal yet different houses in the context, the analysis will be a generic case study of the assets and their atmospheric character.

The Danish building tradition comprises mostly of brick and tile, sometimes with a wooden support structure in the shape of 'bindingsværk' or half-timbering. However what seems to be the classic Danish summerhouse is made of full timber cladding, with more inspiration from the neighbouring countries of Norway and Sweden. As practically every house has it façade treated with paint, or pigmented oil or wood protection, it is hard to decipher the species of the wood. Pine would be a suggestion as it is cheap and easy to process fitting with the first summerhouses being sheds with windows or old railway carriages. The wood can be fitted as logs either vertical or horizontal. Alternative the wood façades are board, which again can be horizontal or vertical. Different boards give different expressions whilst also attaining different properties in terms of weatherproofing. A horizontal cladding especially with logs or the special rounded boards, also known as Blokhus cladding (Blokhus brædder, named by the city of Blokhus at the west coast) gives a

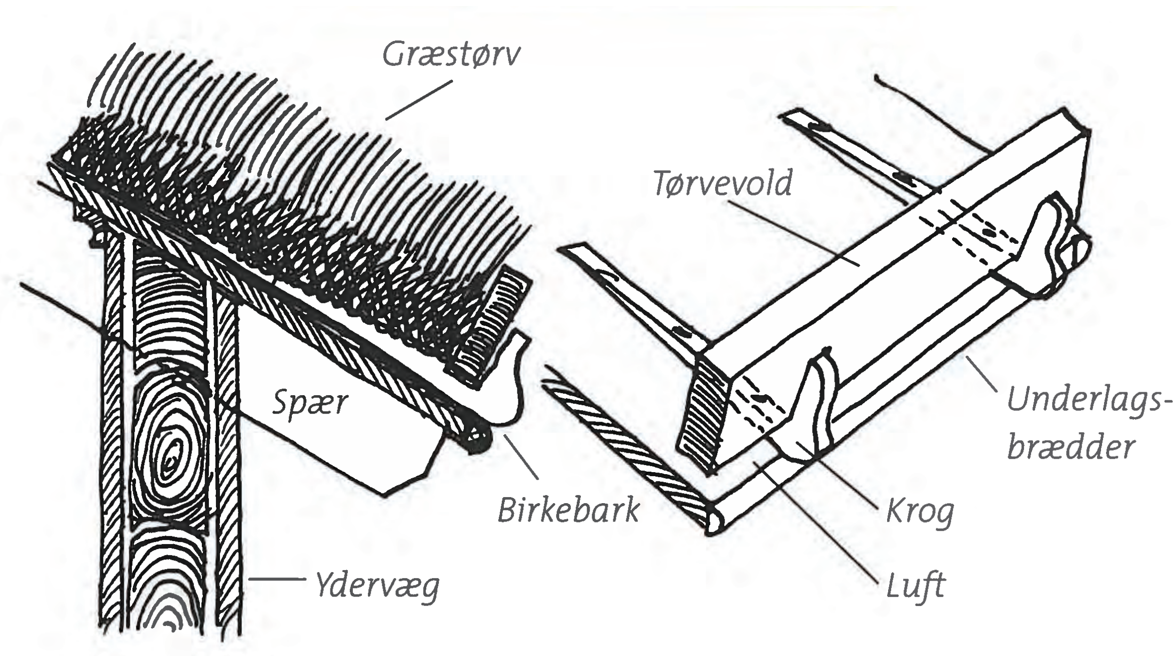


Illustration 42 traditonal peat roof construction

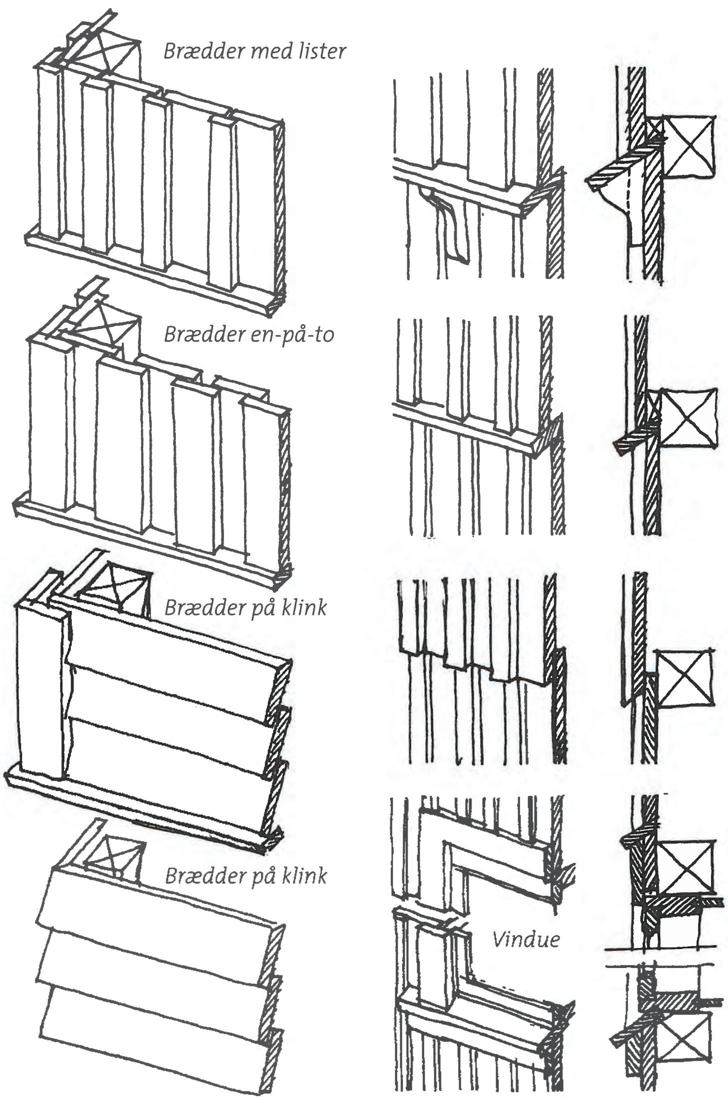


Illustration 43 Tradtional types of wood cladding


Illustration 44 Summerhouses hiding in the landscape

PREVIOUS ABOVE
Illustration of roof detail showing the traditional construction of a peat roof and ending detail with no rain gutter.

PREVIOUS BELOW
Illustration of different types of wood caldding systems often used on danish summerhouses. Note also the detailing in the use of horisontal boards that creates both a natural protection of the end boards as well as an architectural expression

ABOVE
The carefull use of sparse colouring and a green roof allows a cluster of summerhouses to easily blend in with nature in a landscape.

ABOVE NEXT
Traditional Danish summer house painted black and a self-sustaining green roof.


Illustration 45 Traditional summerhouse

more natural expression where the logs seem to be stacked – an easy way of construction also found in American log houses dating back to the settlers. (Vadstrup, Larsen-Martensen 2008)

The roofs on many houses on the west coast are green which is also the case of the houses near the project site. This way of construction is heavy with a density of 250 kg/m2 and prompt for a sturdy support with thick trusses close together. As these are often uncovered on the inside this gives in the interior a certain rhythm and a very clear tectonic conception. A base of at least six layers of birch bark is set on a sloping roof between 15-25 degrees. On top of this are two layers of grass peat set first with the grass layer down and the other with the grass layer upwards being the lush green cover. The construction leaves little need for rain gutters which are seldom fitted resulting in a different end detail to the roof and more freedom to work with this feature.

The traditional Danish summerhouse is fitted into its scenic context, especially in the case of houses in dunes on the west coast. The use of natural materials and treating them naturally, low roof pitch and grass coverage makes the summer house blend into the landscape seeming smaller than apparent. The pigmented treatment of the wood adds contrast making what is visible stand out and the houses appear as small colour spots scattered evenly. The colouring is often used also to contrast the different entities and details on the houses: A base colour, such as black, light blue or dark green is complemented by the contrast of white or red windows, doors and fascia give a very clear conception of the architectural details.

MULTI SENSORY ARCHITECTURE

When experiencing architecture, the senses of the human body work in correlation to each other to gather and process the information in which it encounters. Pallasmaa states;

”Every touching experience of architecture is multi-sensory; qualities of the space, matter and scale are measured equally by the eye, ear, nose, skin, tongue, skeleton and the muscle.” (Pallasmaa, 2011, p 45)

This interaction between all the senses is happening all the time without the person noticing it. An example is when entering the old renaissance cathedrals. The hand touches the cold metal handle and feels the smooth texture of the warned metal. The muscles and the skeleton feel the weight of the heavy wooden doors as they are forced open. The scent of the wood hits the nose and the eyes watch the woodwork on the door. When entering the cathedral, the ears hear the change in noise from the outside and to the vast indoor space, where sound is bounced around the room on the hard surfaces. The time seems to stand still inside the cathedral, compared to the rush of people outside, walking, in cars and on bicycles. Inside the cathedral time slows down and the room encloses the person. (Rasmussen 1959, Pallasmaa 2012)

The most dominate senses are the sense of vision and the sense of touch. These senses work together to give the brain the full image of what is happening in front it. The sense of touch happens long before the skin touches the surface of the wall or the door handles. The touch-first happens when the eye gazes upon the material beforehand. The haptic memory of the mind helps the brain to comprehend materiality, texture, distance and special depth.

Illustration 46 Waves in Venice

The 18th -century philosopher George Berkely was one of the early people to relate touch to sight. He stated that apprehension of materiality, distance and spatial depth would not be possible without the cooperation of this haptic memory.

Good architects use this knowledge and previous encounters to bring in elements, materials and contours, which are moulded for the pleasurable touch of the eye and then the skin. This haptic memory is based on previous encounters of different materials and surfaces and can be related not only to what is in front of us but also to different media. When looking at paintings or photographs our sensory memory makes the feeling of different aspects of the painting apparent.

The use of materials can bring forward, an irresistible urge to touch and feel materials and its textures. The old door handle which has been used countless times, the railing on an old staircase which through years of wear, has been turned silky smooth.

Curtain materials and textures can also bring forward and urge to "taste" the material. As an infant, the baby will put stuff in its mouth to investigate and understand what it has before it. This interaction between sight and oral sensations will follow a person throughout his/her entire life. Curtain colours and delicate details can bring forward a subtle oral sensation by the viewer.

As vision is more directional, sound is omnidirectional. Vision and sight can be obstructed by columns, walls and other parts of the building, whereas sound can travel around objects and channelize through materials. Sound can determine if it is a pleasant room to be in. When entering a building the eyes will be reaching out

"Can architecture be heard? Most people would probably say that architecture does not produce sound, it cannot be heard. But neither does it radiate light and yet it can be seen. We see the light it reflects and thereby gain an impression of form and material. In the same way we hear the sounds it reflects and they, too, give us an impression of form and material..."

Steen Eiler Rasmussen (Rasmussen 1959)

into the room understand the room, whereas the ears will receive the characteristic sounds of the building and thereby help the brain to understand

As well as the hearing can be interpreted as a more passive sense, the smell can be as well. One of the most persistent memories we have is often the sense of smell. When experiencing a familiar smell, the nose can make the eyes remember memories, which before was forgotten, and takes the mind back to that exact same place, where the memory is from.

There is a lot more to Architecture than mere aesthetics perceived by the sense of sight. Any piece of architecture will therefore inevitably confront and trigger of not all then at least several of human senses. As a result, the final design must encounter the multi-sensory architecture and design parameter's and criteria's must not only allow this plurality but push the architecture to be more intricate and sophisticated.

PREVIOUS PAGE
Water on Venetian embankment
The moment of water in the urban setting of Venice offers a multisensory experience, beside from the apparant play of the waves and air bubles. The sound of each hit and retreat is mixed with the smell of salttwater and seaweed whilst the skin can feel small drops from the splashes.

OPPOSITE ABOVE
The Blur Building by Renfo Diller & Socfidio is one of resent years examples of the multisensory architecture, where water is the site, the material and the culinary pleasure of the building.

ABOVE BELOW
Thermal Vals by Peter Zumthor is conceptualised on mountain, stone and water presenting a multi-sensory experience of bathing as a ritual, where differences material, temperature, humidity and light changes as you move through it.


Illustration 47 Blur Building

Illustration 48 Thermal Vals

COLOUR

THEORY

The addition of colours in architecture can have a large impact on how the eyes and the brain both see and understands architecture, but colours also have an impact on the psychology of the human brain.

Colours in architecture can have a range of different uses, either to emphasise the character of the building, its texture or to highlight or hide different aspects of the building itself. A structural part such as a truss or a column can be painted over to make it blend into the surrounding parts of the building and thereby making it less visible for the viewer. (Bjerregaard, 2005)

Some colours can give a new character to a room by changing the way in which it is experienced. By using pale light colours on the smaller room, the room can appear larger to the eye., a hallway can also appear shorter if the wall at the end of the hallway is painted a darker more dominant colour. The perception of a room can be altered or manipulated by the temperature of the colours within: A northern faced room, which can appear cold in the diffuse light, can appear warmer when painted in warm tones, such as cream or ivory, or to the extreme a bright orange.

When adding a colour to a room, the colour can have an impact on people's behaviour and their psychical comfort. Studies have shown that certain colours have a different impact on the brain.

The colours which are listed can also have a different influence on people and their behaviour. Green has shown to have a relaxing effect on humans, but it can also have a negative effect when used in nuances which are too bright. A factory in Manchester had its wall painted green, and because of this, the sickness absence of the workers raised. When the walls were painted over again, the sickness absence decreased to normal.

AGGRESSION EXCITEMENT HIGH ACTIVITY	CALMING HARMONY RELAXING SERENITY
COOLING RELAXING CONCENTRATION CONTEMPLATION	OPTIMISM JOY OF LIFE IRASCIBLE
SUPPRESSES UNASE AND AGRESSION	PHILOSOPHICAL ANXIETY UNEASE CONFUSION
ELEGANCE, SADNESS, BOREDOM, RETICENCE	ENCOURAGING ANTI-DEPRESSIVE STIMULATE INTELLECT

Illustration 49 Colourchart with related perceptions and reactions

INVENTILATE

MICROVENT

For the ventilation of the majority of the New Continuation School, the product Inventilate has been utilized. Inventilate is a highly effective ventilation system, which with a low energy consumption and a high heat recovery system can keep the indoor climate and indoor comfort as well as reduce the energy use of the building. What makes Inventilate differ from conventional ventilation system, is that it does not need ducts to transport the air from a central unit. (Inventilate 2017, Inventilate et al. 2012)

The MicroVent Unit works in pairs and are placed in the wall of the building. One of the microvents will extract polluted air from the room, and use the heat from the air to heat up a regenerator inside the unit. While the first unit extract the polluted air, the other unit will take fresh air from the outside, run it through the regenerator, which has been heated by the polluted air, and blow in fresh air into the room. The two units will then coordinate and shift between each other.

The inventilate can be programmed to ventilate according to CO2 and temperature or the amount of moisture which would be in the room. Each unit can be controlled individually either through the internet, via a computer or a smartphone. The MicroVents has an IP Rating of IP52 on the inside and an IP54 on the outside, which correlates to how dust and water proof it is but can be manufactured with a higher IP Rating if necessary.

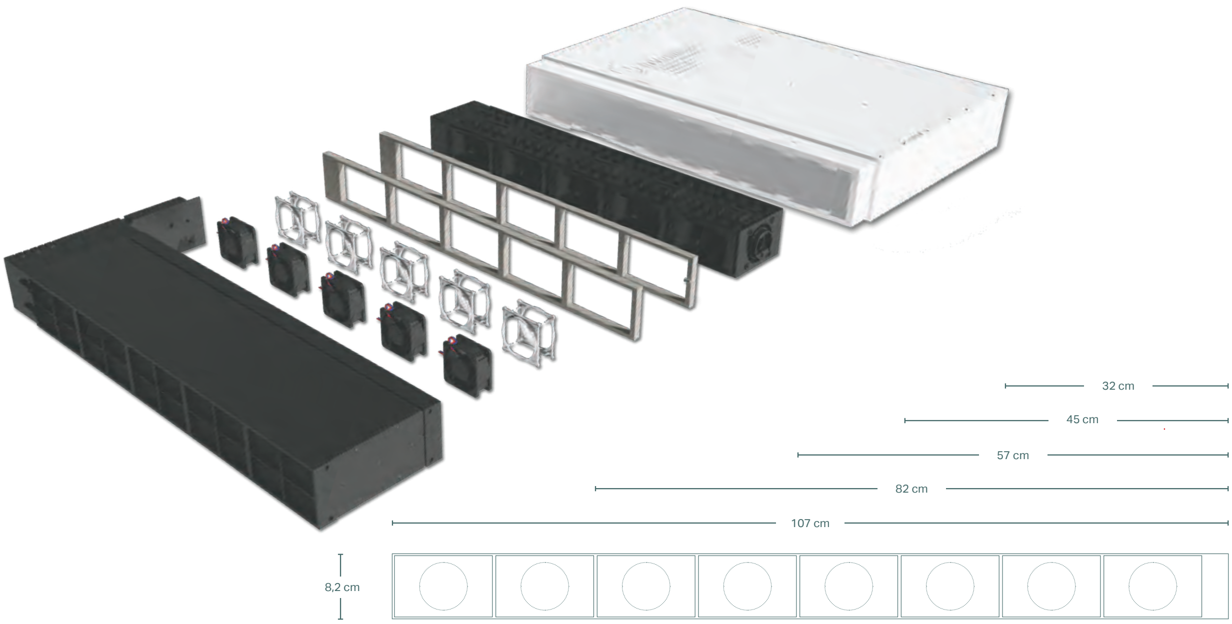


Illustration 50 Inventilate Microvent exploded diagram

Due to the simple design of the MicroVent, the general maintenance and cleaning of the units can be done by the staff of the school. The general maintenance and cleaning consist of firstly checking if all the fans are rotating properly and checking if there should be damage to the cables connection the Microvent to power.

The cleaning of the MicroVent is done by turning off the unit, and carefully dismantling the unit from the wall bracket. When the unit are out of the wall, the ventilator and regenerator can be cleaned with a simple vacuum cleaner. The regenerator can also be cleaned in a dishwasher, if it should be too dirty to clean with just a vacuum cleaner.

By using Inventilate, the school can be constructed with no ventilation ducts and central units in the commonspaces, living units, class rooms and teachers facilities, making it possible not to consider lowered roofs of visible pipes. The maintenance and replacement of units would also become easier due to the simple design and easy replacement.

ABOVE
The ventilation system Inventilate Microvent allows for an effective mechanical ventilation that due to the absent of ducts, valves etc. is as close the opnening a window while maintaining the possibility of sensor control. The simple design keeps maintenance at a minimum with easy access to filters and fans.

VISION

The goal of this project will be to create a new continuation school along the western coast of Denmark. The continuation school which will have a focus on sport, dance and music will be placed in the flowing landscape close to the coast and focus on the how the nature and the view to nature will have a have an impact and influence on the stress levels on the pupils and teachers alike. From the studies on healing architecture on how nature has an influence on the rehabilitation of sick people due to the reduced amount of stress hormones in the body – a similar result could be linked to learning.

Where regular schools are only in use from 8 am in the morning to 4 pm in the afternoon, the continuation school is in use 24/7. The pupils live in rooms in communities of two to four pupils and thereby has a strong social experience during the year at the school. These social communities which come in different sizes, from the two to four person who shares a room together, to the larger social group which is the contact group and the classes and finally the large social group which is the whole school.

Sustainability in the building sector is hastily becoming a major focus. The use of material, the energy use of the building, the energy sources and the impact on the landscape are an all different aspect of the sustainability which will also become a focus in the creation of the new continuation school.

The new continuation school should follow the studies of healing architecture as well as focus on the daily use and social aspect which derives from the continuation school

The building should become a part of the landscape and follow the topography of it

It should embrace the different sizes of social communities which will be found in the Danish continuation school

It should be sustainable and follow the alt should facilitate both learning facilities as well as recreative facilities

Should be able to be in use 24 hours a day.

It should be able to embrace nature and make nature a part of the building as well as making the building a part of nature.

With the integration of large windows or glazed facades the building should offer panoramic views to nature and at the same time feature a high natural illuminance.

It should follow the traditions of the Nordic Architecture where the building is formed by the landscape and not the other way around.

It should be designed and built by using few yet sturdy materials which can endure the rough weather on the west coast

The pallet of materials should be kept simple, to ensure a modest and coherent aesthetic.

The roof should be an intensive typology with naturally inherent plant species to support both biodiversity and building performance.

DESIGN PRINCIPLES

The use of green roofs offer thermal mass and evaporation from plants that works with the natural elements on site resulting in a natural cooling system. Furthermore, the green roof helps rainwater management and with the use of inherent plants species lets the architecture blend in to the landscape.

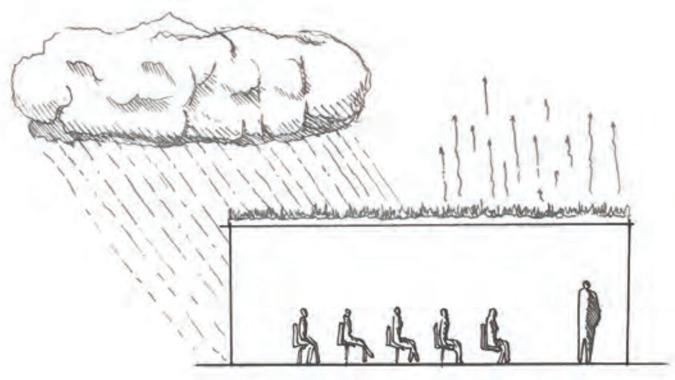


Illustration 51 Design parameter - Green roofs

Views out to nature provide a tranquil setting indoor that de-stresses pupils during classes and in everyday recreational situations. The large windows that facilitates these views also ensure a light interior with a high amount of daylight.

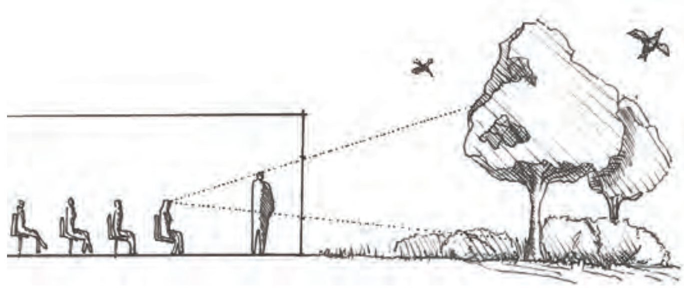


Illustration 52 Design parameter - Views to nature

Courtyards at each commonspace gives the option of staging communities, teaching sessions or relaxation both outside and indoor. With the adaptation of the same material for pavement and funiture as used on the facade, the courtyards should have a coherent and calm expression, letting nature as a backdrop and small plant beds potrude.

Illustration 53 Design parameter - Cortyards and commonspaces

Natural ventilation together with a low SEL -alue ventilation system ensures adequate air change whilst keeping a good energy balance. Per everyday use the Inventilate system will ensure that all requirements by building regulations are fulfilled whilst natural ventilation will kick-in on hot days or during high internal loads to maintain a high quality indoorinvironment.

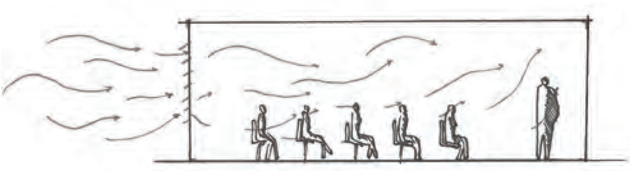


Illustration 54 Design parameter - Natural ventilation

Overhangs from the roof shades the high and intensive summersun where needed to avoid the risk of overheating or the need for active cooling strategies. The overhang should also create shaded outdoor spaces for hot or rainy days as well as offer a dry route between the different functions in the school

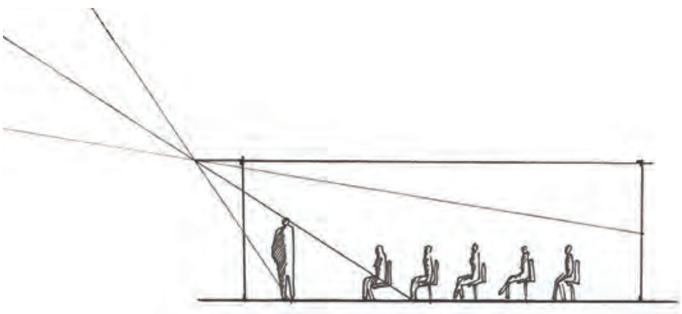


Illustration 55 Design parameter - Integrated overhangs and shading

The pitched roof makes for high room height at gathering points and spaces with a high person load which ensures a positive perception of the spaces as well as allowing larger windows resulting in better daylight factor. The higher ceiling heights comes natural with a higher extivity level, whilst roof lowerings will create small more intimate spaces for quitness and relaxation.

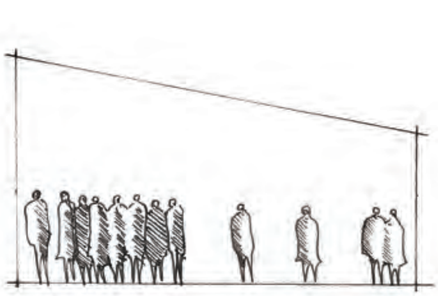


Illustration 56 Design parameter - Mono-pitched roofs

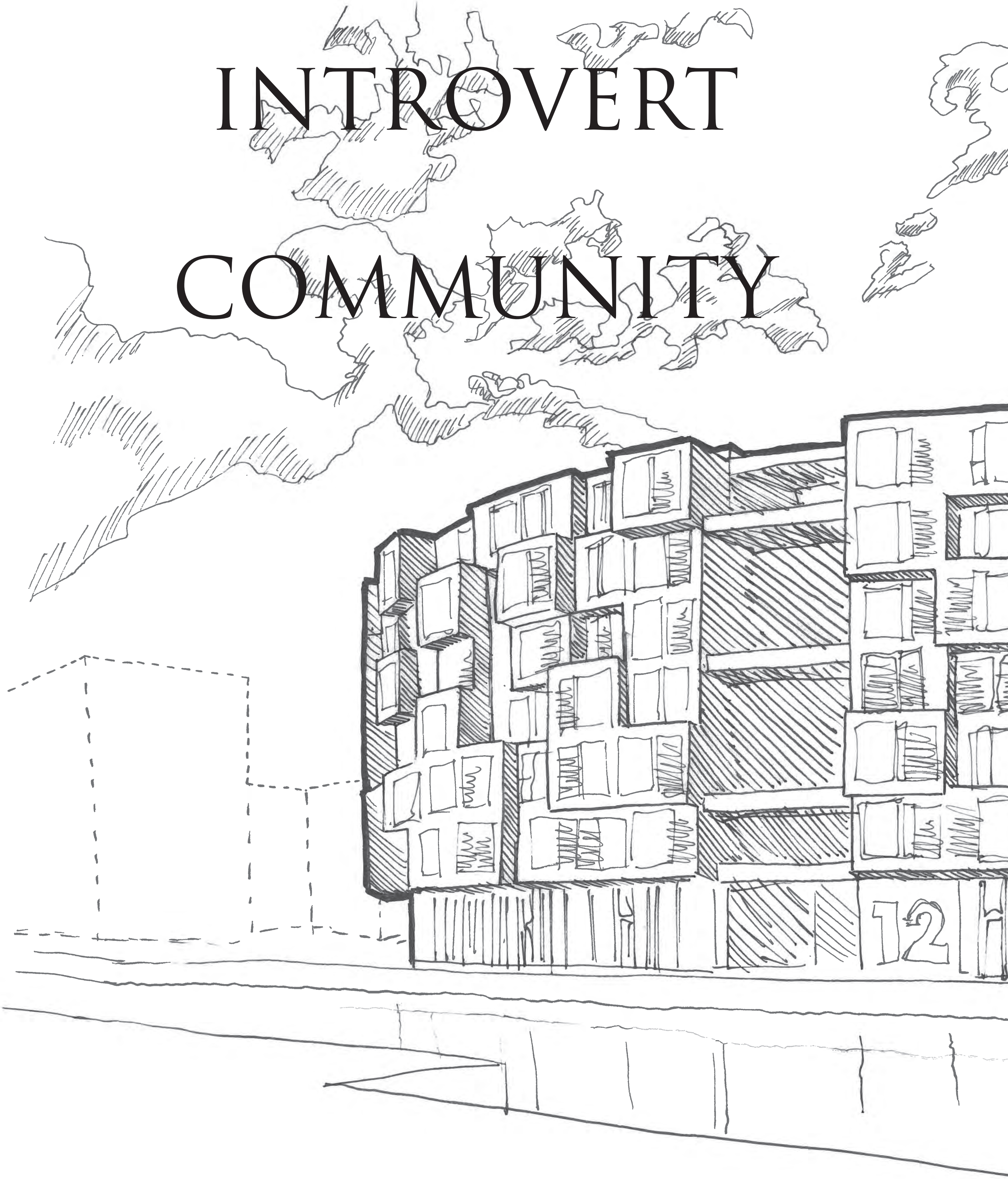
PROCESS

REFERENCES

As the continuation school of the project is expected to be situated in a rural natural context several a case study of different pieces of architecture that facilitates different gestures to their surroundings have been established in order to obtain a deeper understanding of the forces at play. As this context at the same time equals little life around the school there would be little point in opening up many facilities, and therefore a study of introverted designs are featured to establish knowledge about how this can facilitate community where there have not been one before. Finally, with a local plan founding architecture that sits low due to rules regarding roofs and a context with many green roofs, a study of roofs have been done to investigate not only how the roof can support community but also facilitate passive solutions such as solar shading. The studied buildings are from different periods of modern architecture and have very different programs that ads to a diverse study with focus on the specific solutions they express instead of a focus on solely educational architecture.

Illustration 57 Contemporary Danish summerhouse

INTROVERT COMMUNITY



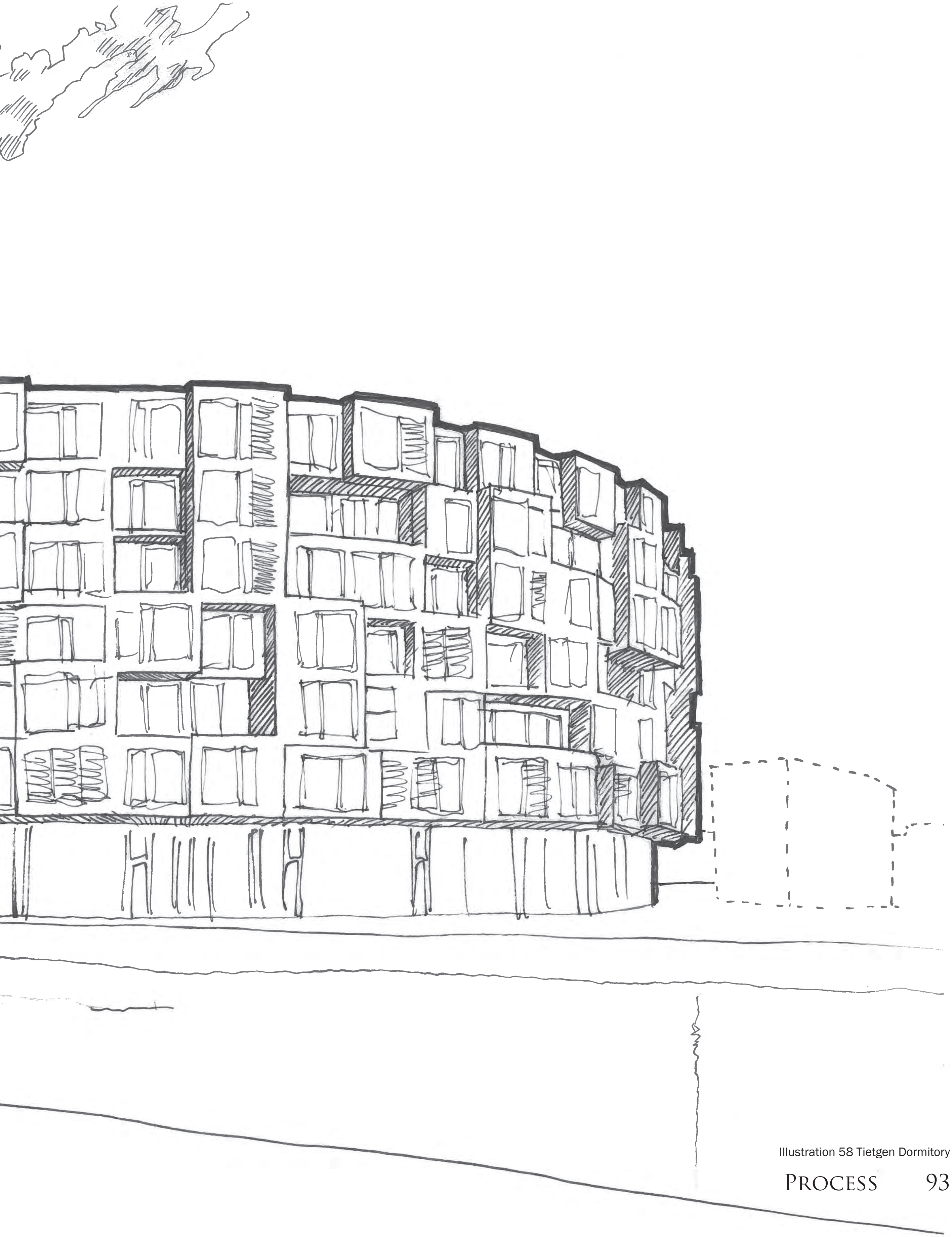


Illustration 58 Tietgen Dormitory

3XN, ØRESTAD GYMNASIUM, 2006 KØBENHAVN

LUNDGAARD & TRANBERG, TIETGENKOLLEGIET, 2006, KØBENHAVN

Programmed specifically for the new Ørestad Gymnasium with an academic focus on digital media and new ways of teaching, the design by 3XN features a central atrium that connects the entire school. With a deliberately under-programming of teaching spaces the Ørestad Gymnaisum not only invites but forces teachers and student to interact, work and relax in the same large volume together. With integrated furniture and many unconventionally shaped rooms the interior is diverse and open, whilst maintaining small niches or closed spaces for quiet sessions.

Apart from the ground level, the facades are active solar shutters, that ads an element of interaction with the context. However as windows are set deep and the shutter system to a great extent hinders direct views from the outside the building is introvert with the energy and dynamic of a modern school confined on the inside. This is also underlined by the articulation of several roof top terraces as main outside spaces. (Sommer 2014)

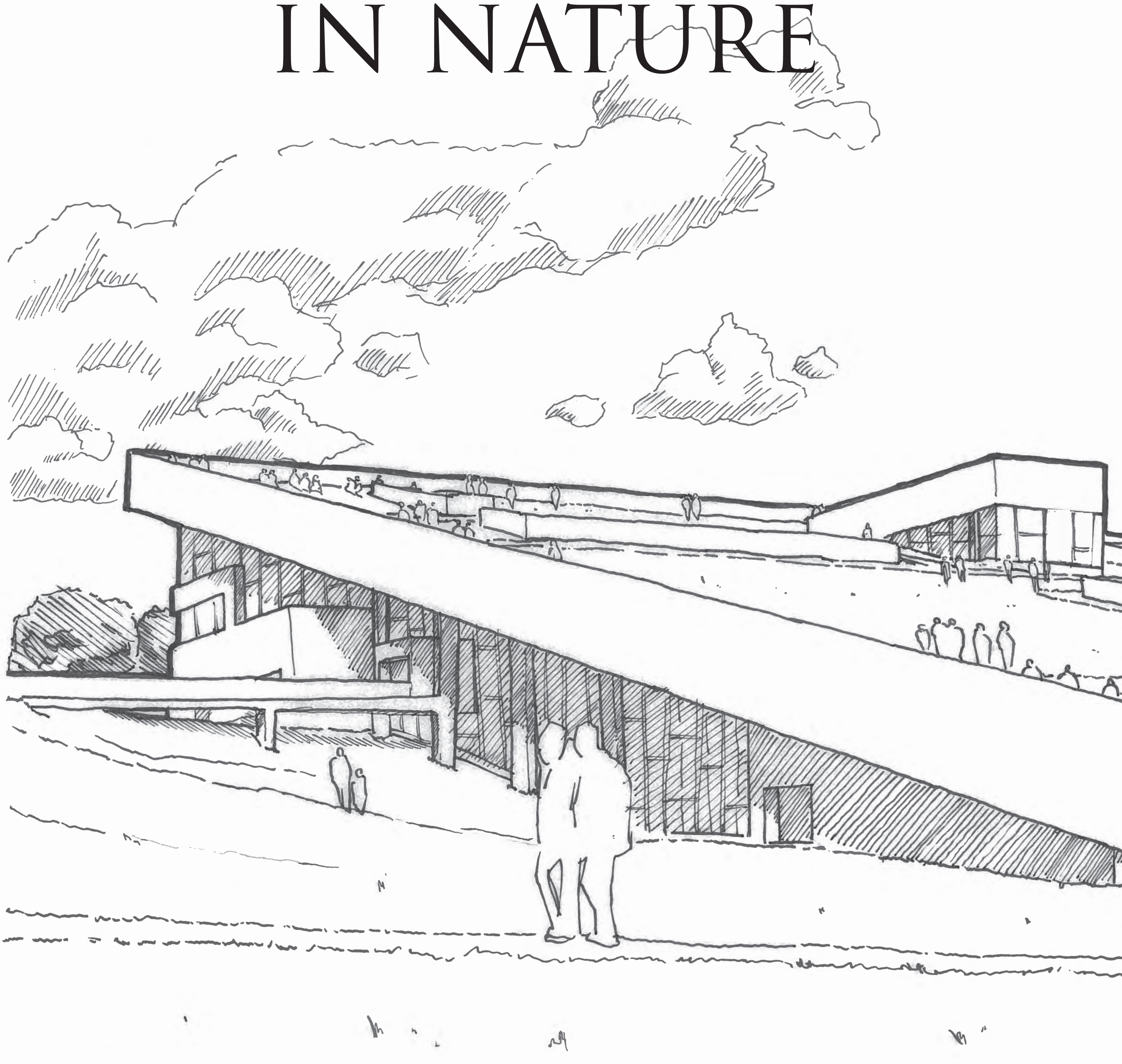
The Tietgen Dormitory situated in Ørestaden, Copenhagen. The round building shape works both introvert and extrovert, by addressing the surroundings as well as focusing inward towards its inner functions. The Building shape also works as an expression of the organization of the building. The dorm rooms are all located in the outer perimeter of the building, facing outwards, where the common facilities are on the inner perimeter, facing inward. The residences are organized into thirty groups of twelve people, whom all share a kitchen, common room and utility room. By making the plan layout like this, the architects are creating different communities between the residents as well as always keeping a visual connection between the different common spaces in the entire building. A small community with the group of twelve people who shares the common kitchen etc. A larger community which would be fx the entire 5th floor and the largest community which would be the whole dormitory. (Sommer 2014)

Illustration 59 Spiral staircase of Ørestaden Gymnasium

Illustration 60 Internal courtyard of Tietgen Dormitory

POSITION

IN NATURE



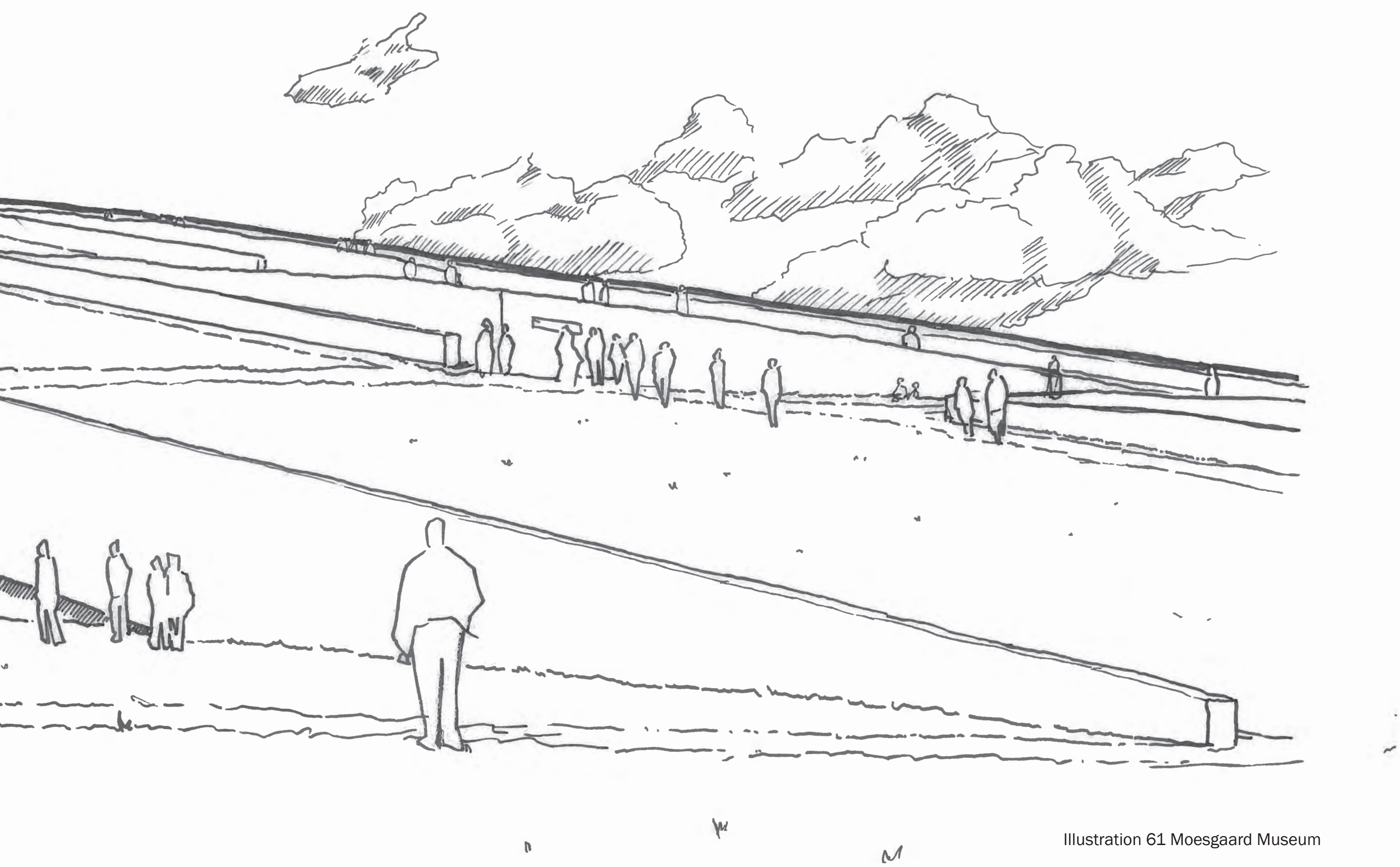


Illustration 61 Moesgaard Museum

CLAUS BONNERUP, ØJNE I NATTEN, 1975, BLOKHUS

BJARKE INGELS GROUP, TIRPITZ MUSEUM, 2018, BLÅVAND

The vacation house made by Claus Bonnerup is located in Blokhus, Denmark, just behind the first row of dunes closest to the North Sea. The purpose of using this project as a reference for the project, was how the building has been integrated into the landscape. The large vacation home has been almost entirely covered by a sand dune and only the main entrance, two large window constructions and the exit to the terrace are visible when visiting the project. By being covered by the surrounding landscape, the architects has been able to make the otherwise large vacation house seem to disappear in the landscape. During the evening the two large windows extruding from the dunes would be filled with light and making the building giving the expression of two glowing eyes in the night. The covering by the landscape of a building of prominent size limits its visual impact in a landscape. Furthermore this approach makes for an apparent embedment in this context and therefore the architecture seems more into a natural position.(Steponaitis, Larsen 2007)

The Museum center Blåvand contains 3 museums, a bunker museum, an amber museum, a history museum and an exhibitions gallery. In respect to the landscape where the building was, the building has placed underneath the dunes and in 4 separate buildings. By doing this, and making the buildings slightly overlap, the have made a courtyard in the middle between the building and creating paths which connect to existing trails. This allows for more quiet at intimate stays within the otherwise rough and windy landscape. (Ghinitoiu et al. 2017)

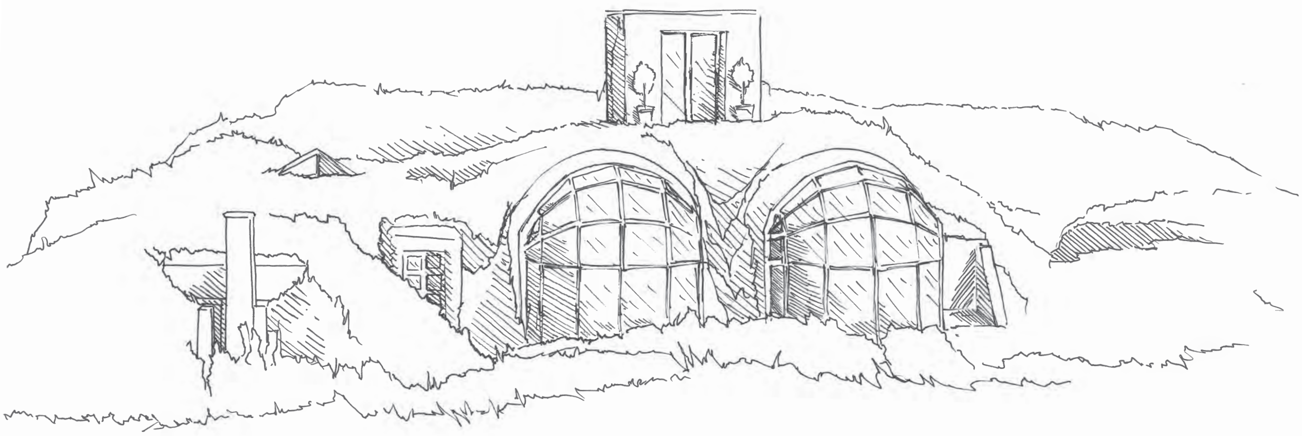


Illustration 62 ”Øjne i natten”

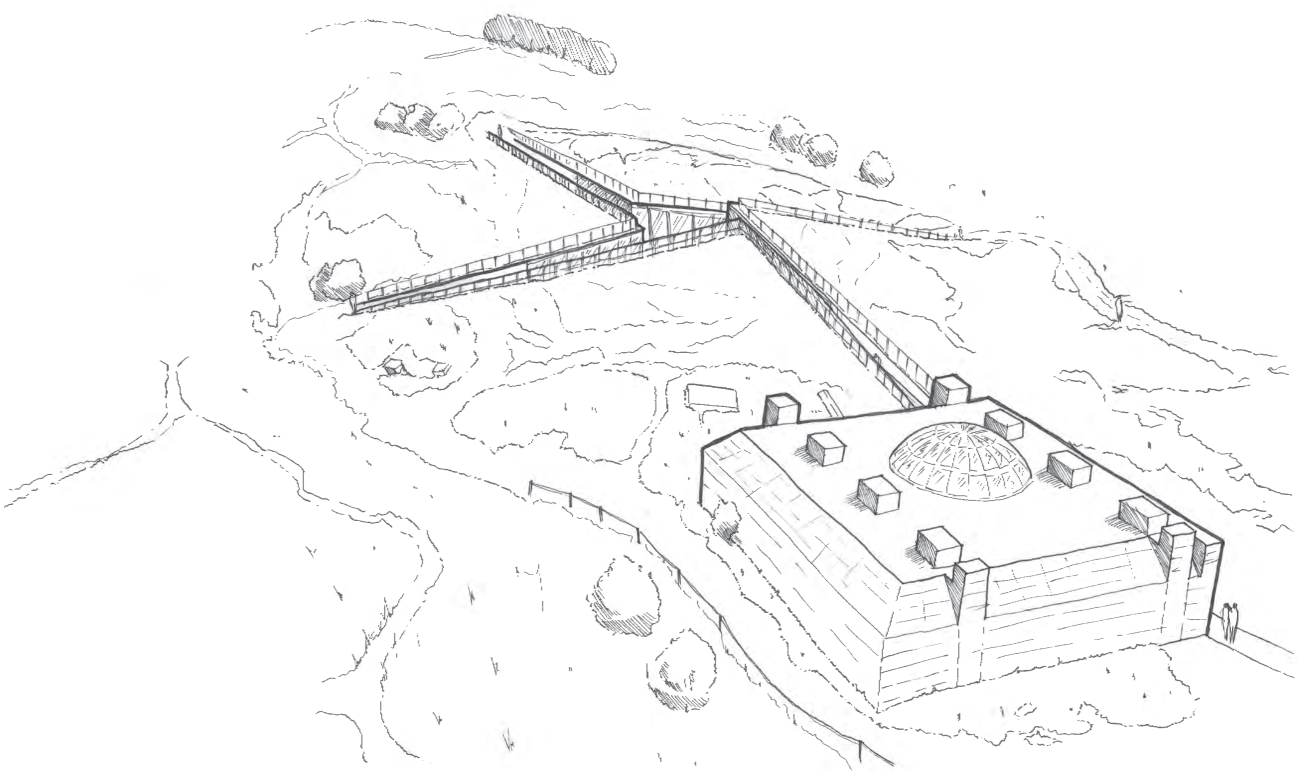


Illustration 63 Tirpitz museum

JØRN UTZON, KINGO HUSENE, 1957-1961, HELSINGØR

WOHLERT ARKITEKTER, LOUISIANA, 1958-2014, HUMLEBÆK

For large scale projects which used the landscape as an advantage instead of a boundary, the Kingo Houses by Jørn Utzon is settlement that by utilizes the sloping landscape to place the houses. The building consists of a squared outer wall of 15 by 15 meters that encloses one of the L-shaped houses creating a clear boundary between the garden and the landscape. By using the system of the squared perimeter and the house maintained in one corner, Utzon had the opportunity to place and rotate each individual house according to the landscape. The courtyard walls of each of the individual houses was also made specifically for each house, taking privacy, shade and view into account when designing them. Despite the clear and strict geometry of the individual houses the careful position in the landscapes makes for an organic and dymanic masterplan. (Sommer 2014)

The Louisiana Museum of Modern Art has since its opening in 1958 gone through several expansions. The many expansions have been placed to follow the natural landscape has become an inspiration for this project. When walking through the different expansions, the architects has been able to control the views of which the visitors will experience. (Sommer 2014)

Illustration 64 Siteplan of Kingo Houses

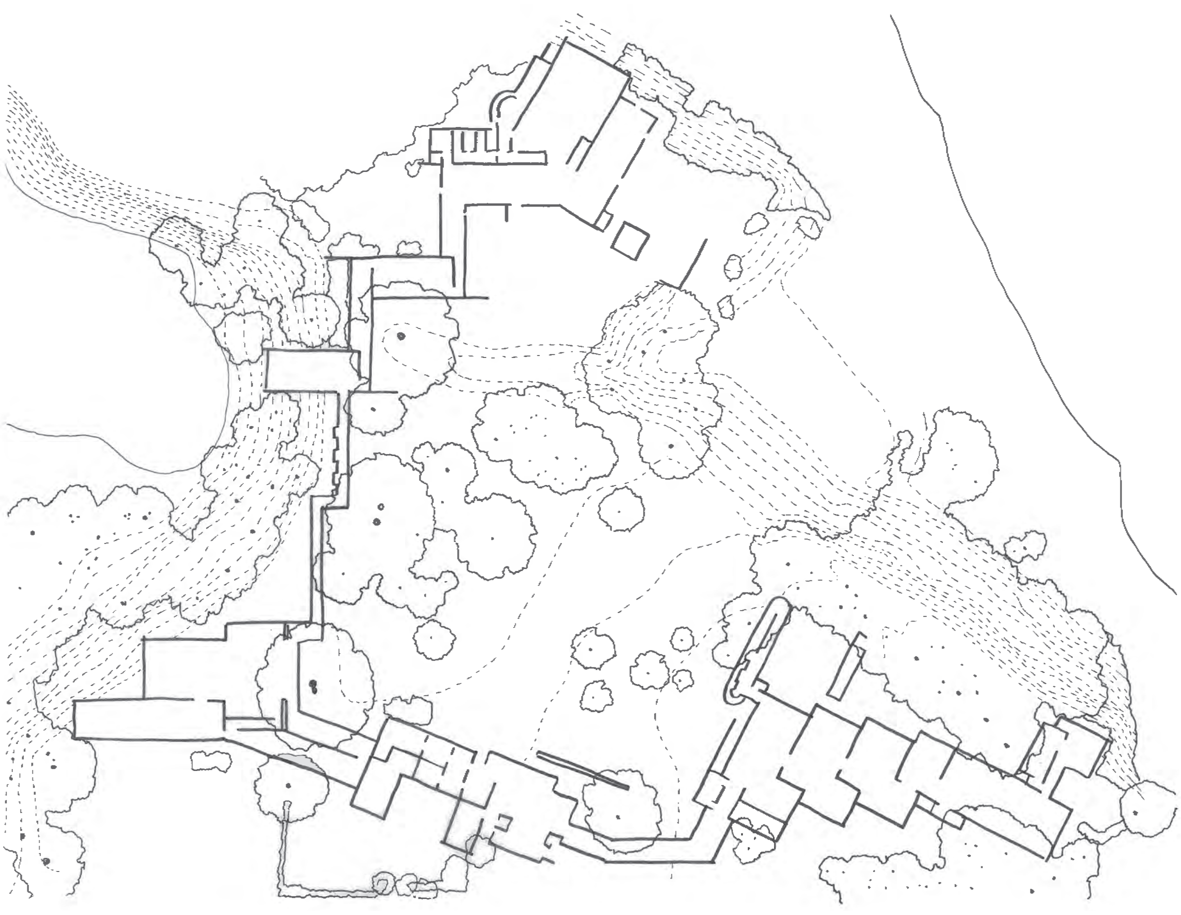
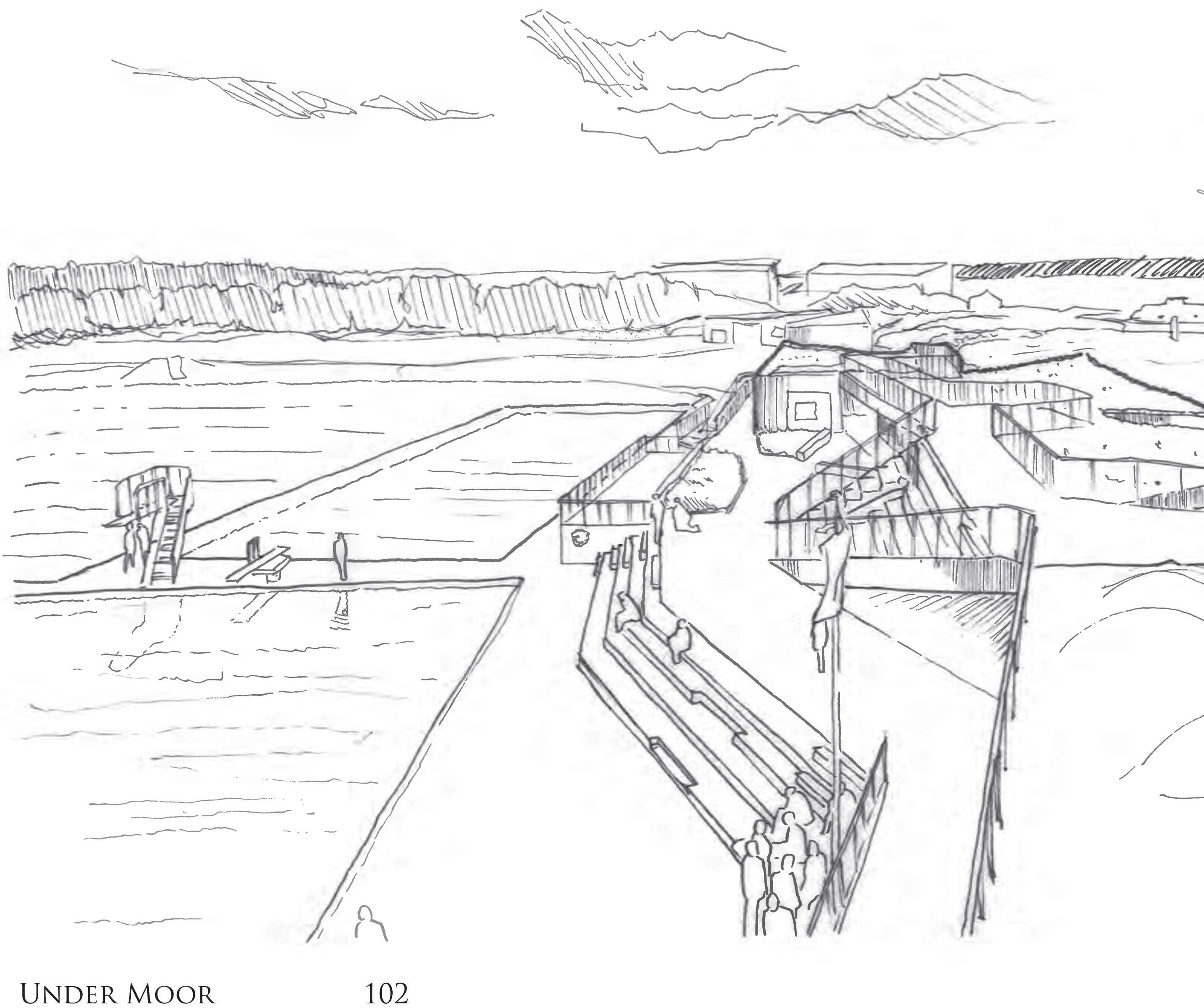


Illustration 65 Siteplan of Louisiana

UTILISING ROOFTOPS



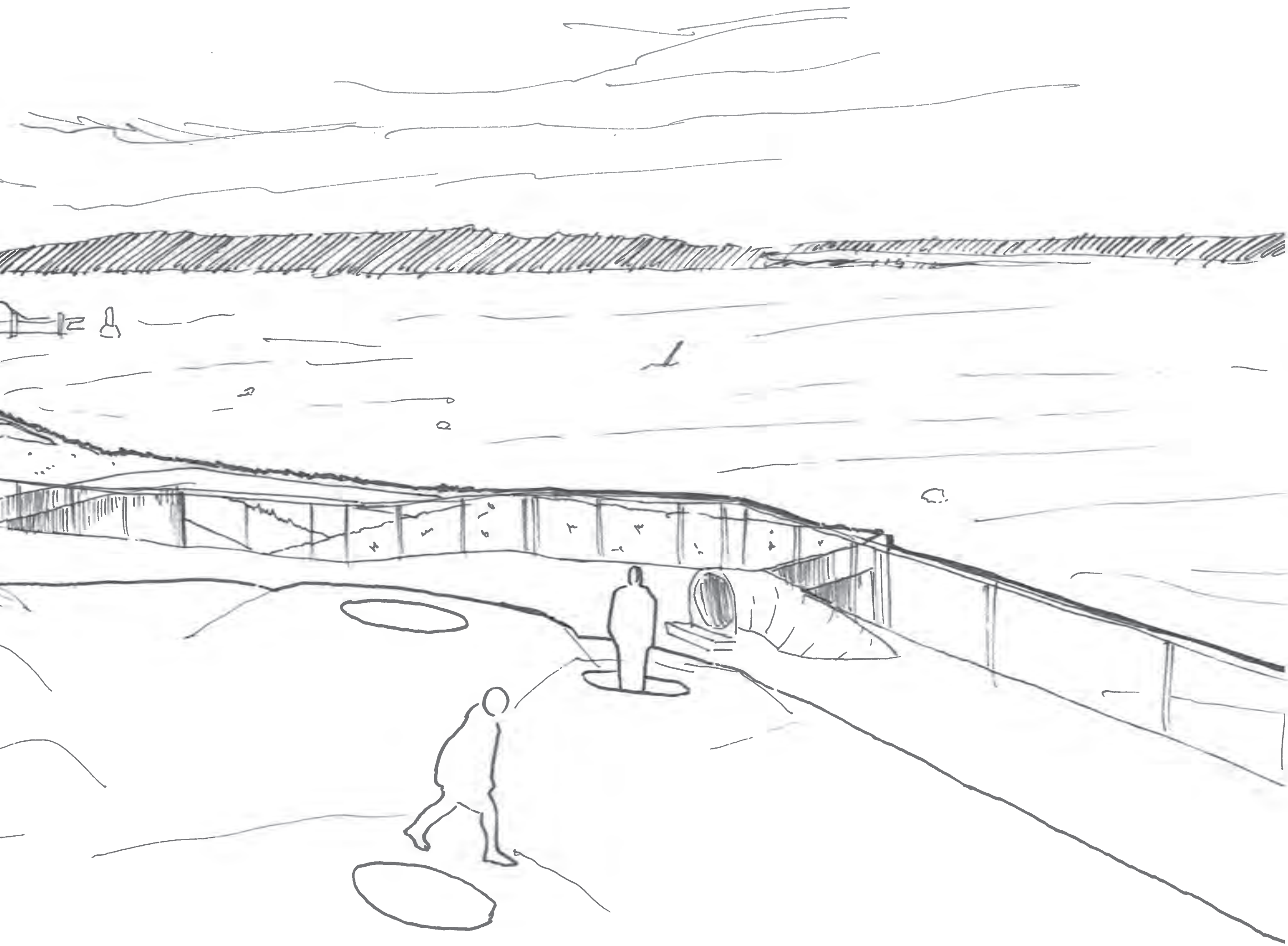


Illustration 66 Vestre Fjordpark

ADEPT, VESTRE FJORDPARK, 2017, AALBORG

MU ARCHITECTURE & ARCHICOP, FRENCH SUMMER SCHOOL, 2014, BRIIS-SOUS-FORGES

The Vestre Fjordpark is placed on the edge of Aalborg right next to the Limfjord. The building has been divided into smaller building according to the functions of which each building holds. All of the small buildings are placed with a distance to each other to make small spaces and passages of which visitors can have a visual connection between the man-made landscape of the pools and the more natural environment of the fjord. Covering all of the buildings are a large roof, which transforms into large stairs, trampolines and a walkway at several places, inviting the visitors to use the roof for both relaxation and play. With the use of different materials on the roof, the architects have given different areas of the roof its own respective expression.

The expression the layout of the building gives the expression of the dunes of the western coast of Denmark or at least the movement in between the dunes, where movement is never in a straight line. You either walk over the dunes or in a zigzag pattern between the large sand formations. (Hjortshøj 2017)

The all wooden French summer school by Mu Architecture, has a flowing roof which goes from having no overhang at all and being flush with the façade to extrude out from the façade and thereby naturally creating an overhang. As well as with the roof on the Vestre Fjordpark by Adept, a series of openings has been made in the overhangs to make light come through and making the roofs seem lighter.

The façades are made with wooden lamellar, which goes from ground to the edge of the roof, making the roof disappear. When the roofs extrude from the façade to make an overhang, the lamellar will continue around the edge of the overhang to create a connection between the roof and the façade. (Griffiths 2015)


Illustration 67 The joining roof at Vestre Fjordpark


Illustration 68 The integrated roof at the French School

HENNING LARSEN, MOESGAARD MUSEUM, 2014, AARHUS

SNØHETTA, OSLO OPERA HOUSE, 2007 OSLO

The Moesgaard Museum is situated in the sloping landscape south of Aarhus. The museum houses prehistoric exhibitions as well as other types of exhibitions. The large building rises up out of the landscape, giving the expression of "the earth opening up to reveal its hidden treasures and history" at a dramatic scale. The Large sloping roof which has been made, are covered in grass, which both enhances the expression of "the earth opening up", but also gives the visitors an opportunity to scale the large building and making the roof useable for other venues. As the slope of the roof is a natural continuation touching the hill below the large building again seems to blend in and appear with a lesser visual impact despite the conventional vertical facades on three other sides. A second quality to the raised roof is the view into the landscape and towards the sea Moesgaard provides. (Lindhe et al. 2015)

The Oslo Opera House features is a clear concept of front- and backstage where all the needed pragmatism of a modern opera and ballet stage sits quietly at the back of the house away from the public allowing the front to be expressive. Described as carpets by Snøhetta different sloping faces are interwoven around the main stage and foyer attaching the building not only to the ground but the water edge as well. This allows for the public to access a major part of the Opera House without ever entering it. Being at the waterfront of Norway's capital it central position in the city makes for an attractive urban setting where the accessible "roof" has become a new place of gathering. With the vertical glazing at the foyer protruding the slopes the façade and front of the opera is dynamic, dramatic and creates a significant but easily recognizable expression. (Snøhetta 2008)

Illustration 69 The "urban carpets" of Oslo Opera House

Illustration 70 Intensive roof on Moesgaard Museum

CONCLUSION ON REFERENCES

The overall growth of a student at a continuation school comes down to much more than a well-designed classroom: There is a need of private space as well as spaces for the different communities and interactions between both students and teachers. Used day and night the spaces need to functional connected supporting the daily routines as well as keeping up the needed level of control in order to maintain a healthy interrelationship between everyone.

The traditional Danish summerhouse is fitted into its scenic context, especially in the case of houses in dunes on the west coast. The use of natural materials and treating them naturally, low roof pitch and grass coverage makes the summer house blend into the landscape seeming smaller than apparent.

Adapting to the landscape at the site and positioning the different buildings accordingly, a dynamic yet coherent plan can arise, that will offer both interesting views as well as open spaces for stays or contemplation. By digging into the ground or letting the landscape move over buildings covering them and thus integrating architecture into the scenery. This limits the visual impact of otherwise large scale entities and also addresses the possibilities activating the roof by making this an usable part of a building. By doing so proses the question of how to facilitate the latter which could be as an inviting gesture in the case of Vestre Fjordpark, as a mere understated opening for the natural curiosity of the human seen at Moesgaard or the Oslo Opera House that falls in between these two extremes.

At the same time roof can function as a natural part of the energy strategy as with Moesgaard where openings are found on the east, west and north façade to avoid overheating. In the case of the Vestre Fjordpark and the French School the roof is an integrated part maintaining a seamless connection with the façade only to at other places protrude into overhangs ensuring shading from high summer sun.

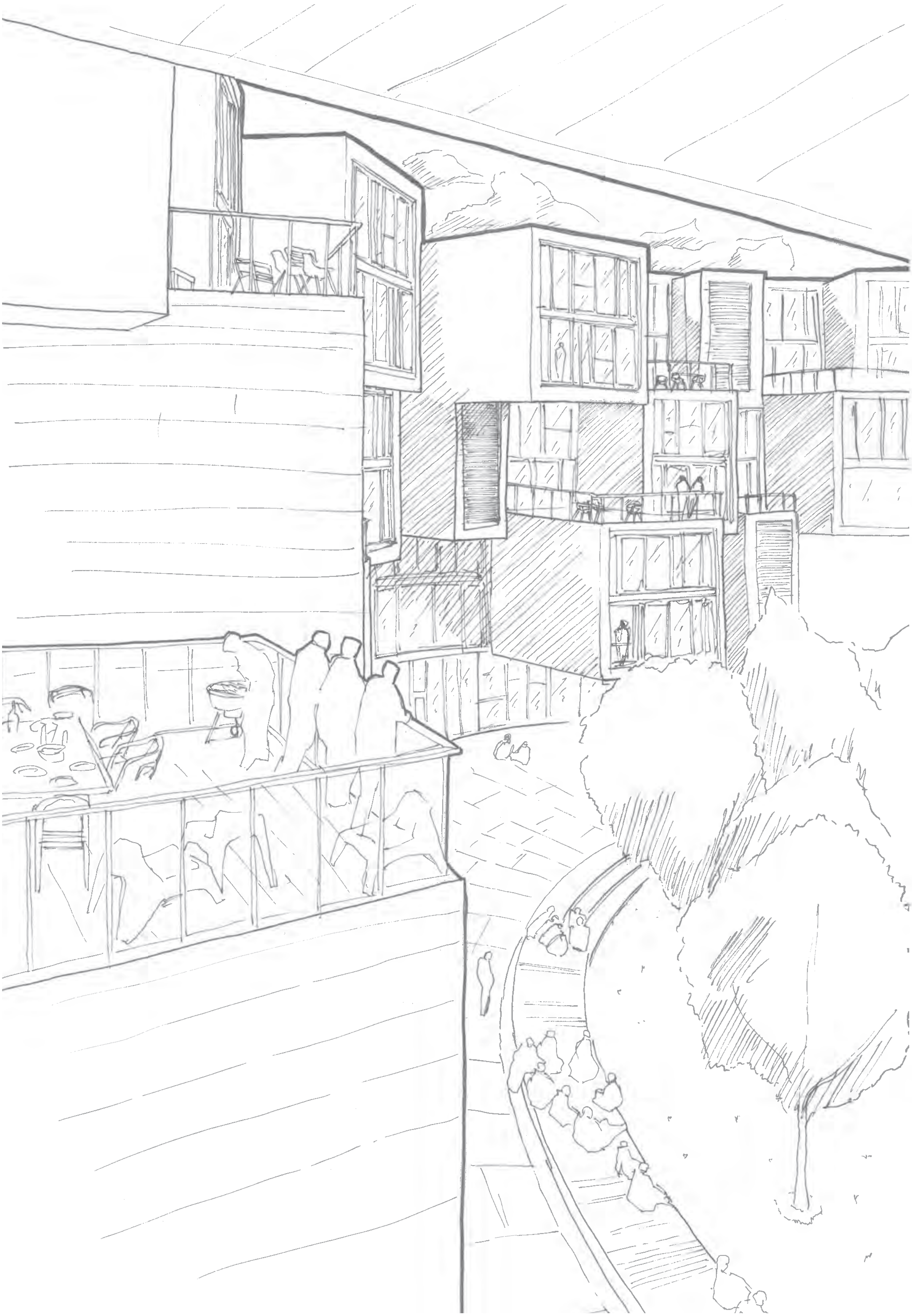
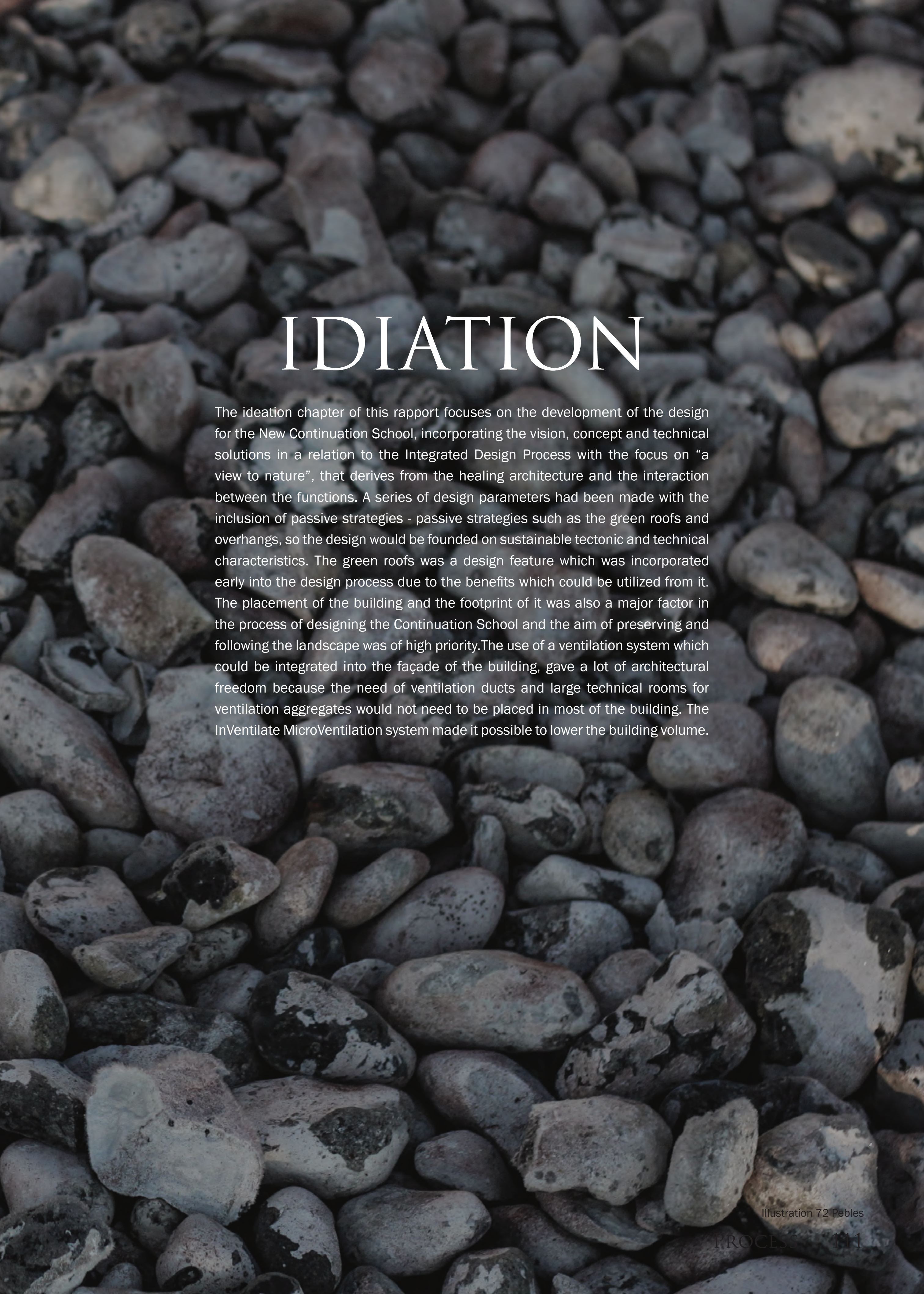


Illustration 71 Balconies and common spaces at Tietgen Dormitory



IDIATION

The ideation chapter of this rapport focuses on the development of the design for the New Continuation School, incorporating the vision, concept and technical solutions in a relation to the Integrated Design Process with the focus on “a view to nature”, that derives from the healing architecture and the interaction between the functions. A series of design parameters had been made with the inclusion of passive strategies - passive strategies such as the green roofs and overhangs, so the design would be founded on sustainable tectonic and technical characteristics. The green roofs was a design feature which was incorporated early into the design process due to the benefits which could be utilized from it. The placement of the building and the footprint of it was also a major factor in the process of designing the Continuation School and the aim of preserving and following the landscape was of high priority.The use of a ventilation system which could be integrated into the façade of the building, gave a lot of architectural freedom because the need of ventilation ducts and large technical rooms for ventilation aggregates would not need to be placed in most of the building. The InVentilate MicroVentilation system made it possible to lower the building volume.

Illustration 72 Pebles

INITIAL

GESTURES

The initial gestures and iterations in the design process focused on different of which the building could interact with the landscape. No particular volume or form was investigated, but more the way a volume could be placed either between the dunes partly dug into a dune or completely covered by the landscape. Initial ideas were placing volumes according to how the landscape was shaped, according to the design parameter of preserving the landscape.

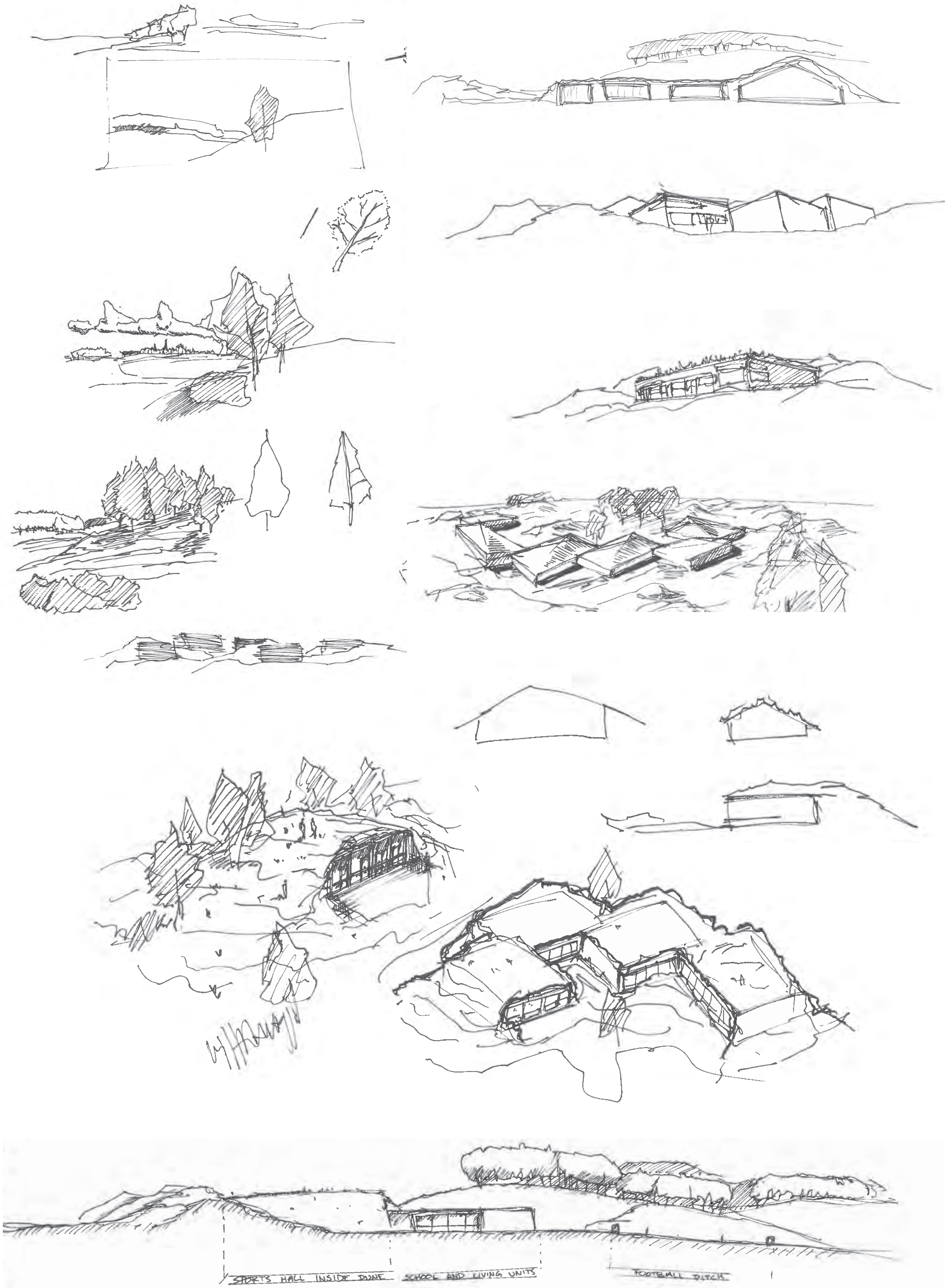


Illustration 73 Process sketches of roof covering

The concept of “hiding the building with the landscape” was derived from how the vacation houses in the context had been placed. With the grass-covered roof, the vacation houses disappeared into the landscape from certain angles – a characteristic which was found crucial due to the size in which finished school would have.

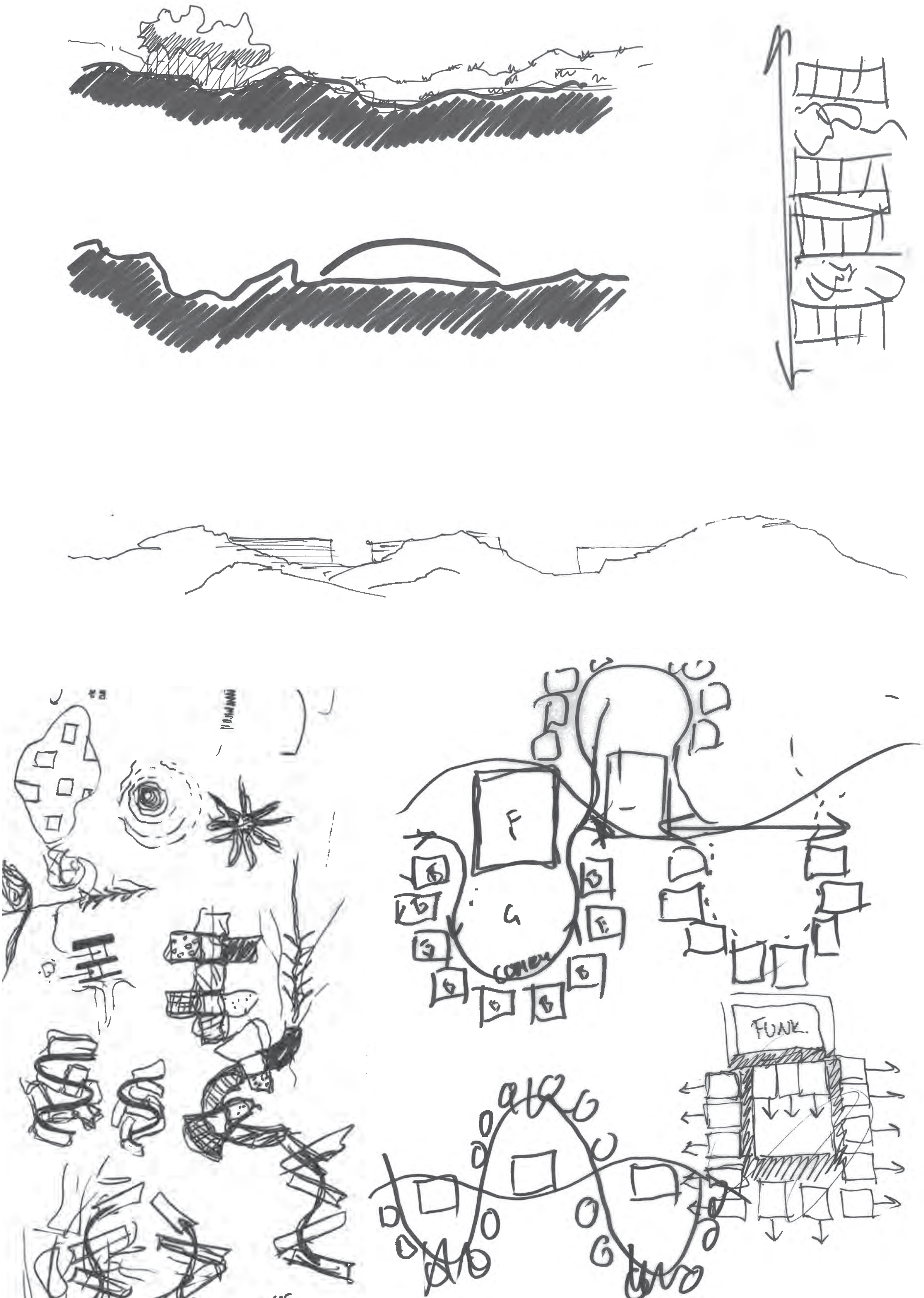


Illustration 74 Process sketches of organisation in the landscape

Different combinations of covering parts of the building to “hide” the size of the school were made where the largest functions would be camouflaged as sand dunes and the rest of the functions would be placed “in between” the dunes. Experiments, where the sports hall would be connected to the football pitch, was also made, due to the way the landscapes goes from flat in the east to hilled towards the west.

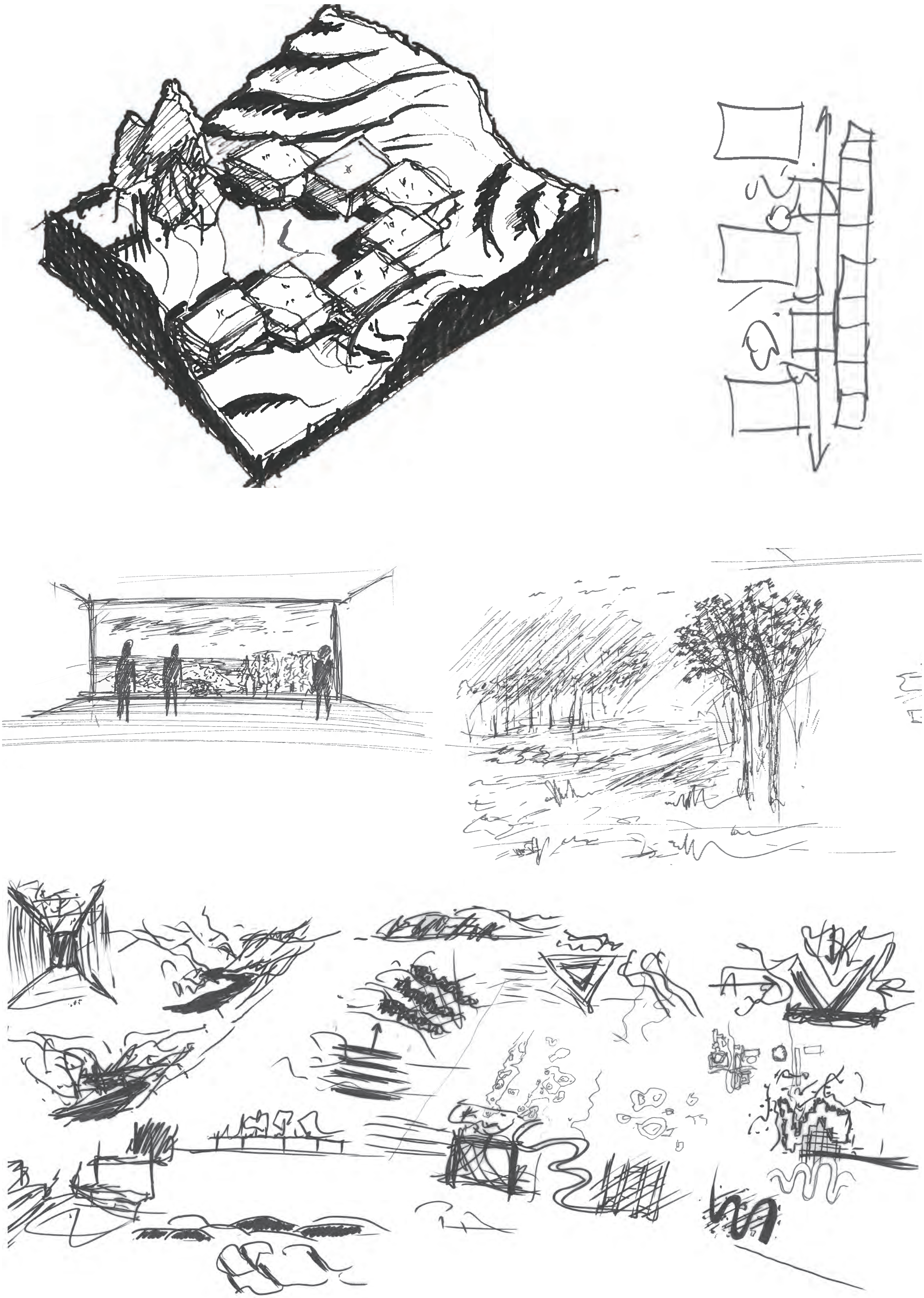


Illustration 75 Process sketches of contact to nature

By covering up parts of the building as “fake dunes”, the idea of letting people walk upon the buildings, thereby not taking away landscape, but raising it up and making it a vantage point.

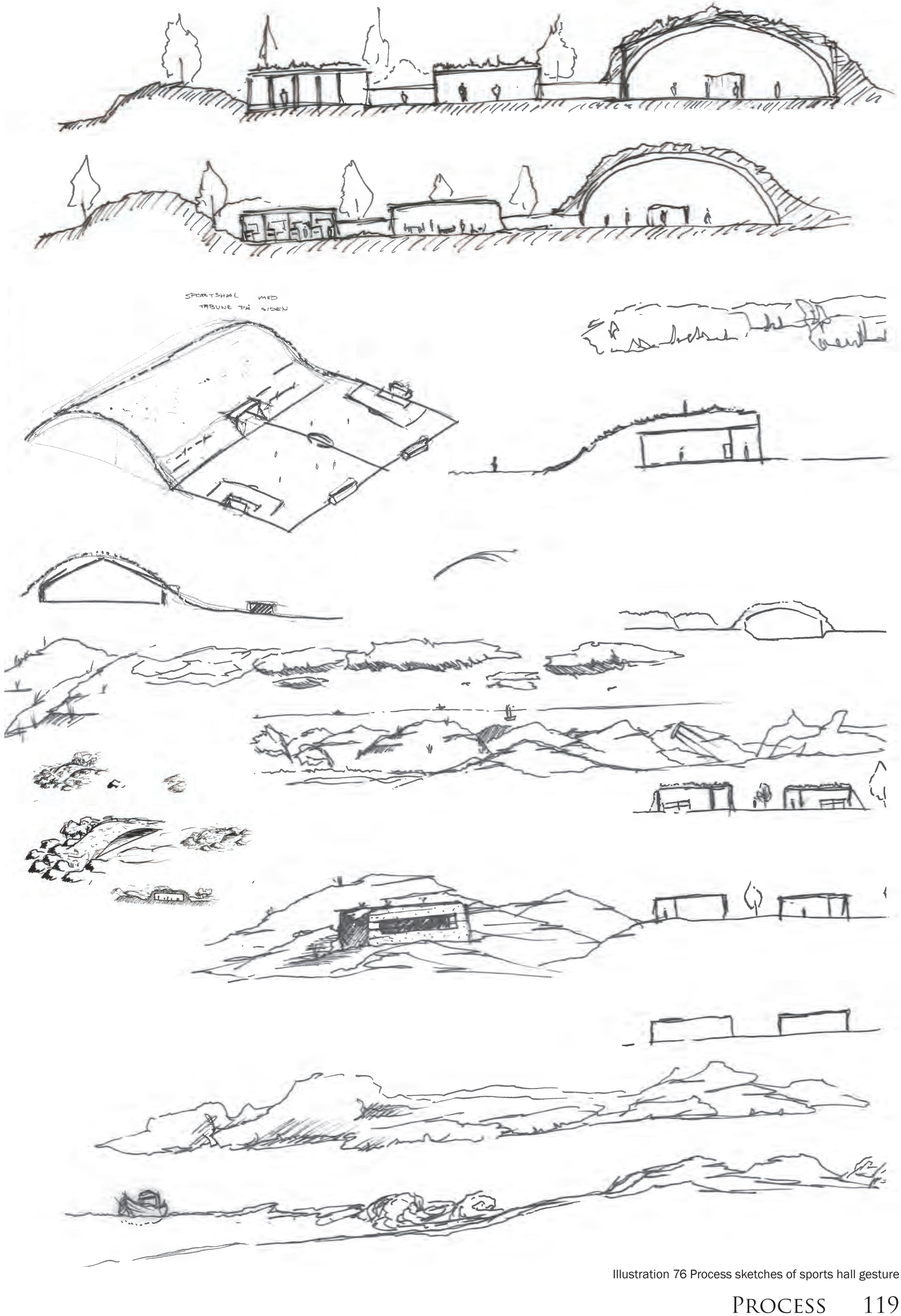


Illustration 76 Process sketches of sports hall gesture

From these initial gestures, the way of which a building could interact with the landscape, the connection between sports hall and football field and the concept of scaling the buildings roofs and using them as a vantage point, would be taken into further investigations later in the design process.

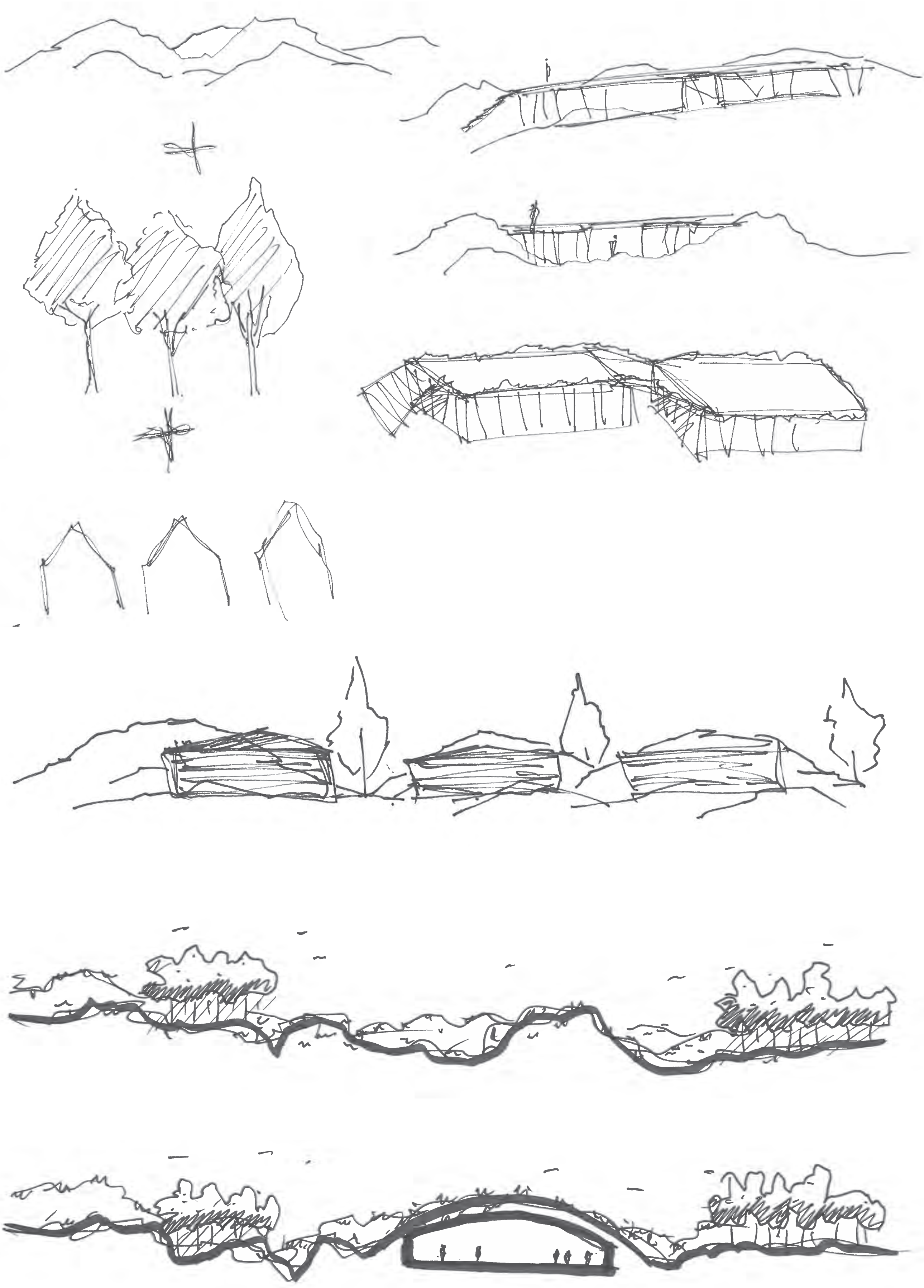


Illustration 77 Process sketches of overall conceptualisation of gestures

CONCEPT

BUNKERS

An evident source of inspiration for how to integrate buildings into the hilly landscape of the western coast, except for the vacation houses, is the remainder of the German world war two bunkers, which are scattered along the Danish west coast.

The scattering of different volumes into the landscape and then connecting them with hallways or with covered paths gave the opportunity to let the landscape "decide" where the different volumes should be placed. Iterations where three volumes would be placed together in a cluster connected by the roofs, which would make it possible to create covered courtyards, as well as letting the users scale the volumes and walk between them.

An investigation into how the dunes would work as barriers for the wind made iterations where the many volumes would be connected creating large courtyards. The large courtyard would be shielded from the wind and making nice outdoor areas which could be used by the users in the month where the weather would be warm.

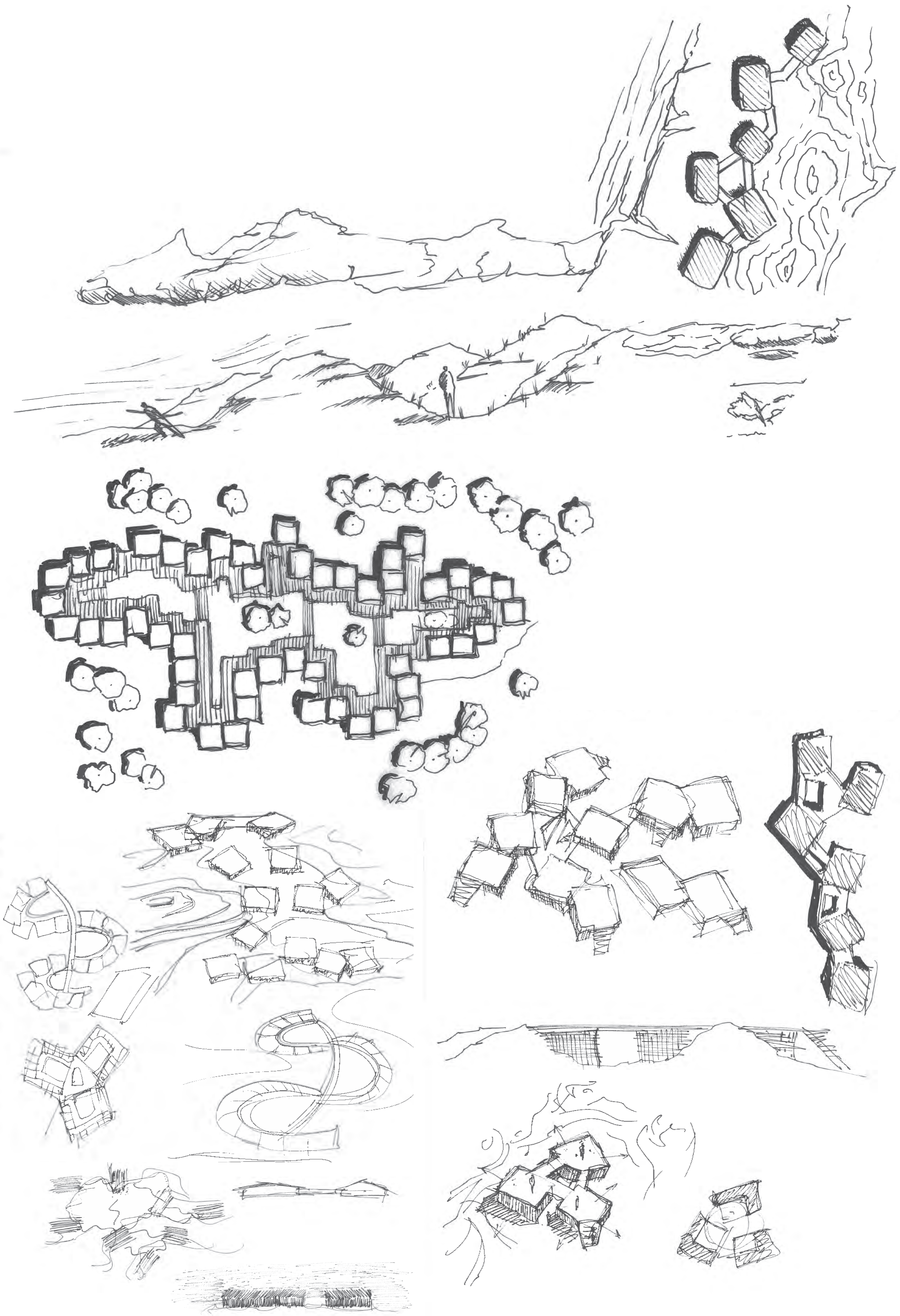


Illustration 78 Process sketches of bunker inspired organisation

CONCEPT

MONOLIT

One of the problems which were illustrated when visiting the Ingstrup Continuation School, which was a case study for this project, was that the school was located in a series of the building which was scattered across a large area. This meant that the classrooms had been in many different places and the pupils had to walk from building to building to go to class. To make a more centralized school, different iterations of making one large building was made.

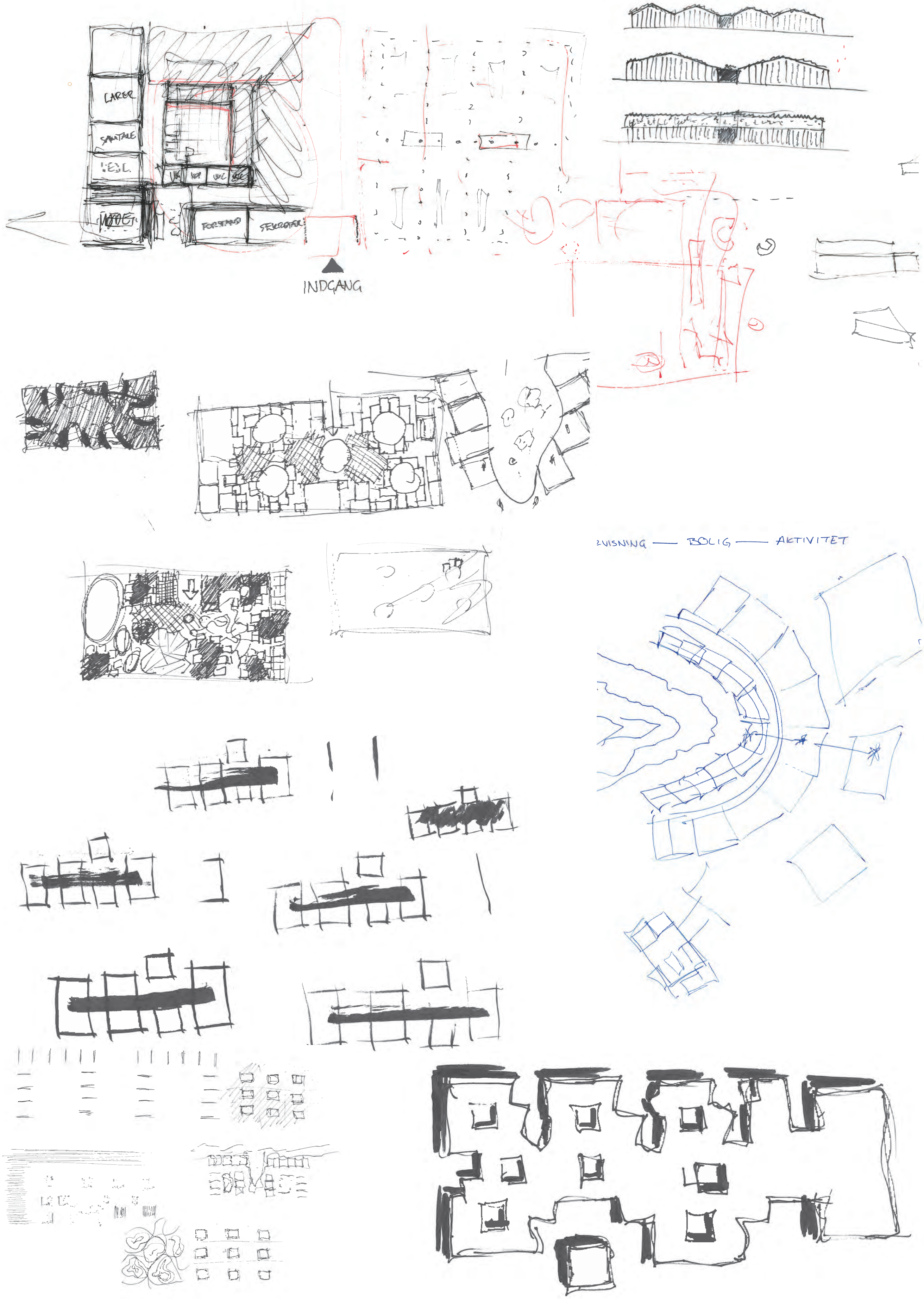


Illustration 79 Process sketches of onceptualisation of monolit

These iterations were made with a large main hallway through the middle of the building from one end to the other. To add sufficient amounts of daylight and landscape into the building, different courtyards and openings in the building were made to "let the landscape into the building". Around the outer ring of the building, the classrooms and living units would be placed to make sure that the view of nature would be in all the rooms.

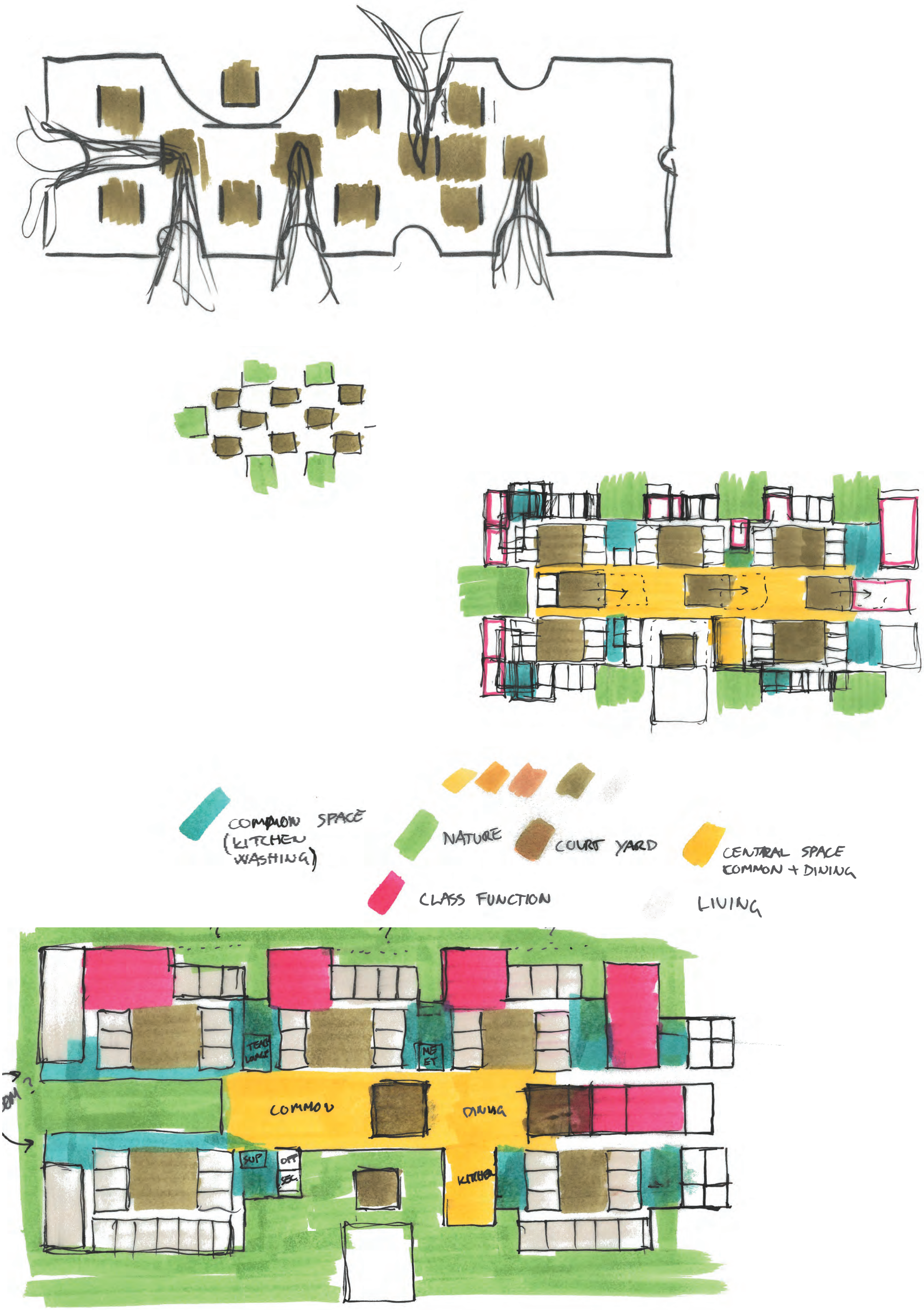


Illustration 80 Process sketches of organisation of monolit

The large building had a drawback, in how the building would sit in the landscape. The hilled landscape would have to be flattened to make space for the building and there were no clear correlation between building and topography. Therefore this compact concept was discarded to make way for a more divided consisting of smaller entities. Some of the things that were found interesting with the large monolith building were the central hallway and the placement of the sports hall to the east towards the flat part of the site.

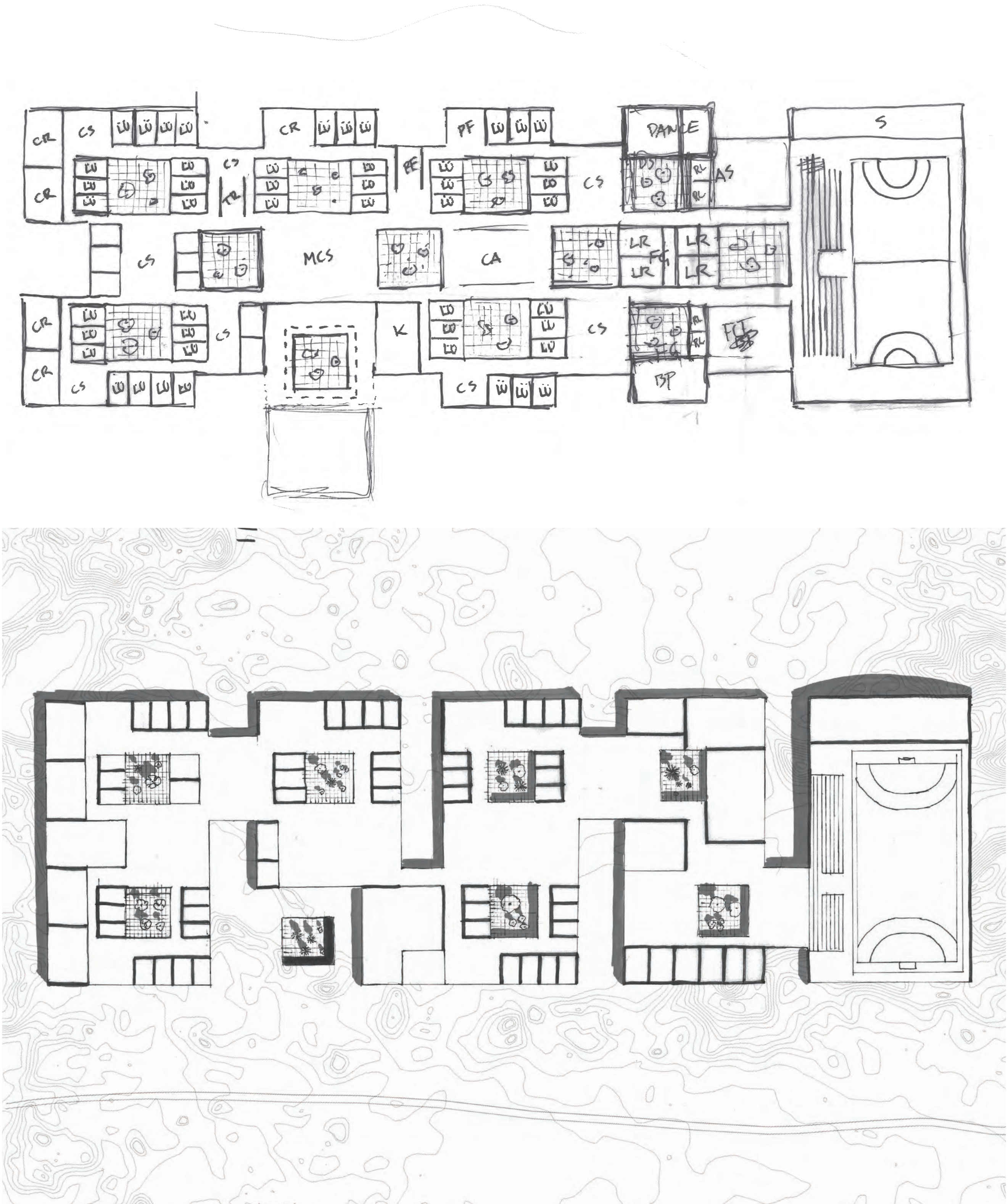


Illustration 81 Process sketches of plan solution on monolit

CONCEPT UTZONISED

Due to the many living units, common rooms and classrooms, it felt natural to create groups/clusters with a set amount of each function. With the inspiration in Jørn Utzon's additive systems, the clusters would be made into identical clusters. These clusters would then be placed both according to each other and according to the landscape.

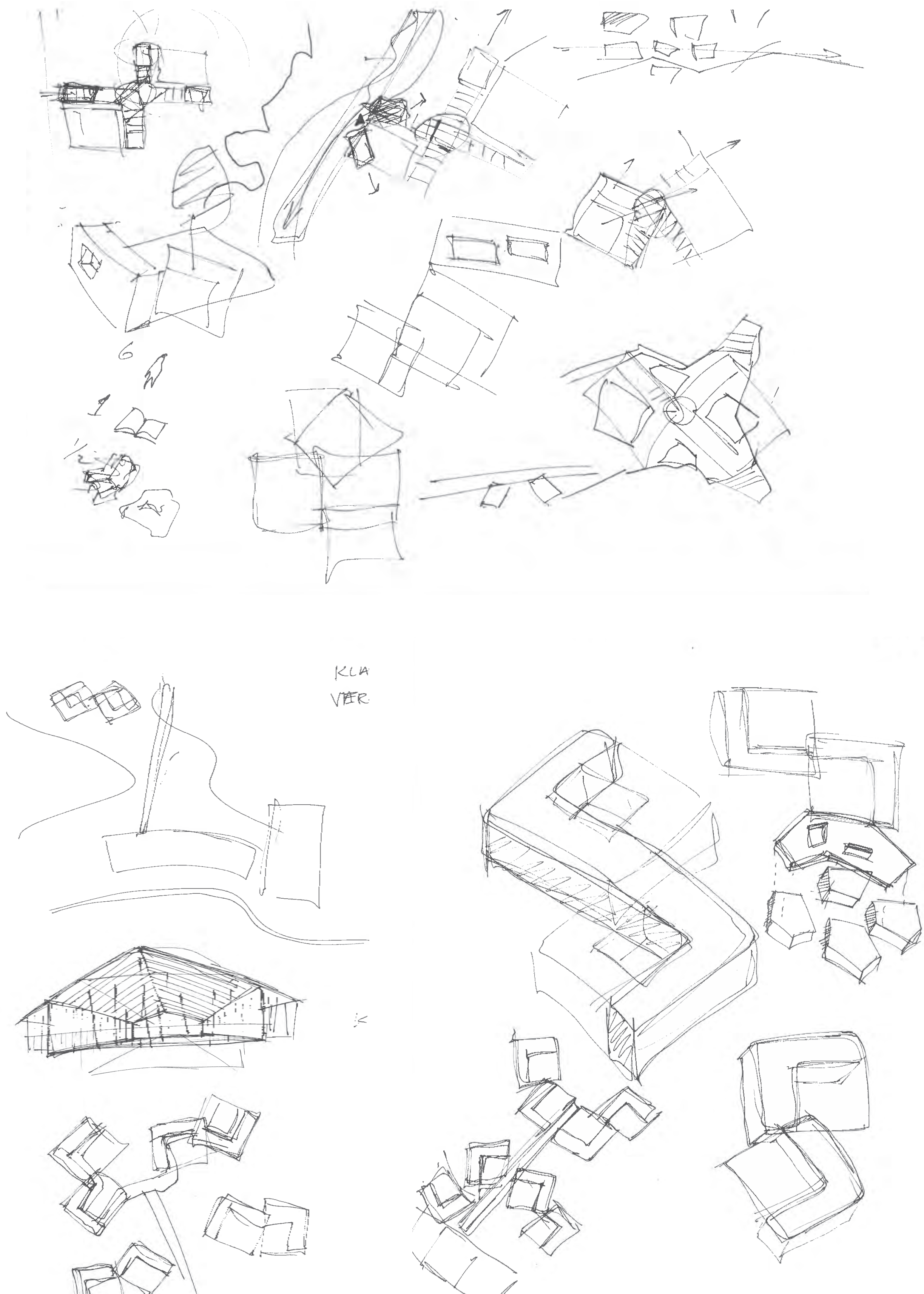


Illustration 82 Process sketches of connection for adaptation

The L-shaped clusters, inspired by the Kingo Houses by Jørn Utzon went through numbers of iteration. The clusters were paired and then connected to a central hallway which connected the whole school to each other. Due to the shape of the clusters and the way they were connected to the central main hallway, the way the pupils would be moving from one cluster to the other would cause a disturbance for the pupils living in the cluster connected to the main hallway.

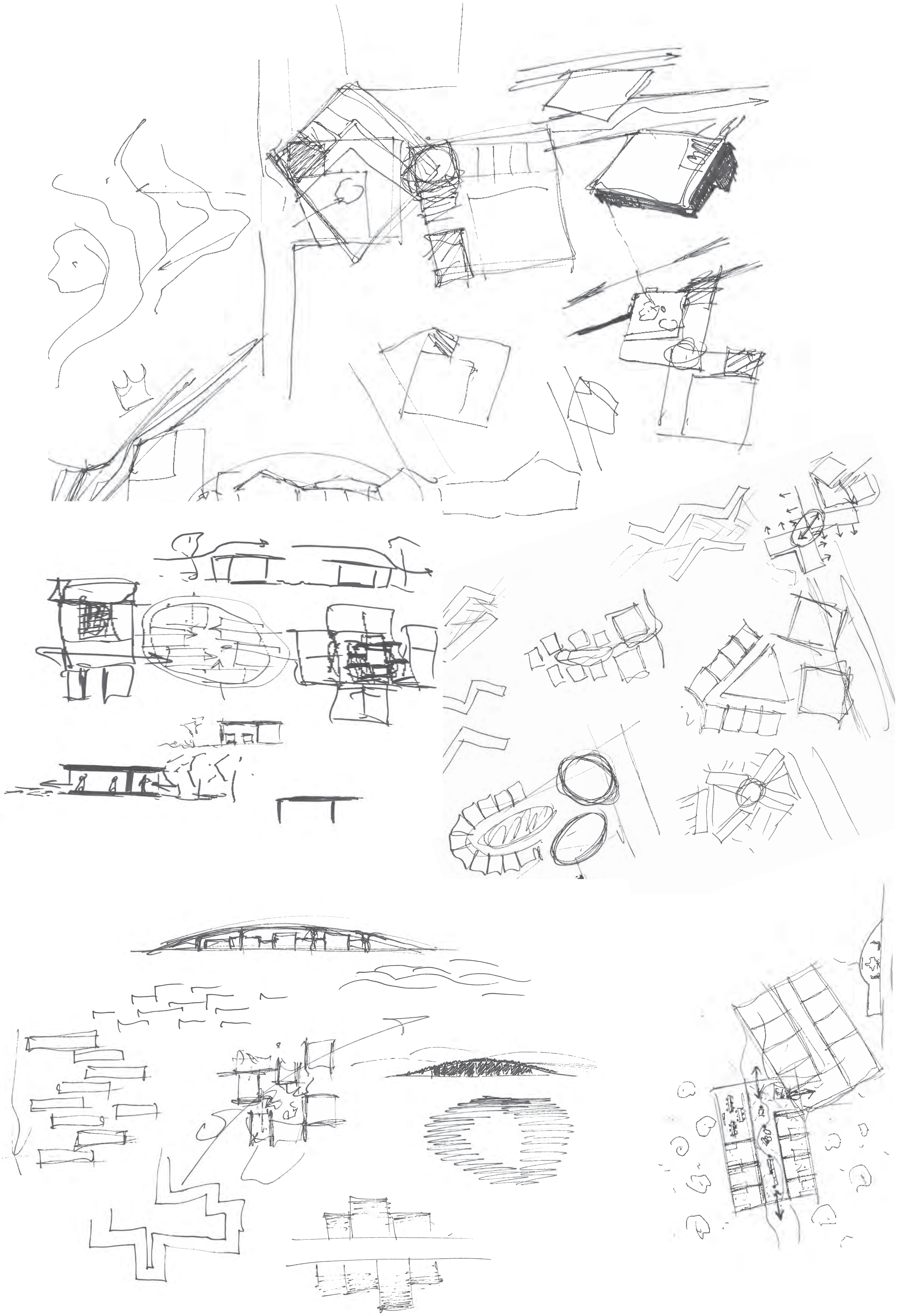


Illustration 83 Process sketches of cluster organisation

To the south of the clusters at the bottom of the main hallway, the other functions of the school would be placed. By doing this, the more public functions such as canteen and main common space will be closest to the main entrance.

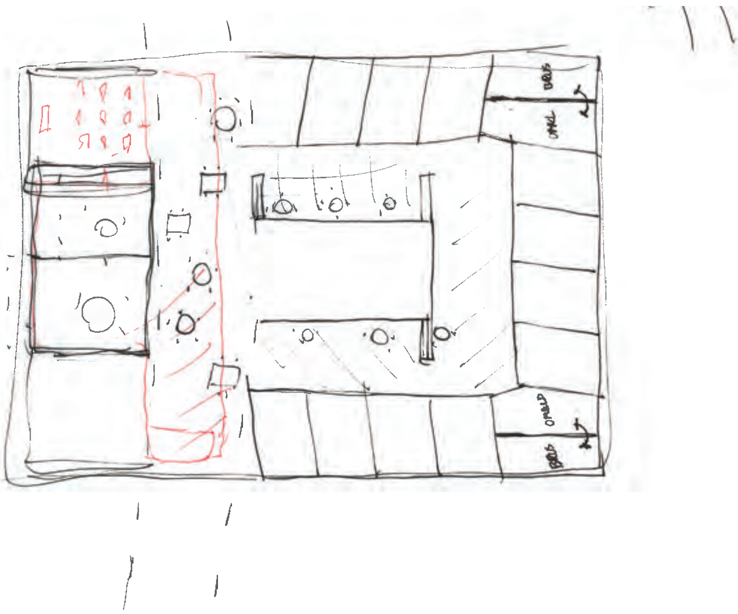
This system with the central hallway and the clusters connected to it as well as the cluster of other functions (canteen, kitchen, main common space etc.), was brought along to the later design process.

Illustration 84 Process sketches of plans for adaptive concepts

CONCEPT

FINALISED

From the Utzon inspired clusters and main hallway, new iteration was made. The paired clusters were merged together into four instead of eight clusters and would fit twelve living units, one classroom, one special function, and three common rooms. The rectangular clusters were created around a courtyard and along the hallway around courtyard would work as common spaces. The clusters would be connected to the main hallway and between the living units and the hallway, the classrooms would be placed to shield off the cluster from the hallway.



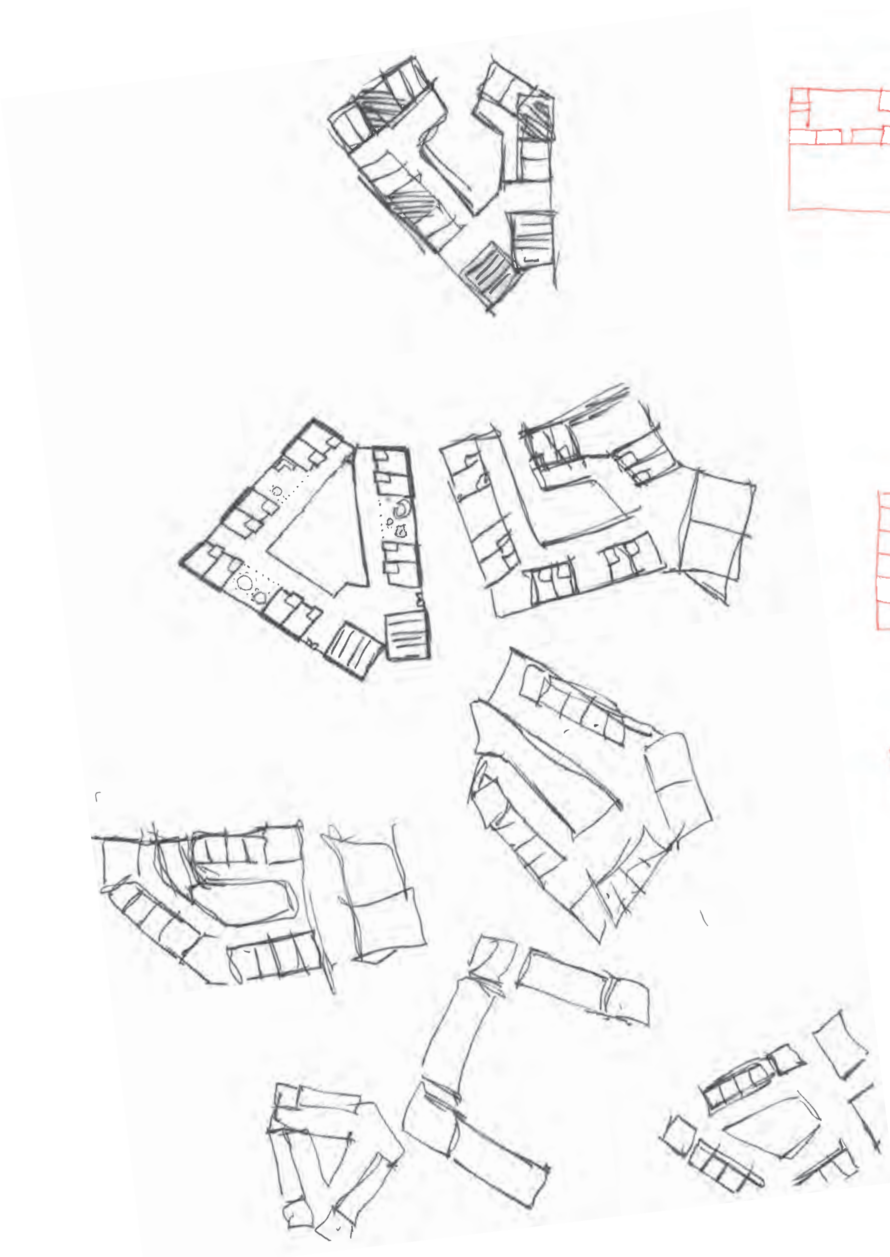


Illustration 85 Process sketches of developing cluster for final concept

To integrate the hallway more into the cluster, the classrooms would be moved to the opposite side of the hallway, thereby making less wasted space. To make more regular common rooms for the pupils, the common rooms were also moved from the hallway, to be placed in between the living units.

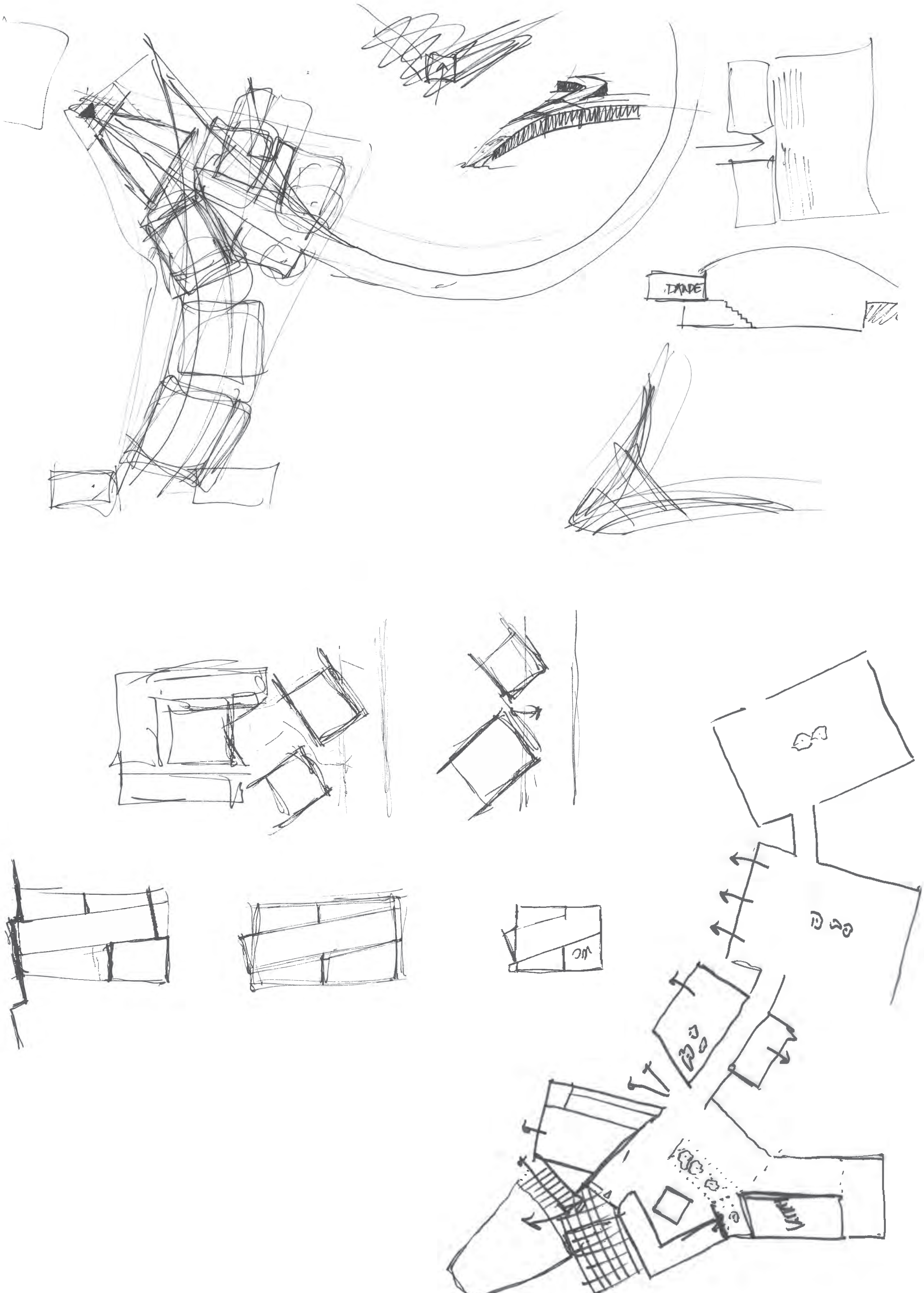


Illustration 86 Process sketches of main common space connection

The closed clusters would later be opened up to nature. The main hallway would be curled around the landscape, to follow the topography more strictly as well. From the iterations of the initial gestures and the work with the bunkers, the large roof was spanning across the whole school and touching down on different places, making it possible for the user to use the green roof of the building.

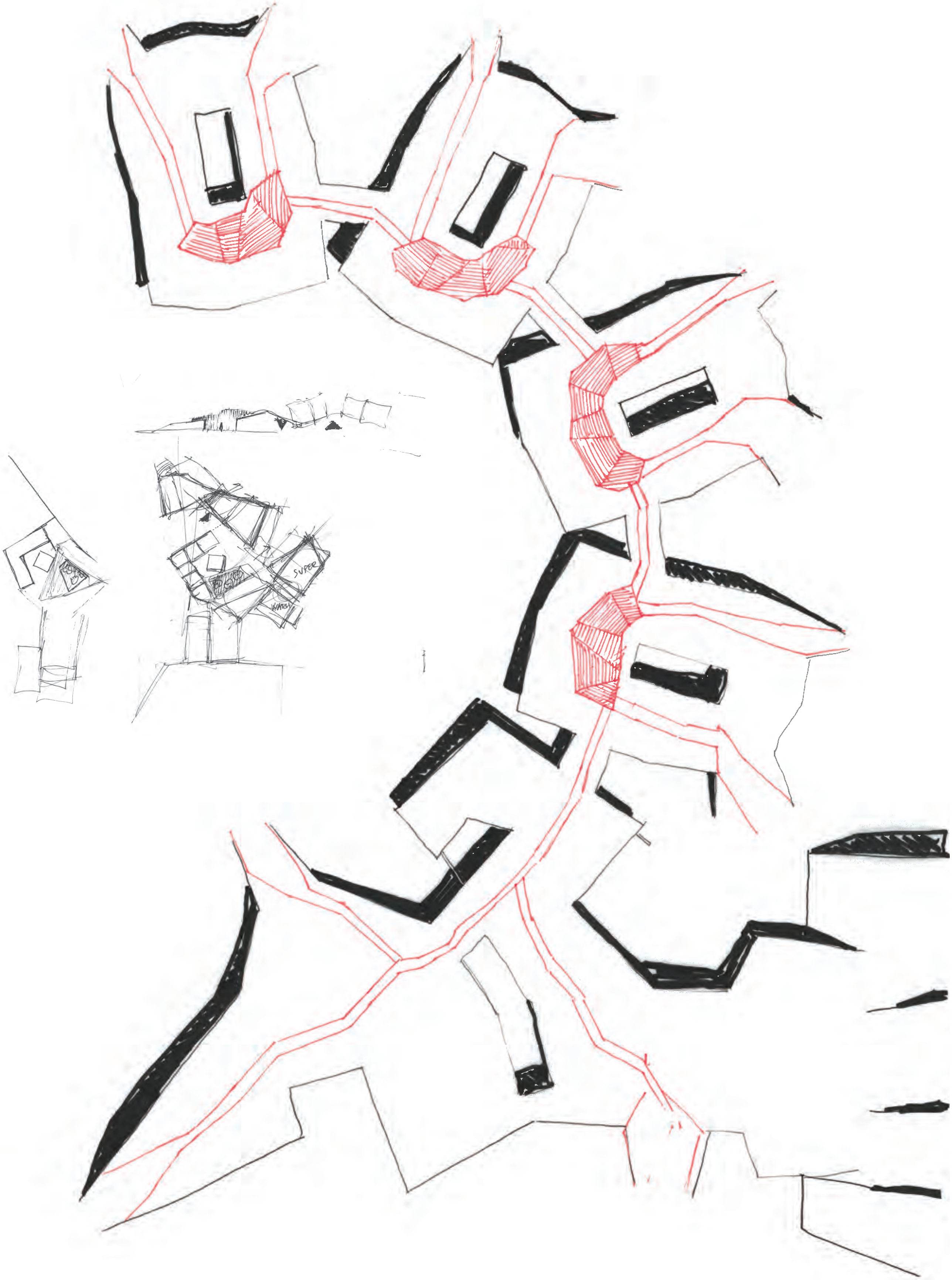


Illustration 87 Process sketches of roof gesture for finalised concept

MATERIALITY

When designing architecture, the combination of different materials and surfaces help give a building or a room a certain expression or atmosphere. Materials in white, grey and blue, can give a room a cooler expression and thereby make the room seem cooler. Materials such as wood can have an opposite effect on a room, and give it a warmer expression.

Wood can also be obtaining different tactilities according to the number of processes in which the wood goes through in the production. Wood can be kept in a rough or be planed and sanded to give a smooth surface.

From a maintenance and sustainability aspect, different materials offer different possibilities. The maintenance of the materials will also play a large role when choosing materials which will be exposed to the harsh weather of the western coast of Denmark. The hard wind which comes from all directions will carry sand from the landscape and sandblast all surfaces it hits meaning a durable material should be chosen for the facades of buildings placed in this area along the coast.

Concrete and burned clay bricks, which has been used in Denmark for centuries, has a long lifespan and can withstand the harsh environment of the western coast. Yet, the process of creating the concrete and clay bricks are harder on the environment, due to the use of non-renewable natural sources as well as having a large CO2-footprint. Wood opposite to concrete and bricks is a natural and renewable building material.

Being a natural material, a wooden construction will be able to breathe and transport moisture through the construction. Depending on the type of wood, exposed wood can have a high degree of maintenance, yet different technologies can offer less maintenance and larger lifespan for the exposed wood.


Illustration 88 Vertical wide boards and lamella with wooden window frames


Illustration 89 Horisontal wide boards and lamella with wooden window frames


Illustration 91 Vertical thin vertical lamella and dark window frames


Illustration 90 Vertical randomly spaced boards with concrete pavement

Presentation

FUNCTIONS

From the previous sections, the program is manifested from the analysis and cases. Tables follow presenting the individual room functions, their areas, numbers and considerations regarding views, natural lighting and ventilation. To further elaborate any special requirements for different rooms comments will also be included. Different diagrams will highlight zones and interconnectivity of these to conclude a final building concept.

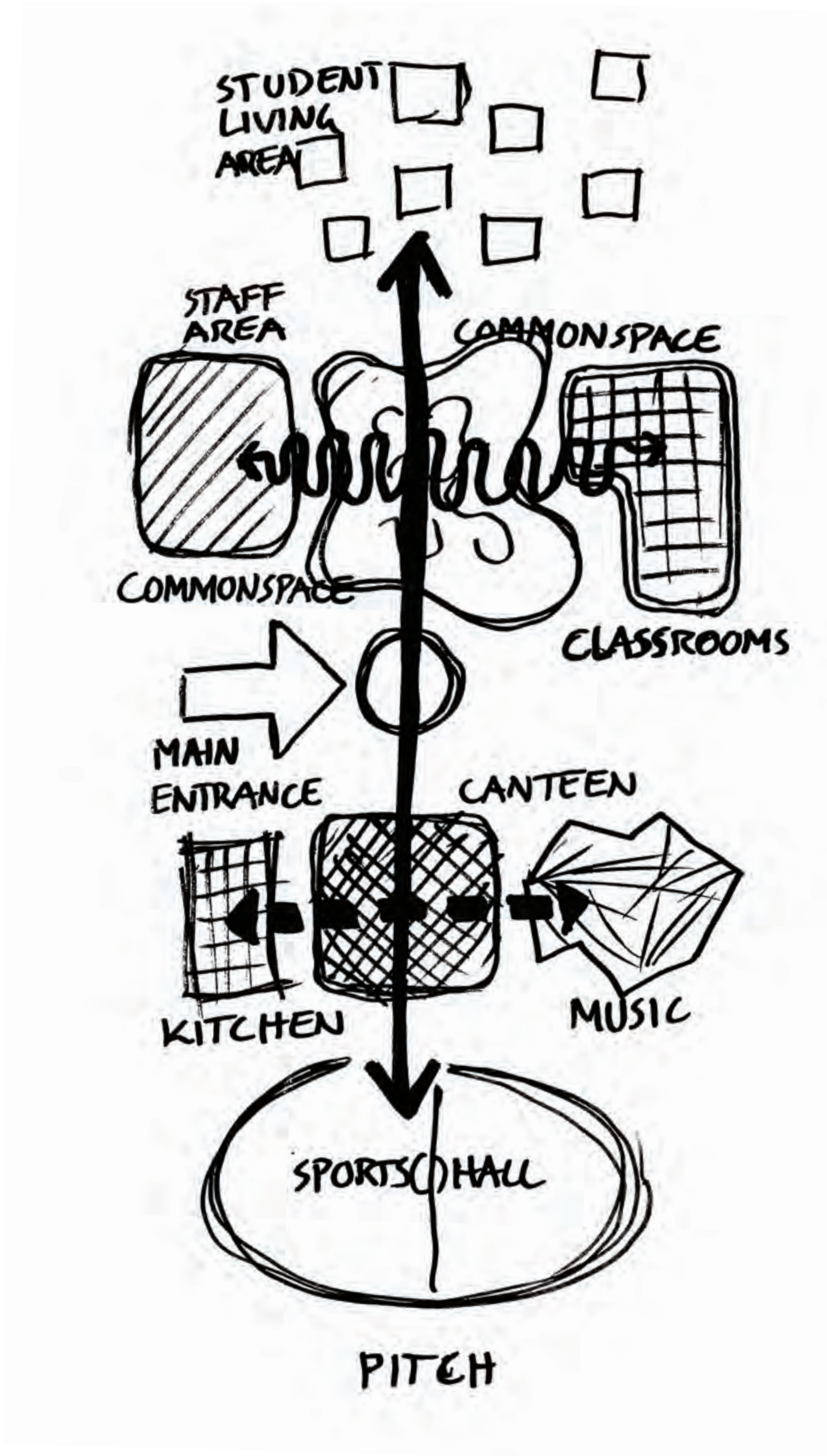
Illustration 92 Thatched summer house

CONNECTIVITY

The functions in the program have been established through different sources, taking a starting point in the current situation at Ingstrup Efterskole. The visit, the interview conducted there and building program from the architectural firms currently working on a revision of Ingstrup Efterskole have had a major influence. Apart from these, old plans from the different building permits of the continuation school have been retrieved to give a more detailed understanding of the many functions found. (Jammerbugt Kommune 2018)

Through the dialogue with the school, it became clear that one of the biggest obstacles during a regular day is the widely spread of classrooms and other educational functions resulting in much time spend transitioning around the school area. A wider focus on community was desired to facilitate the different bonds that occur during a stay at a continuation school. Another wish was a larger sporting hall with suitable seating and a functional linkage to the common area and canteen in order to host larger events. At the same time, a proper space for larger gatherings such as parents evening or open house would be desirable.

The different functions are programmed in groups of either primary or secondary importance with respect to everyday life at the school and their potential effect on the users in terms of either educational assets or experience wise. The building program that follows will present the different groups and their contending rooms with addressed needs both physical as well psychological. The presented science and research has been used where relevant to establish the different characteristics of the functions.



ABOVE
Diagram presenting the major functions/areas and their interrelations through different flows which again have different characteristics.
Illustration 93 Conceptual function & flow diagram

PRIMARY FUNCTIONS

COMMENTS

Each of the pupil living units should function as small dorm rooms, each with the capacity of four students, though not all will be full at all times. The pupil living units shuld contain a shared bathroom, adequate storage for four young persons and a desk for individual studying. The living units for the pupils should be homely and slightly cave-like giving a sense of safety.

The superintendant flat functions as a regular housing unit for the superintendant living at the school, with all appurtenant such as kitchen dining area, sveral bedrooms and one or more studies. The flat should be open and light and offer all commedeties and luxury of a modern home.

The overnight watch apartment should merely function as a flat during nights and weekends when the superintendant is not present.

Living areas

Pupil Living Unit
Superintendant flat
Overnight watch flat
Wash/cleaning room

COMMENTS

Each classroom should fit approximately 25 to 30 pupils with a plan solution that allows for a flexible use of the rooms according to different learning settings.

One of the classrooms will cover the ProEf10 class and should apart from having adjacent common spaces also feature an plan suited for group and project work.

The physics room should function as a science laboratory suited for a elementary school level and be adjacent to a regular classroom with the possibility of opening up between these two. The classrooms should be light and open, but introduced to colours of both bright and pale to create an interesting and balaced environment for learning. Furthermore materials should be tactile to excite the senses and in touch with the colour sheme.

Classrooms

Classroom
Special functions
Music hall
Music studio
Storage

COMMENTS

Different common rooms should be distributed throughout the school allowing for different activities and atmospheres to accomodate different groups and settings. The common rooms will serve both the near and the far communities where some are smaller and should be close to the living units facilitating the meeting between smaller groups of pupils whilst larger spaces should gather the whole school.

Specificly the common room serving the ProEf10 class should function as a space for studying and working with projects in groups.

The common rooms should be fore vibrant in their design and colouring to present different spaces according to the activities, but at the same time function as a whole when used for larger gatherings.

Social areas

Commonroom ProF10
Main common space
Common room
Study space

COMMENTS

The different sport facilities should be organised in order to serve each other as functional as possible with especially the locker rooms as center. Furhter more all of these functions needs a great deal of storage of equipment.

The sport hall should be fitted with a sort of seating and space suitable for hosting events and competitions.

Colours should be at play and give way to the high intensity of activities whilst light and views can let the border between inside and outside be obliterated.

The sporting facilities should be ventilated and possibly cooled to a lower operative temperature

Sports hall
Locker room
Ref. Locker room
Dance studio
Action sports storage
Gym

Outdoor areas

No.	Unit area	Total area	Natural light	View	Natural vent.	Strategy
48	21	988	■	■	■	MICRO
1	184	184	■	■	■	MICRO
1	92	92	■	■	■	MICRO
2	30	60				CAV

No.	Unit area	Total area	Natural light	View	Natural vent.	Strategy
4	74	296	■	■	■	MICRO
4	56	224	■	■	■	MICRO/CAV
1	225	225	■	■		VAV
7	15	105	■	■	■	MICRO
1	52	1				

No.	Unit area	Total area	Natural light	View	Natural vent.	Strategy
1	75	75	■	■	■	MICRO
1	259	259	■	■	■	MICRO
12	64	768	■	■	■	MICRO
1	157	157	■	■	■	MICRO

1	1627	1627	■	■	■	VAV
5	29	145				CAV
2	6	12				CAV
1	182	282	■		■	CAV
1	147	147				
1	176	176	■			

No. Unit area Total area Natural light View Natural vent. Strategy

Illustration 94 Table of primary room functions

SECONDARY FUNCTIONS

COMMENTS

The teachers room should be near a common space allowing for easy and open communication between pupils and teachers.
Smaller serving rooms for the staff includes the secretary and superintendant office together with a supervision and meeting room. All of these should be light and open in their conception continueing with the warm and light sensing atmosphere between staff and students.
All staff functions should follow building regulations in terms of daylight factor and be kept light and warm with relation to the class rooms.

Staff rooms

Teacher room
Teacher lounge
Supervision room
Secretary
Superintendent office
Copy room
Wardrobe
Kitchenette
Meeting room
Cleaning room

COMMENTS

The kitchen should be a modern production kitchen sizeable for cooking meals to 150 people several times at a day, and with serving functions such as a dish wash, and different depots including cold storage.
The kitchen will have to fulfill the requirements of a working space.

Production kitchen

Service
kitchen
Hallway
Scullery
Office
Pre room
Locker room
Delivery
Storage
Cold storage
Freezer storage

COMMENTS

The football pith will be fitted with artificial grass to withstand the harsh winter and frquent use. Furthermore the pitch should be adjacent to a slope that can be used as seating.
Parking space should not only be for cars but a large parking area for the pupils bikes should be incorporated. This latter must be covered to protect the bikes from the rough weather.
Car parking will mostly be empty and only be fully utilised when parents bring pupils to and from the school. It should therefore be integrated into the landscape or the architecture to avoid a sea of tarmac.

Football Pitch
Bike parking
Action sports cleaning

No.	Unit area	Total area	Natural light	View	Natural vent.	Strategy
1	27	27	■	■	■	MICRO
1	29	29	■	■	■	MICRO
1	19	19	■	■	■	MICRO
1	19	19	■	■	■	MICRO
1	21	21	■	■	■	MICRO
1	7	7				
1	4	4				
1	11	11	■	■		CAV
1	27	27	■	■	■	MICRO
1	8	8				

No.	Unit area	Total area	Natural light	View	Natural vent.	Strategy
1	13	13				CAV
1	69	69	■	■		CAV
1	28	28				CAV
1	7	7	■			MICRO
1	11	11	■	■	■	MICRO
1	5	5				
1	5	5				MICRO
1	12	12				MICRO
1	7	7				
1	7	7				
1	7	7				
1	NA	NA				
1	374	374				
1	42	42				

Illustration 95 Table of secondary room functions

DESIGN

The design chapter presents the finalised design and its different features both architectural and technical. Starting from the outside the siteplan shows the school's formal adaptation to the landscape followed by façades that highlights the replication of the dunes. Zooming closer and opening up the building the functional correlation of the complex leads to the presentation of the building plan. Elaborating the design the direct implementation of the design features from the program is displayed. As a completion the main functions of the common spaces, living units and sportshall is presented with more detail.

Illustration 96 Facade detail - Vestre Fjordpark

CONCEPT

Illustration 97 Design conceptualisation

Illustration 98 Visualisation sportshall arriving via access road

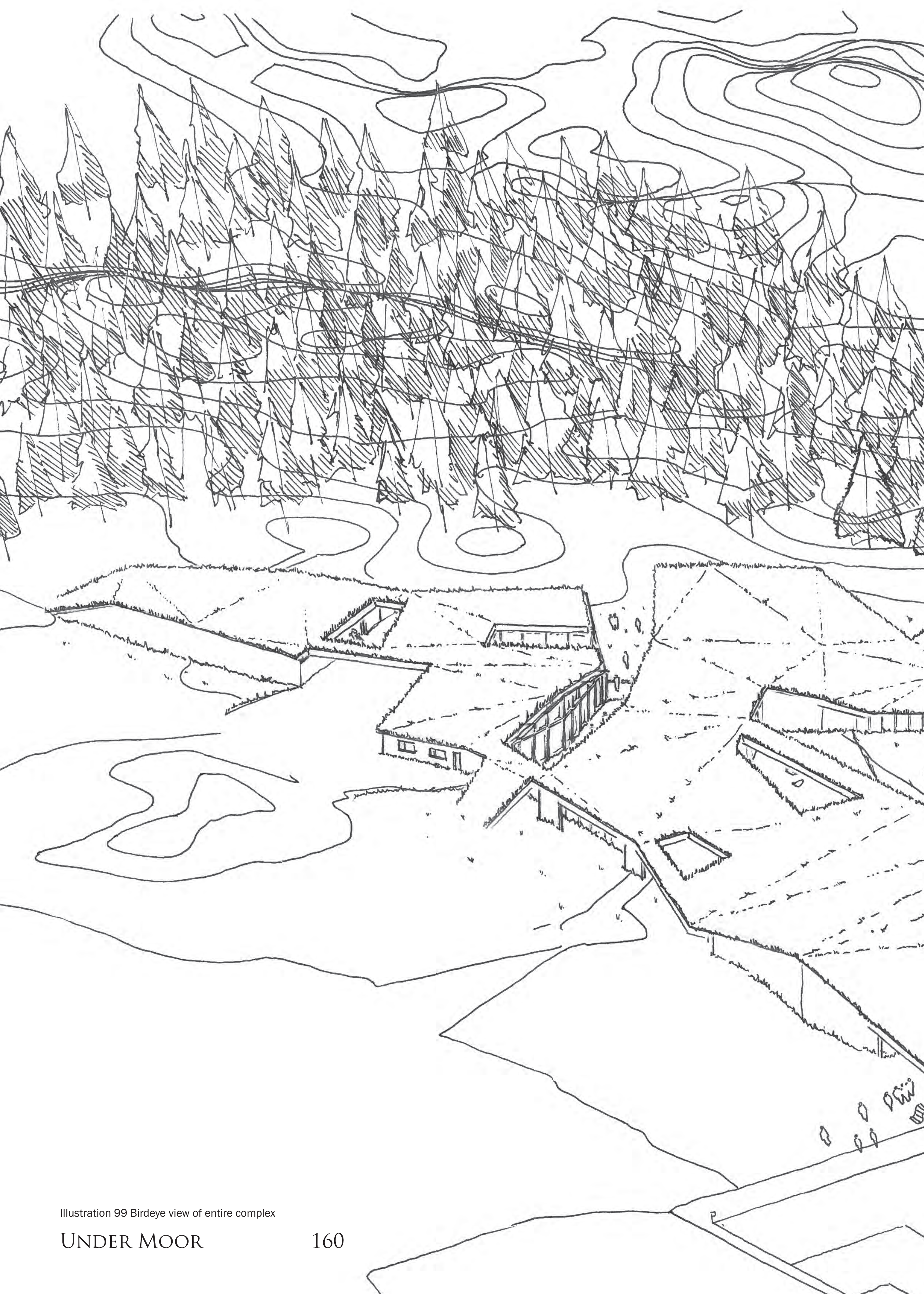


Illustration 99 Birdeye view of entire complex

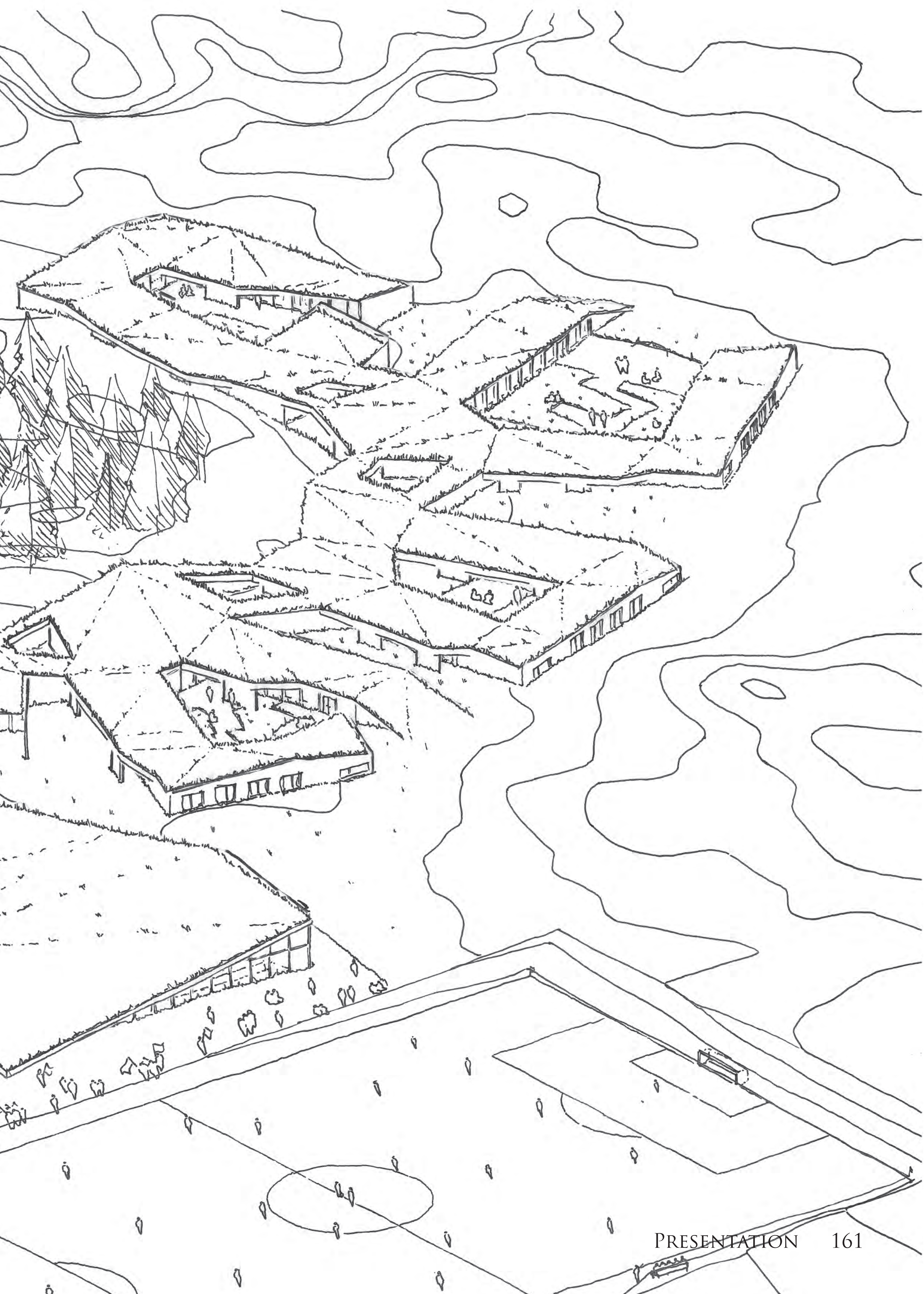


Illustration 100 Siteplan 1:100

FACADES

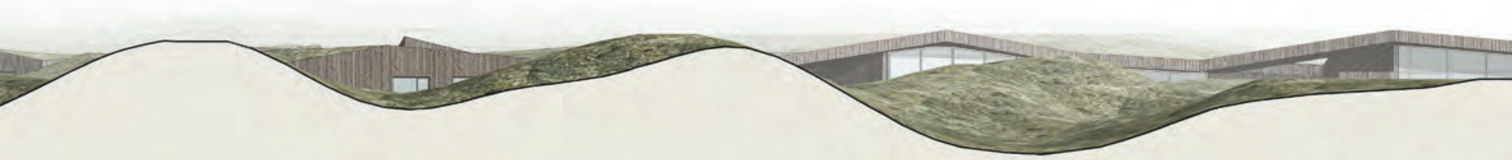
For the facades a wide vertical cladding with little spacing was chosen as these wide lamellas would represent what is found on the different smaller summerhouses that are scattered around in the area. The wide planks will have a sense of simplicity and solidity to it giving the whole building a more dense and firm expression. By using unpainted or unoiled wood the building will in time weather and blend in with the sand and soil on the ground and the vegetation on top of the intensive green roof

To add to the simplicity of the facades the windows around the school has been kept in large windows with wooden frames. The wooden frames will help let the windows blend into the long façades creating a unity. The façade has been made to run from terrain all the way to the edge of building hiding the roof construction only letting the vegetation reach above. The façade gets a flowing and dynamic expression as a result of the wavy roof created by the changing directions and elevations of the mono-pitched roof segments. The results as a building that formally blends into the landscape, but with a sharp and crisp edge all around.

Illustration 101 South facade 1:500

FACADES

To shade from the sun towards the south, overhangs are protruding from the façade over the function and hallway which has windows facing south. To integrate the overhangs in the design of the building, the top of the façade will follow the overhang out from the wall. The cladding will follow the edge of the overhang, touching down to the ground where the wall segments which holds the overhang are placed.



The larger lamellas would also make it possible to make details around the InVentilate out-, and intake. By letting the lamellas to be milled thinner around the InVentilate system, the system can be hidden behind the lamellas giving the façade a uniform look and integrate the ventilation system even more. The wood which have been chosen for the lamellas is pine that has undergone an impregnation in furfuryl alcohol, a bio-based liquid derived from agricultural waste which afterwards hardens. After the treatment, the wood's cellwalls will be 50% thicker than ordinary pine, ensuring a hard wood with a durability against rot and fungi. (Kebony 2018)

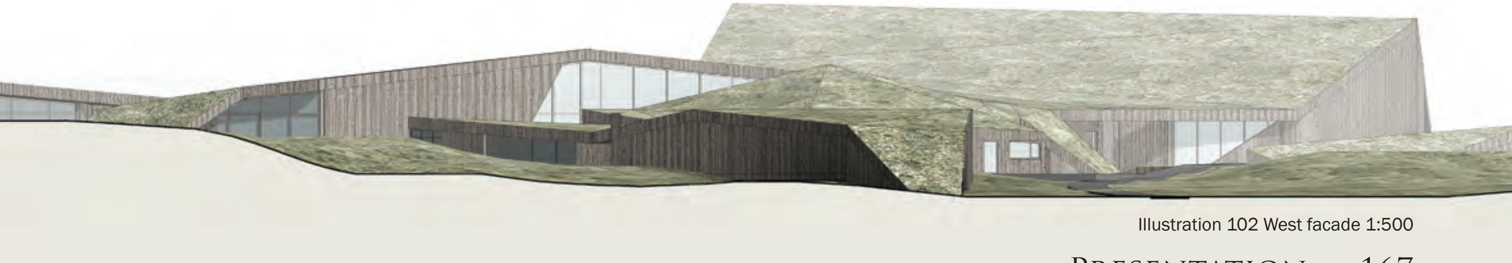


Illustration 102 West facade 1:500

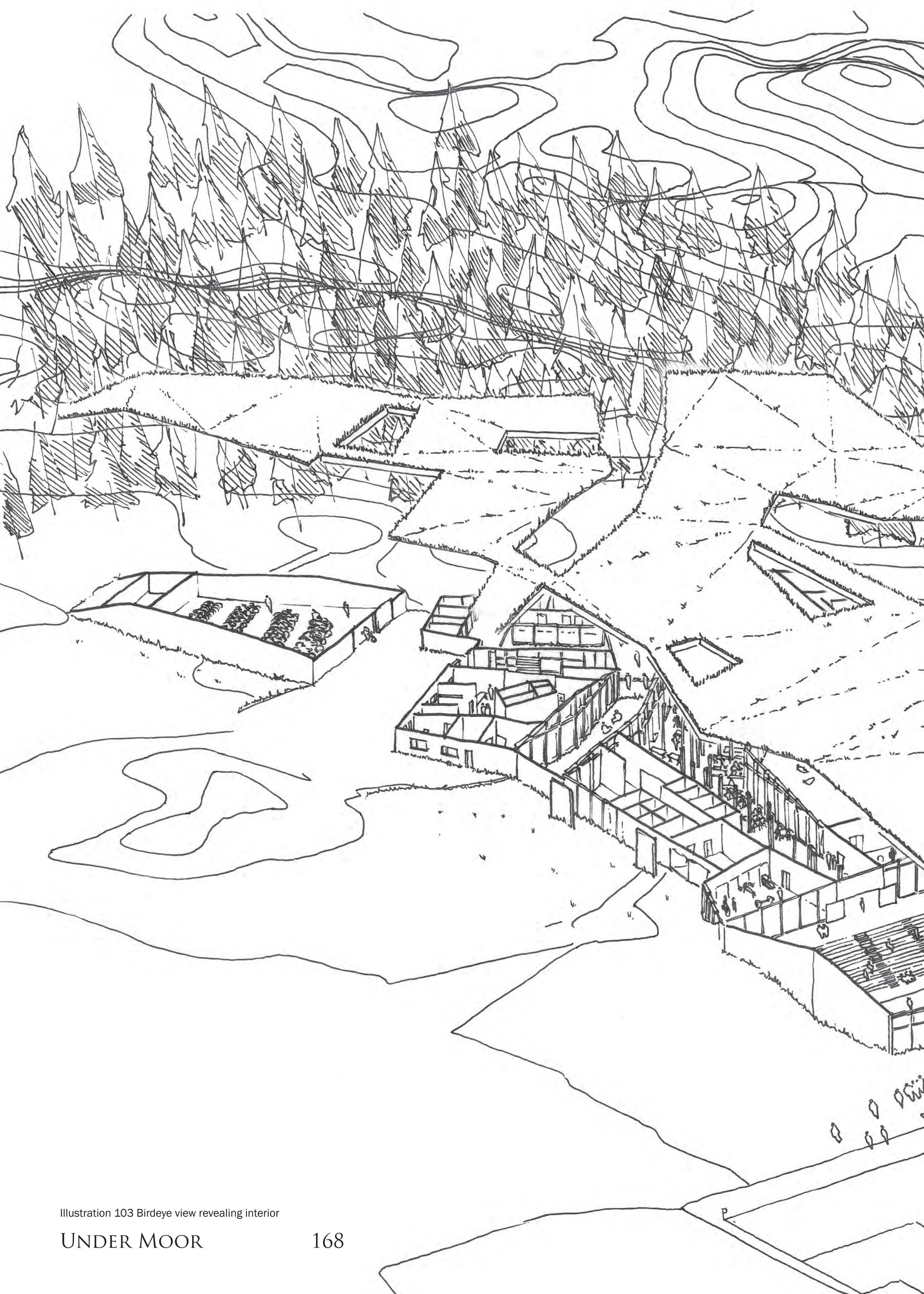
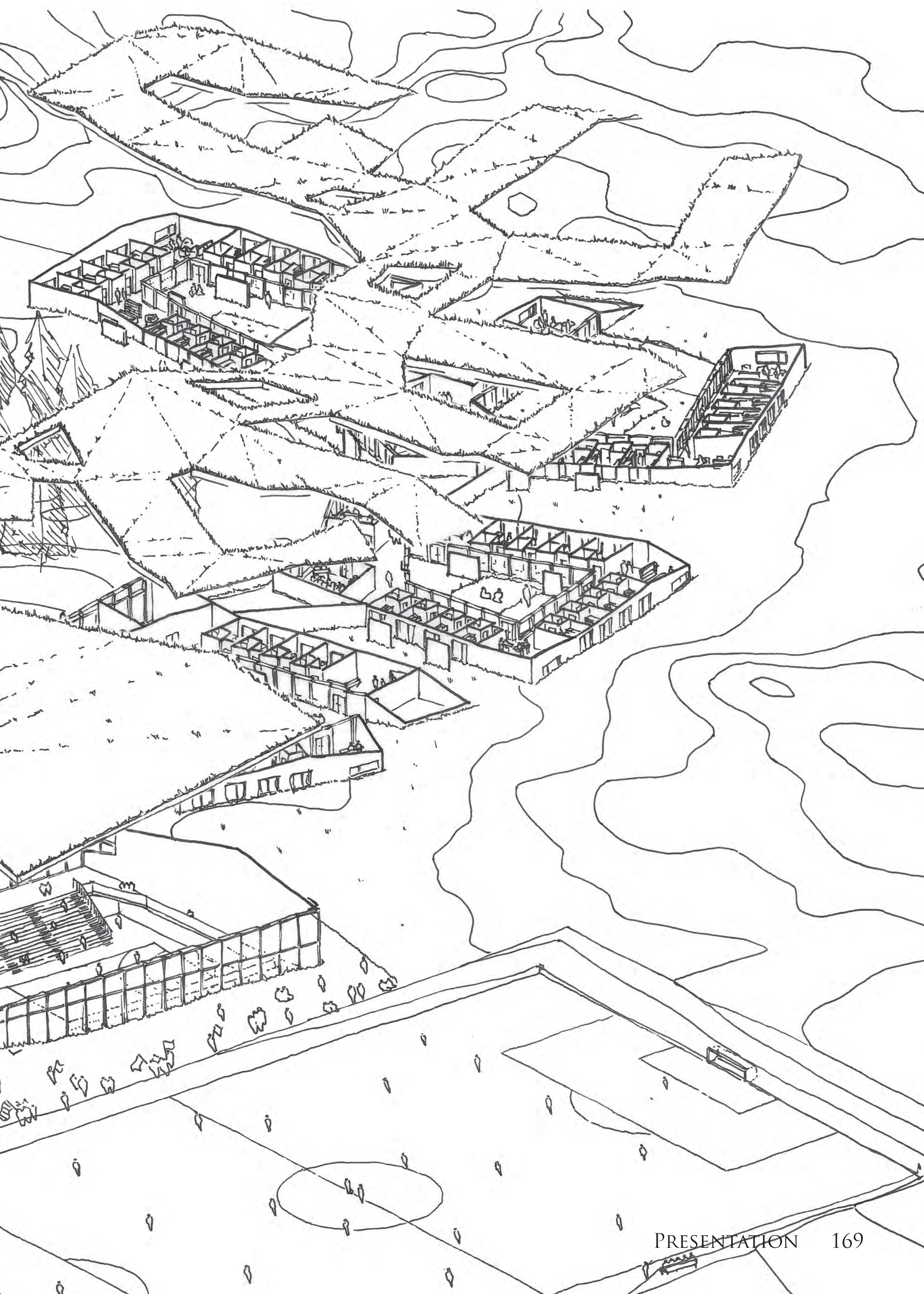


Illustration 103 Birdeye view revealing interior



BUILDING FUNTIONS

The different functions have been divided into a cluster of which function should be connected to each other. The groups are; the living clusters (yellow), the teacher's facilities (grey), the common facilities (green) and the sports facilities (red). The circles depict the size of the different function according to each other and the amount of circles depicts the of the individual function.

On the diagram to the left, the function has been placed on the plan of the school showing of the interaction between the function and their placement on the school. The dashed lines show connections between functions.

The common functions, teachers facilities, and the sports facilities have all been placed in the southern part of the school. Because of the placement, the common functions can be used by visitors. The common function and the teacher's facilities have also been placed close together to keep the

OPPOSITE
Diagram showing the different functions of the school all relative in sizes and grouped according to the room program and the overall layout of the building.

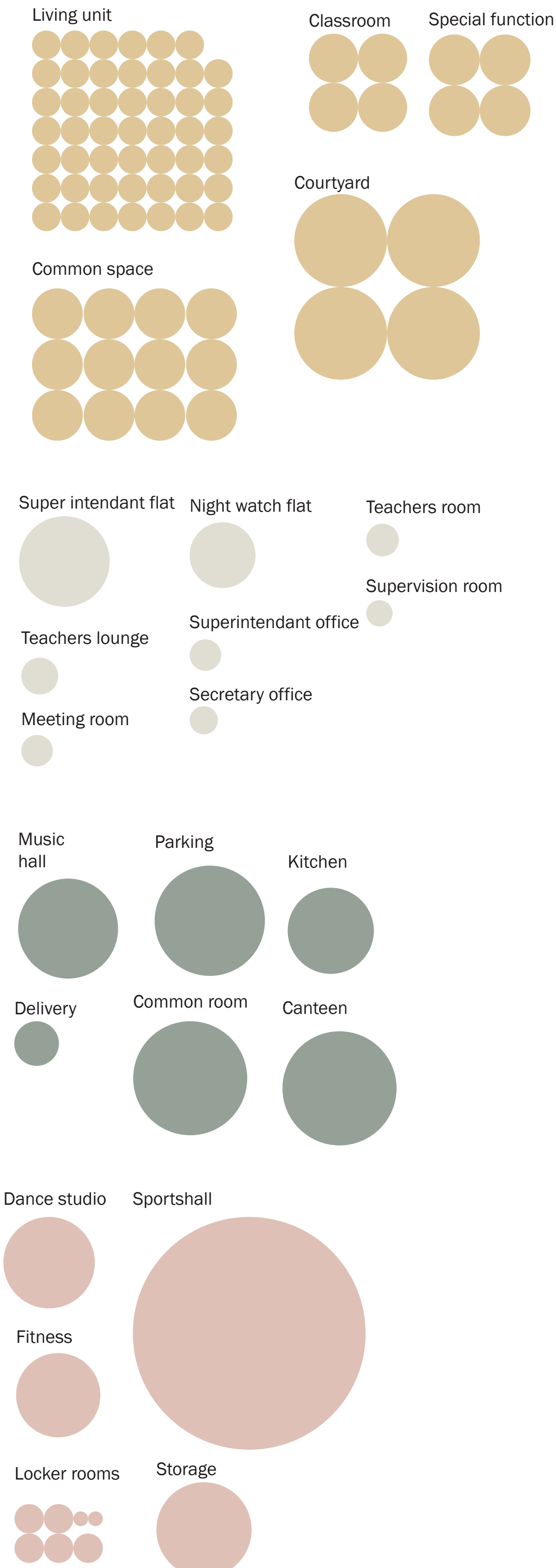


Illustration 104 Function groups

FUNCTION DIAGRAM

connection between teachers and the pupils. The relationship between the teachers and pupils on a continuation school are very important, due to the role of guardians which the teachers become.

The classrooms and living units have been placed together in northern part of the building in clusters. By doing this, the pupils will be walking between the clusters when they go to and from lessons or when they visit each other during the free time. By doing this, the whole school will be in use during the day and have people walking back and forth between the buildings.

To the east, the sports facilities are placed due to the more flat area of the site which will be best suited for the football pitch which should be adjacent to the sports hall etc. The sports hall are placed next to the canteen and kitchen to give the opportunity to use the sports hall and canteen for events such as sports tournaments.

OPPOSITE
Diagram showing how different room functions have been placed on the plan of the school with the interaction between the function and their placement on the school. The dashed lines show connections between functions whilst the solid line highlights the building envelope.

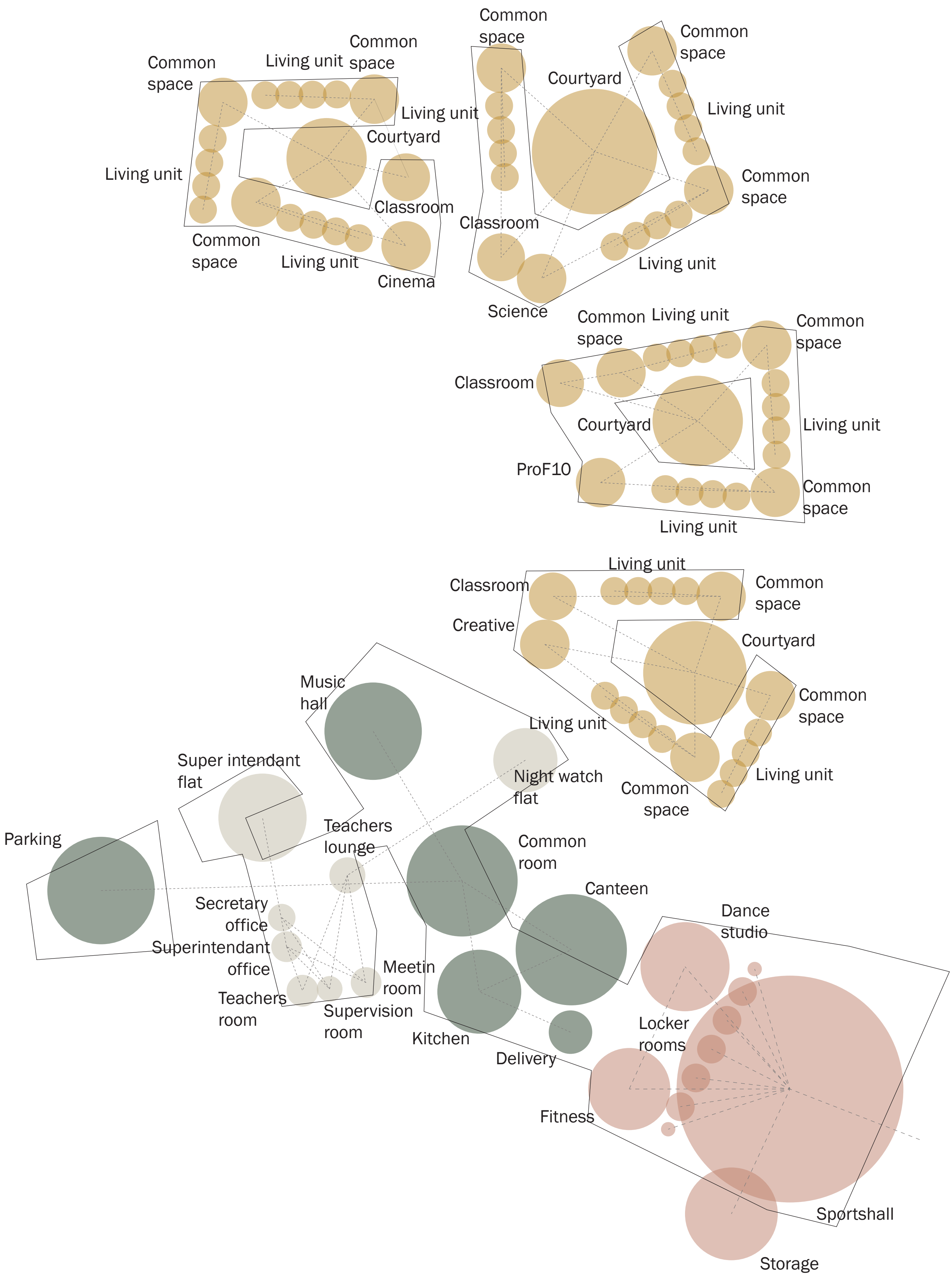


Illustration 105 Function diagram

BUILDING PLAN

The final building lays in the lower part of the area between the tree-covered hills to the west and the hill to the east. The building follows the contours of the landscape

The floor in the school will be an in-situ casted concrete wearing surface to give a conherent expression throughout. Concrete as the top layer of the floor construction is chosen because of its durability with the amount of wear and tear the floor will have to endure. By using concrete the floor will be naturally sanded and cleaned by the pupils and teachers walking on it as they will drag sand inside from under their shoes.

The intensive green roof that covers the entire school is laced with the same vegetation that is found in the landscape around the school, making the school resample the dunes which are to the west of the building. The flowing green roof will help camouflage the size of the building, by making it blend into the swirly landscape during the day whereas, in the evening, the light from windows glow and reveal the community found hiding underneath.

The vertical wood cladding works as a contrast to the otherwise horizontal building adding rythm and seriality. Running along the entire facade, a fascia filled with medium-large rocks ads a transitioning border to the vegetation. This groundwork lets the substantial building rest lightly in the landscape whilst functioning as a constructive element protecting the end pieces of the cladding.

Illustration 106 Building plan 1:1000

WALKTHROUGH

Arriving from the east by the small road one is met by the predominance of the sports hall overlooking the football pitch in front of it, through an S-curve to reach the southern façade where the large glazing at the kitchen reveals part of the life found on the complex. A pavement of grass and concrete grid draws the landscape close to the building. A wedge of solid concrete creeps around the corner and with an overhang invites towards the main entrance. Inside the building immediately opens up on the right side with the teachers' zone. Internal glazings divide the individual rooms from the central plaza allowing the low hierarchy and openness of the modern continuation school. A largely glazed façade towards east allows for a visual contact to the main common space and canteen through an internal courtyard carved in from the northern landscape.

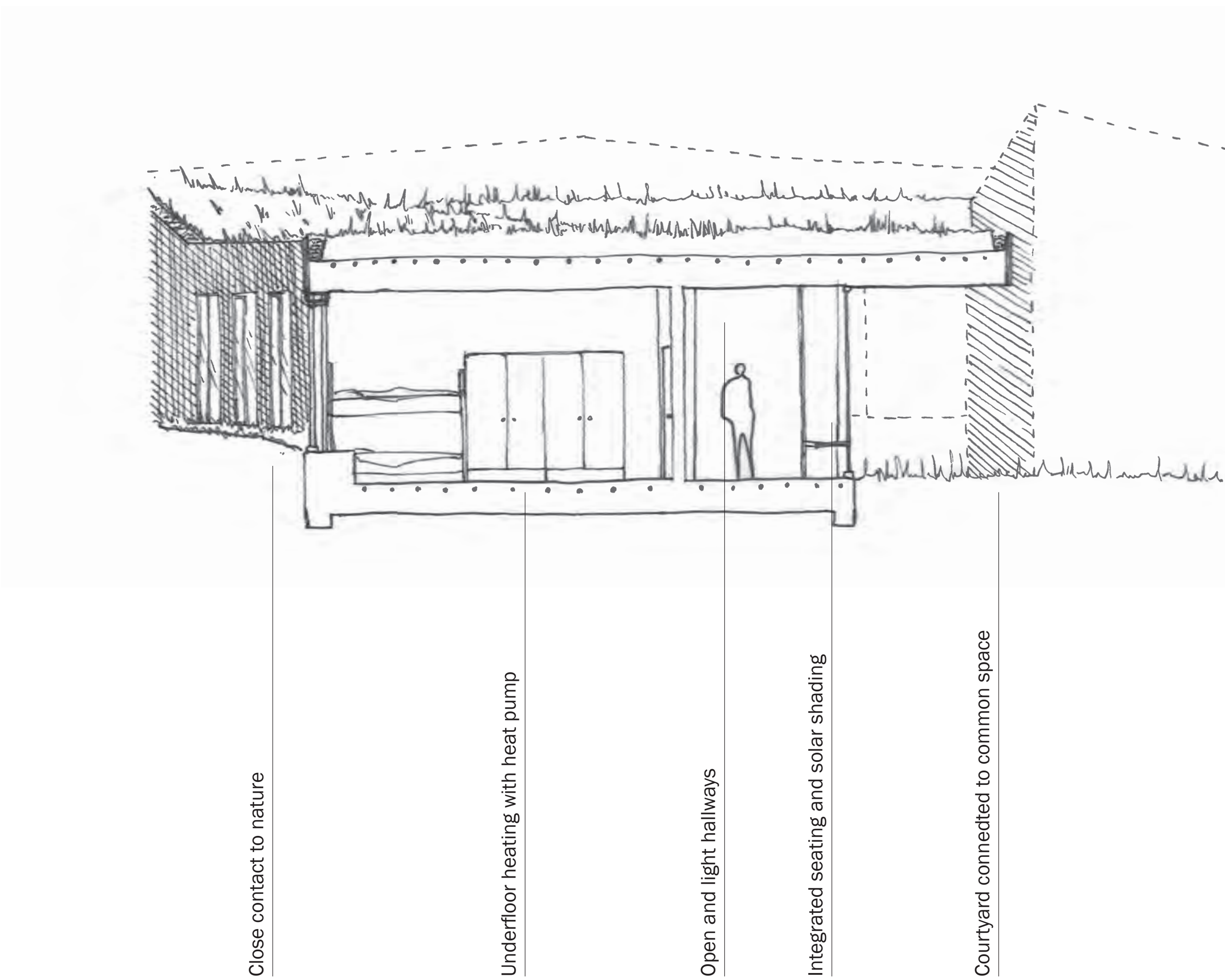
Moving through this slice of nature – the courtyard – a short outside walk under a glazed overhang the main common space is reached. Here there is room for activities and recreational time for the whole school with different facilities such as pool- and pong tables etc. Moving from the common space and south-eastward the canteen opens up through a series of columns and directly adjacent is the production kitchen. Through the canteen and a smaller area of soft furniture, the large sports hall is reached and entered down the bleacher stand. From the top of the stand, a walkway leads to the opposite side of the hall allowing direct access to the pitch outside. Down in the sports hall underneath the stand, a hallway leads to five generous locker rooms and two smaller ones for teachers or referees.

The music hall is connected at the entrance to the common space to the north, with two sliding doors allowing an integration between the two spaces for hosting larger events. In its own, the music hall seats approximately 150 people corresponding to the whole school including staff. Moving north and outside, but still under the green roof the first of a series of four living and teaching clusters is reached. Each cluster is organized by the same concept of one classroom, one special function and then three groups consisting of for living units with a common room adjacent. The classrooms have a layout that allows for different setup of teaching sessions. The hallways in the clusters are as a rule glazings looking out to courtyards with thick columns. In between these different elements are scattered being either doors to the outside, seating arrangements or solar shading in the shape of thin lamellas.

The first cluster features the create function with facilities for arts and crafts but connected to the adjacent classroom with a large sliding door giving the possibility of flexible sessions. The second cluster contains the ProF10 unit which is a more business-minded class with a lot of group work. The intermediate space between the classroom and ProF10 room is intended for studying and working in groups close to the teacher. The third cluster holds the science classroom that is fitted with high tables and chair allowing a more active teaching session around experiments and with a connected classroom for a classic one-way session. The last cluster features the media room that can be utilised as a room for working with movies etc. or projecting movies as a part either a teaching session or as recreational entertainment.

Illustration 107 Visualisation of living room cluster

DESIGN FEATURES



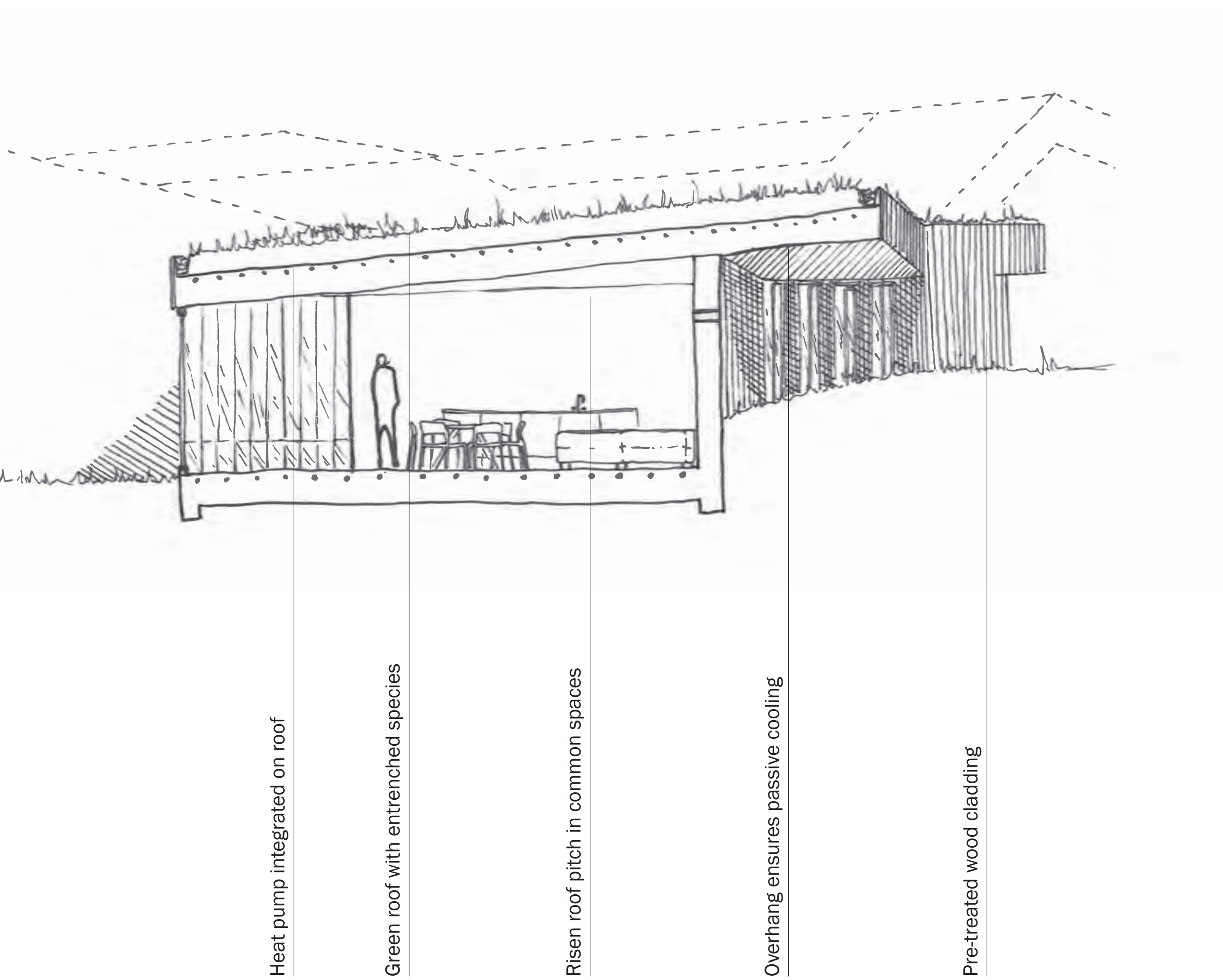
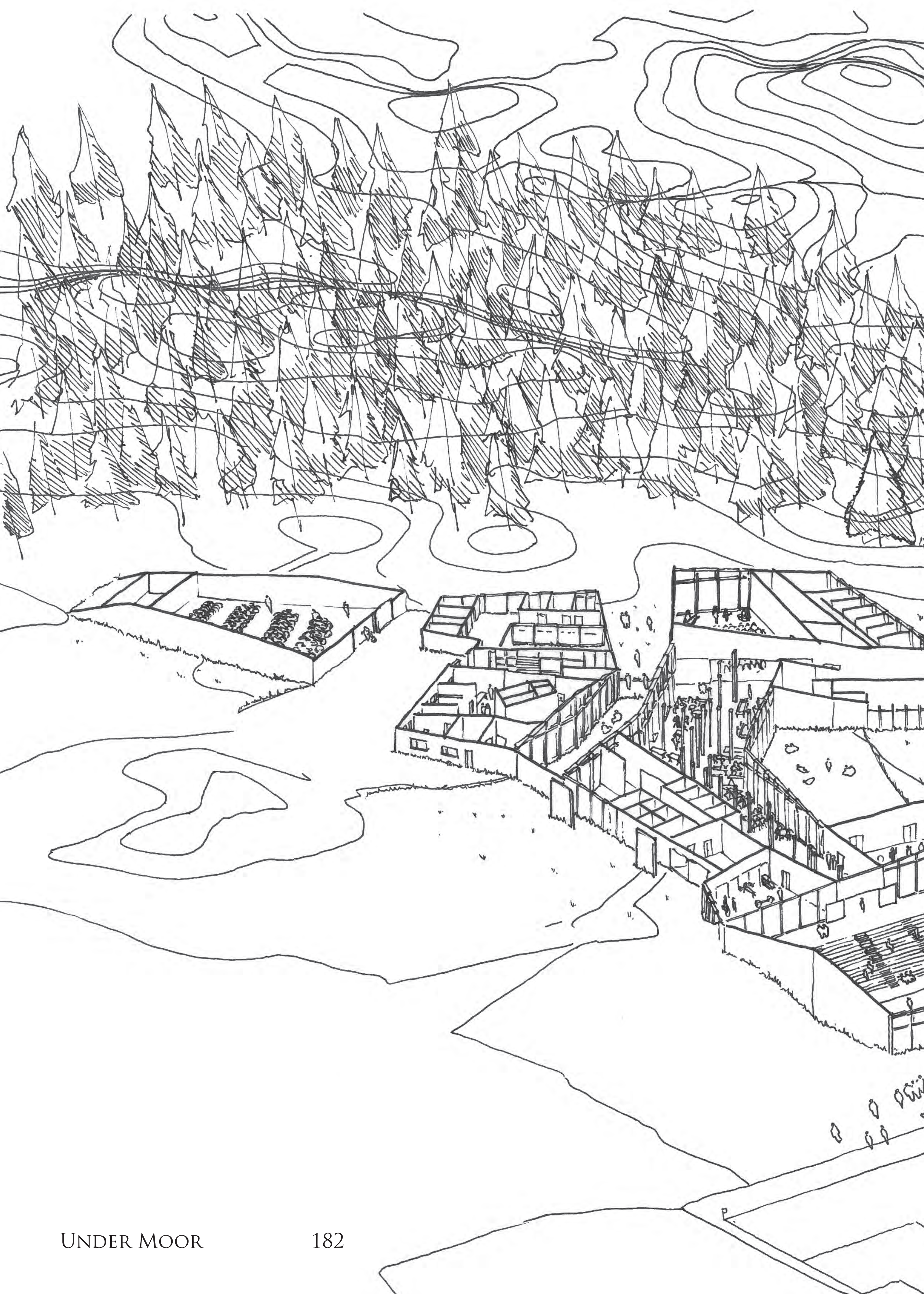


Illustration 108 Integration of design features



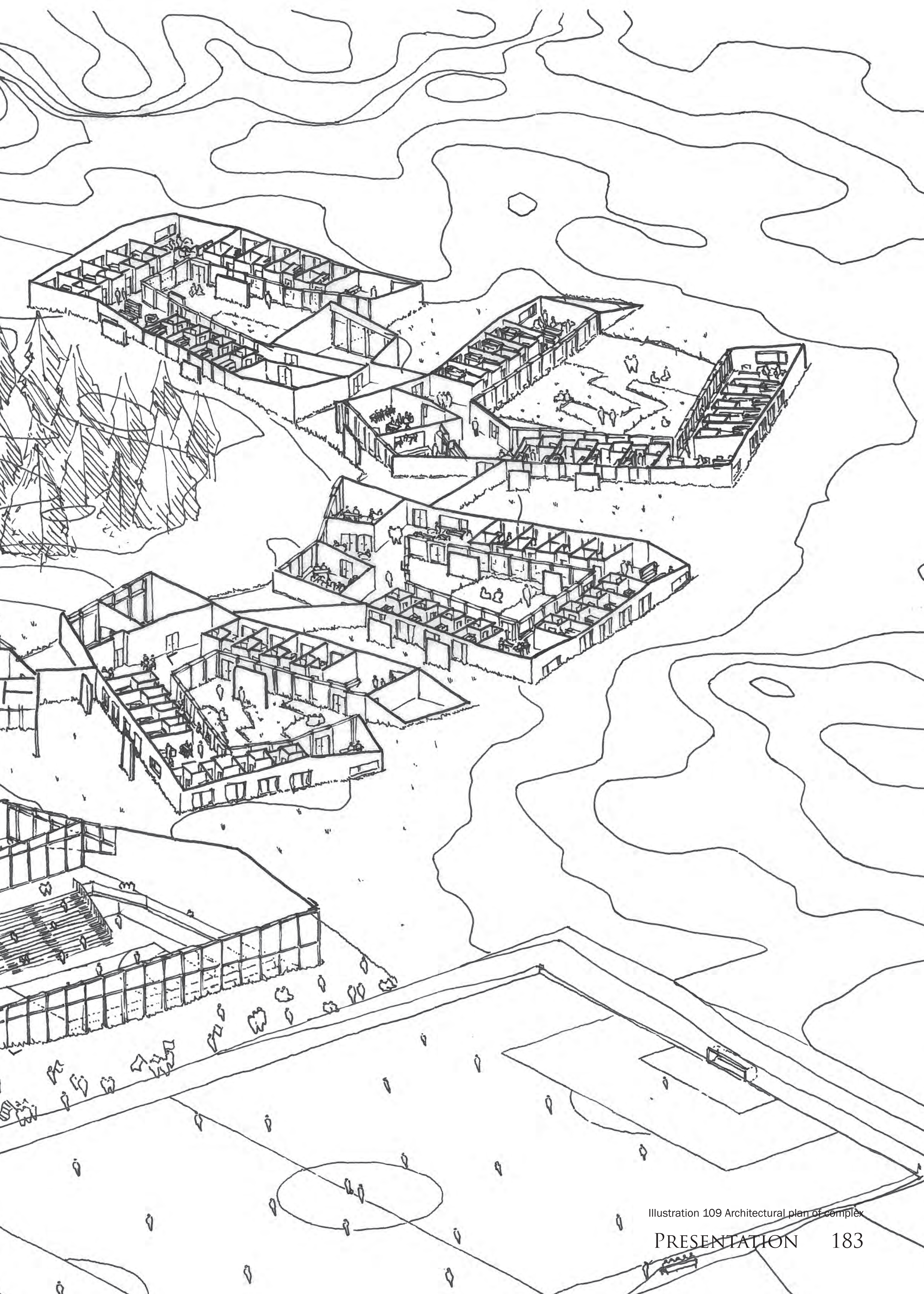


Illustration 109 Architectural plan of complex

COMMON SPACE

The main common space is located in the southern part of the school. The common space consists of the main common space and the canteen, that are connected end to end from the hallway to the sports hall. The large common space will serve as a meeting point for the whole school both during daytime and dinner, but can also host larger events. Facilities such as Fussball tables, table tennis, pool tables and sofas invite the pupils to gather and meet crosswise of the different clusters of living units.

North of the large common space, a large outdoor terrace is placed where an overhang will shelter from rain giving the opportunity to sit outside and experience the landscape, hearing the rain and smelling the wet grass while sitting dry under the overhang.

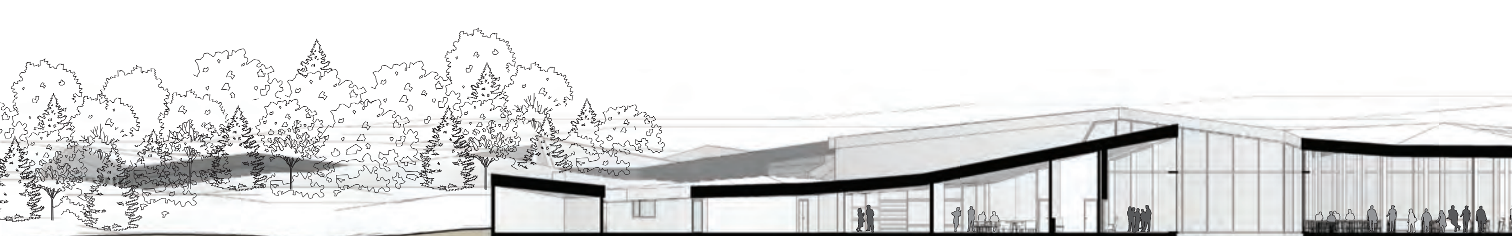


Illustration 111 plan extract 1:1000

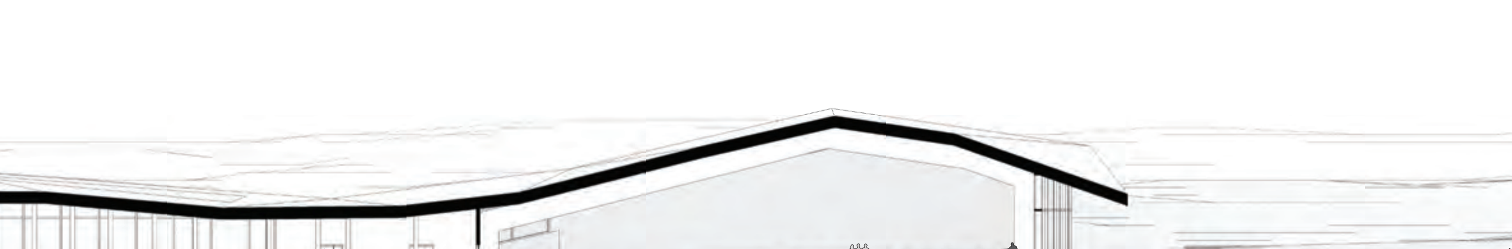
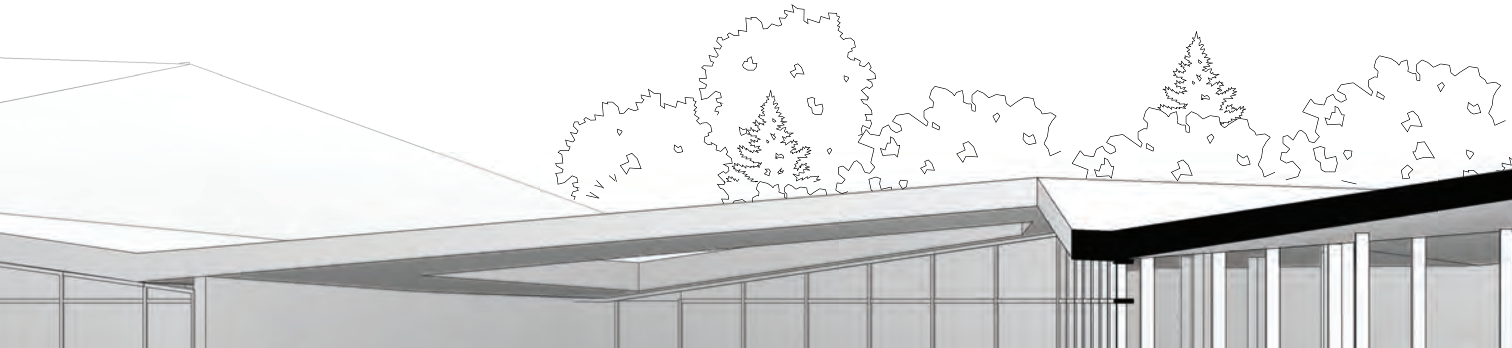


Illustration 110 Section AA - common space + sportshall

STUDY SPACE

The study space will be function as an area of which the pupils can ask for counseling, get help for homework or talk to the teachers if they have personal problems. The close relationship between teachers and pupils are a very important part of being at a continuation school, where the teachers are not only teachers but also functions as guardians for the pupils.

All the pupils are divided into contact groups where the groups have a teacher appointed as a contact teacher. Due to this close relationship, the study space has been placed close to the common space, to ensure that the teachers and pupils can easily get in contact with each other. The study space, as well as all of the other teachers' facilities, are kept open and with internal glazings to ensure visual contact between teachers and pupils.



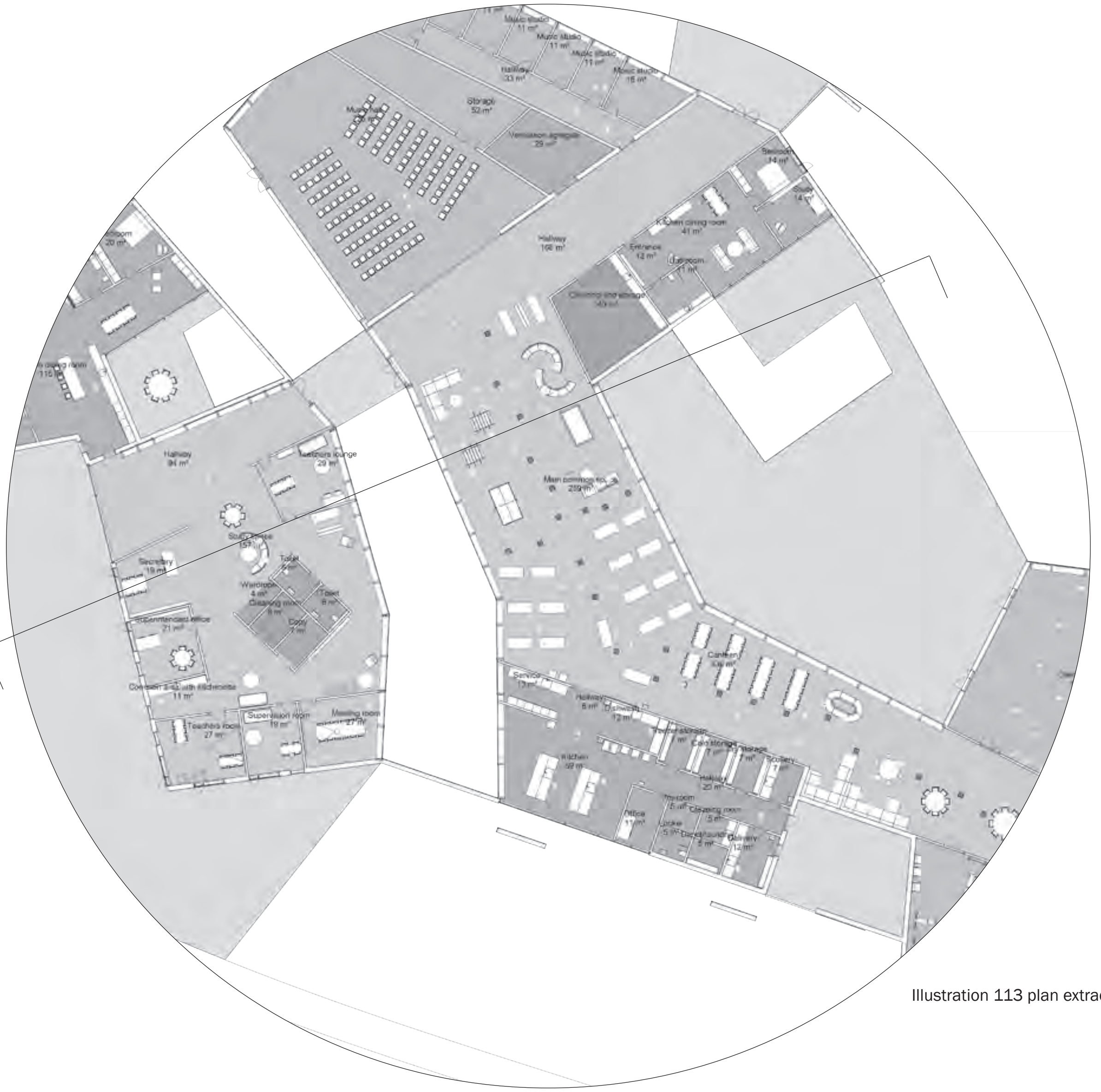
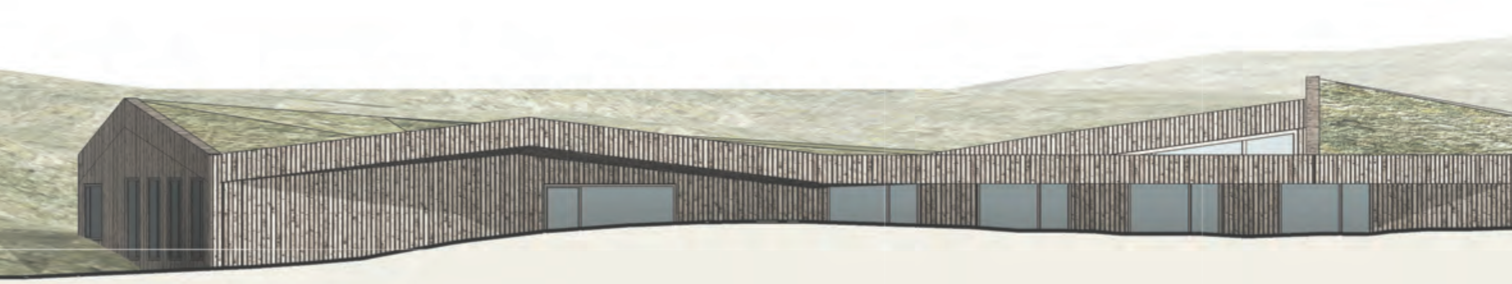


Illustration 113 plan extract 1:500

Illustration 112 Section BB - common space ~~+ teachers area~~

LIVING UNITS

The living units consist of a single bedroom and a bathroom housing a maximum of four pupils and will primarily be in use when the pupils are asleep and in the morning. The room has been angled which give a direct view through the room from the entrance and out the large window. The entrance has been pushed in to make a small niche and thereby creating a little distance from the hallway and the possibility for the pupils to add individual marks on their room, for instance by adding pictures or artwork. On either side of the room bunk beds are placed and oriented towards each other to facilitate the small community in each living unit.



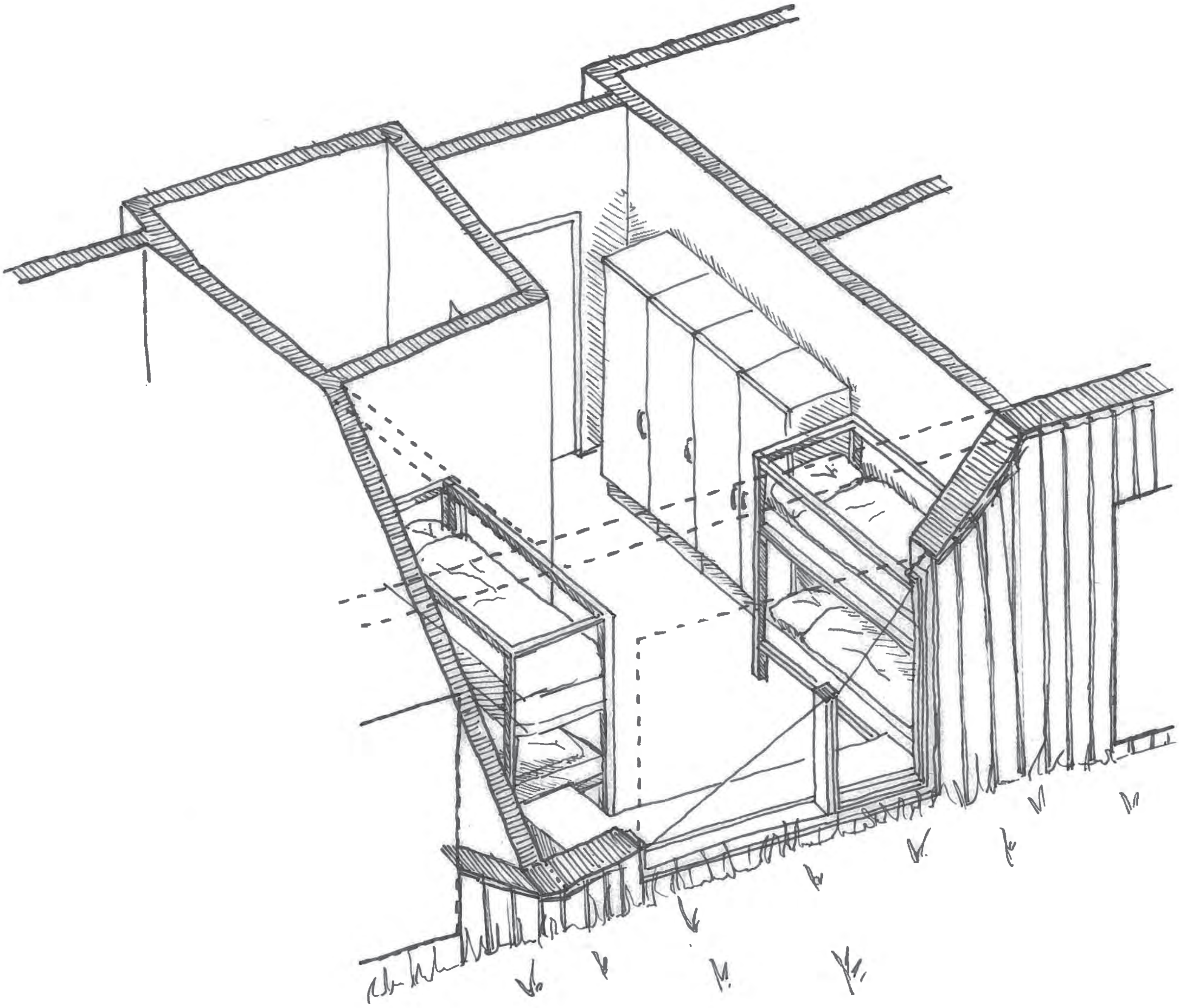


Illustration 114 Axometry of living unit

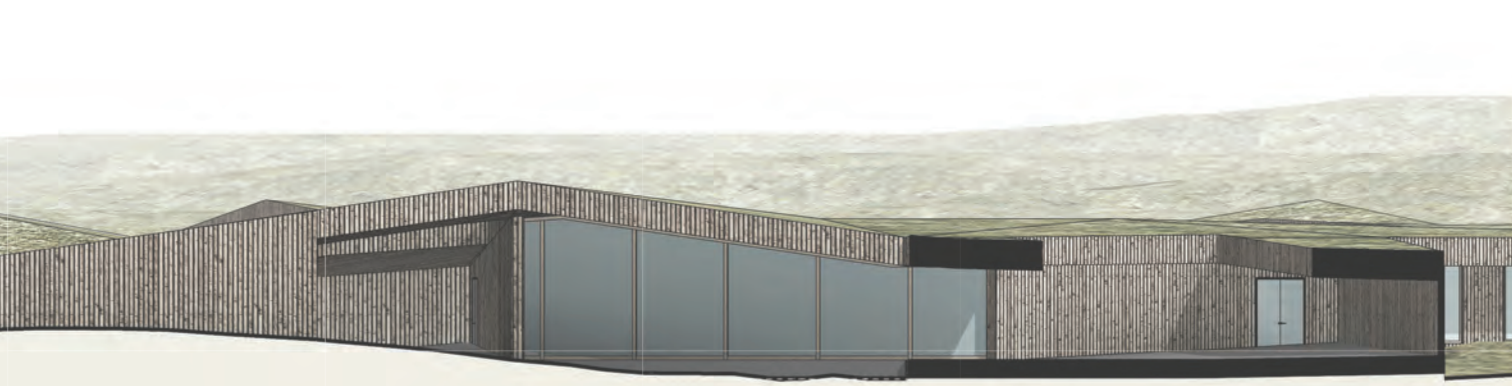


Illustration 115 South facade of northern most living unit cluster

Under the large window, the window sill has been lengthened into a plinth creating a built-in furniture which both serves as a place to sit and as a compartment for smaller belongings. Four cabinets ensures addequate storage of clothes for each pupil. Additional storage space is ensured by small boxes on wheels that roll in under the bottom bunk beds.

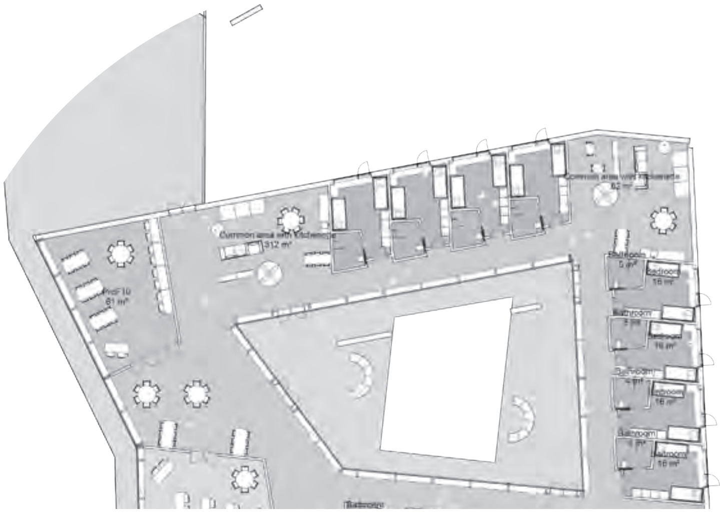


Illustration 117 plan extract 1:500

Illustration 116 Section CC - common room + living units + classroom

The flooring has been kept in the same smooth concrete as in the rest of the school and is also equipped with floor heating as the rest of the school. The CLT walls which make up the living units construction have been limed to lighten up the wood and thereby brighten the room. By exposing the wood, the living units will resemble the small vacation houses which are scattered in along the west coast giving a warm and homely feeling.

Illustration 119 plan extract 1:500

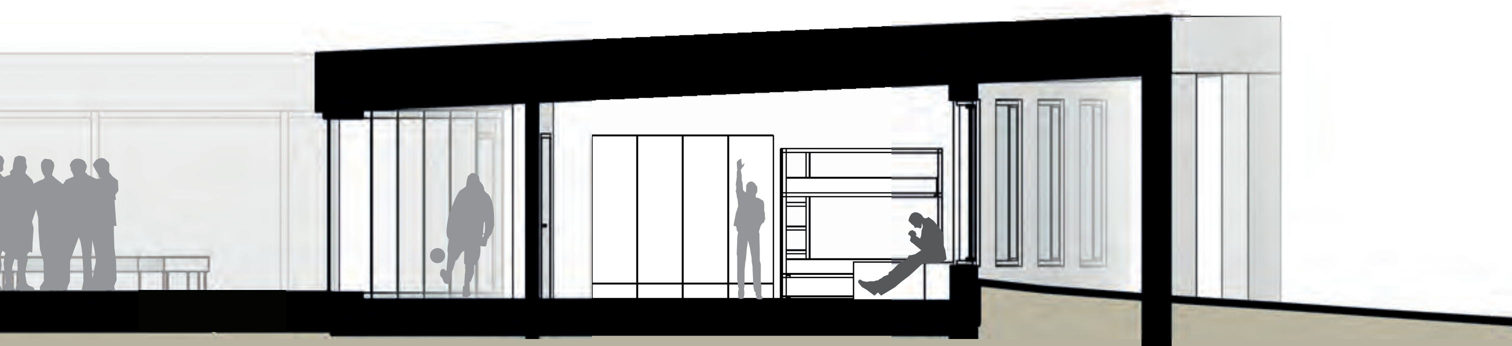
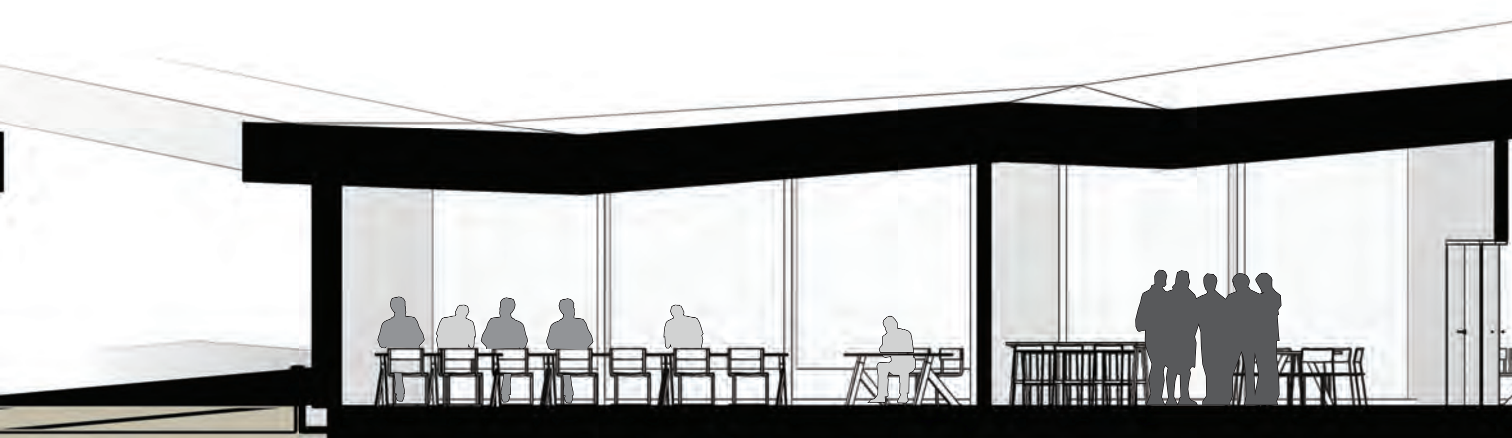


Illustration 118 Section DD - Living units cross section

CLASSROOMS

The large class rooms give a lot of freedom for the teachers to plan classes and place the tables and chairs according to the type of teaching that will take place. The tables can be arranged in groups or in long rows according to what will be the optimal solution.

The large windows that open up to the landscape will give the expression of having lectures out in the nature. This should lower the stress levels of the pupils leading to a higher concentration and more effective learning. Furthermore, the large windows ensure a high daylight factor which is also related to a proper learning environment.



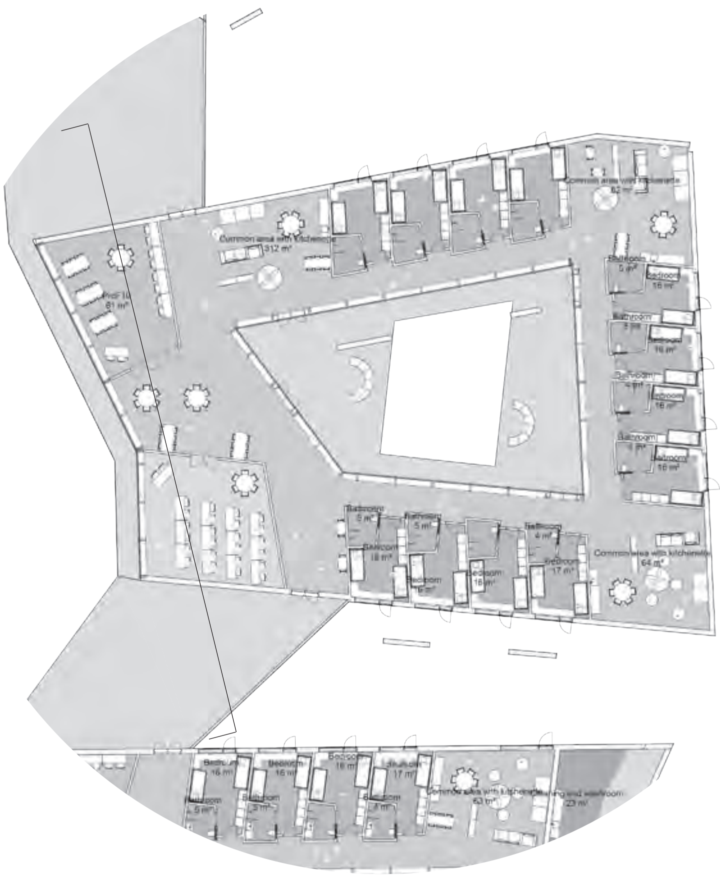


Illustration 121 plan extract 1:1000

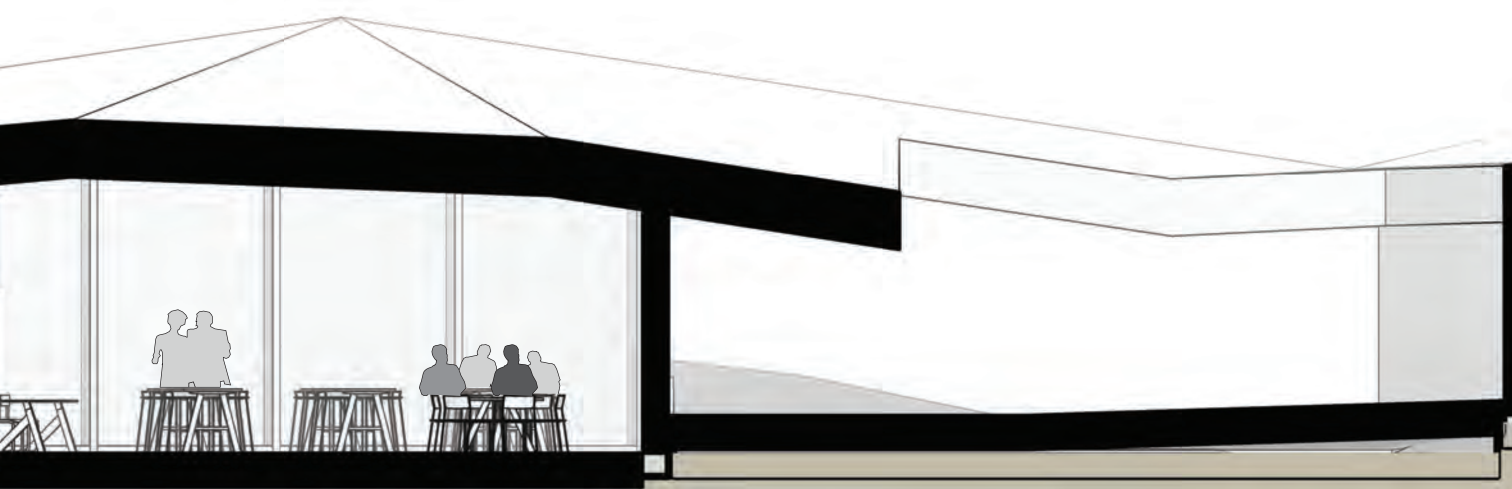


Illustration 120 Section EE classroom + study space

COMMON ROOMS

The living units are divided into groups of four where they share a common room. The common room is equipped with a small kitchenette, sofas, lounge chairs etc. The common rooms will be used by the pupils for both relaxation and as a study room. The common rooms are not reserved for the four living units to which it is adjacent to but is free to be used by all of the pupils attending the school. All of the common rooms have windows that offer views to the landscape surrounding the school as well as to the adjacent courtyard. The courtyards lets the community flow outside and again mix up with other pupils or groups.
The walls are painted white to give this a different expression than that of the living units. The white wall, grey floor and wooden lamellas in the ceiling will be contrasted by the colors which will be added to the room by furniture.
The hallways around the courtyard also function as common spaces, with its built-in furniture, giving the opportunity to the pupils to sit and talk or to, for example, read a book as part of a study session.

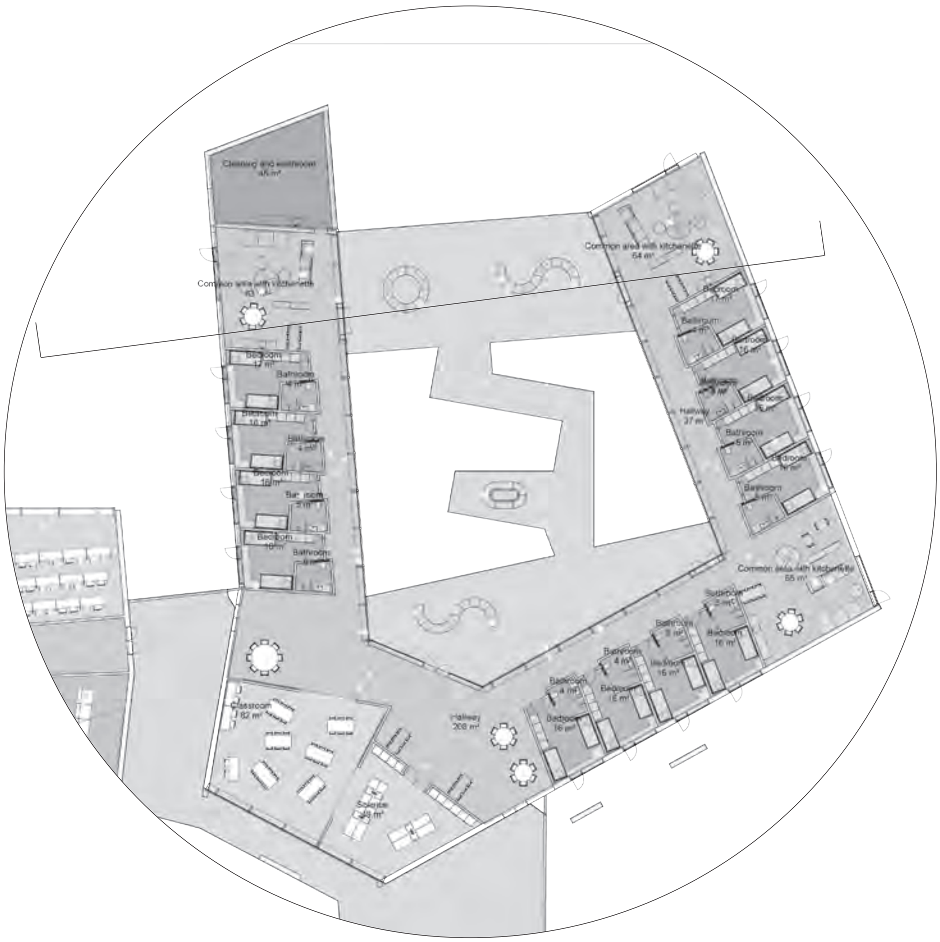
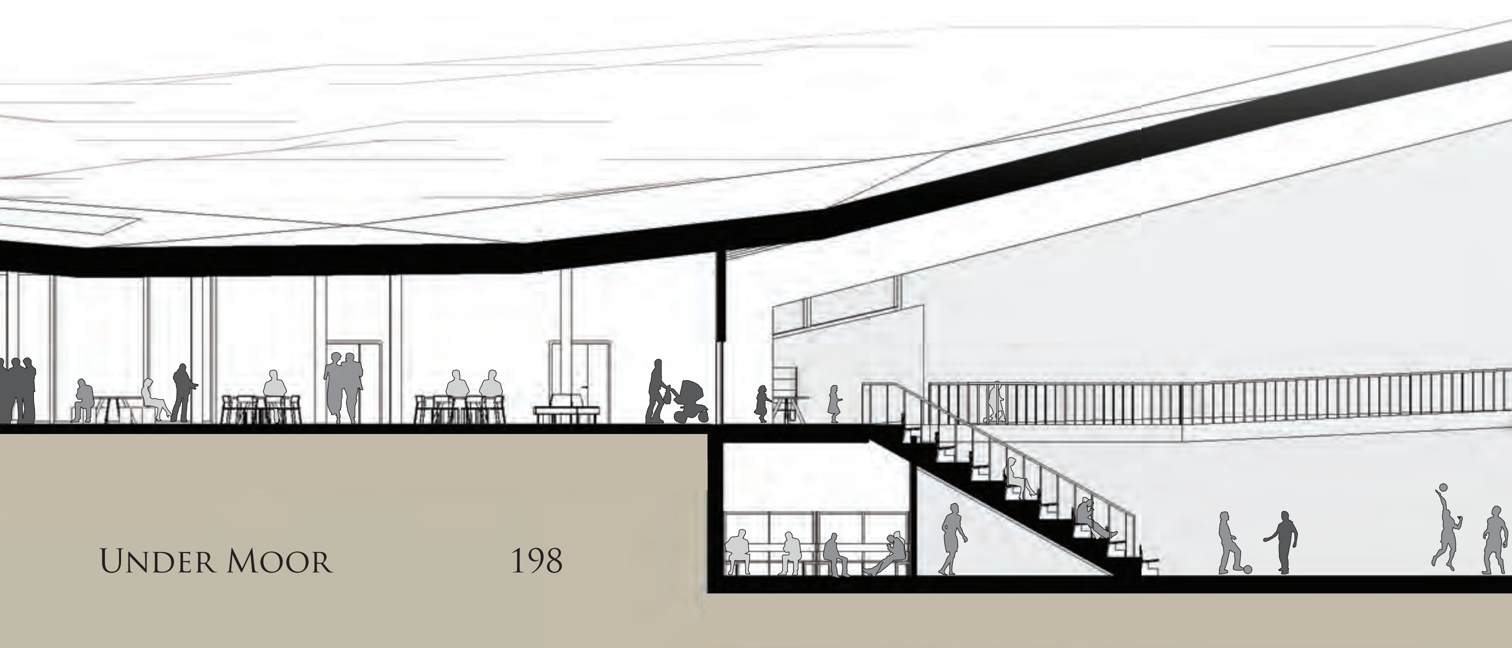


Illustration 123 plan extract 1:500

Illustration 122 Section FF - Common rooms and connection to courtyard

SPORT SHALL

The sports hall have been lowered down into the ground equalling a full story in order to reach a sufficent clearance above the pitch. When entering from the common space and canteen, the users will enter through a set of large sliding doors to find themselves on a plateau looking down over the spectators stand and down into the sports hall. With seating for 350 people, the sportshall will be large enough to accommodate handball/ football tournaments and other events. By lowering the sports hall an letting people enter it from ground level, will make it accessible by people in wheelchair and people who have trouble walking. Locker rooms are found under the spectator stands where five regular locker rooms and two referee/teachers locker rooms have been placed. Also at ground level, the large storage space for the entire sportshall is placed, giving easy access for the user.



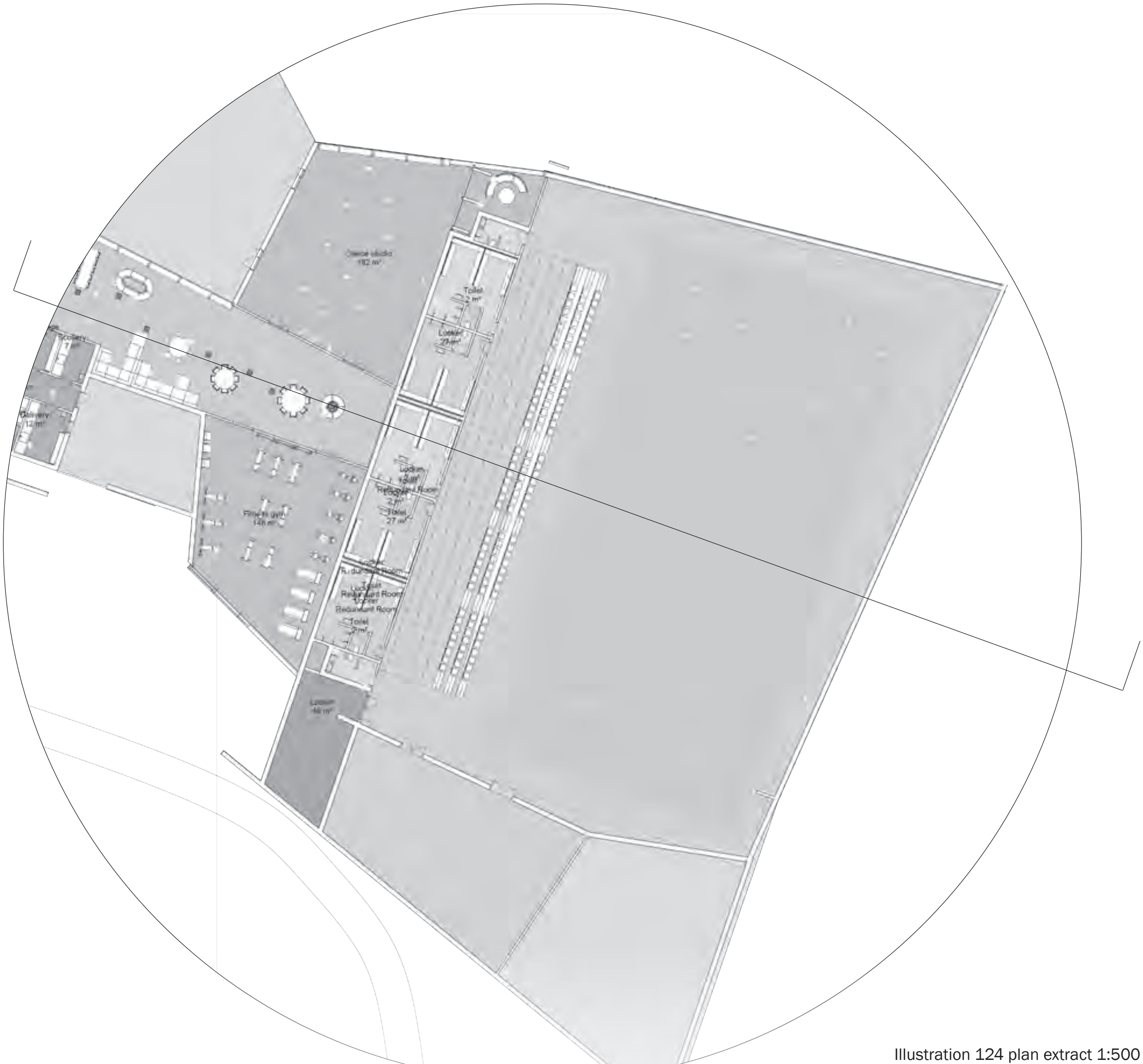
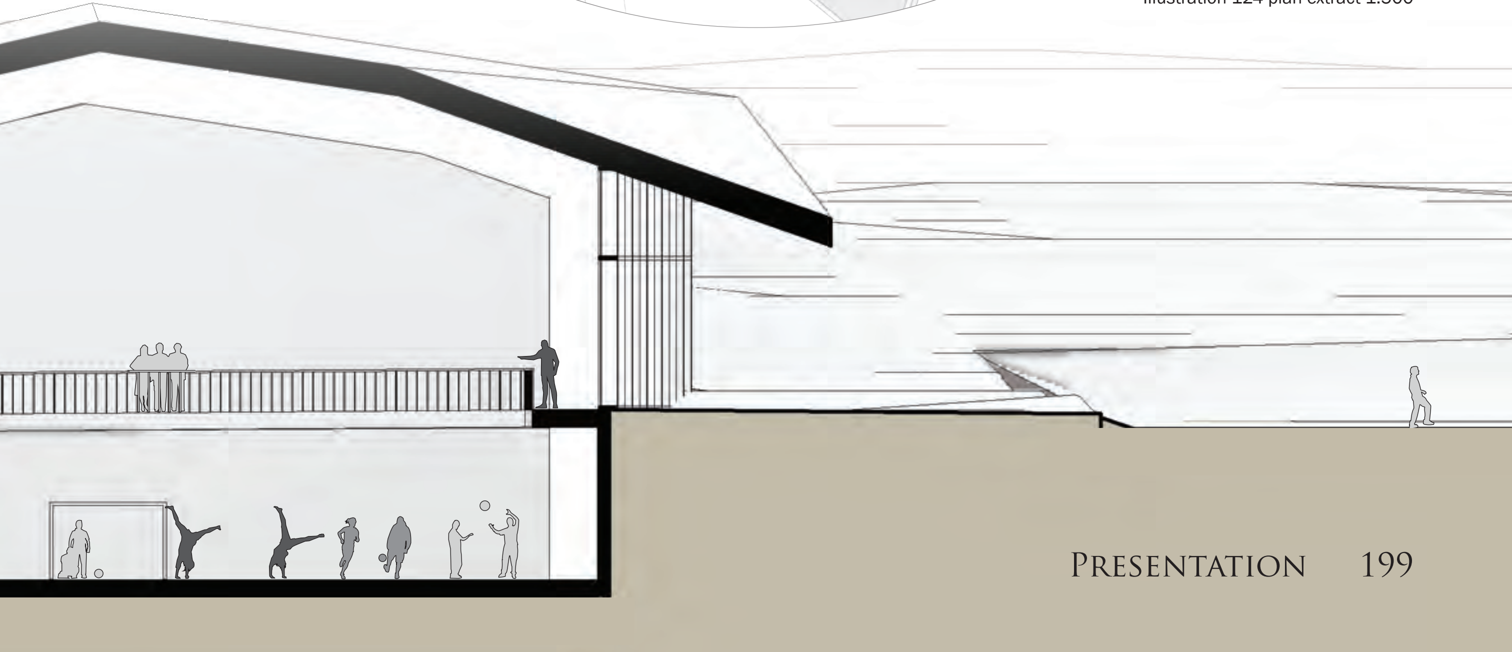
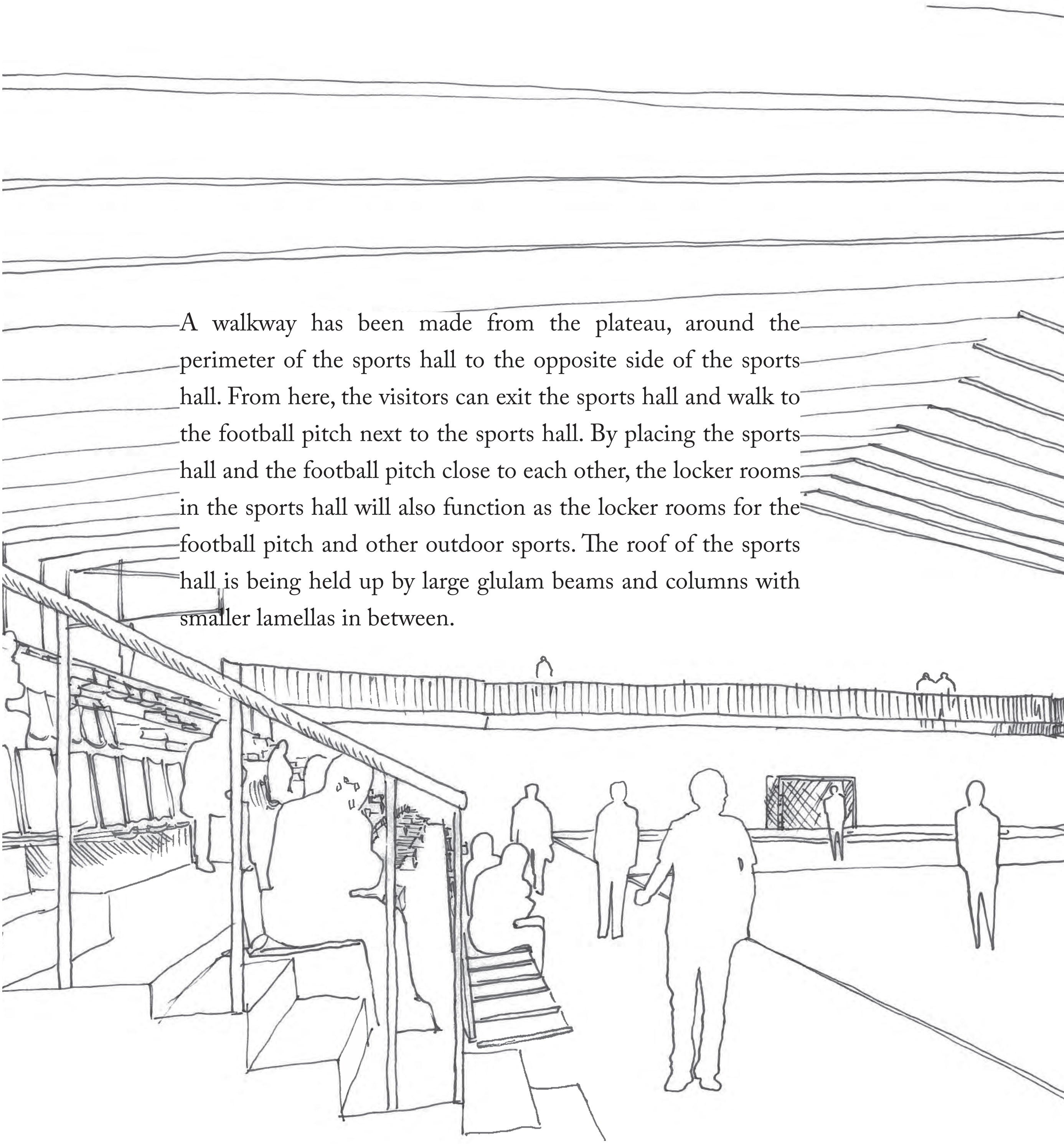


Illustration 124 plan extract 1:500





A walkway has been made from the plateau, around the perimeter of the sports hall to the opposite side of the sports hall. From here, the visitors can exit the sports hall and walk to the football pitch next to the sports hall. By placing the sports hall and the football pitch close to each other, the locker rooms in the sports hall will also function as the locker rooms for the football pitch and other outdoor sports. The roof of the sports hall is being held up by large glulam beams and columns with smaller lamellas in between.

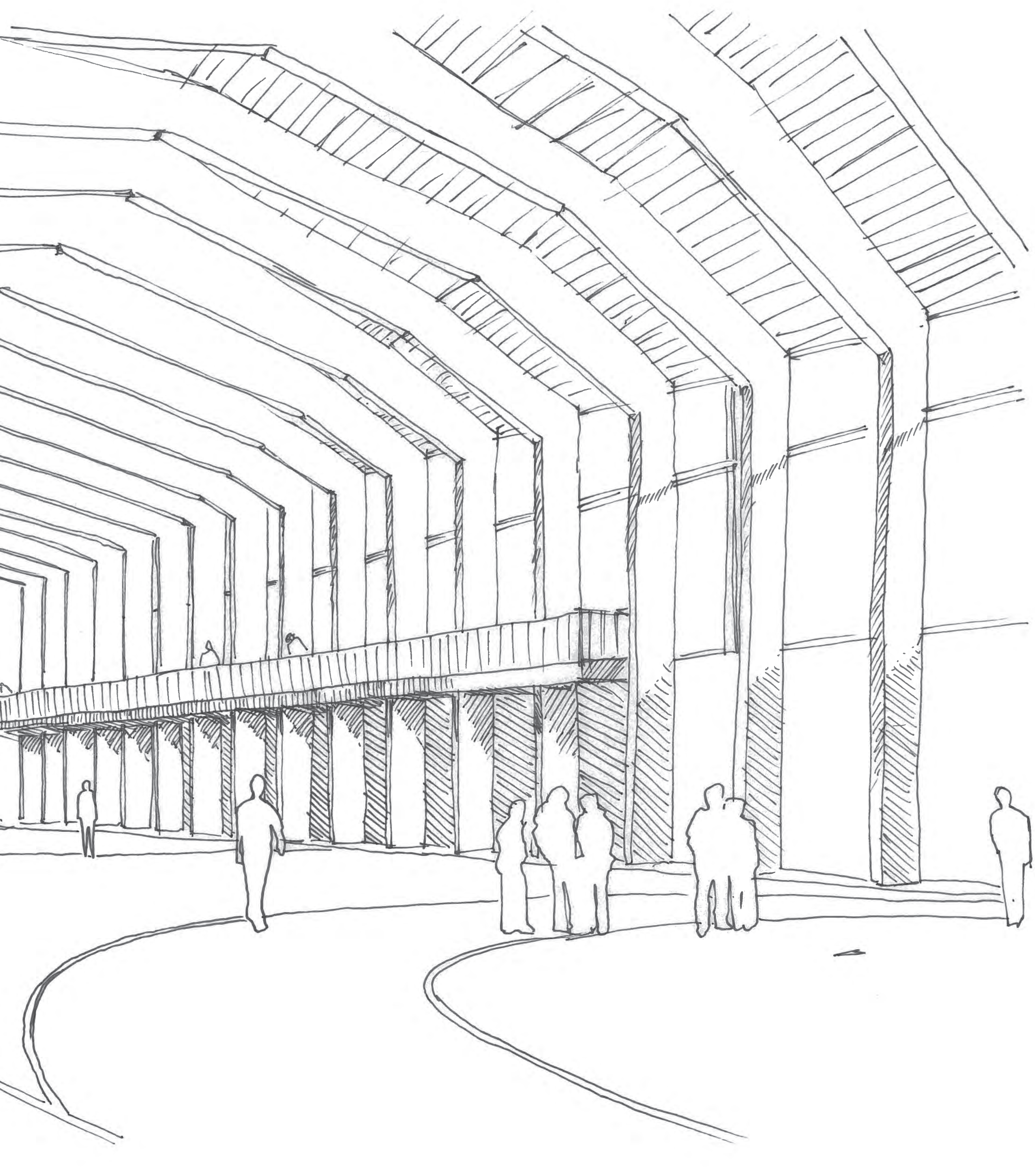


Illustration 125 Section GG - Sportshall

TECHNE

The design features a variety of both new and well tested solutions. To present the implementation of these technologies strategies of ventilation and construction principles will be followed by detail drawings of key elements. Following are the energy and indoor climatic results and considerations regarding the discipline of digital modelling.

Illustration 126 Facade detail - Vestre Fjordpark

VENTILATION

In the rooms that are too large to use the Inventilate system for ventilation, conventional mechanical ventilation system with a central agregate and supply ducts would be incorporated. This would be rooms/functions such as the sports facilities (sports hall, dance studio and gym), the Music Hall and the production kitchen.

Sports hall. Due to the difference in use of the sportshall, two central units has been implemented into this function. At most of the time, the sports hall would only be used by a smaller number of students playing handball, indoor football etc. A smaller central unit would be sufficient to keep the indoor comfort of the sports hall at acceptable level. This system would supply fresh air via large ducts hung from the ceiling in order to ensure adequate distribution. In the cases where the sports hall would host different tournaments, such as handball or large open-house events, the amount of people load would be higher. To accommodate

the higher number of people, a second larger central unit would start up and the spectator stands would act as a pressure box. From under the seating fresh air will be blown in, pass by the spectators and be extracted in the ceiling.

In the music hall, a VAV system has been implemented as in the sports hall. The music hall is only in for short periods of time, yet when it is in use, it occupies the entire school, which means that the Inventilate systems would not be sufficient. Therefore, a larger systems with ducts had to be used.

Due to the poluted air outlet and special need, the kitchen will as well have its own CAV system.

VENTILATION STRATEGY

Illustration 127 Ventilation strategy

HEAT PUMP ON THE ROOF

As a sustainable initiative for the new Continuation School, a heat pump system has been implemented in the design. A heat pump is a system which draws energy in the form of heat from the environment. Through a closed piping system which is filled with a cooling agent and a compressor, the temperature of the environment can be raised and used for heating.

The heat pump system consists of four main components; an evaporator which extracts the heat from the environment. A condenser which releases the heat from the system, A compressor to raise the pressure of the liquid and thereby the temperature and lastly an expansion valve which lowers the pressure of the liquid.

The way in which the heat pump works is by circulating a coolant in a closed pipe system. The pipe system is placed into the ground where the liquid in the pipes obtain the energy in the ground. The liquid store in the pipes runs into the evaporator. In the evaporator, the liquid starts to boil and turned to steam. The steam goes through the compressor, where the pressure and the temperature is raised. After the temperature has been raised in compressor, the steam releases the heat energy as it goes into condenser. From the condenser the heat energy is transferred to the heating system of the building (floor heating or radiators). After the energy has been released, in the condenser the gas turns into a liquid again. The liquid then goes through a valve and back into the evaporator where the process starts over.

The heat pump system uses a curtain amount of energy, but the energy delivered by the system I 2-5 times larger than the amount of energy used


Illustration 128 Icopal Energy roof

by the system, which makes the heat pumps very effective.

When implementing heat pumps for this project, the pipes has been placed under the soil on the roof. The reason for this was due to the choice of preserving the landscape around the school. A Danish company has been creating roofs with the pipes just under a layer of roofing felt. After correspondence with the company about placing the heat pipes under a layer of soil on top of the roofs, their conception was that this should as a rule be possible though an actual research and testing had not yet been done. The system that is currently being produced and fitted onto mostly commercial buildings has been tested to function almost as effective with a thick layer of snow on top of the roffing felt.

To further validate the hypothesis of the possibility of having heat pump tubes in soil on a roof contact was established to a company specialised in ground heat pumps. Again the immideate conclusion was, that this should be possible. Usually heat pump tubes are placed aprroximately one meter into the ground to avoid frost damage. As the soil of the roof is a part of the building envelope some temeprature transfer will occur from the inside resulting in a warmer soil thus limiting the risk of frost damage to the tubes.

CONSTRUCTION

The structure of the clusters which houses the living units, common rooms and classrooms, will be created by a cross-laminated wood roof plate which rests on loadbearing walls constructed with CLT and a series of gluelaminated timber columns on the opposite side.

The mono-pitch roof changes slope and height throughout the different functions of the building strategicly ordered according to expected occupancy. Rooms that have a high person capacity and activity have a higher ceiling height relative to smaller spaces. The ceiling of the rooms will follow the roof construction giving the ceiling a weaving and dynamic expression.

The columns that run along the hallways will be used to make integrated furniture. The 100 x 500 mm columns will be connected to each other at chosen places, to make furniture which can be used by the pupils for relaxation and study. This also adds stiffness to the entire construction.

The inner walls of the building will be created from CLT as well for an easy construction and the possibility of exposed surfaces. The overlapping layers in the wood and the mass of the wall will work as a barrier for sound and lower the amount of noise and sound transmitted from one room to another. The walls can be kept natural, showing off the wood or painted over. The wooden walls will also be able to breathe and thereby obtaining moisture in the air and releasing it again, creating a healthier environment for the users of the building.

The roof will towards the south extend outward, creating an overhang that will help shade the hallways and other rooms from the sun in the summer month. The overhang will rest on wooden walls which will also help shade during the summer as well as creating outdoor niches which can be used by the users. ‘

The walls can due to the use of CLT for both the outer and inner walls be pre-fabricated off-site at a factory. The CLT also has a lower density compared to concrete, making it cheaper and easier to transport and erect at the site.

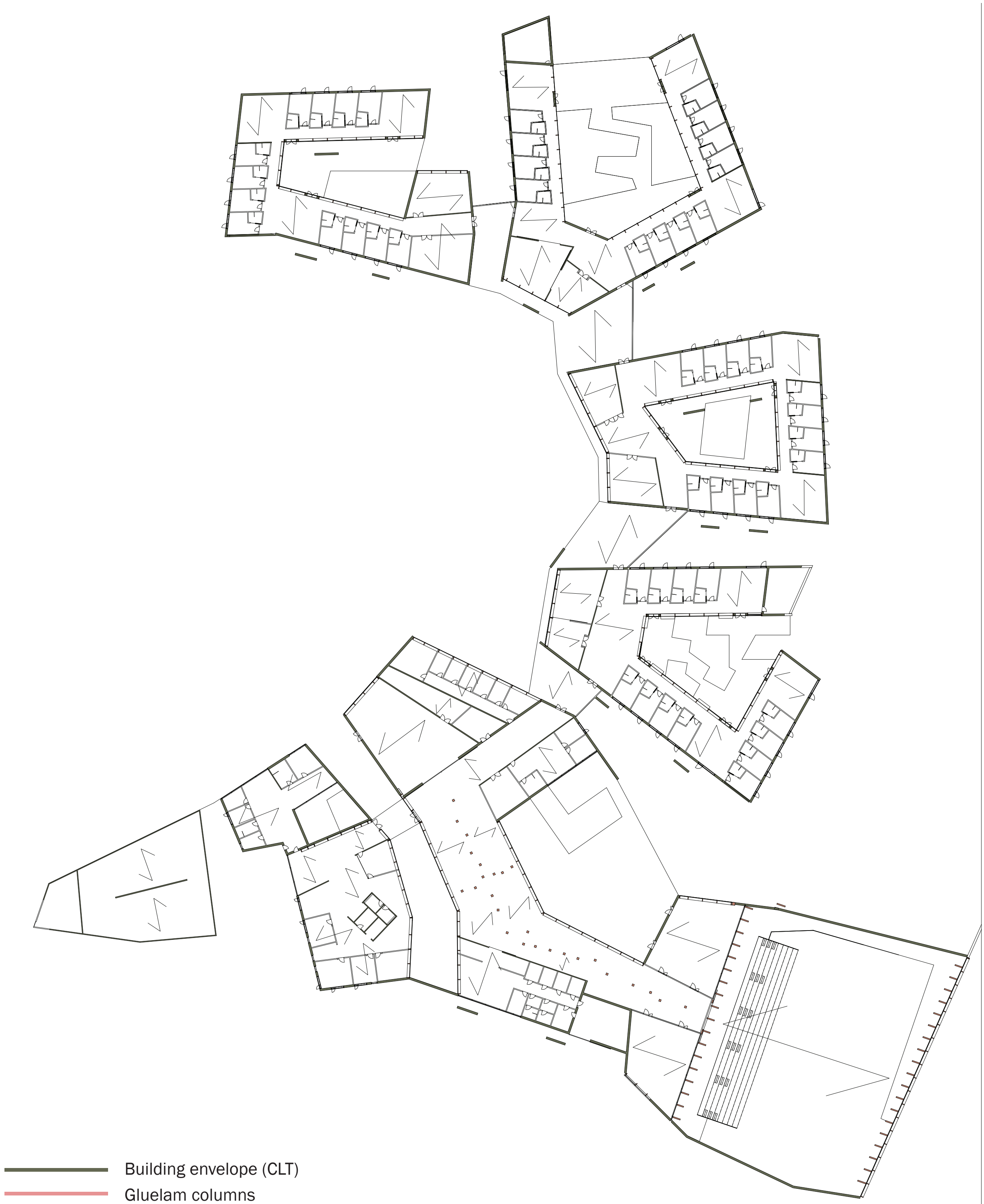


Illustration 129 Construction principle

DETAIL INTEGRATION OF INVENTILATE

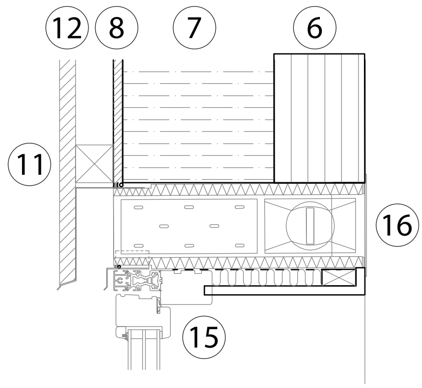


Illustration 130 Detail 1:10 vertical section - Inventilate integrated above window

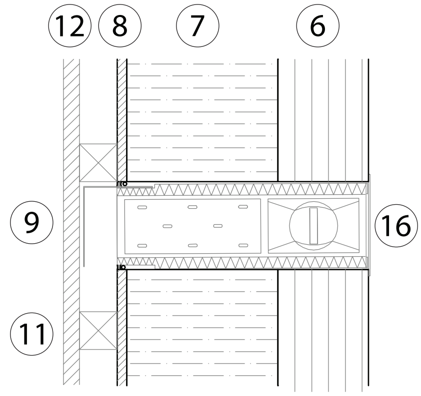


Illustration 131 Detail 1:10 vertical section - Inventilate integrated in thermal envelope

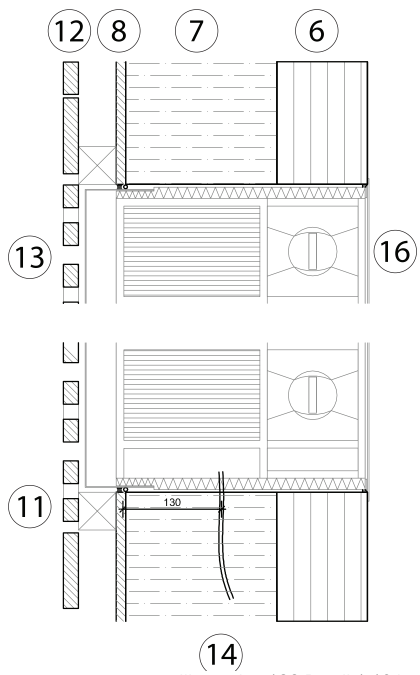


Illustration 132 Detail 1:10 horisontal section - Inventilate integrated in thermal envelope

6 CLT 120mm
7 Hard insulation 200mm
8 OSB 12mm
11 Spacer
12 Facade cladding
15 Window
16 InVentilate MicroVent

6 CLT 120mm
7 Hard insulation 200mm
8 OSB 12mm
9 Zink panel
11 Spacer
12 Facade cladding
16 InVentilate MicroVent

6 CLT 120mm
7 Hard insulation 200mm
8 OSB 12mm
11 Spacer
12 Facade cladding
13 Facade Cladding
14 240V Power connection
16 InVentilate MicroVent

DETAIL ROOF CONSTRUCTION

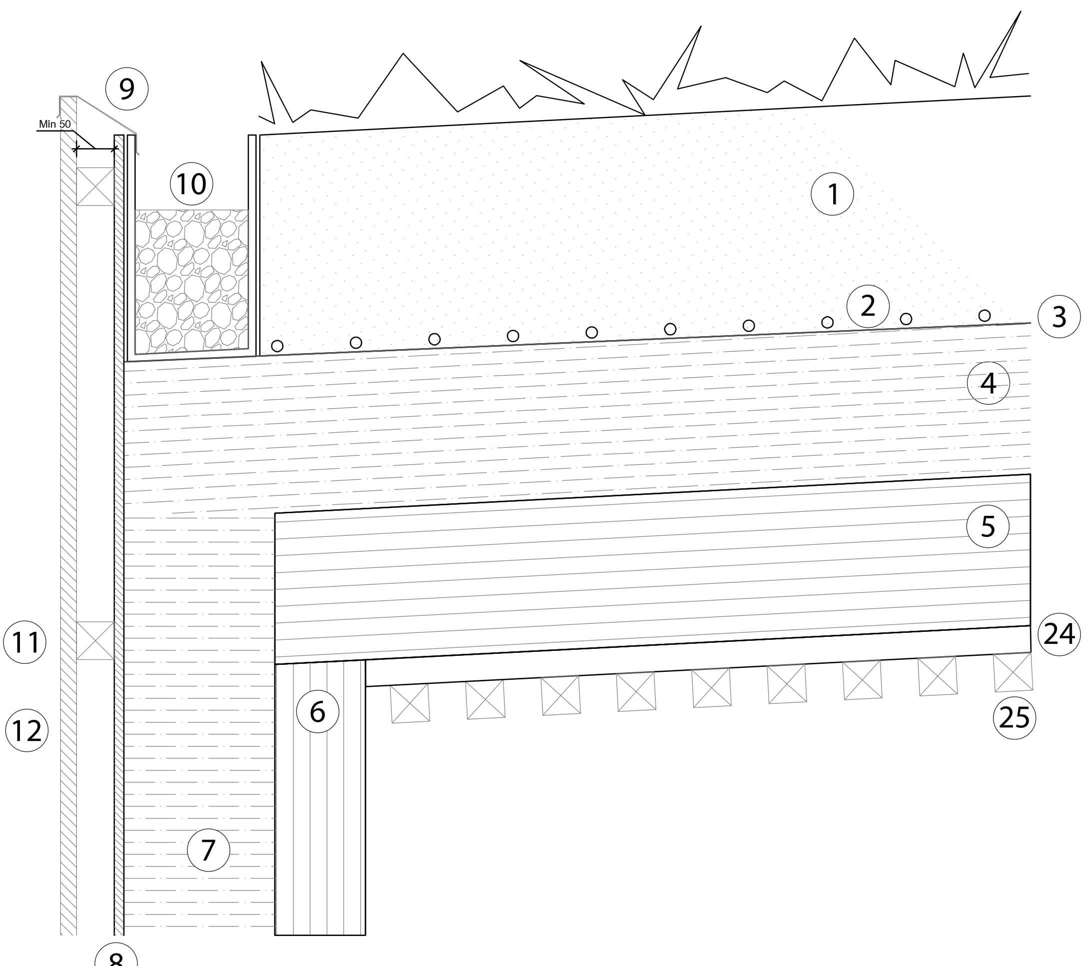


Illustration 133 Detail 1:10 vertical section - thermal envelope: roof and wall

1. Soil 300mm
2. Heat pump pipes
3. Roofing felt
4. Hard insulation 200mm
5. CLT 200mm
6. CLT 120mm
7. Hard insulation 200mm
8. OSB 12mm
9. Zink panel
10. Fascine
11. Spacer
12. Facade Cladding

24. Troldtekt
25. Wooden lamella

DETAIL GROUND FOUNDATION

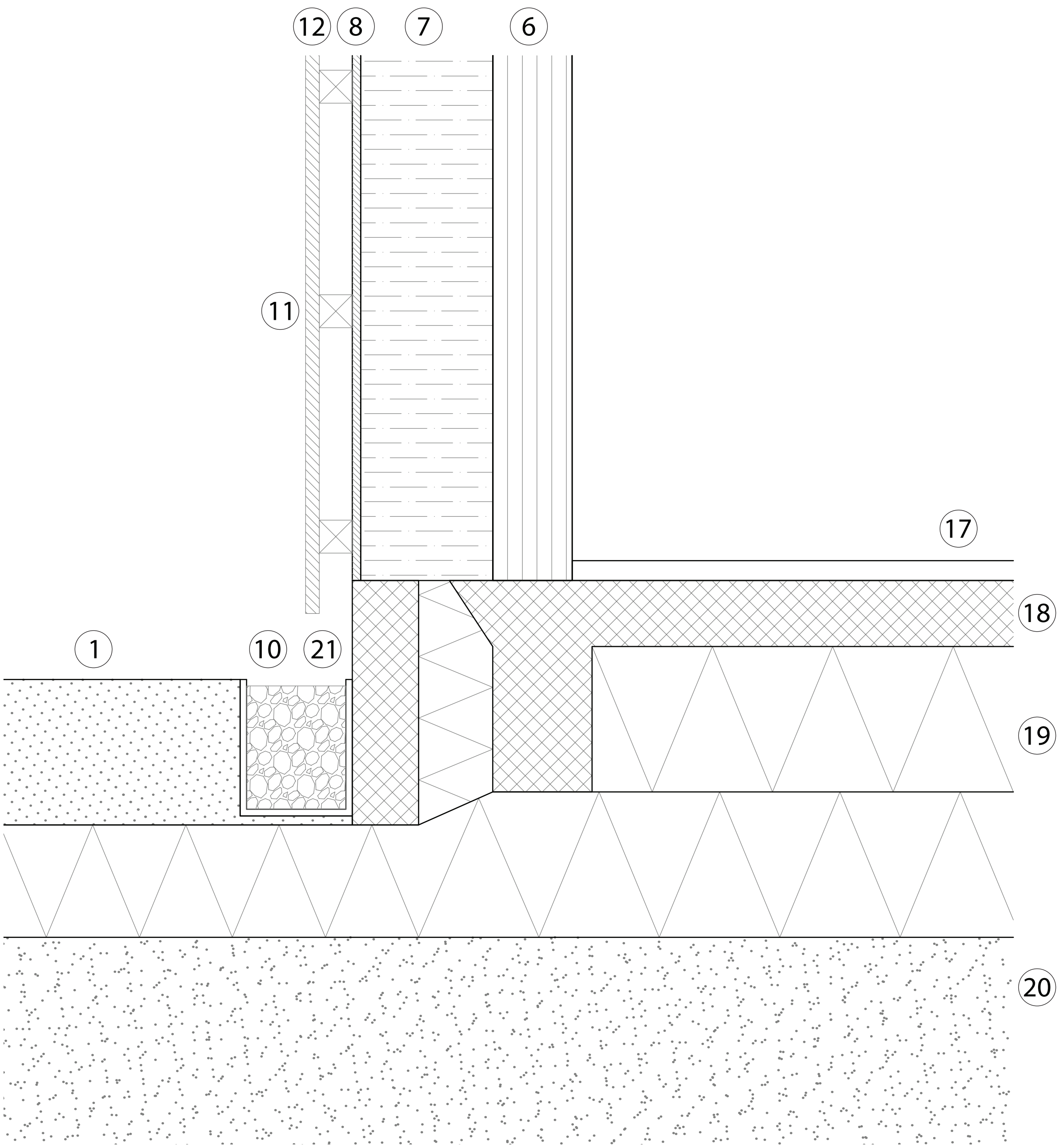


Illustration 134 Detail 1:10 vertical section - thermal envelope: foundation and grounding

1 Soil 300mm
6 CLT 120mm
7 Hard insulation 200mm
8 OSB 12mm
9 Zink panel
10 Fascine
11 Spacer
12 Facade Cladding
17 Wearing layer 30 mm
18 Concrete foundation100mm
19 2 x High pressure polystyrine 220mm
20 Sand base
21 Concrete footing 100mm

DETAIL WINDOW IN WALL

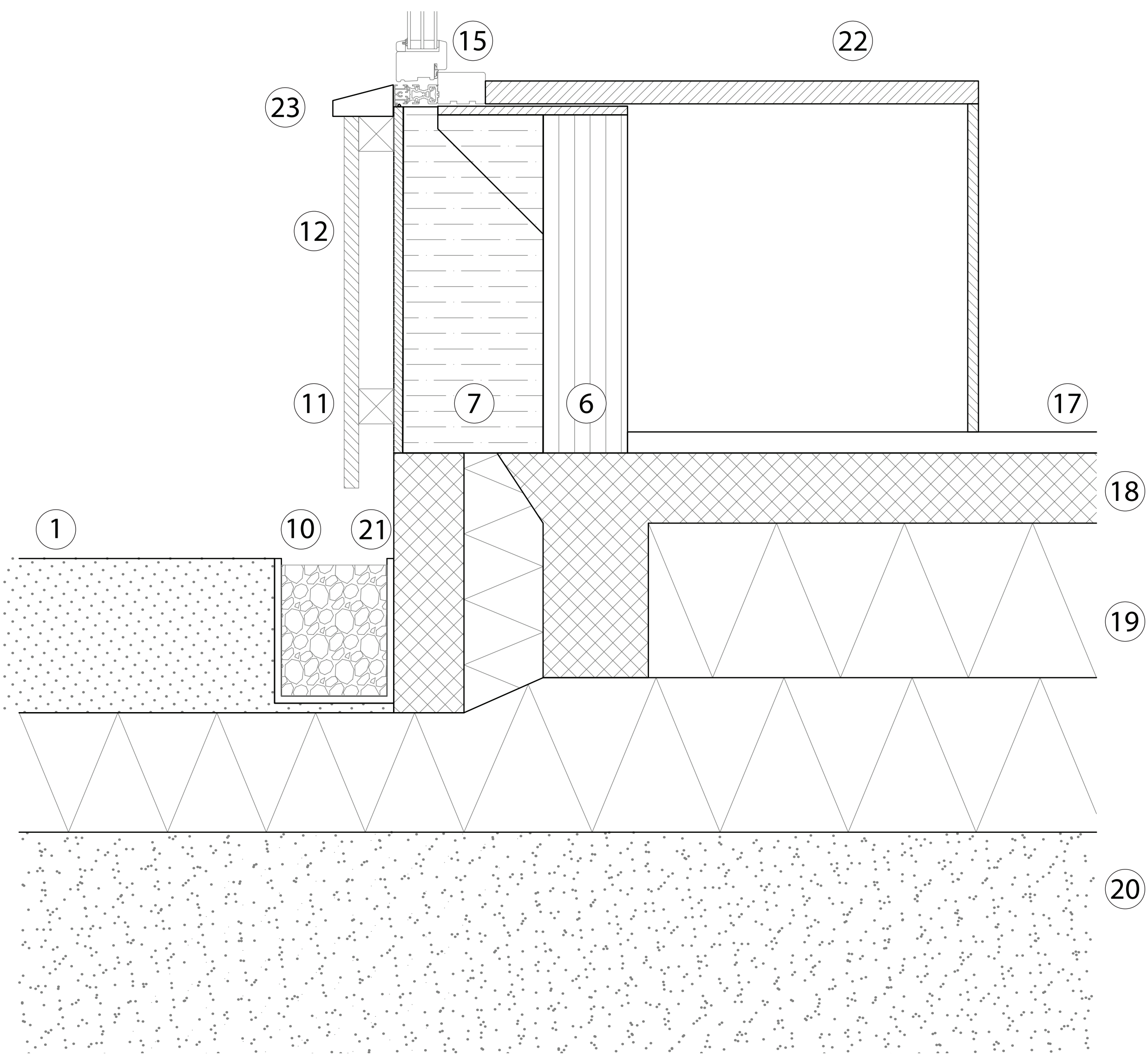


Illustration 135 Detail 1:10 vertical section - thermal envelope: foundation and integrated seating

1 Soil 300mm
6 CLT 120mm
7 Hard insulation 200mm
8 OSB 12mm
9 Zink panel
10 Fascine
11 Spacer
12 Facade Cladding
15 Window
17 Wearing layer 30 mm
18 Concrete foundation100mm
19 2 x High pressure polystyrine 220mm
20 Sand base
21 Concrete footing 100mm
22 Plinth
23 Wooden profile

DAYLIGHT

To ensure that the rooms in the school would get the sufficient and necessary amount of natural daylight, a daylight factor analysis was done for the new continuation school. The aim for the daylight factor should be 2% at the work places according to the Danish Working Environment Authority and at least 300 lux of daylight in 50% of the entire room according to the Building Requirements of 2018. (Christoffersen, Byggeforskningsinstitut 2008)

Overall the building has a high daylight factor in the most occupied rooms and in any working environment. The large glazed facades at the common spaces, canteen and classrooms helps to facilitate this. As the Hallways are intended for studying as well there has been a focus on ensuring that the daylight factor would be high in these spaces. The small common rooms adjacent to the living units are on purpose kept with a lower daylight factor in order to create more intimate spaces.

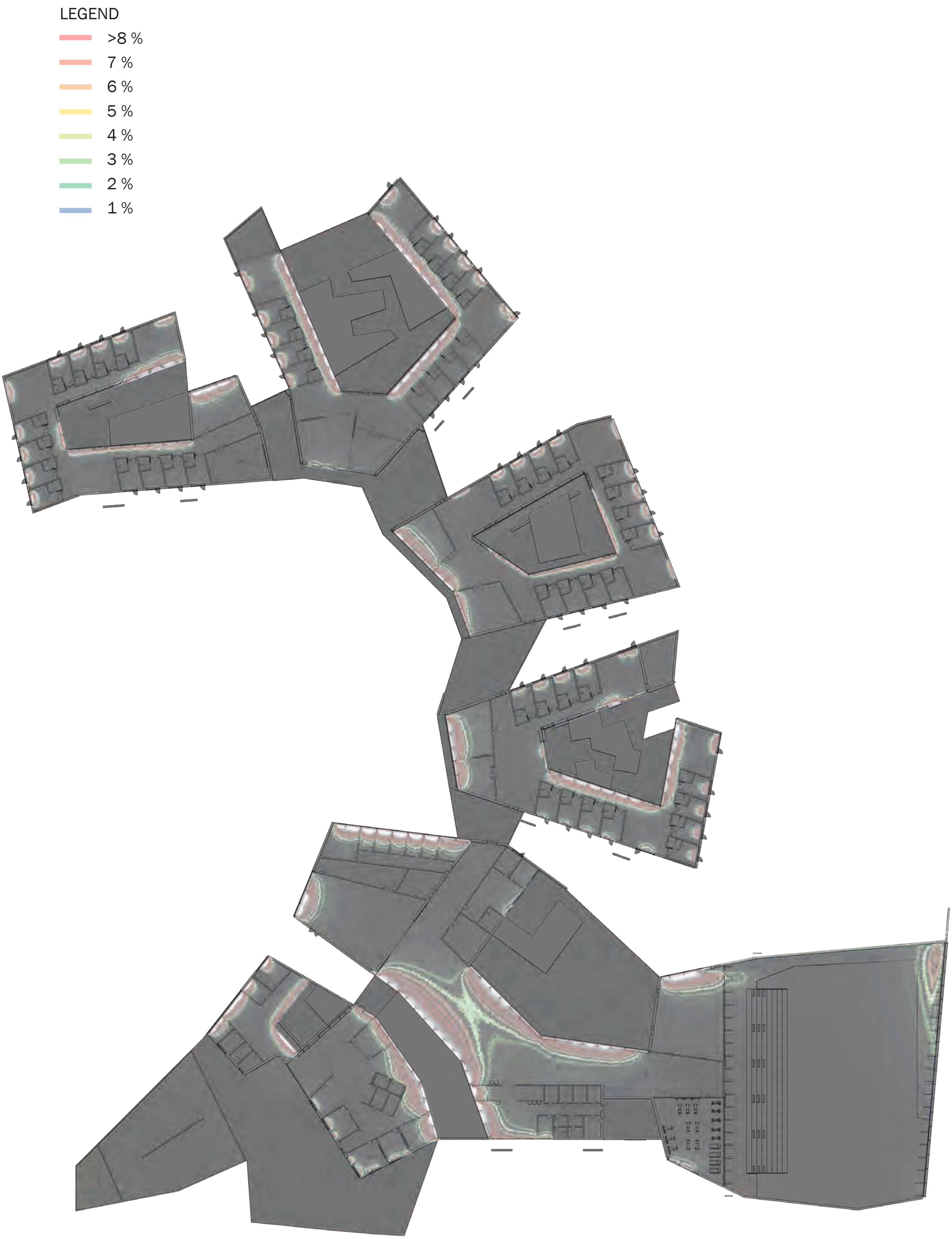


Illustration 136 Daylight factor results

FIRE

Due to the different use of the building, the different parts of the school will have different classes according to usage and according to risk. The clusters containing the living units, classrooms, and common spaces, are a category 4 in usage and risk class 1 according to the Danish Building Regulation. These categories correspond to if the section of the building has sleeping accommodations, if the persons know the placement of the escape routes and can help themselves to safety. §85 BR18 (Trafik- Bygge- og Boligstyrelsen 2018)

The larger rooms which has a higher number of persons in the room, will have a different risk class. The risk classes also corresponds to the number of floors which the building has. The sports hall and large common room, canteen etc. is a risk class 2. This is due to the rooms either only being one floor above ground level and one floor under ground level as well as the number of person must not exceed 1.000 persons. §86 BR18 (Trafik- Bygge- og Boligstyrelsen 2018)

The building needs to be designed to provide safe and easy evacuation in the case of fire. The design needs to be according to early detection of the fire, warning for the persons in the building, peoples ability to brind themselves to safety by themselves and notification to the rescue service. §92 BR18 (Trafik- Bygge- og Boligstyrelsen 2018)

When evacuating the building, the escape openings needs to lead to the outdoor. The escape routes needs to be dimensioned to the number of people which in the case of fire has to use the escape route. The escape openings has to be easy to open, and has to be able to be opened without the use of keys or other tools. The doors in the escape routes has to open outward if the room accommodates more than 150 people. §94 BR18 (Trafik- Bygge- og Boligstyrelsen 2018)

The warning systems differs according to usage class of the rooms. For the clusters of living units, smoke detectors are a requirement, whereas in the rooms which has a usage class of 3 the warning has to be spoken in the form of voice alert facilities. §93 BR18 (Trafik- Bygge- og Boligstyrelsen 2018)

Illustration 137 Evacuation plan out of scale

RESULTS

With the dynamic simulation tool of Bsim the indoor climate of the living units have been investigated for four different orientation corresponding to the final design – North, south, east and west. In the model each type of living unit is set up equally with regards to the chosen systems and loads. In general the living units are used during the night, but with a lower met.. In the morning and the evening the person load is higher as all students are expected to be present at these points of the day getting ready for bed or a new day. In between these hours the person load is lowered to accommodate expected time spend studying or attending classes, but with some activity in each room.

The ventilation is set up with the inventilate system running as primary for maintaining a desired CO2 level, with the venting set at a higher CO2 level for this to work as a cooling active during the summer. This results in somewhat high air changes during hot summer days, however when looking into the details this is only for shorter periods as can also be seen on the generally low average air-change. It is worth pointing to the fact that the high air change might be considered to be experienced as a draft, but on a warm day this will benefit the experience air quality as the draft will have a cooling effect on the skin despite a high air temperature.

In general the living units perform well according to the desired levels of CO2 and temperature with very few hours of excess temperature. These results can be ratified by especially two implications: First of all the lower person load during the mid-day helps avoid excess temperatures at these points. The western faced living units have the highest hours of excess temperature and the highest average

Bsim results Living unit	BR15 cat. B	North faced	South faced	East faced	West faced
Temperature(°C) avg.	20-24 winter	21,60	21,76	21,75	21,77
Temperature(°C) max.	23-26 summer	24,48	28,50	27,66	28,46
AirChange(-h) avg.	-	1,42	1,89	1,87	1,89
AirChange(-h) max.	-	6,60	6,60	6,60	6,60
Ventilation avg. (m^3/s)	-	0,0189	0,0199	0,0194	0,0198
Ventilation max. (m^3/s)	-	0,0450	0,0450	0,0450	0,0450
Venting avg. (m^3/s)	-	0,0054	0,0128	0,0194	0,0128
Venting max (m^3/s)	-	0,0692	0,0692	0,0692	0,0692
Co2(ppm) avg.	1010 ppm	668,2	642,2	649,0	650,0
Co2(ppm) max.	-	858,7	858,6	858,2	858,3
Hours > 21 (°C)	-	7625	8286	8497	8525
Hours > 27 (°C)	100 hours	0	16	6	18
Hours > 28 (°C)	25 hours	0	1	0	2
Hours < 19 (°C)	-	0	0	0	0

Illustration 138 Bsim results

temperature as the higher activity late in the day is added to a direct heat load from the afternoon sun. The southern faced living rooms are furthermore fitted with an overhang that shades for the hot summer sun. AS the north faced living units does not gain nearly the same amount of energy from the sun these feature a much lower maximum temperature, but on the other hand have a higher average Co2 level. This is due to the fact that with less need for cooling the airchange will naturally be lower implicating less extracted polluted air. However, the north faced living units are still within a desired level and features a maximum close to the other units.

The building complex comes down with an annual energy consumption of 19,5 KWh/m2 per year that is within the building class 2020 of 20 KWh/m2 per year. The result is based upon an assumption regarding the U-value of the green roof from the different research articles. The calculation does not take the effect of the heat pump into account as the desire was to reach the 2020 class without any active strategies. The use of low SEL ventilation from the Inventilate has also been a deciding factor as well as the use of low lambda value insulation. The standadised values for person-load and appliances have been used according to the building type set as institution. As with the case of the Bsim model some excess temperatures do occur during the summer, however it is within the limitations. Furthermore steps can be taken to limit the negative effect of this by ensuring access to natural ventilation providing the mentioned cooling effect by the wind.

Heated area	9273 m^2
Transmission loss	2,5 W/m^2
Total energy frame	19,5 KWh/m^2 per year
Heating	17,9 KWh/m^2 per year
Room heating	13,0 KWh/m^2 per year
Domestic hot water	3,5 KWh/m^2 per year
Electricity	2,8 KWh/m^2 per year
Excess temperature	3,7 KWh/m^2 per year

Illustration 139 Be18 results

MODELLING

Coming from a semester that featured experiences in an actual architectural office through an academic internship many experiences and competencies was broguht to the project. A substantial part of this was the handling of a professional competition entry and the use of BIM (Building Information Modelling) as a design tool. With the technology at hand today the possibility of designing a project using only computers are indeed possible and intruiging. However, despite the many apparent benefits this approach might present there is a reel risk of loosing control and perspective on the project. Working digital is working out of scale and therefore it was from the beginning chosen that the use of digital tools should not be implemented before it was absolutely neccesary. This meant much time spend with drawing plans and sections by hand and working with foam models of both building and topography. With this method preleminray studies are still possible as mere conceptual.

The line to cross from the analogue to the digital will have a major effect on the project with the mentioned risk of loosing touch with the architecture. However, changing to digital drawing too late can cause a lack of precision and thoroughly preparation for the synthesis. In general, the rule of digital modelling is in rough terms garbage in equals garbage out. Therefore preparations for the model are equally important leading back the need for a thorough analogue phase and a strong concept not the least. From the architectural offices several competencies in handling the digital models have been implemented such as setting up drawings to be directly printed from the digital model instead of the extensive work in graphic tools to shine up plans and sections. The use of digital BIM tools also helps keep an eye on rooms sizes and numbers etc. that are important in the case of keeping within a competition brief or budget.

Illustration 140 Analogue modelling

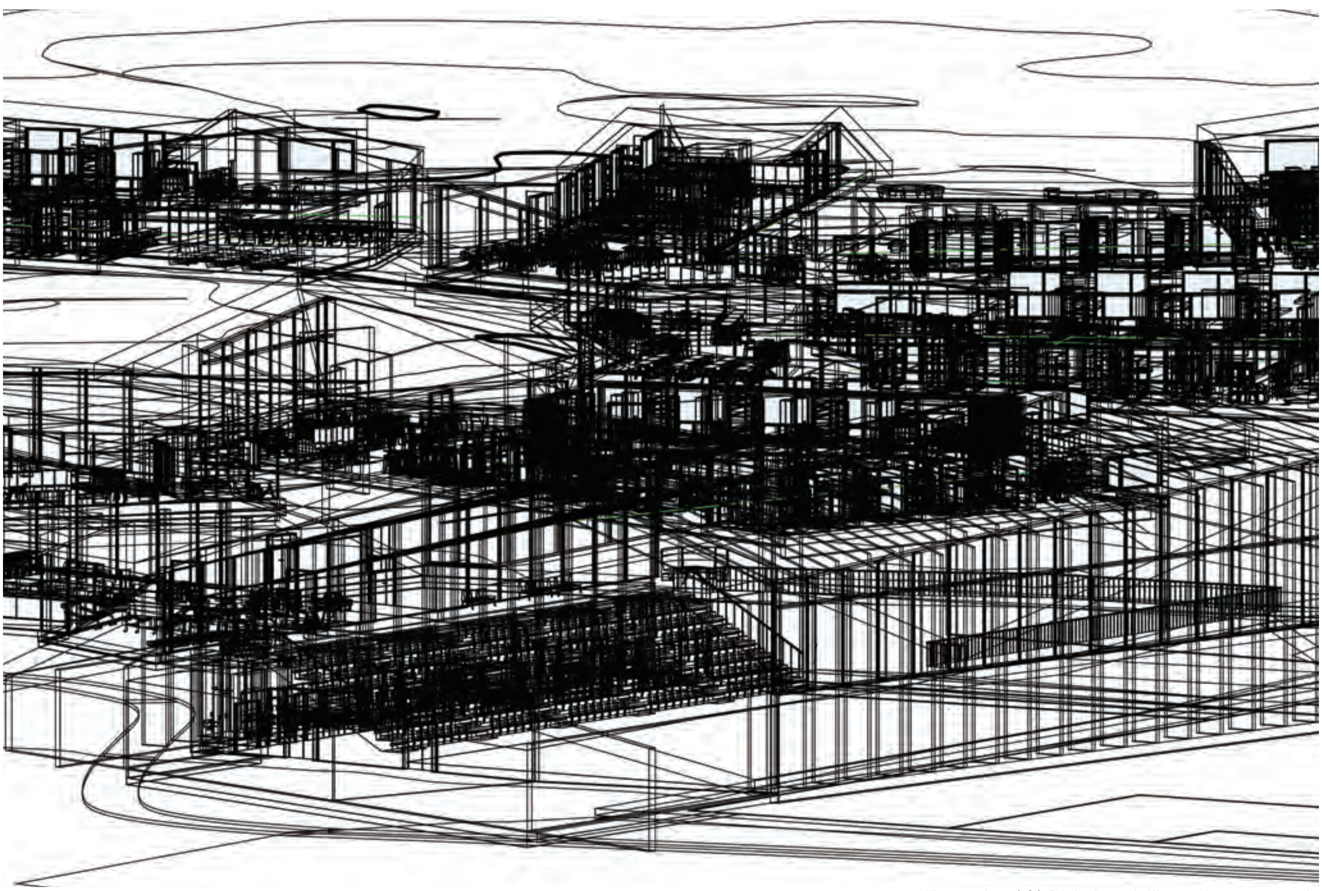


Illustration 141 Digital modelling at its most caotic

EPILOGUE

CONCLUSION

Under the Moor is a continuation school project that rests in the intriguing and dynamic landscape of the West coast of Northern Jutland. With wooden cladding that ages with time and a intensive green roof consisting of naturally inherent plants the complex becomes a part of the scenery with nature being an active part of it. Through a design process with a base in healing architecture the school offers large openings towards nature in every possible room and function, which have a calming and positive effect on the well-being of the pupils as well as the high amount of daylight will add to its qualities as a learning environment.

With an overweight of natural materials both on the inside and outside and a general limited palette of materials the complex have a pleasant and easy comprehendible materiality. The soft touch of wood is found inside on the exposed CLT walls and outside on the cladding used both on the façade and terraces keeping a low fluctuation in surface temperature. With the grain of wood perceivable not only by sight, but also touch the tactility of these surfaces are engaging. The concrete will due to the floor heating have a pleasing feel in the winter due to the warmth and a cooling effect in the summer.

Designed to fulfil the building class 2020 the school has a low energy profile that is further improved by the installation of a heating pump under the soil on the roof. With a hybrid ventilation of the product Inventilate and natural ventilation as the key strategy a good indoor environment is ensured with very few hours of excess temperatures. The use of wood cladding on the ceiling adds to the acoustic properties as well as the crooked angles that are inherent in the design.

Illustration 142 The path at the end

REFLECTION

The focus on designing a building with the complexity and size in a landscape must to be handled with care. Incorporating the research of healing architecture, green roofs and at the same time designing a functional school that functions 24/7 a day have resulted in different elements of the project being prioritised less.

The music hall has been deprioritized regarding the complexity of acoustics. The task of designing a functional music hall which can reflect, absorb and diffuse sound could be a small project in itself. The overall form of the music hall has been formed from the knowledge and experienced during the 6th semester at Aalborg University which focused on similar elements. The fact that the case of Ingstrup Continuation school also first and foremost is a sport school did affect the choice of focus. (Kristensen 2016)

During the design process, different iterations of walkways and recreational spaces placed on top of the roof of the building were made. The gesture of walking up on the building and using the green roofs as an additional outdoor space was chosen not to be a part of the final design. The reason for not bringing this to the final project was due to the desire that the pupils should go out into the landscape around the building to experience nature instead. As well as the desire to experience nature, the regulations concerning railing etc would result in the building being less aesthetic as well as this would interfere with the green roofs which played a large part of the project.

The placement close to the western coast of Denmark, where the weather can be very rough, a simulation which could depict how the wind would have wroked around the building site, would have been preferred. The tools of which could create this simulation would just not be accurate enough to give an acceptable result which would be fitting during the design process. To get a result from the simulation programs that would be sufficient, the program must be able to simulate on vegetation as large trees are close to the building. Apart from vegetation, the size of the model that would have to be simulated in the program to obtain a sufficient result, would need a computer with a lot more processing power, than possible

Renewable energy sources which could have been implemented into the design could be either photovoltaic cells or solar heating panels. These technologies were ruled out as they would not fulfil the design parameters set up for this project focusing on blending in with the landscape. These technologies would also result in the heat pump not functioning properly as it would be shaded by the panels.

The whole approach to sustainability was the hardest choice during the project. As sustainability is a very wide spread definition many approaches could have been taken towards this theme. For instance different calculative methods such as a DGNB matric or an LCA calculation could have been implemented. However these are widely time consuming efforts that in the end can have little impact on the final design. Furthermore, the DGNB score does not take any landscaping elements into account. AS economy and professional design process on the other hand plays a significant role this would require much knowledge about these matters than what is part of the curriculums at Architecture and Design.

Should the project be further developed more detailing of especially the classrooms would be an interesting path to follow. From the research found during the project there was little information regarding specific layout and arrangement of classrooms for pupils of this age.

The concept of the heat pump in soil on the roof is as described a hypothesis that at first glance seems possible, but this system could be interesting to follow and test perhaps on a smaller scale as the combination of an intensive roof with a high biodiversity producing energy is a very intriguing solution towards a more sustainable building sector.

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LIST OF ILLUSTRATIONS

APPENDIX

APPENDIX 1 DETAILED RESULTS OF BARRET ET. AL.

Insights from main study results, by design parameter.

Design parameters (factors)	Propositions from the literature	Findings from this study
Naturalness		
*Light (Daylight)	Natural light significantly influences the reading vocabulary and science scores. Large windows were found to be associated with better learning results over a one year period [10,38].	Different
*Light (E light)	Poor quality of electrical lighting causes headaches and impairs visual performance [39]. Full-spectrum fluorescent lamps with ultraviolet supplements had better attendance, achievement, and growth than did students under other lights [40].	Consistent and goes further
Sound (Good acoustics)	Significant effects of reverberation time (RT) on speech perception and short-term memory of spoken items were found [41].	Weak support
Sound (Noise)	External and internal noise were found to have a significant negative impact upon performance [42–44]	Weak support
*Temperature (sun heat)	The performance of two numerical and two language-based tests was significantly improved when the temperature was reduced from 25 °C to 20 °C [19].	Consistent
*Temperature (control)	Occupants with more opportunities to adapt themselves to the thermal environment will be less likely to suffer discomfort [45].	Consistent
*Air quality (CO_2 level)	The mental attention of pupils are significantly slower when the level of CO_2 in classrooms is high [46] and when the air exchange rate is low [19,47]	Consistent
Links to nature (Window view)	Patients assigned to rooms with windows looking out on a natural scene had shorter postoperative hospital stays than those similar rooms with windows facing a brick building wall [7].	Weak support
Links to nature (Access to nature)	Mental Attention increases when children are surrounded by more natural, greener environments [48]	Weak support
Individualisation		
*Ownership (Distinct design feature)	An attractive physical environment in school is associated with fewer behaviour problems, whereas a negative physical environment is not [49].	Consistent
*Ownership (Nature of the display)	Permanent student artwork enhanced the student's sense of ownership over the learning process [50]. There was a significant positive effect on children's self-esteem [51].	Consistent
*Ownership (Furniture)	Specialized facilities are essential to student wellbeing and achievement [52–54].	Different
*Flexibility (Room layout)	Significantly more exploratory behaviour, social interaction and cooperation occurred in spatially well-defined behaviour settings [55,56].	Consistent
*Flexibility (Size)	Girls' academic achievement was negatively affected by less space per student; boys' classroom behaviour was negatively affected by spatial density conditions [57].	Different
Connection (Pathway)	Movement and circulation have a significant effect on reading comprehension [10].	Weak support
Level of stimulation		
*Complexity (Room diversity and display diversity)	Learning scores were higher in the sparse-classrooms than in decorated-classrooms [27]. However; Read et al. [58] found that the space with differentiated ceiling height and wall colour may be too stimulating for children. Children in Low Visual Distraction conditions spent less time off-task and obtained higher learning scores than children in the High Visual Distraction condition [59].	Different/Consistent
*Colour (Wall and Classroom colour)	Off-task behaviours clearly dropped when the colours of the classroom walls were changed from off-white to saturated colours [58,60] Children prefer the colour red in the interior environment. Cool colours were favoured over warm colours for children from 3 to 5 years old [61]	Consistent

Light has the highest impact on Overall Progress among other design parameters. However, window size alone was not significantly correlated with the learning progress. Only when the orientation and risk of glare was taken into consideration, could the pupils benefit from the optimum glazing size.
Not only the quality but also the quantity of electrical lighting has a significant positive correlation with the pupils' learning progress
RT was not measured in this study. However, there is some evidence to support the relationship between the RT and some design strategies, e.g. room shape and carpet area. In the bivariate correlation analysis these factors were found to be significantly correlated with the learning rate, however, these aspects did not feature in the MLM results.
Noise level was not tested in this study. However, the factors that affect the noise level, e.g. distance from the main traffic and busy areas adjacent to the room being studied, displayed a bivariate correlation with the learning rate. However, these aspects did not feature in the MLM results.
Factors affecting the temperature were correlated with the learning progress. Un-wanted sun heat was a problem where external shading was absent.
Pupils perform better in the room that where the temperature was easy to control.
Factors affect the CO_2 are correlated with the learning progress. E.g. pupils perform better in the room that has mechanical ventilation, large volume or large window openings.
The quality of view out of the window shows a bivariate correlation with learning progress where window sills are below children's' eye-level. That said this aspect did not feature in the MLM results.
Classrooms with wooden furniture displays a bivariate correlation with the pupils' learning progress as are those with dedicated outdoor play areas. That said this aspect did not feature in the MLM results.

Architectural design elements that make the room unique and child-centred are significantly correlated with the learning progress
Personal displays by the children create a 'sense of ownership' and this was significantly correlated with learning progress
Furniture and features in the class that were ergonomic and comfortable for the children were significantly correlated with learning progress significantly
Flexibility measures investigated in this study were breakout spaces and rooms, storage solutions, number of different learning zones and potential display area. More learning zones for younger children and fewer for older children correlated with learning progress. Breakout zones within the room were correlated with learning progress.
Larger rooms with simpler shapes (squarer) enabled older children to better function in whole class learning. However, complex room shapes for younger children facilitated learning zones and enabled flexibility.
Wider and more orienting corridors showed a bivariate with better learning progress. However, these aspects did not feature in the MLM results.

This research found that it is the overall room and display diversity measure that correlates with learning progress.
The overall room and display diversity from under-stimulation to overstimulation was curvilinear which indicated that only when the room has an intermediate level of stimulation does it have a positive effect on pupils' learning progress.
Rooms with a balance of light colour or white walls with highlighting of a feature wall or organized bright display colours had the best correlation with learning progress. A brightness colour scale was used to distinguish colour elements. Added colour elements in the room with bright coloured furniture, carpets and other elements were also correlated with learning progress.

APPENDIX 2 CALCULATIONS FOR VENTILATION NEEDS

Living Unit

Co2 calculation of ventilation need						
Timer	8,00	76,00	CO2 total load	MikroVent type	1 x MV 6	
Pers	4,00	19,00	CO2 load per person			
q		0,08	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	76,00	m3/h	
V		48,00	Roomvolume	21,11	l/s	0,02 m3/s
N		4,00	No. Pers.	1,32	L/s pr. m2	1,32 l/s m2
n		1,58	Airchange h-1	16,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	1,58	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Superintendant flat

Co2 calculation of ventilation need						
Timer	400,00	95,00	CO2 total load	MikroVent type	1 x MV 6	
Pers	5,00	19,00	CO2 load per person			
q		0,10	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	95,00	m3/h	
V		495,00	Roomvolume	26,39	l/s	0,03 m3/s
N		5,00	No. Pers.	0,16	L/s pr. m2	0,16 l/s m2
n		0,19	Airchange h-1	165,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	0,19	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Overnight Watch Flat

Co2 calculation of ventilation need						
Timer	8,00	19,00	CO2 total load	MikroVent type	1 x MV 2	
Pers	1,00	19,00	CO2 load per person			
q		0,02	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	19,00	m3/h	
V		279,00	Roomvolume	5,28	l/s	0,01 m3/s
N		1,00	No. Pers.	0,06	L/s pr. m2	0,06 l/s m2
n		0,07	Airchange h-1	93,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	0,07	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Classroom

Co2 calculation of ventilation need						
Timer	6,00	494,00	CO2 total load	MikroVent type	4 x MV 8	
Pers	26,00	19,00	CO2 load per person			
q		0,49	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	494,00	m3/h	
V		274,00	Roomvolume	137,22	l/s	0,14 m3/s
N		26,00	No. Pers.	2,11	L/s pr. m2	2,11 l/s m2
n		1,80	Airchange h-1	65,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	1,80	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Physics Classroom

Co2 calculation of ventilation need						
Timer	4,00	494,00	CO2 total load	MikroVent type	VAV	
Pers	26,00	19,00	CO2 load per person			
q		0,49	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	494,00	m3/h	
V		150,00	Roomvolume	137,22	l/s	0,14 m3/s
N		26,00	No. Pers.	2,74	L/s pr. m2	2,74 l/s m2
n		3,29	Airchange h-1	50,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	3,29	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Music Hall

Co2 calculation of ventilation need						
Timer	2,00	3040,00	CO2 total load	MikroVent type	VAV	
Pers	160,00	19,00	CO2 load per person			
q		3,04	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	3040,00	m3/h	
V		1035,00	Roomvolume	844,44	l/s	0,84 m3/s
N		160,00	No. Pers.	3,67	L/s pr. m2	3,67 l/s m2
n		2,94	Airchange h-1	230,00	Rum m2	0,00 m3/s m2

			850,00		Luftskifte h-1	2,94		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Music Studio	Co2 calculation of ventilation need							
	Timer	4,00	76,00	CO2 total load	MikroVent type	1 x MV 6		
	Pers	4,00	19,00	CO2 load per person				
	q		0,08	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	76,00	m3/h		
	V		33,00	Roomvolume	21,11	l/s	0,02	m3/s
	N		4,00	No. Pers.	1,92	L/s pr. m2	1,92	l/s m2
	n		2,30	Airchange h-1	11,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	2,30		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Teachers Room	Co2 calculation of ventilation need							
	Timer	4,00	285,00	CO2 total load	MikroVent type	2 x MV 8		
	Pers	15,00	19,00	CO2 load per person				
	q		0,29	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	285,00	m3/h		
	V		105,00	Roomvolume	79,17	l/s	0,08	m3/s
	N		15,00	No. Pers.	1,76	L/s pr. m2	1,76	l/s m2
	n		2,71	Airchange h-1	45,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	2,71		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Teachers Lounge	Co2 calculation of ventilation need							
	Timer	4,00	285,00	CO2 total load	MikroVent type	2 x MV 8		
	Pers	15,00	19,00	CO2 load per person				
	q		0,29	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	285,00	m3/h		
	V		105,00	Roomvolume	79,17	l/s	0,08	m3/s
	N		15,00	No. Pers.	1,76	L/s pr. m2	1,76	l/s m2
	n		2,71	Airchange h-1	45,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	2,71		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Supervision Room	Co2 calculation of ventilation need							
	Timer	1,00	57,00	CO2 total load	MikroVent type	1 x MV 4		
	Pers	3,00	19,00	CO2 load per person				
	q		0,06	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	57,00	m3/h		
	V		45,00	Roomvolume	15,83	l/s	0,02	m3/s
	N		3,00	No. Pers.	1,06	L/s pr. m2	1,06	l/s m2
	n		1,27	Airchange h-1	15,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	1,27		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Secretary Office	Co2 calculation of ventilation need							
	Timer	8,00	38,00	CO2 total load	MikroVent type	1 x MV 4		
	Pers	2,00	19,00	CO2 load per person				
	q		0,04	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	38,00	m3/h		
	V		60,00	Roomvolume	10,56	l/s	0,01	m3/s
	N		2,00	No. Pers.	0,53	L/s pr. m2	0,53	l/s m2
	n		0,63	Airchange h-1	20,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	0,63		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Superintendant Office	Co2 calculation of ventilation need							
	Timer	8,00	38,00	CO2 total load	MikroVent type	1 x MV 4		
	Pers	2,00	19,00	CO2 load per person				
	q		0,04	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		

	ci		350,00	Concentration of fresh air	38,00	m3/h	
	V		60,00	Roomvolume	10,56	l/s	0,01 m3/s
	N		2,00	No. Pers.	0,53	L/s pr. m2	0,53 l/s m2
	n		0,63	Airchange h-1	20,00	Rum m2	0,00 m3/s m2
			850,00		Luftskifte h-1	0,63	
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Meeting Room	Co2 calculation of ventilation need						
	Timer	1,00	285,00	CO2 total load	MikroVent type	2 x MV 8	
	Pers	15,00	19,00	CO2 load per person			
	q		0,29	CO2 total load m3/h	n= Vl/Vr		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
	ci		350,00	Concentration of fresh air	285,00	m3/h	
	V		120,00	Roomvolume	79,17	l/s	0,08 m3/s
	N		15,00	No. Pers.	1,98	L/s pr. m2	1,98 l/s m2
	n		2,38	Airchange h-1	40,00	Rum m2	0,00 m3/s m2
			850,00		Luftskifte h-1	2,38	
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Main Commonroom	Co2 calculation of ventilation need						
	Timer	8,00	1425,00	CO2 total load	MikroVent type	10 x MV 8	
	Pers	75,00	19,00	CO2 load per person			
	q		1,43	CO2 total load m3/h	n= Vl/Vr		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
	ci		350,00	Concentration of fresh air	1425,00	m3/h	
	V		1107,00	Roomvolume	395,83	l/s	0,40 m3/s
	N		75,00	No. Pers.	1,61	L/s pr. m2	1,61 l/s m2
	n		1,29	Airchange h-1	246,00	Rum m2	0,00 m3/s m2
			850,00		Luftskifte h-1	1,29	
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Common Space	Co2 calculation of ventilation need						
	Timer	8,00	304,00	CO2 total load	MikroVent type		
	Pers	16,00	19,00	CO2 load per person			
	q		0,30	CO2 total load m3/h	n= Vl/Vr		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
	ci		350,00	Concentration of fresh air	304,00	m3/h	
	V		210,00	Roomvolume	84,44	l/s	0,08 m3/s
	N		16,00	No. Pers.	1,21	L/s pr. m2	1,21 l/s m2
	n		1,45	Airchange h-1	70,00	Rum m2	0,00 m3/s m2
			850,00		Luftskifte h-1	1,45	
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Service	Co2 calculation of ventilation need						
	Timer	8,00	76,00	CO2 total load	MikroVent type		
	Pers	4,00	19,00	CO2 load per person			
	q		0,08	CO2 total load m3/h	n= Vl/Vr		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
	ci		350,00	Concentration of fresh air	76,00	m3/h	
	V		75,00	Roomvolume	21,11	l/s	0,02 m3/s
	N		4,00	No. Pers.	0,42	L/s pr. m2	0,42 l/s m2
	n		1,01	Airchange h-1	50,00	Rum m2	0,00 m3/s m2
			850,00		Luftskifte h-1	1,01	
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Kitchen	Co2 calculation of ventilation need						
	Timer	8,00	76,00	CO2 total load	MikroVent type		
	Pers	4,00	19,00	CO2 load per person			
	q		0,08	CO2 total load m3/h	n= Vl/Vr		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
	ci		350,00	Concentration of fresh air	76,00	m3/h	
	V		75,00	Roomvolume	21,11	l/s	0,02 m3/s
	N		4,00	No. Pers.	0,42	L/s pr. m2	0,42 l/s m2
	n		1,01	Airchange h-1	50,00	Rum m2	0,00 m3/s m2
			850,00		Luftskifte h-1	1,01	
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Scullery	Co2 calculation of ventilation need		

Timer	8,00	76,00	CO2 total load	MikroVent type		
Pers	4,00	19,00	CO2 load per person			
q		0,08	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	76,00	m3/h	
V		75,00	Roomvolume	21,11	l/s	0,02 m3/s
N		4,00	No. Pers.	0,42	L/s pr. m2	0,42 l/s m2
n		1,01	Airchange h-1	50,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	1,01	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Office

Co2 calculation of ventilation need						
Timer	3,00	57,00	CO2 total load			
Pers	3,00	19,00	CO2 load per person			
q		0,06	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	57,00	m3/h	
V		24,00	Roomvolume	15,83	l/s	0,02 m3/s
N		3,00	No. Pers.	1,98	L/s pr. m2	1,98 l/s m2
n		2,38	Airchange h-1	8,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	2,38	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Pre Room

Co2 calculation of ventilation need						
Timer	8,00	76,00	CO2 total load			
Pers	4,00	19,00	CO2 load per person			
q		0,08	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	76,00	m3/h	
V		75,00	Roomvolume	21,11	l/s	0,02 m3/s
N		4,00	No. Pers.	0,42	L/s pr. m2	0,42 l/s m2
n		1,01	Airchange h-1	50,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	1,01	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Locker Room

Co2 calculation of ventilation need						
Timer	1,00	285,00	CO2 total load			
Pers	15,00	19,00	CO2 load per person			
q		0,29	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	285,00	m3/h	
V		90,00	Roomvolume	79,17	l/s	0,08 m3/s
N		15,00	No. Pers.	2,64	L/s pr. m2	2,64 l/s m2
n		3,17	Airchange h-1	30,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	3,17	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Bathroom

Co2 calculation of ventilation need						
Timer	8,00	76,00	CO2 total load			
Pers	4,00	19,00	CO2 load per person			
q		0,08	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	76,00	m3/h	
V		75,00	Roomvolume	21,11	l/s	0,02 m3/s
N		4,00	No. Pers.	0,42	L/s pr. m2	0,42 l/s m2
n		1,01	Airchange h-1	50,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	1,01	
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h			

Sportshall

Co2 calculation of ventilation need						
Timer	2,00	6650,00	CO2 total load			
Pers	350,00	19,00	CO2 load per person			
q		6,65	CO2 total load m3/h	n= Vl/Vr		
c		1000,00	Concentration in room	Vl=n*Vr	Air stream	
ci		350,00	Concentration of fresh air	6650,00	m3/h	
V		14290,00	Roomvolume	1847,22	l/s	1,85 m3/s
N		350,00	No. Pers.	1,29	L/s pr. m2	1,29 l/s m2
n		0,47	Airchange h-1	1429,00	Rum m2	0,00 m3/s m2
		850,00		Luftskifte h-1	0,47	

	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Ref Locker room	Co2 calculation of ventilation need							
	Timer	0,50	19,00	CO2 total load				
	Pers	1,00	19,00	CO2 load per person				
	q		0,02	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	19,00	m3/h		
	V		36,00	Roomvolume	5,28	l/s	0,01	m3/s
	N		1,00	No. Pers.	0,11	L/s pr. m2	0,11	l/s m2
	n		0,53	Airchange h-1	50,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	0,53		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Gym n' Dance Studio	Co2 calculation of ventilation need							
	Timer	4,00	7650,00	CO2 total load				
	Pers	60,00	127,50	CO2 load per person				
	q		7,65	CO2 total load m3/h	n= Vl/Vr	VAV		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	7650,00	m3/h		
	V		1000,00	Roomvolume	2125,00	l/s	2,13	m3/s
	N		60,00	No. Pers.	6,38	L/s pr. m2	6,38	l/s m2
	n		7,65	Airchange h-1	333,00	Rum m2	0,01	m3/s m2
			850,00		Luftskifte h-1	7,65		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Gym	Co2 calculation of ventilation need							
	Timer	6,00	2550,00	CO2 total load				
	Pers	20,00	127,50	CO2 load per person				
	q		2,55	CO2 total load m3/h	n= Vl/Vr			
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	2550,00	m3/h		
	V		600,00	Roomvolume	708,33	l/s	0,71	m3/s
	N		20,00	No. Pers.	14,17	L/s pr. m2	14,17	l/s m2
	n		4,25	Airchange h-1	50,00	Rum m2	0,01	m3/s m2
			850,00		Luftskifte h-1	4,25		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Canteen	Co2 calculation of ventilation need							
	Timer	3,00	3040,00	CO2 total load				
	Pers	160,00	19,00	CO2 load per person				
	q		3,04	CO2 total load m3/h	n= Vl/Vr	20 x MV 8		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	3040,00	m3/h		
	V		1530,00	Roomvolume	844,44	l/s	0,84	m3/s
	N		160,00	No. Pers.	2,48	L/s pr. m2	2,48	l/s m2
	n		1,99	Airchange h-1	340,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	1,99		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Teachers Area	Co2 calculation of ventilation need							
	Timer	1,00	285,00	CO2 total load				
	Pers	15,00	19,00	CO2 load per person				
	q		0,29	CO2 total load m3/h	n= Vl/Vr	2 x MV 8		
	c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
	ci		350,00	Concentration of fresh air	285,00	m3/h		
	V		507,50	Roomvolume	79,17	l/s	0,08	m3/s
	N		15,00	No. Pers.	0,55	L/s pr. m2	0,55	l/s m2
	n		0,56	Airchange h-1	145,00	Rum m2	0,00	m3/s m2
			850,00		Luftskifte h-1	0,56		
	BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Sportshall

Co2 calculation of ventilation need							
Timer	2,00	2550,00	CO2 total load				
Pers	20,00	127,50	CO2 load per person				
q		2,55	CO2 total load m3/h	n= Vl/Vr			
c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
ci		350,00	Concentration of fresh air	2550,00	m3/h		
V		14290,00	Roomvolume	708,33	l/s	0,71	m3/s
N		20,00	No. Pers.	0,50	L/s pr. m2	0,50	l/s m2
n		0,18	Airchange h-1	1429,00	Rum m2	0,00	m3/s m2
		850,00		Luftskifte h-1	0,18		
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Sportshall

Co2 calculation of ventilation need							
Timer	2,00	6650,00	CO2 total load				
Pers	350,00	19,00	CO2 load per person				
q		6,65	CO2 total load m3/h	n= Vl/Vr			
c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
ci		350,00	Concentration of fresh air	6650,00	m3/h		
V		14290,00	Roomvolume	1847,22	l/s	1,85	m3/s
N		350,00	No. Pers.	1,29	L/s pr. m2	1,29	l/s m2
n		0,47	Airchange h-1	1429,00	Rum m2	0,00	m3/s m2
		850,00		Luftskifte h-1	0,47		
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

Sportshall

Co2 calculation of ventilation need							
Timer	2,00	9200,00	CO2 total load				
Pers	370,00	19,00	CO2 load per person				
q		9,20	CO2 total load m3/h	n= Vl/Vr			
c		1000,00	Concentration in room	Vl=n*Vr	Air stream		
ci		350,00	Concentration of fresh air	9200,00	m3/h		
V		14290,00	Roomvolume	2555,56	l/s	2,56	m3/s
N		370,00	No. Pers.	1,79	L/s pr. m2	1,79	l/s m2
n		0,64	Airchange h-1	1429,00	Rum m2	0,00	m3/s m2
		850,00		Luftskifte h-1	0,64		
BR20 l/s pr m2	0,30	0,08	Min ventilation m3/h				

APPENDIX 3 DETAILED RESULTS OF BSIM - NORTHFACED

North													
ThermalZone7337	**Sum/Mean**	**1 (31 days)**	**2 (28 days)**	**3 (31 days)**	**4 (30 days)**	**5 (31 days)**	**6 (30 days)**	**7 (31 days)**	**8 (31 days)**	**9 (30 days)**	**10 (31 days)**	**11 (30 days)**	**12 (31 days)**
qHeating	673,44	136,62	113,81	116,56	0	0	0	0	0	0	59,58	108,89	137,97
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	0	0	0	0	0	0	0	0	0	0	0	0	0
qVenting	-143,29	0	0	0	-0,01	-22,75	-3,39	-23,65	-79,65	-13,84	-0,01	0	0
qSunRad	549,67	9,9	20,24	40,59	59,17	81,83	91,97	95,09	62,31	41,91	26,25	12,36	8,03
qPeople	1063,76	108,48	97,98	108,48	104,98	108,48	0	0	108,48	104,98	108,48	104,98	108,48
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1151,25	-152,38	-140,22	-163,68	-93,15	-74,16	-44,47	-29,12	-28,32	-46,74	-97,01	-129,76	-152,23
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-992,6	-102,48	-91,67	-101,73	-70,99	-93,81	-44,11	-42,31	-63,43	-86,58	-97,07	-96,3	-102,11
Sum	-0,28	0,13	0,14	0,22	0	-0,41	0	0	-0,6	-0,28	0,22	0,18	0,14
tOutdoor mean(°C)	8,1	0,7	0,4	-0,7	7,1	11,5	14,2	17,8	17,9	14,5	9,8	3,4	0,7
tOp mean(°C)	21,6	21,7	21,7	21,7	20,4	21,7	20,8	22	22,2	21,7	21,6	21,7	21,7
AirChange(/h)	1,4	1,1	1,1	1,1	1,1	1,6	1	1,9	3	1,5	1,1	1,1	1,1
Rel. Moisture(%)	69,8	82,2	84,9	86,3	78,7	53,7	53,6	59,2	60,2	60,1	62,8	75,1	81,1
Co2(ppm)	668,7	747,3	747	746,9	749,1	741,6	350,5	350	616,9	734,6	747,3	746,2	746,5
PAQ(-)	0	-0,2	-0,2	-0,2	0	0,2	0,3	0,1	0,1	0,1	0,1	-0,1	-0,2
Hours > 21	7625	744	669	733	85	728	281	741	744	707	739	715	739
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours > 28	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	0,37	0,03	0,03	0,03	0,03	0,03	0,02	0,03	0,03	0,03	0,03	0,03	0,03
HtRec	1781,12	270,75	247,67	297,2	162,51	100,33	39,83	10,72	16,7	43,05	112,74	213,21	266,4

APPENDIX 4 DETAILED RESULTS OF BSIM - SOUTHFACED

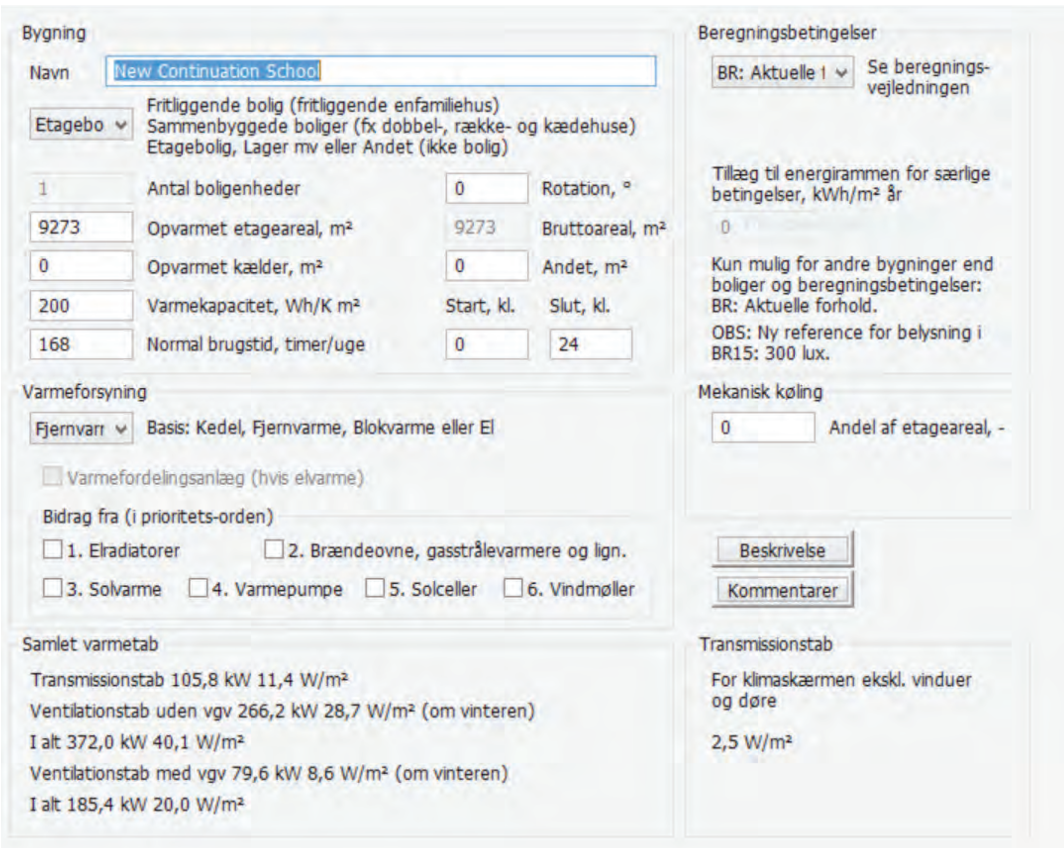
South													
ThermalZone7337	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	398,91	105,06	64,91	33,73	0	0	0	0	0	0	15,56	65,99	113,66
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	0	0	0	0	0	0	0	0	0	0	0	0	0
qVenting	-613,83	0	0	0	-71,69	-87,4	-22,75	-50,98	-169,58	-135,87	-75,57	0	0
qSunRad	1418,16	44,8	79,87	149,66	161,25	148,69	121,91	130,01	172,43	177,77	139,04	58,44	34,3
qPeople	1063,76	108,48	97,98	108,48	104,98	108,48	0	0	108,48	104,98	108,48	104,98	108,48
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1205,59	-154,78	-144,03	-169,85	-105,83	-76,15	-50,42	-31,81	-42,57	-53,4	-89,88	-132,22	-154,65
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1062,41	-103,42	-98,62	-121,91	-88,84	-93,99	-48,75	-47,22	-69	-94,11	-97,9	-97,04	-101,61
Sum	-1	0,14	0,11	0,1	-0,13	-0,37	0	0	-0,25	-0,63	-0,28	0,14	0,17
tOutdoor mean(°C)	8,1	0,7	0,4	-0,7	7,1	11,5	14,2	17,8	17,9	14,5	9,8	3,4	0,7
tOp mean(°C)	21,9	21,7	21,9	22,2	21,5	21,9	21,2	22,3	23	22,3	21,8	21,8	21,7
AirChange(/h)	1,9	1,1	1,2	1,3	1,6	2,2	1,5	2,6	4,2	2,9	1,7	1,1	1,1
Rel. Moisture(%)	65,6	81,5	81,8	76,5	59	52	52,5	58,1	57,2	55	58,3	74,5	81,4
Co2(ppm)	642,9	744,6	739,4	729,9	719,5	692,2	350,5	350	536,7	646,7	715,3	744	745,7
PAQ(-)	0	-0,2	-0,2	-0,1	0,2	0,3	0,3	0,1	0,1	0,2	0,2	-0,1	-0,2
Hours > 21	8286	738	667	737	633	744	373	744	744	720	735	715	736
Hours > 27	16	0	0	0	0	0	0	1	12	3	0	0	0
Hours > 28	1	0	0	0	0	0	0	0	1	0	0	0	0
Hours < 19	1	0	0	1	0	0	0	0	0	0	0	0	0
FanPow	0,39	0,03	0,03	0,04	0,03	0,03	0,02	0,03	0,04	0,03	0,03	0,03	0,03
HtRec	1835,54	274,61	260,78	330,36	163,77	96,73	39,22	10,72	13,78	45,98	117,9	214,76	266,93

APPENDIX 5 DETAILED RESULTS OF BSIM - EASTFACED

East													
ThermalZone7337	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	567,67	131,65	97,18	71,05	0	0	0	0	0	0	33,8	100,04	133,95
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	0	0	0	0	0	0	0	0	0	0	0	0	0
qVenting	-624,07	0	0	0	-68,56	-120,92	-49,74	-108,78	-177,33	-79,63	-19,11	0	0
qSunRad	1245,22	15,32	38,09	89,04	159,27	180,18	165,54	203,49	178,6	114,32	66,99	21,86	12,51
qPeople	1063,76	108,48	97,98	108,48	104,98	108,48	0	0	108,48	104,98	108,48	104,98	108,48
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1215,7	-153,14	-142,15	-166,85	-108,26	-75,89	-58,13	-38,93	-45,01	-49,6	-93,92	-130,9	-152,92
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1037,35	-102,17	-90,94	-101,51	-87,51	-92,44	-57,67	-55,78	-64,91	-90,63	-96,16	-95,78	-101,87
Sum	-0,48	0,14	0,16	0,21	-0,09	-0,58	0	0	-0,18	-0,55	0,07	0,19	0,15
tOutdoor mean(°C)	8,1	0,7	0,4	-0,7	7,1	11,5	14,2	17,8	17,9	14,5	9,8	3,4	0,7
tOp mean(°C)	21,9	21,7	21,7	21,7	21,6	22	21,7	22,7	22,9	22	21,6	21,7	21,7
AirChange(/h)	1,9	1,1	1,1	1,1	1,5	2,3	1,8	3,4	4,2	2,3	1,2	1,1	1,1
Rel. Moisture(%)	66,6	82,5	85,6	86,1	55,9	49,2	51,1	57,2	57,2	56,9	60,7	75,4	81,5
Co2(ppm)	649,4	747,3	747	745,8	729,4	680,9	350,5	350	530,9	676,7	741,3	746,2	746,5
PAQ(-)	0	-0,2	-0,2	-0,2	0,2	0,3	0,3	0,1	0,1	0,2	0,1	-0,1	-0,2
Hours > 21	8497	743	666	726	646	744	569	744	744	720	738	718	739
Hours > 27	6	0	0	0	0	0	0	6	0	0	0	0	0
Hours > 28	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	0,38	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03
HtRec	1773,35	270,74	247,62	297,87	158,76	98,35	36,74	10,73	12,58	46,4	114	213,21	266,35

APPENDIX 6 DETAILED RESULTS OF BSIM - WESTFACED

West													
ThermalZone7337	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	559,83	131,45	95,78	61,51	0	0	0	0	0	0	36,09	99,75	135,25
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	0	0	0	0	0	0	0	0	0	0	0	0	0
qVenting	-604,13	0	0	0	-53,52	-128,64	-67,49	-98,9	-163,5	-77,06	-15,03	0	0
qSunRad	1244,86	15,62	39,39	99,67	145,91	195,18	188,83	195,1	158,11	112,69	61,05	22,23	11,07
qPeople	1063,76	108,48	97,98	108,48	104,98	108,48	0	0	108,48	104,98	108,48	104,98	108,48
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1208,83	-153,28	-142,1	-167,54	-106,83	-76,19	-58,98	-40,08	-39,31	-45,95	-94,84	-131,04	-152,69
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1056,37	-102,13	-90,89	-101,9	-90,7	-99,52	-62,36	-56,1	-63,98	-95,49	-95,61	-95,73	-101,97
Sum	-0,89	0,14	0,16	0,21	-0,18	-0,69	0	0,01	-0,2	-0,83	0,15	0,19	0,15
tOutdoor mean(°C)	8,1	0,7	0,4	-0,7	7,1	11,5	14,2	17,8	17,9	14,5	9,8	3,4	0,7
tOp mean(°C)	21,9	21,7	21,7	21,7	21,6	22,1	21,9	22,7	22,9	22	21,6	21,6	21,7
AirChange(/h)	1,9	1,1	1,1	1,1	1,5	2,5	2,1	3,2	4	2,4	1,3	1,1	1,1
Rel. Moisture(%)	66,7	82,5	85,3	85,4	59,3	48,1	50,3	57,2	57,6	56,6	61,8	75,3	81,3
Co2(ppm)	650,5	747,3	746,8	744,2	729,4	682,6	350,3	350	539,7	685,5	737,4	746,2	746,5
PAQ(-)	0	-0,2	-0,2	-0,2	0,2	0,3	0,3	0,1	0,1	0,2	0,1	-0,1	-0,2
Hours > 21	8525	741	667	716	665	740	588	744	744	720	743	716	741
Hours > 27	18	0	0	0	0	0	0	9	9	0	0	0	0
Hours > 28	2	0	0	0	0	0	0	2	0	0	0	0	0
Hours < 19	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	0,38	0,03	0,03	0,03	0,03	0,04	0,03	0,03	0,03	0,04	0,03	0,03	0,03
HtRec	1788,38	270,73	247,71	299,38	165,11	102,78	36,74	10,73	12,44	50,41	112,78	213,21	266,36


Bygning
Navn
New Continuation School
Etagebo
Fritliggende bolig (fritliggende enfamiliehus)
Sammenbyggede boliger (fx dobbel-, række- og kædehuse)
Etagebolig, Lager mv eller Andet (ikke bolig)
1
Antal boligenheder
0
Rotation, °
9273
Opvarmet etageareal, m²
9273
Bruttoareal, m²
0
Opvarmet kælder, m²
0
Andet, m²
200
Varmekapacitet, Wh/K m²
Start, kl.
Slut, kl.
168
Normal brugstid, timer/uge
0
24
Beregningsbetingelser
BR: Aktuelle
Se beregnings-vejledningen
Tillæg til energirammen for særlige betingelser, kWh/m² år
0
Kun mulig for andre bygninger end boliger og beregningsbetingelser: BR: Aktuelle forhold.
OBS: Ny reference for belysning i BR15: 300 lux.
Varmeforsyning
Fjernvarr
Basis: Kedel, Fjernvarme, Blokvarme eller El
Varmefordelingsanlæg (hvis elvarme)
Bidrag fra (i prioritets-orden)
1. Elradiatorer
2. Brændeovne, gasstrålevarmere og lign.
3. Solvarme
4. Varmepumpe
5. Solceller
6. Vindmøller
Mekanisk køling
0
Andel af etageareal, -
Beskrivelse
Kommentarer
Samlet varmetab
Transmissionstab 105,8 kW 11,4 W/m²
Ventilationstab uden vgv 266,2 kW 28,7 W/m² (om vinteren)
I alt 372,0 kW 40,1 W/m²
Ventilationstab med vgv 79,6 kW 8,6 W/m² (om vinteren)
I alt 185,4 kW 20,0 W/m²
Transmissionstab
For klimaskærmen ekskl. vinduer og døre
2,5 W/m²

APPENDIX 8 BE18 MODEL KEY RESULTS

Nøgletal, kWh/m² år

Renoveringsklasse 2

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
110,3	0,0	110,3
Samlet energibehov		28,6

Renoveringsklasse 1

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
52,7	0,0	52,7
Samlet energibehov		28,6

Energiramme BR 2015 / 2018

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
30,1	0,0	30,1
Samlet energibehov		25,0

Energiramme Byggeri 2020

Uden tillæg	Tillæg for særlige betingelser	Samlet energiramme
20,0	0,0	20,0
Samlet energibehov		19,5

Bidrag til energibehovet

Varme	17,9
El til bygningsdrift	2,8
Overtemp. i rum	3,7

Netto behov

Rumopvarmning	13,0
Varmt brugsvand	3,5
Køling	0,0

Udvalgte elbehov

Belysning	0,0
Opvarmning af rum	0,0
Opvarmning af vbv	0,0
Varmepumpe	0,0
Ventilatorer	2,8
Pumper	0,0
Køling	0,0
Totalt elforbrug	24,8

Varmetab fra installationer

Rumopvarmning	1,4
Varmt brugsvand	3,5

Ydelse fra særlige kilder

Solvarme	0,0
Varmepumpe	0,0
Solceller	0,0
Vindmøller	0,0

	MWh	Januar	Februar	Marts	April	Maj	Juni
	Varmebehov						
+1	Trans.- og vent.tab	83,31	76,14	89,38	53,80	36,63	24,06
2	Vent. VF (total)	0,00	0,00	0,00	0,00	0,00	0,00
3	Vent. VGV nedreg.	0,00	0,00	0,00	0,00	0,00	0,00
4	Varmetab	83,31	76,14	89,38	53,80	36,63	24,06
5	Solindfald	5,80	12,08	25,68	34,83	43,51	43,32
6	Internt tilskud	41,60	37,57	41,60	40,26	41,60	40,26
7	Fra rør og VVB konst.	3,91	3,53	3,91	3,78	3,91	3,78
8	Samlet tilskud	51,30	53,19	71,18	78,87	89,01	87,36
9	Rel. tilskud, -	0,62	0,70	0,80	1,47	2,43	3,63
10	Del af rumopv.	1,00	1,00	0,87	0,00	0,00	0,00
11	Variabl. varmetilsk.	0,00	0,00	0,00	0,00	0,00	0,00
12	Tot. tilskud	51,30	53,19	71,18	78,87	89,01	87,36
13	Rel. tilskud, -	0,62	0,70	0,80	1,47	2,43	3,63
14	Udnyt. faktor	1,00	1,00	1,00	0,68	0,41	0,28
15	Varmebehov	32,01	22,96	15,93	0,00	0,00	0,00
16	Vent. VF (centralvarme)	0,00	0,00	0,00	0,00	0,00	0,00
17	I alt	32,01	22,96	15,93	0,00	0,00	0,00

Juni	Juli	August	September	Oktober	November	December	I alt
24,06	9,57	9,14	22,77	44,05	69,32	83,31	601,48
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
24,06	9,57	9,14	22,77	44,05	69,32	83,31	601,48
43,32	46,86	37,87	28,39	18,76	7,74	4,66	309,49
40,26	41,60	41,60	40,26	41,60	40,26	41,60	489,78
3,78	3,91	3,91	3,78	3,91	3,78	3,91	46,01
87,36	92,36	83,38	72,43	64,26	51,78	50,16	845,28
3,63	9,65	9,13	3,18	1,46	0,75	0,60	
0,00	0,00	0,00	0,00	0,00	0,92	1,00	
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
87,36	92,36	83,38	72,43	64,26	51,78	50,16	845,28
3,63	9,65	9,13	3,18	1,46	0,75	0,60	
0,28	0,10	0,11	0,31	0,69	1,00	1,00	
0,00	0,00	0,00	0,00	0,00	16,12	33,14	120,17
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	16,12	33,14	120,17

UNDER MOOR	1:200 Scale	01 NO.
BUILDING PLAN	MSc4 - 06	DRAWING FOLDER
MASTER THESIS	AALBORG UNIVERSITY	
ARCHITECTURE AND DESIGN		


UNDER MOOR
1:500
Scale
02
NO.
SITE PLAN
MSc4 - 06
DRAWING FOLDER
MASTER THESIS
AALBORG UNIVERSITY
ARCHITECTURE AND DESIGN
N

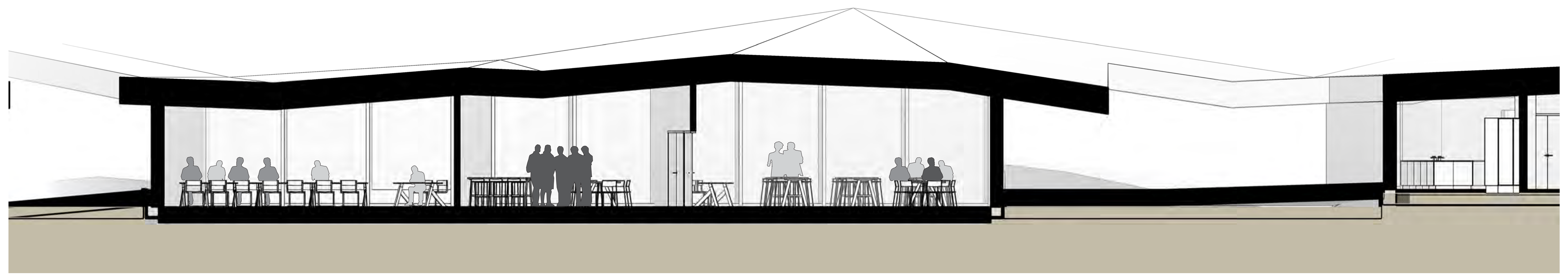
1 North facade
1 : 200

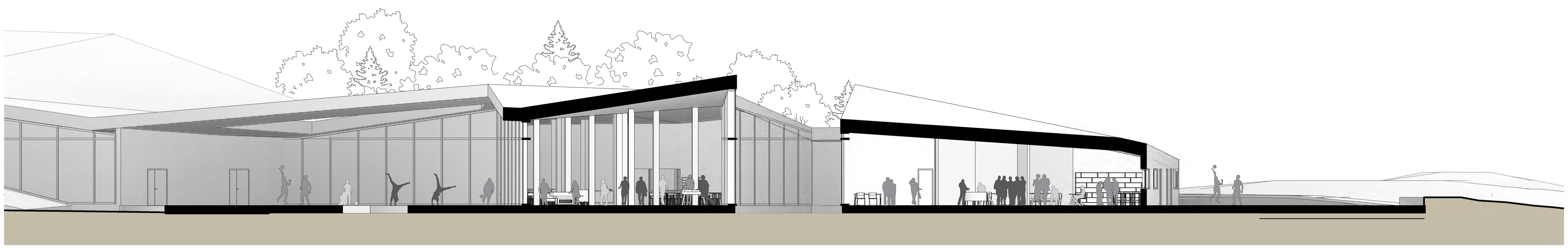
2 South facade
1 : 200

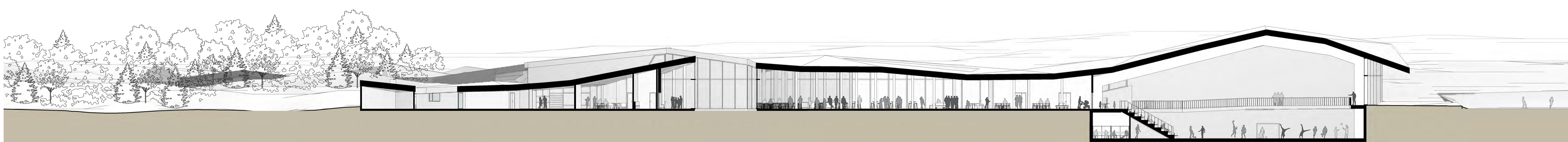
3 East facade
1 : 200

4 West facade
1 : 200

UNDER MOOR		1:200 Scale	03 NO.
FACADES	MSc4 - 06	DRAWING FOLDER	
MASTER THESIS		AALBORG UNIVERSITY	
ARCHITECTURE AND DESIGN			







UNDER MOOR	1:200 & 1:100 Scale	04 NO.
SECTIONS	MSc4 - 06	DRAWING FOLDER
MASTER THESIS	AALBORG UNIVERSITY	
ARCHITECTURE AND DESIGN		