BETWEEN THE BRIDGES

4TH SEMESTER MASTER, ARCHITECTURE MA4-ARK17, OCTOBER 2010, ARCHITECTURE & DESIGN, AALBORG UNIVERSITY
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Title Page

A 4th semester Master Project in Architecture at
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Title: Between the Bridges

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Synopsis

The aim of the project is to design an energy-efficient housing complex in Nørresundby. The project site is between the Aalborg Bridge and the Railway Bridge at the waterfront. Recent years have implemented a total urban transformation throughout the northern side of the Limfjord by the Aalborg municipality. The aim was to transform the derelict slaughterhouse area into new business areas and attractive neighborhoods connected to the fjord.

The surrounding areas, both in the physical elements and the weather conditions will be taken into consideration throughout the project.

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Preface

This project is a Master Project developed be group 17 of the 4th semester Master Architecture, Architecture & Design at Aalborg University. This project was prepared in the period of July 1 - September 29, 2010 and focuses on integrated design in the development of low-energy architecture at the waterfront in Nørresundby. The focus is to design a low-energy building with particular emphasis on integrating the architectonic and technical solutions.
This project concentrates on fulfilling the energy Class 1 in the Danish Building Regulations.

The project takes focus in the local plan for the area. In the local plan 12.072, there is expected to make a building that has 3-4 stories.

The report is divided into 4 phases:
- Analysis
- Sketching Phase
- Synthesis Phase
- Presentation Phase

A CD is found at the back of the report, which includes calculations from Be06 and lighting investigations.

Introduction

Architecture is changing. The reason is the climate changes, which are considered one of the world's greatest challenges. Nowadays architects around the world think more about sustainability and low-energy architecture. The importance of low-energy architecture is now more important than ever to minimize the global warming.
When designing new houses with low-energy standard, it may be need to spend more in the initial construction, while gaining later on in lower service costs.

It is important to look at the environment when designing a low-energy architecture and have active strategies to reduce the energy consumption. By applying a number of energy saving principles, the energy efficiency of the building can be dramatically increased.

This project, explains the design of a low-energy housing complex at the waterfront in Nørresundby in northern Denmark.

Method

The main method used in this project will be Integrated Design Process, IDP. IDP is where the technical, functional, energy consumption, indoor environment, construction and aesthetic solutions are worked with simultaneously from the beginning of the project.

The IDP contains following phases:
- Problem formulation
- Analysis phase
- Sketching phase
- Synthesis phase
- Presentation phase

Problem formulation:
This phase will describe the problem or idea that will be solved in the project.

Analysis:
This phase includes analysis of the project site in connection to the landscape, urban development, weather, the sun and wind, as well as an analysis of indoor climate, energy consumption and construction.

Sketching phase:
Through the sketching process architectural and technical ideas are tested in relation to each other to find the best solution for the project. That will be done by using hand sketches, computer drawings as well as models.

Synthesis phase:
The final shape and structure is found with calculations and adjustments.

Presentation phase:
The final outcome will be presented in a report, 3D visualizations and physical models.
[Mary-Ann Knudstrup, Integrated Design Process]

Tools

A number of design tools are available for use in the different phases, in order to have the integrated design process function optimally.

Analysis phase:

The analysis phase is a general start where studies on basic principals are performed and overall ideas and concepts can be tested.
The tools applied may be:

- Pre-designed spreadsheets regarding:
  Energy consumption
  Internal heat gains
  CO2 and sensory pollution
  24-hour average, max and min temperature
  Daylight factor

Sketching phase:

In the sketching phase the developing ideas are becoming more detailed, and the tools applied here may be:

- Hand sketches
- Digital sketches in SketchUp, AutoCAD, ArchiCAD
- Physical models
- Pre-designed spreadsheet calculations regarding:
  Natural ventilation

Synthesis phase:

The design is now becoming even more detailed and developing into its final shape.
The tools may be:

- Hand sketches
- Digital sketching in SketchUp, AutoCAD and ArchiCAD
- Artlantis

[Mary-Ann Knudstrup]

Analysis Phase

Context Analysis

The building site is the former slaughterhouse area, located on the sunny side of the Limfjord.
The area, which is centrally located in Nørresundby between the Railway Bridge and Limfjord Bridge, has in many years been used for slaughterhouse and other industrial purposes.
An obvious quality of the area is the marina and harbor promenade, which together create an attractive waterfront in Nørresundby.

Recent years have implemented a total urban transformation throughout the northern side of the Limfjord.
It is Aalborg municipality aims to transform the derelict port land to new business areas and attractive neighborhoods connected to the fjord. The objectives of the effort have particularly been to strengthen urban, cultural and economic life to ensure more satisfactory traffic terms and better conditions for children and adolescents. Transformation of the slaughterhouse area is one of the highest priorities in this urban transformation.

The local plan ensures opportunity for new housing in most of the area. Furthermore, the aim of the municipality is to create a good living area and open spaces for the residents. A part of the area will therefore be used for open public areas related to the homes in the area. It is an important goal of the plan is to ensure that the area as a whole will have a coherent green character.

The local plan is designed to ensure that the area along the bay is transformed into a publicly accessible port promenade for the entire city's population and to allow public passage through the area, both in east-west and north-south direction. The waterfront is conceived as a part of a comprehensive recreational connection along the entire northern coast of the fjord. Therefore the coastal part of the area must be used and arranged for public promenade, with the possibility to establish minor recreational facilities on the fjord.

Ill. 3 The large area is the local plan area, the smaller area is the project site.

The area can be used for mixed urban purposes as housing, shops, professional services, restaurants, institutions and audience-oriented businesses and recreation. The area at the waterfront is to be used for housing complexes while most of the area at Vestergade will be used for future commercial uses.
This overall breakdown for different applications are chosen partly to the give the housing complexes optimum light and view conditions at the fjord, and partly because the areas closest Vestergade, because of traffic noise, is not suitable for housing.
The location along Vestergade is good for business functions because of the high visibility of the cityscape and the good transport accessibility.

The promenade will be the primary connection through the area, but the open structure ensures many crossing opportunities. Paths will be laid in the green area at the railroad trails, which connects the promenade with Vestergade.

The local plan allows for placement of pontoons at the Limfjord, which can be used for recreational application, like bathing, rowing clubs or similar. It is also a possibility to establish shops, café, restaurant, facilities for kayaks and similar functions in the area.
[Local plan 12-072]

Facilities And Surroundings

The area holds a wide range of different facilities, for everyday use within walking and bicycling distance: shops and supermarkets, kindergartens, schools, institutions of higher education and a church.

Lindholm Strandpark, (beach park), is just less than 8 hectares and is located just west of the building site. The beach park is adjacent to the new urban area by Lindholm Brygge and the mixed density along Thistedvej.
The park is well cared for beach, beach volleyball and large green areas surrounded by beech trees. A bridge leads to an island with built fireplace, benches, grass and shrubs. The beach was awarded the Blue Flag in 1995 for clean bathing water.
[http://www.aalborgkommune.dk]

Ill. 4 Facilities

Infrastructure

The red stripes show the main traffic around the area. The lighter red shows the main road for cars and busses and the darker red shows the railroad tracks. The yellow stripe shows a pedestrian path. The main traffic from Aalborg comes from the Aalborg Bridge and through Vestergade, located at the project site.

The entry into the area is from Vestergade.
In the development of the Master Plan, there is made an assessment of future traffic to and from area, and the new access road into the area.

Ill. 5 Infrastructure

View

There is a a spectacular view over The Limfjord from the site.

This is the view to the west side of The Limfjord. The twin towers, is a spectacular building in the new residential area on the old DAC industrial zone. It is a high-rise project that includes two concrete silos element.

View to the southwest over to Aalborg. At the right side of the picture, is the railway-bridge.

The railway-bridge is a 404m bridge, which connects Nørresundby to Aalborg. It was built from 1935-1938. The bridge has a 29m opening in the middle for boats and ships to pass through. As seen on this picture, the bridge has a spectacular construction.

A newly built housing complex next to the building site. This is a project of a 3-6 storey high housing complexes on the west side of the project site. These buildings are shaped in u-form, which has a semi-private area between them. The plan is to have three complexes in the coming years and some of them are built.

View to the south towards Aalborg. The Aalborg Bridge can be seen at the left side of the picture.

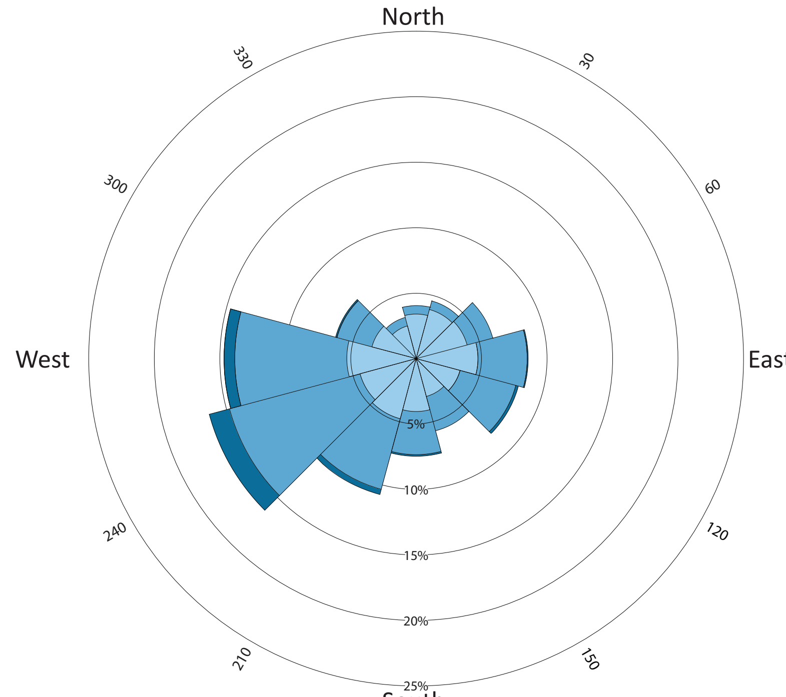
Ill. 6-11 View in Aalborg

Macro Climate

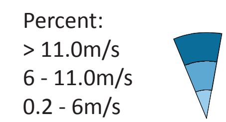
Wind

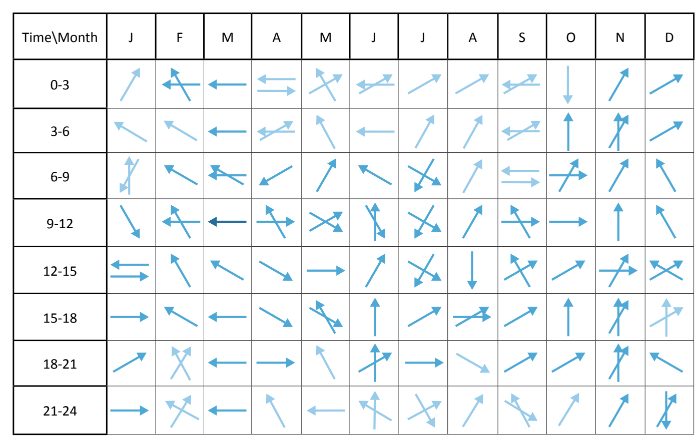
Following chapter explains the investigation of the macro climate, which considers the local conditions of the sun and wind. Different diagrams are used to explain the investigation.

The main concerns regarding the wind conditions is the utilization of natural ventilation and impact of outdoor spaces. The wind rose shows the annual wind speed and direction on the area. In order to use the wind for natural ventilation, the direction of the wind is important.
According to the wind rose, the dominant wind is from west and southwest. It also shows that the wind can be very strong from west.
The wind square illustrates the wind direction from hour to hour and shows that the wind direction changes frequently.
One of the main concerns of the wind conditions is how to use these information's for natural ventilation and the possibility for some sort of shielding for the outdoor areas.



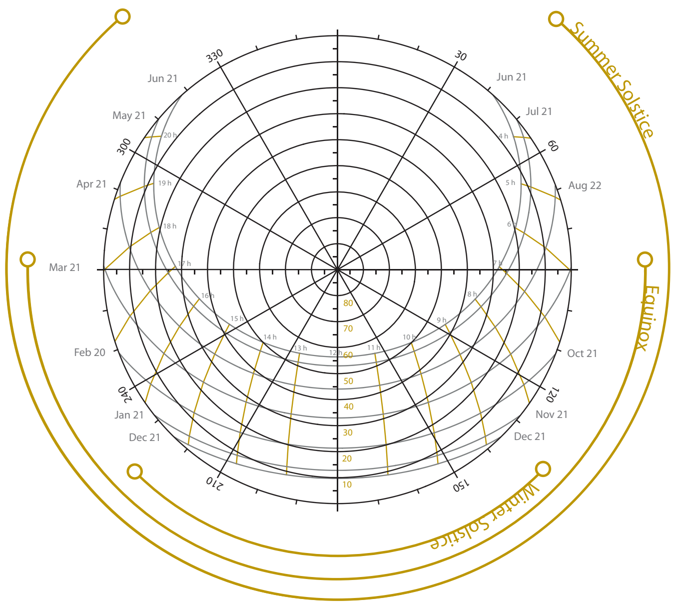
Ill. 12 Wind rose





Ill. Wind square

Sun

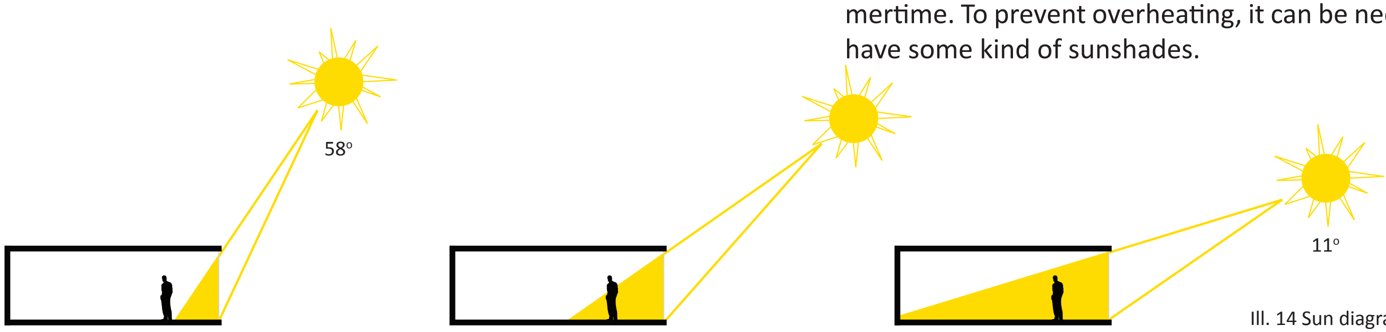


Ill. 13 Sun diagram

Daylight is an important factor when building in Denmark. The average amount of sunshine in January is 43 hours and 209 hours in June. [www.dmi.dk]
The sun diagram explains the angle of the sun over the year. This diagram gives the idea of how the building should be designed in order to gain solar heating from the sun in different times of the year.

The angle of the sun is at its lowest in the wintertime where the winter solstice is at the 21. of December. In the wintertime, the sun can easily penetrate deep into the building. (see ill. 14)
Here is where the sun plays an important role in heating the apartments in order to get the energy consumption to class 1 because of the cold weather.

As there is a great view over the Limfjord to south, it would be optimal to have large windows facing south. Having large windows towards south is good concerning the energy consumption. It is important to supply the building with direct sun, both for the indoor climate and for the solar gain. Large windows to the south can however give problems with overheating in the summertime. To prevent overheating, it can be necessary to have some kind of sunshades.



Summer solstice, 21.June 12am

Equinox, 21.March, 21.September 12am

Winter solstice, 21.December 12am

Ill. 14 Sun diagram

Low-energy architecture is an important part of the term sustainability. Sustainability is not only the production of greener energy but is also a decrease in the need for energy. The importance of low-energy architecture is now more important than ever to minimize the global warming. In 2006 the energy frame for Danish buildings was reduced significantly and two new low-energy frames were introduced.

The demands can be divided into three categories:
1. Minimum demands – this reduces the energy consumption considerably in comparison to the average existing house today.
2. Class 1, low-energy houses, which use approximately 50% less energy than the minimum demand.
3. Class 2, low-energy houses, which use approximately 25% less energy than the minimum demand. [BR08]

Class 1
The energy frame for a class 1 can be expressed with the following formula:

$$Q\ [kWh/m2] = 35 + \frac{1100}{A}$$

Class 2
The energy frame for a class 2 can be expressed with the following formula:

$$Q\ [kWh/m2] = 50 + \frac{1600}{A}$$

The new energy demands recently introduced in Denmark will hopefully generate a market for low-energy buildings. When designing new houses with low-energy standard, it may be need to spend more in the initial construction, while gaining later on in lower service costs.

There are a many principles that are important when designing low-energy architecture. The following factors are some of the things that should be considered:
- Insulation
- Heat recovery
- Energy efficient windows
- Passive solar gains
- Compact shape

Insulation:
High R-value and low thermal heat loss coefficient on external walls, slab foundation and roofs is a necessity. This will prevent heat lost during the cold wintertime.
Construction reducing thermal bridging is of great importance. The transmission loss though the building envelope must not exceed 6 W/m2 of the building envelope. The air change rate through leaks in the buildings envelope must not be more than 1,5 l/s per m2 heated floor area at a pressure of 50 Pa.
Airtight thermal envelope is important for energy consumption, humidity and the lifetime of the building. Gaps in the building envelope will allow moisture to seep in, which can damage the building over time.

Heat recovery:
Mechanical ventilation system is used to exchange stale air from the most polluted rooms like kitchen and bath and fresh air is vented into the living room and bedrooms. This is an important issue in order to have good indoor climate because of the air tightness of the building.
Energy efficient windows:
It is important to have good energy-efficient windows with low U-factors to minimize the heat loss.

Passive solar gains:
Passive use of solar energy is a significant factor. Large windows in the south side will result in heat gain from the sun in the wintertime and also reduces the need for electricity. Having large windows to the south can increase the need to have some kind of sunshades to prevent overheating in the summertime.

Compact shape:
The shape of the building is of high importance. The more compact the building is, the more energy efficient it is.

Low U-values reduce heat loss through the building envelope, and are defined according to the Danish Building Regulations, BR08.

U-values

External walls and basement walls in contact with the soil	0,20 W/m^{2}K
Partition walls and floors against unheated spaces or space that are more than 8°C lower than the room concerned	0,40 W/m^{2}K
Ground slabs, basement floors in contact with the soil and suspended upper floors above the open air or a ventilated crawl space	0,15 W/m^{2}K
Ceiling and roof structures, including sloping walls directly against the roof	0,15 W/m^{2}K
Windows and doors	1,50 W/m^{2}K
Skylights and rooflights	1,80 W/m^{2}K

Design Parameters

Building Type:

The main goal in this project is to build a low-energy housing complex. This can be accomplished by having well-isolated outer walls and by having large window facades in south.

General:

The relevant requirements stated in the Danish building regulations will be used throughout the design process to fulfill the low-energy standard class 1.

Architecture:

The building is to uphold an adequately high level of architectural quality. The building is to have open space rooms with plenty of daylight.
The building is to obtain a correlation between function, energy and aesthetics.

Materials:

Materials from the local plan will be taken into consideration. The building is to have materials, such as stone, with high thermal mass. There are to be light-colored materials and possible mix of materials for different expression.

Orientation:

The main living areas, like the living room, are to be placed in south direction, while bathrooms and sleeping areas can be placed in north. This is to minimize the need of electricity by getting more daylight in the areas where people are most during the day.

Ventilation Strategy:

To ensure low energy consumption, it is necessary to integrate both natural and mechanical ventilation.
Natural ventilation will be used in the summer time and mechanical ventilation in the wintertime.

Indoor Climate:

Good indoor climate is of great importance, both concerning air quality as well as good acoustic environment.

View:

The great view over The Limfjord will be exploited by providing large windows to the south.

Room Program

This room program illustrates the minimum area for each room and the time of the day the different functions will be used.
All dwellings have an open living room in connection with kitchen, toilet and at least one bedroom. Furthermore, all dwellings have terraces giving each dwelling a private outdoor area.

Room program	Area min. - m^2	Function	Ventilation	Light perception	Primary time of use	Orientation
Entrance	5	Access point	Natural	Bright/ Diffuse	am pm	N
Living area	30	Entertainment, relaxation, social & TV	Natural	Bright	am pm	S
Kitchen	20	Cooking & eating	Natural & mechanical	Bright	am pm	S/N
Dining area	10	Eating & social	Natural	Bright	am pm	S/N
Master bedroom	15	Sleeping, privacy & relaxation	Natural	Diffuse	am pm	S/N
Children bedroom	20	Sleeping, privacy, relaxation & playing	Natural	Bright	am pm	S/N
Bathroom	10	Shower/bath & wc	Natural & mechanical	Bright	am pm	E/W
Outdoor area	20	Relaxation, play		Skylight		S/N

Vision

The vision is to combine low-energy architecture with attractive dwellings for the inhabitants. The housing complex must be able to fulfill and adjust to individual needs and demands of its residents. Every apartment should have a small, private outside area as well as a common outside area. The site is to have defined semi-public and even private green areas for the inhabitants in order to create safe playgrounds and give the sense of privacy from the residences.
All dwellings are to have light and spacious rooms, primarily lit by daylight. With the building being on the waterfront, there is a fantastic view over The Limfjord. To get the most out of the view, large windows will be at the south side of the building.

Problem Formulation

How can I create a sustainable, low-energy housing complex with strong identity and attractive ways of living?

Conclusion Of Analysis Phase

The analysis phase makes grounds for the following sketching phase. The location of the area, the aspects of low-energy architecture and the different design principles will have great importance when initiating the process of solving the problem formulation.

The building site has been under total urban renovation in the recent years. It is Aalborg municipality aims to make attractive neighborhoods connected to the fjord. Furthermore, the aim of the municipality is to create a good living area with open public areas. All this makes this an exciting area for the residents.

In the following sketching phase the context will be taken into consideration in order to get the best result possible.

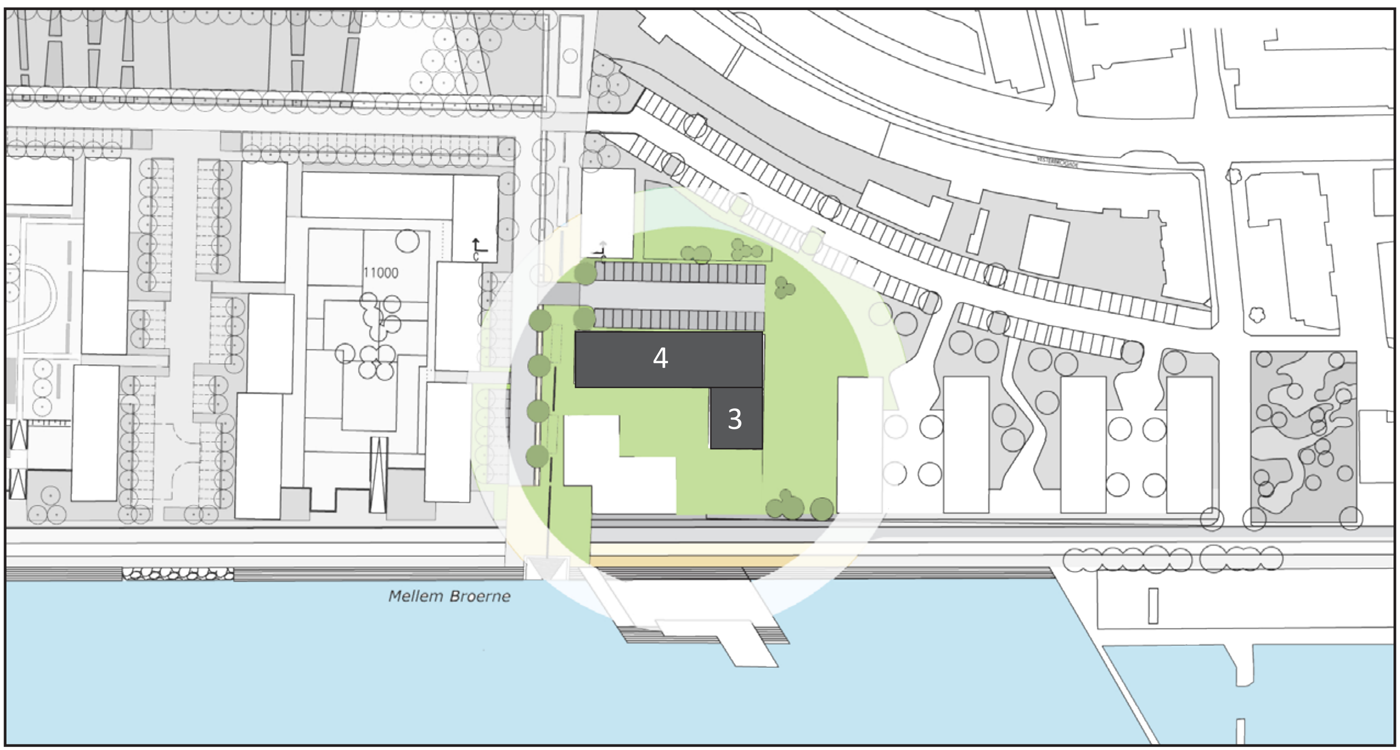
Sketching Phase

During the analysis phase different thoughts and ideas have come up about the project. These ideas span from the shape, façade expression, number of dwellings, the size of the building etc. The sketching phase starts with gathering all the ideas and narrowing them down to come up with a design proposal. This proposal will than be worked with in the Synthesis Phase where the final design takes place.
In the Sketching Phase, initial sketches will be shown and the thoughts that came up with some of the sketches will be explained. The design process will be illustrated and explained.
The Sketching Phase is seen as a process of collecting ideas and proposals for solutions of technical, aesthetic and functional character.

Initial Sketches

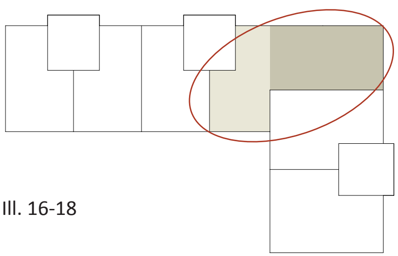
According to the local plan from the municipality, the shape of the building is to be a combination of two boxes. The box on the north side is to be 4 floors and the south part is to be 3 floors. There are some requirements from the municipality, which has to be followed. These requirements are followed through the sketching phase.

One of the requirements is that the width of the building can be maximum 14,5m including balconies. The following sketches show the initial ideas and drawings, with the apartments having maximum width.



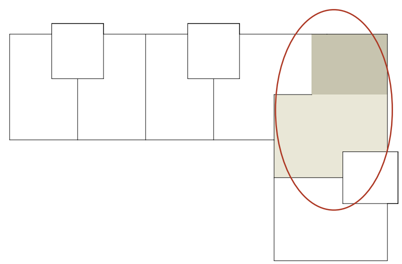
Ill. 15 the project area

On these simple sketches, the width of the building is about 14,5m. One of the first things was to figure out the best way to dispose the apartments and find out the best amount of dwellings on each floor. The main idea was to arrange the apartments in a way, so all of the apartments could be bright and have good amount of daylight.

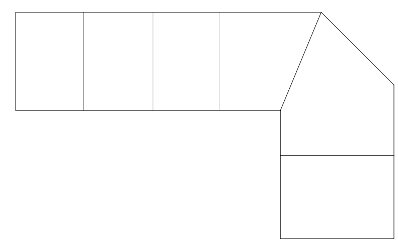


Ill. 16-18

Having the width of the building 14,5m, the apartment in the top right corner had the biggest problems concerning good daylight quality. Most of the apartment has only daylight from north and east and large area in the middle has very little sunlight. This apartment on this drawing is very large and is considered uninteresting.

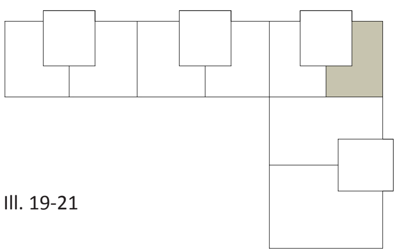


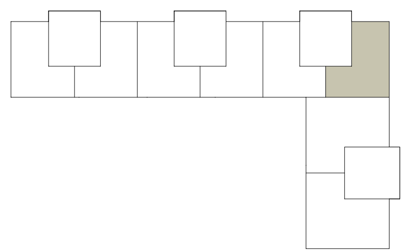
Here is another drawing where the apartment in the corner is changed. In this way, the apartment has better lighting conditions but there is still a large area without good daylight quality.

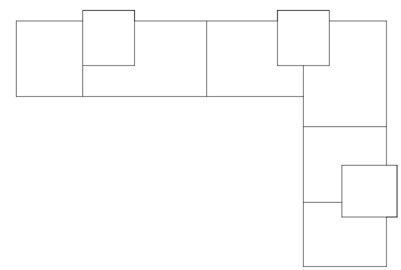


In this drawing, the corner of the apartment is cut off. This could give better lighting conditions but there is still a large area without daylight.

These sketches show the building with the width being 10m.







Ill. 19-21

The first impression is that this could give more open and bright apartments, although the two dwellings in the right corner only have daylight from north.

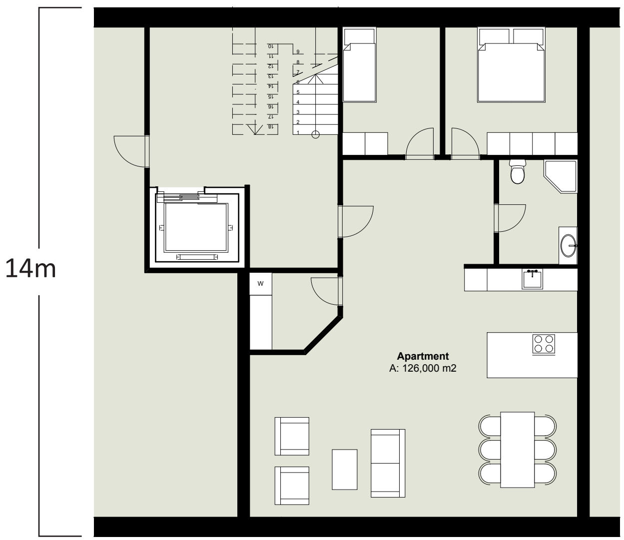
Here the east part is changed from 15m to 11m giving the left dwelling some daylight from south. This is also considered a better option for the dwellings on the east side of the building.

The dwellings on this drawing are wider than in the previous sketches. Disposing the dwellings in this way would mean fewer but perhaps better apartments on each floor. The dwelling in the corner also benefits from this change, giving it daylight from three directions.

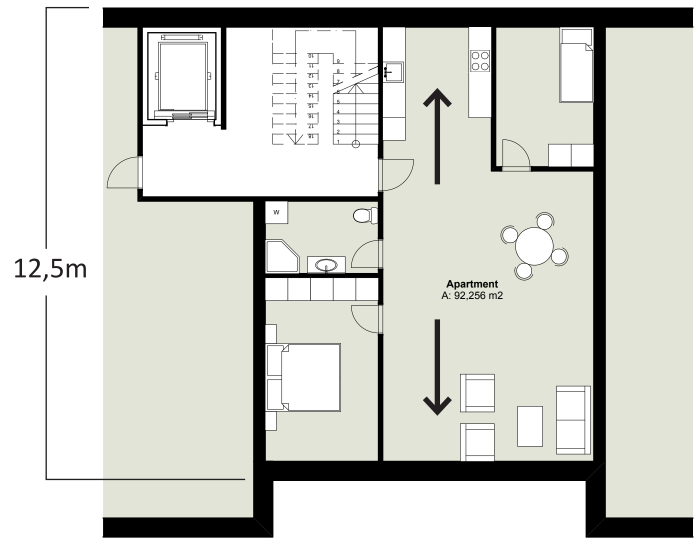
Plan Design

Experiments were made early in the sketching phase with the plan in different sizes. The following sketches explain the plan ideas and the process of the plan design.

On the sketches here below, there are two plan drawings, one with width of 14m and another with 12,5m.



Ill. 22 Plan

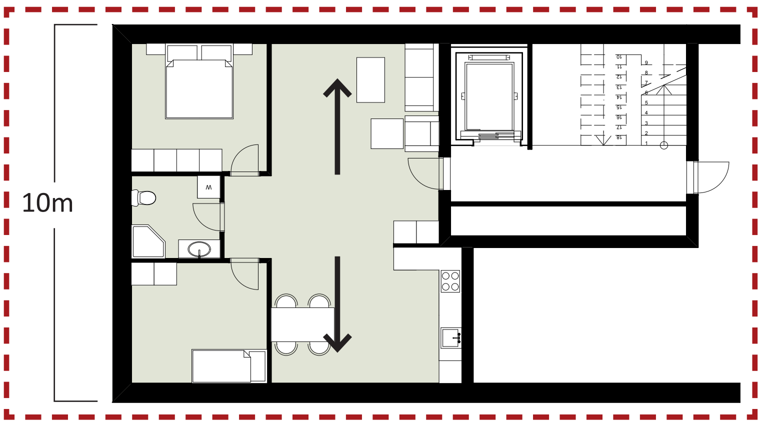


Ill. 23 Plan

In this drawing the apartment has a width of 14m. Here there is a large area in the middle of the apartment, which has little daylight. There is also a disadvantage, that the bedrooms on the north side close the north façade so there is only daylight from south in the living room and the kitchen.

Here is apartment that has a width of 12,5m. This apartment has also a large area, which has a little daylight. This apartment has an advantage from the previous one with the light coming from two directions, north and south.

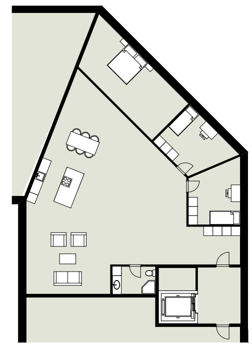
Further experiments were made with the width of 10m.



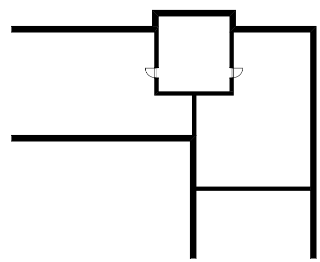
Ill. 24 Plan

With the width of 10m, the outcome gives an open and bright apartment. This dwelling has an open living area from north to south, which gives the dwelling a view and daylight from both directions.

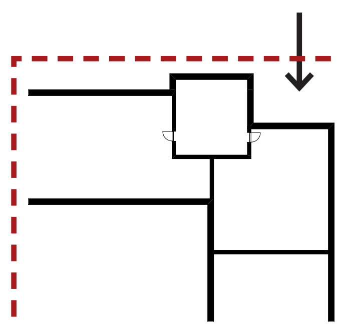
Based on these investigations, the width of 10m was considered the best solution.



Here is a plan where a part of the corner is cut off. This plan shows a very large apartment with about 200m^2. In this apartment, there is a large space without good daylight conditions and it is hard to get a good usage of the space.



Here is another example for the dwelling in the corner. The Ill. 27 cuts a part of the corner, which means that the dwelling has better possibilities to be open and bright.
After working with these three examples, the Ill 27 is considered the best solution.



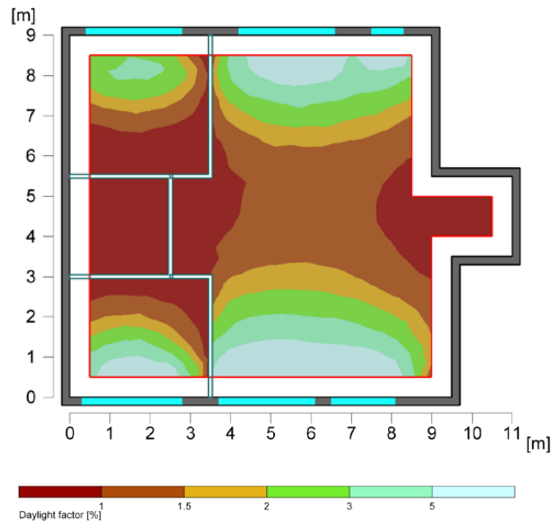
Ill. 25-27

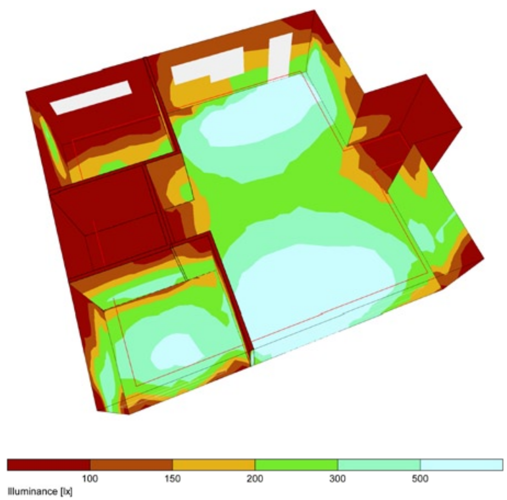
Daylight

Daylight investigations were made in two apartments using the program Relux.
The illustrations 28-29 show the daylight factor respectively in % and Lux.
These measurements were taken the 21. of July.

The ideal daylight factor is between 2-5%.
These illustrations show good daylight factor in the bedrooms, kitchen and the living room. The daylight factor in these rooms is from 2% to above 5% and as suspected, the daylight factor in the bathroom is 0%. In the middle of the room, the daylight factor is 1,5%, which is not great but is considered acceptable.

Illustration 29 shows the luminance in Lux.
As seen on this illustration, the dwelling has a luminance of 300-500lx, which is very acceptable.

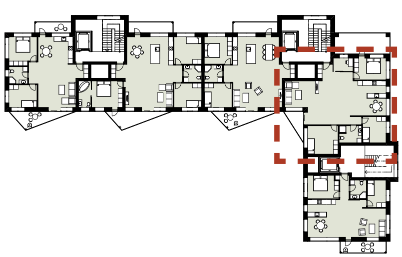


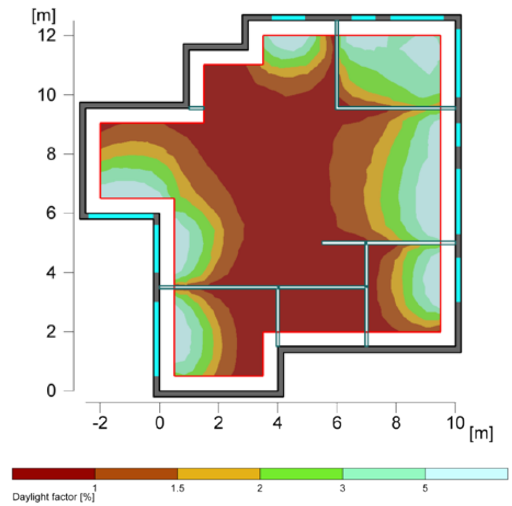


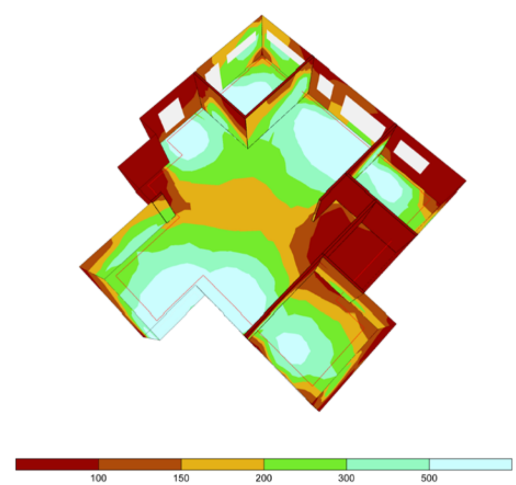
Ill. 28-29 Daylight factor

Illustrations 30-31 show the daylight factor in the dwelling in the corner. As seen on these illustrations, the daylight factor in the middle of the dwelling is poor and not acceptable.

As a result of this measurement it was decided to redesign the dwelling in order to get a better result.
The process is explained on the next page.

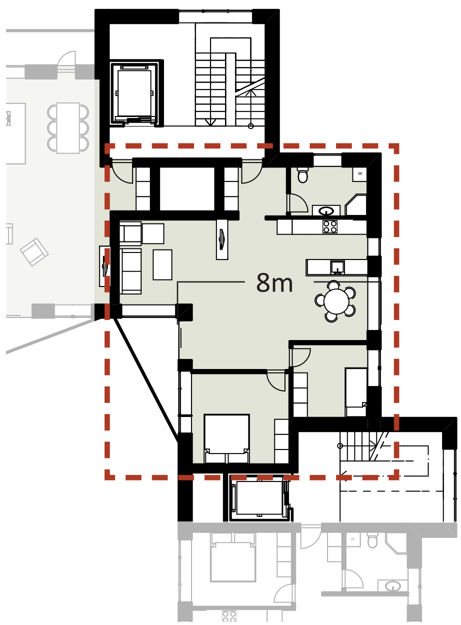


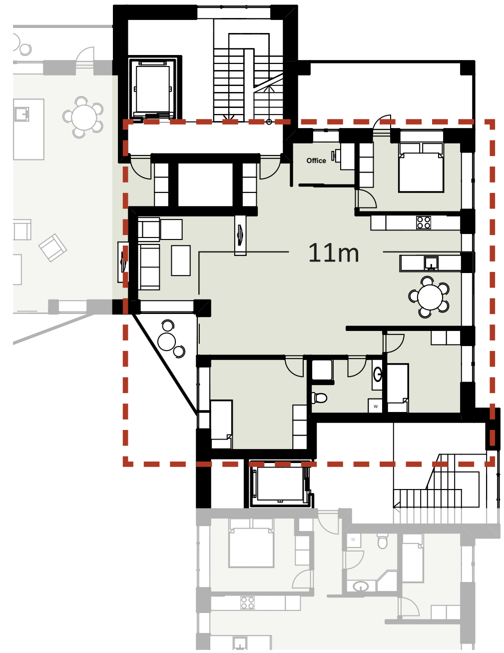




Ill. 30-31 Daylight factor

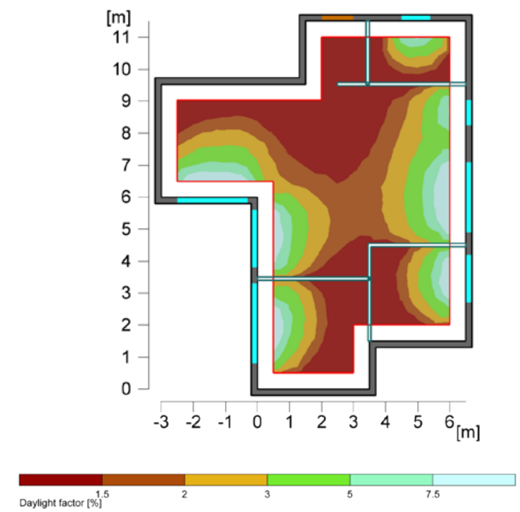
The previous width of 11m was reduced to 8m. By doing this, not only will the lighting conditions improve, but also the dwelling gets better usage of the space. In the dwelling with the width of 11m, there was some space in the middle, which was difficult to use.
Further daylight investigation was made after this change. The result of these changes will be visualized on the next page.

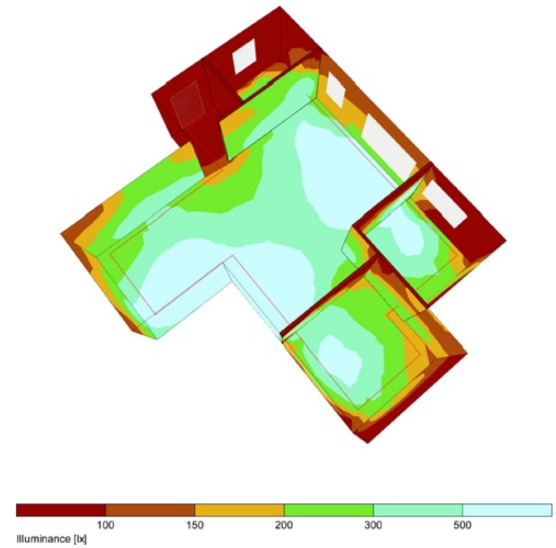




Ill. 32

These results confirm that the daylight factor has improved significantly. There is only a very small area in the dwelling, which has less then 2% of daylight. The kitchen, dining area and living room have over 500 lux and most of the dwelling has about has about 300-500 lux.



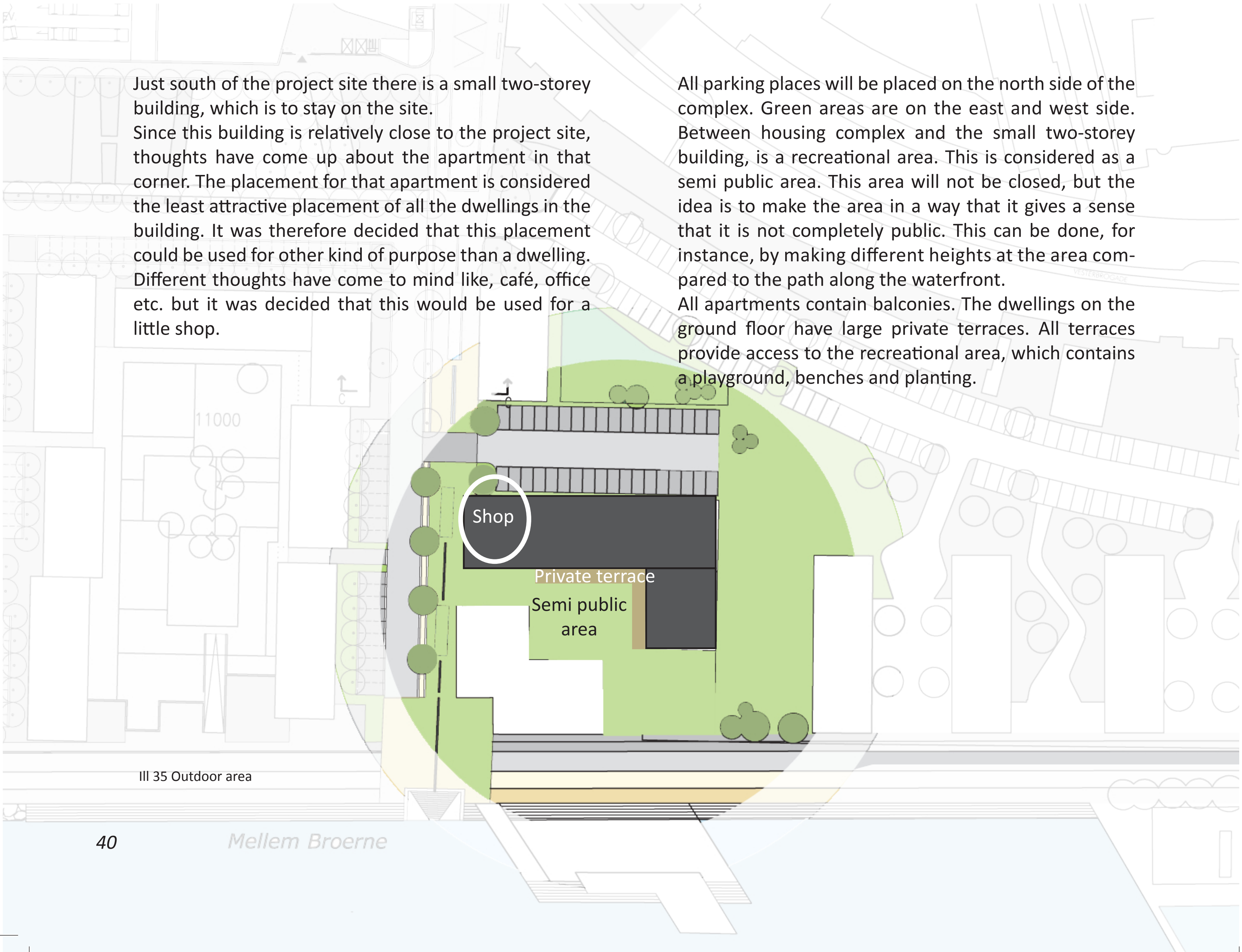


Ill. 33-34 Daylight factor

Outdoor Area

Just south of the project site there is a small two-storey building, which is to stay on the site.
Since this building is relatively close to the project site, thoughts have come up about the apartment in that corner. The placement for that apartment is considered the least attractive placement of all the dwellings in the building. It was therefore decided that this placement could be used for other kind of purpose than a dwelling. Different thoughts have come to mind like, café, office etc. but it was decided that this would be used for a little shop.

All parking places will be placed on the north side of the complex. Green areas are on the east and west side. Between housing complex and the small two-storey building, is a recreational area. This is considered as a semi public area. This area will not be closed, but the idea is to make the area in a way that it gives a sense that it is not completely public. This can be done, for instance, by making different heights at the area compared to the path along the waterfront.
All apartments contain balconies. The dwellings on the ground floor have large private terraces. All terraces provide access to the recreational area, which contains a playground, benches and planting.



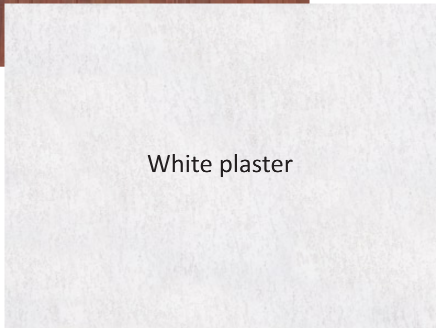
Ill 35 Outdoor area

Materials

In this chapter both materials on the exterior of the building and interior of the apartments are visualized and described. An important element in the design is the consideration about the materials both inside and on the outside of the complex.
In this project, one of the basic design criteria has been to reach the Danish building regulation energy class 1, which means that demands of insulations in the roof, floors and exterior walls from the beginning has been important for the building.

The staircases will have dark wooden cladding. The outer walls will have white plaster, placed on the insulation, to give the building a light expression. The windows and wooden staircases will stand in contrast to the white façade, where the contrast between the two materials contributes to an interesting expression on the façade.
The ceiling and interior walls have white gypsum plates and the floors have parquet. This will give the dwellings bright interior as well as contributing to good acoustics.
There is also a sound insulation under the wooden floors.
The outdoor terraces and baldonies have the same wooden flooring as in the inside to create cohesion with the building interior and to apply a warm surface to the cooler exterior.
Concrete walls are placed as dividing walls between apartments and are part of the structural system, acting as carrying and stabilizing elements with the walls in the staircases.

Example for the staircase



Example for wooden floors

Ill 36-38 Materials

Synthesis Phase

Ventilation

To ensure low energy consumption, it is necessary to integrate both mechanical and natural ventilation system. Mechanical ventilation system is necessary for a low-energy house to keep heating expenses down in the winter period.
Ventilation system for your home has three essential purposes:

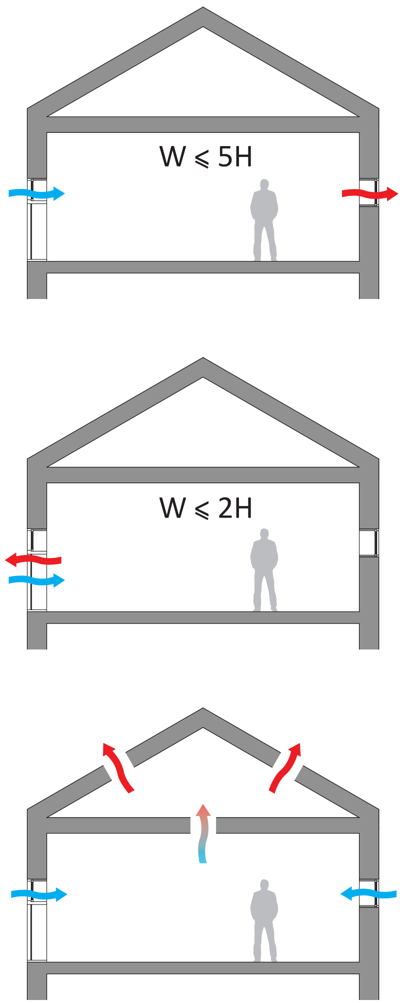
- to ensure clean indoor air
- to regulate the humidity in the air
- to conserve energy

Natural Ventilation

Cross ventilation

Single-sided ventilation

Stack ventilation



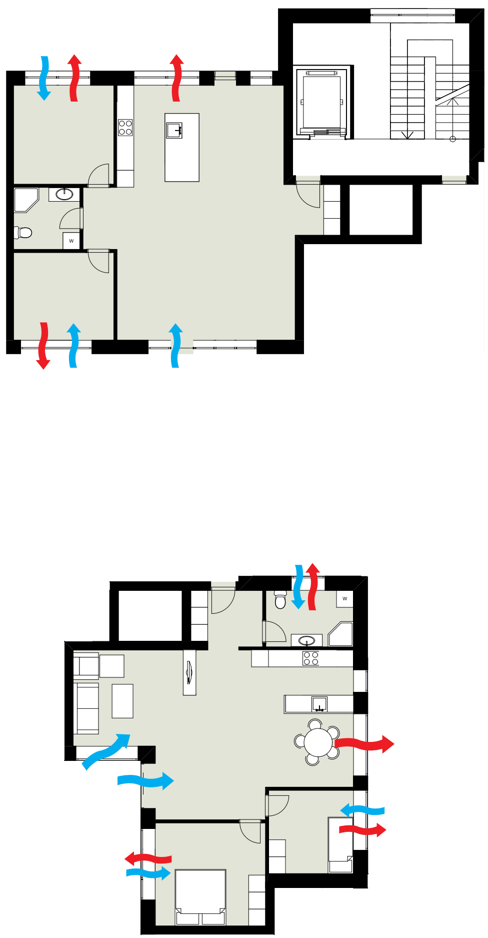
Ill. 39 Ventilation

There are three different types of natural ventilation:
- cross ventilation
- single-sided ventilation
- stack ventilation

Cross ventilation:
An effective type of ventilation caused by wind pressure with two adjacent openings. Openings can also be through roof or floor.

Single-sided ventilation:
Most often used in smaller rooms. With one or more openings in only one wall or caused by an adjacent closed door. The difference between indoor temperature and outdoor temperature, operates the airflow in this case because of differences in air density.

Stack ventilation:
Often used in office-buildings. A shaft (atrium, hallway, staircase etc.) has an opening on top causing hot air to raise forcing cooler air to enter due to thermal buoyancy.

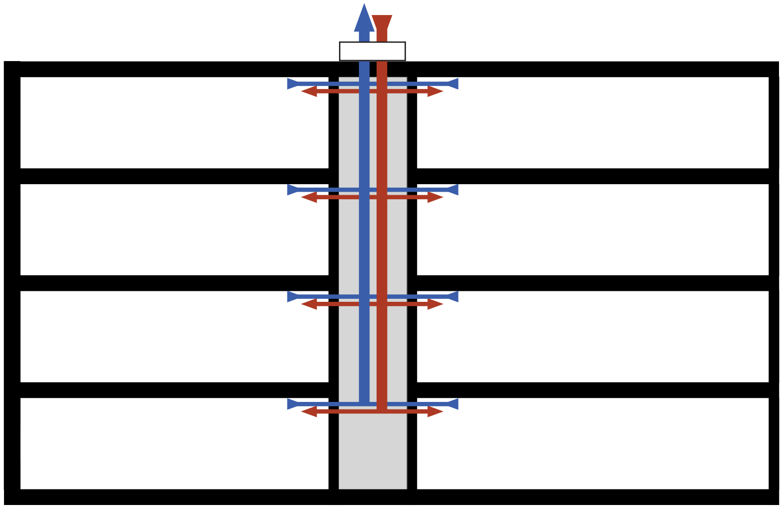


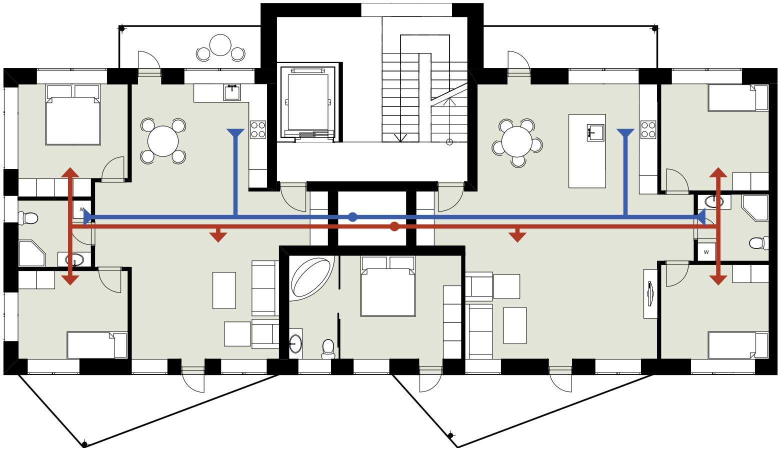
Ill. 40-41 Ventilation

Regarding the natural ventilation, the ratio between depth and height of the living room and kitchen, allow the possibility of cross ventilation, whereas the bedrooms can have single-sided ventilation.
Both systems need steady wind to work, which the specific location, along with the orientation of the building, fulfills very well.

Mechanical Ventilation

The mechanical ventilation will only be in use during the winter period. The inlets are situated in the living room and bedrooms, and the exhausts are placed in the most polluted rooms, which are the bathroom and kitchen. The ducts for ventilation and pipes are situated in the core and are connected to the aggregate on top of the building, where the cleanest air is found.
Mechanical ventilation will be used in conjunction with a district heating system.





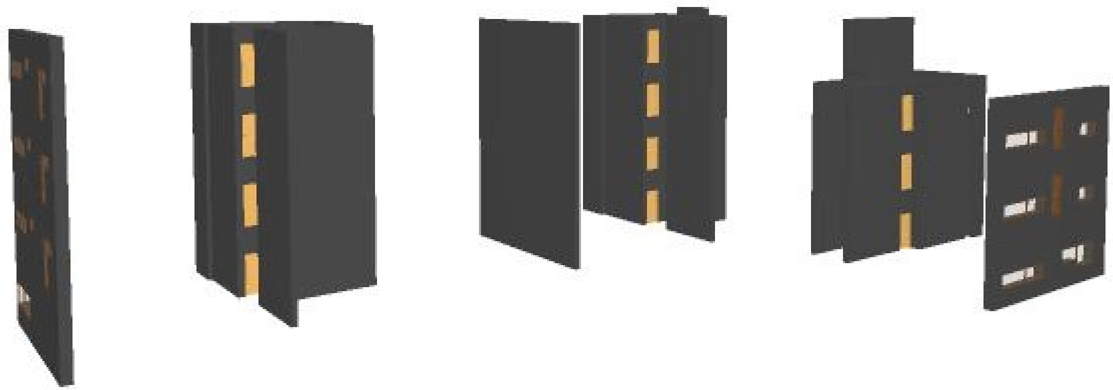
Ill. 42-43 Ventilation

Construction

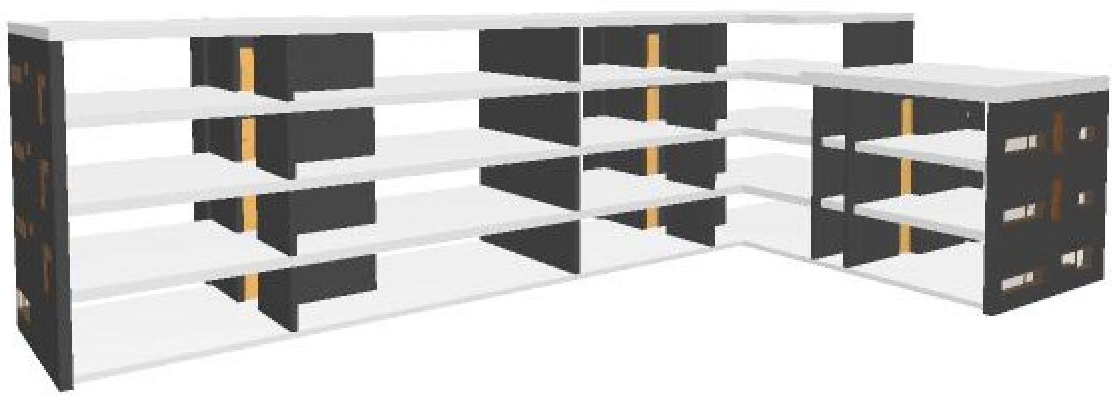
In this the chapter the structural system of the building will be presented.

The structural system is based on a combination of bearing interior– and exterior walls and cores. The bearing interior walls are the common walls between the apartments and the bearing exterior walls are the walls at each end of the building. All of the interior walls inside the apartments are nonbearing. This provides freedom and flexibility in the interior layout and the possibility to remove some of the walls in order to change the layout.
The common interior walls and cores stabilize the structure.
Additional columns support the external balconies.

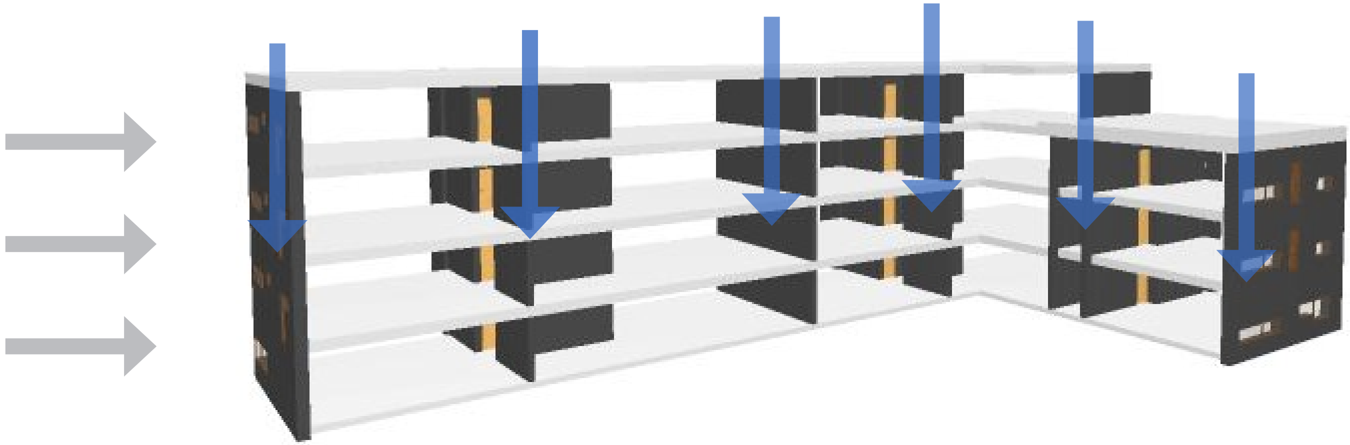
Bearing walls



Slabs

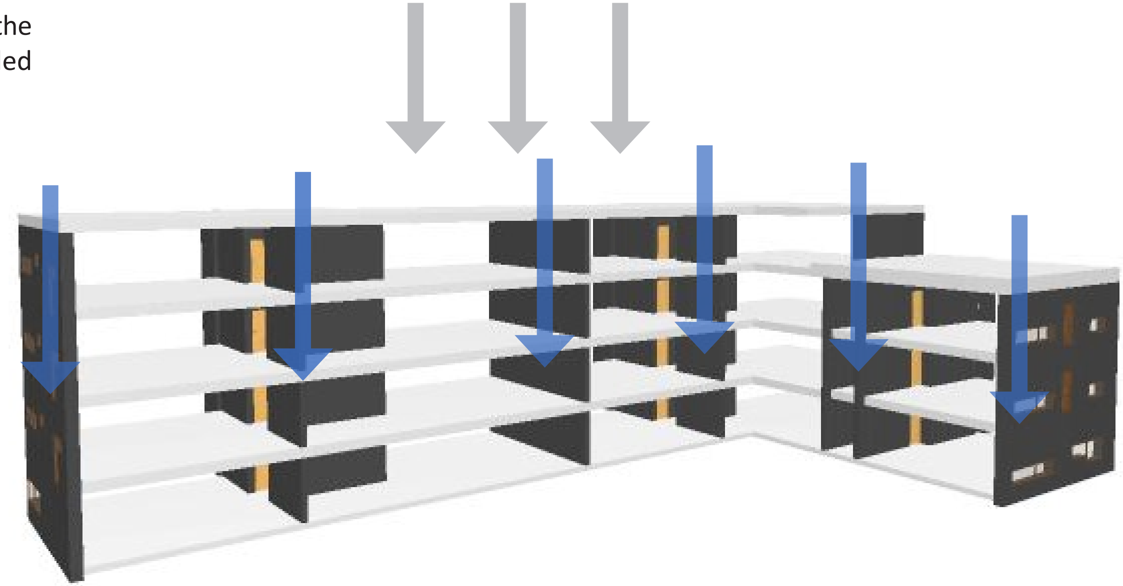


Ill. 44-45 Construction



The horizontal loads are transferred through the floor structure to the stabilizing cores and the bearing walls down to the foundation

The static diagram shows how the horizontal and vertical loads are led down to the foundation.



The vertical loads are led through the cores and the bearing walls and down to the foundation

Ill. 46-47 Construction

U-values

The outer walls consists of:
8mm plaster, 200mm façade-batts, 15mm plywood, 145mm flexi-batts/45x145 poles, vapor barrier, 45mm flexi-batts, 75mm concrete.
U-value 0,1W/m2K

Deck:
20mm wooden flooring, 75mm insulation, 180mm concrete deck, suspended ceiling for ventilation and water pipes and 13mm plasterboard.

Floor:
20mm wooden flooring, 180mm concrete, 460mm insulation and 200mm lightweight aggregate.
U-value 0,07W/m2K

Roof:
Double roofing felt, 440mm insulation, 200mm concrete and 13mm plasterboards.
U-value 0,07W/m2K

Be06

In order to fulfill the energy Class 1 in the Building Regulations, Be06 has been used to calculate the energy consumption.

U-values used in the calculations:
External walls – 0,1W/m2K
Floor – 0,07W/m2K
Roof – 0,07W/m2K
Windows are low-energy windows from Velfac, which offer – 0,11W/m2K

The results from these calculations show that the building has an energy consumption of 34,7kWh/m2 year.
To achieve the standard of Class 1, the building can have maximum energy consumption of 35,4kWh/m2 year. The results confirm that the building complies with the energy consumption of Class 1 from the Danish Building Regulations.

The key numbers are shown in the appendix at the back of the report.

Presentation

In the following phase, the plan solutions, façade solutions, sections, site plan and master plan, and visualizations of interior and exterior are presented.

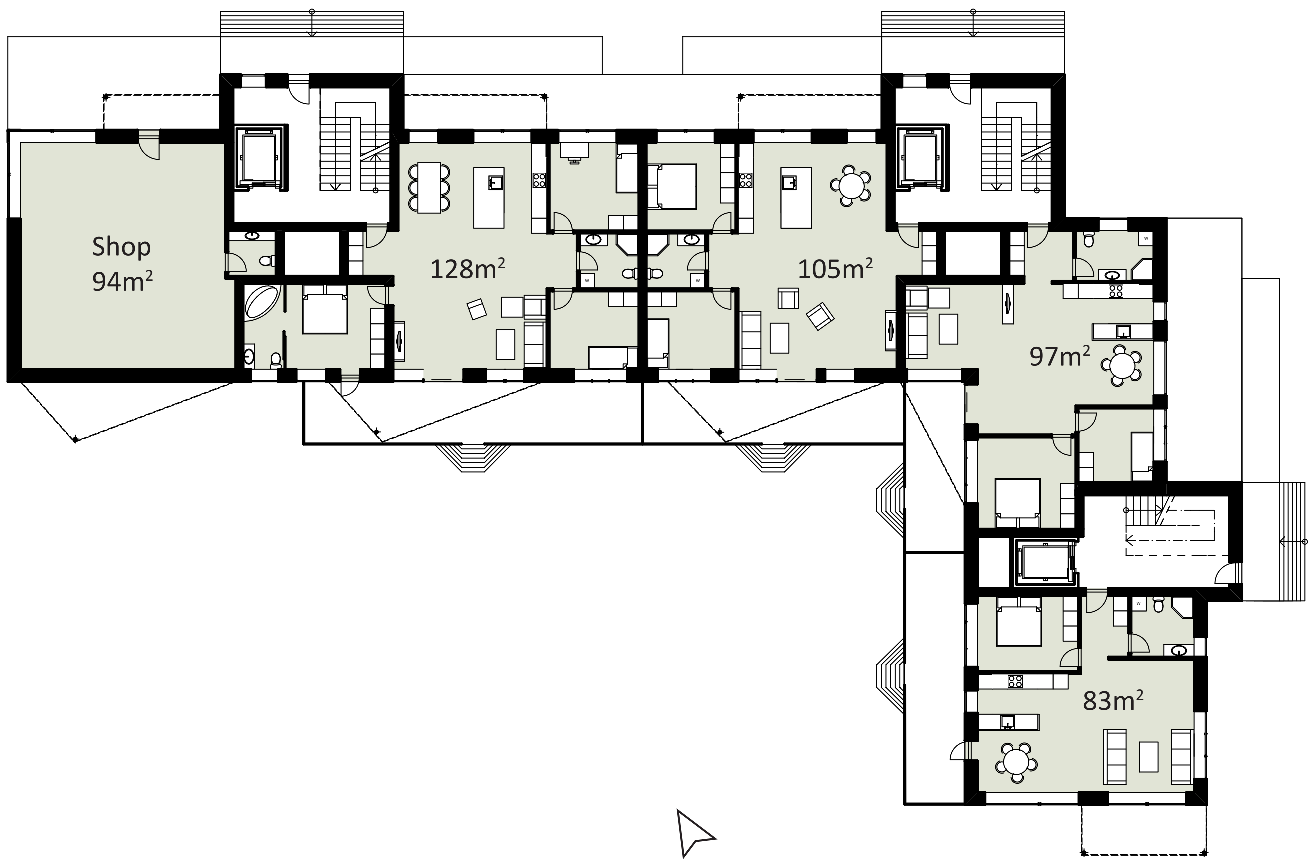
The Dwellings

In the following chapter, the plan solution will be presented. The building includes 19 dwellings from 93m2-128m2. The main concept in the plan solution is that all dwellings are to have an open living room in connection with kitchen, open from north to south. By doing that, the building has daylight coming from both directions and the dwellings have view to both directions.

Every apartment has an outdoor terrace or balcony. The dwellings on the ground floor have a large wooden terrace in connection with the recreational area at the back of the building.

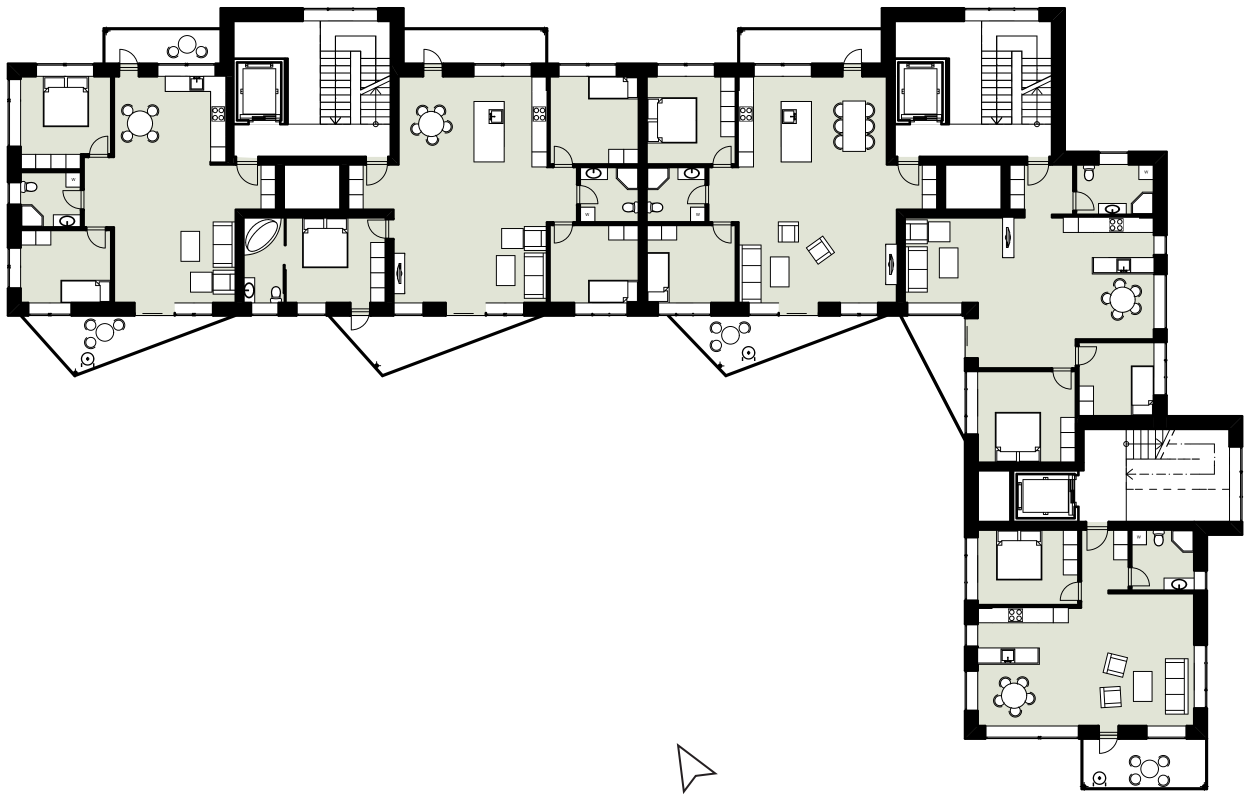
The floor plans are presented in 1:300 with two additional plans in 1:100.

Plan Solution



Ground floor 1:300

Ill. 48 Plan solution



1. floor 1:300

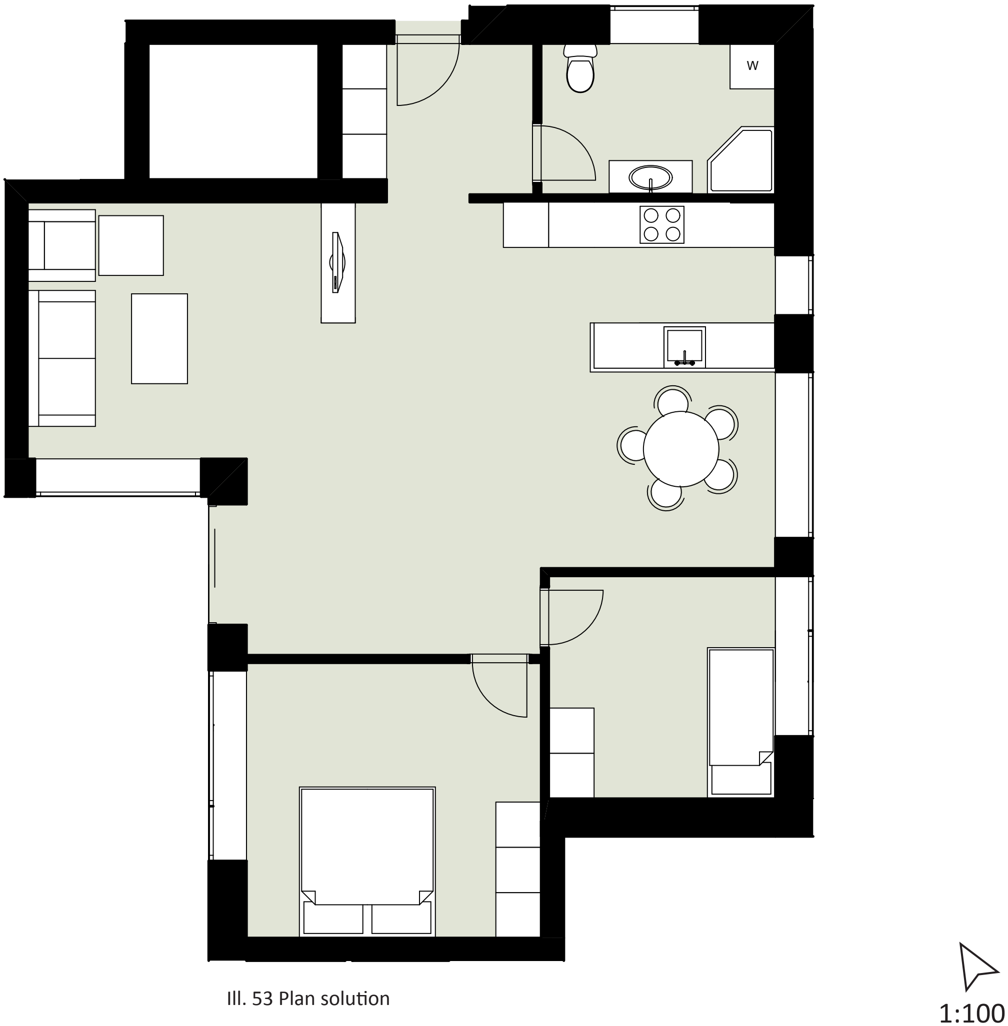
Ill. 49 Plan solution

2. floor 1:300

Ill. 50 Plan solution

Ill. 51 Plan solution

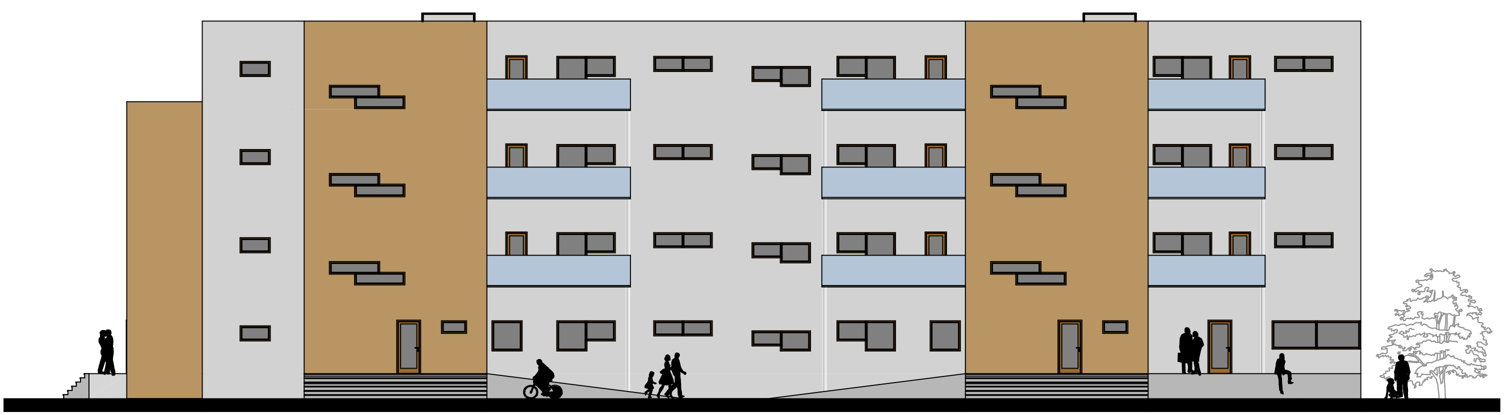
Ill. 52 Plan solution



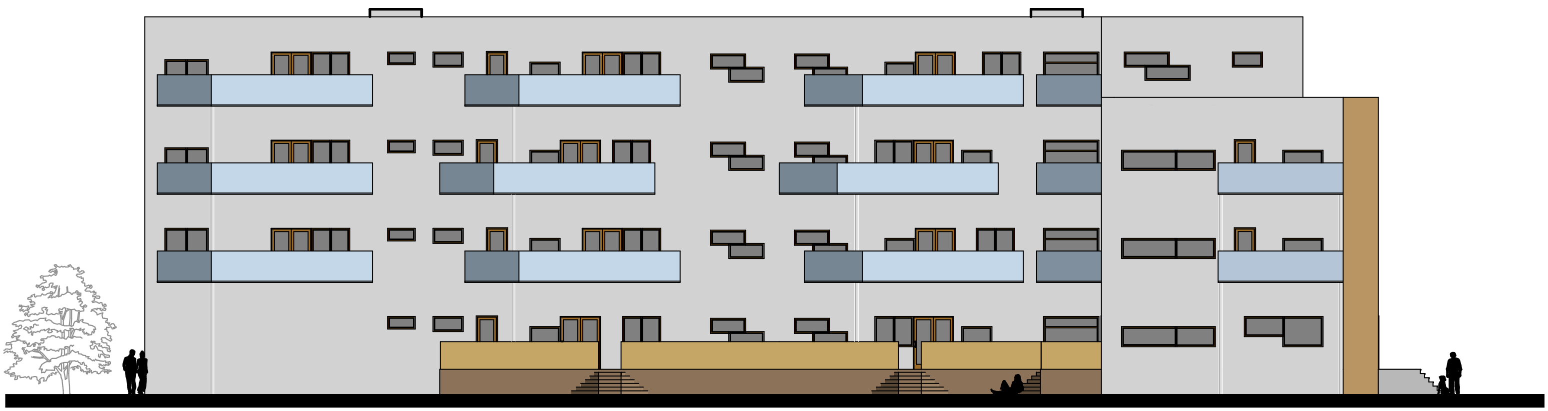
Ill. 53 Plan solution

Interior Renderings

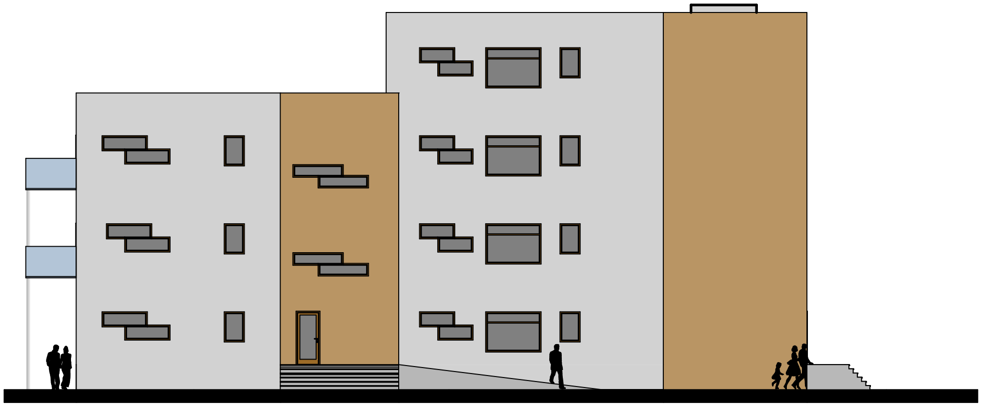
Elevations



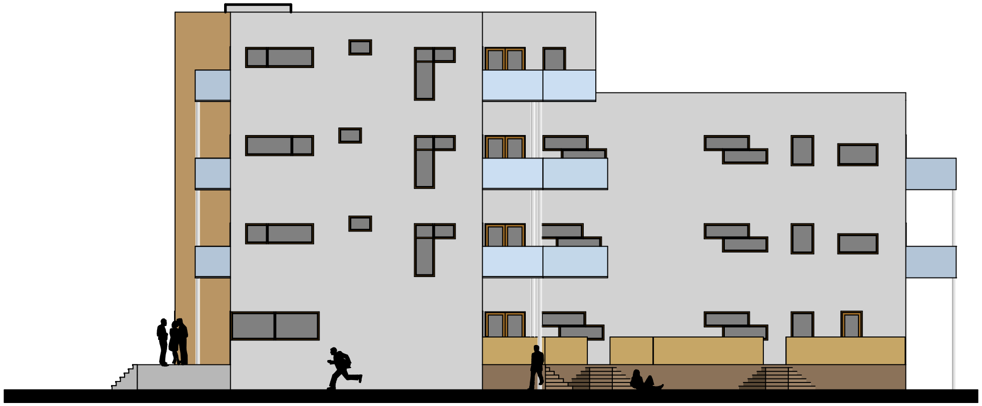
Ill. 56 North façade



Ill. 57 South façade



Ill. 58 East façade



Ill. 59 West façade

Section

Ill. 60 Section

Ill. 61 Master plan 1:500


TIL LEJE

Conclusion

The aim of the project has been, to create energy-efficient housing complex, using integrated design process. This project fulfills the requirements for a low-energy standard, class 1 from the Danish Building Regulations with energy consumption of 33,7 kWh/m² year.

The approach to the integrated design process is characterized by a selection of many aspects within architecture. In this project, this approach has been to focus on achieving a good overall idea from the start of the project.

This project offers an architectural and sustainable study of traditional principles, which the integrated design process has created between technical and architectural issues. Technical issues like the thick insulation, low U-values, large windows towards south, good daylight factor and good ventilation strategy has been a priority throughout the project. These are the elements being used to create this low-energy building. A part of working with integrated design process is to constantly making adjustments to achieve the best result. All in all, the project is the outcome of an integrated design process where different aspects have affected the product along the way.

The plan solutions were an important issue in this project. The goal was to make well-lit dwellings with good spatial qualities. The outcomes are bright apartments with plenty of daylight. All apartments have view from at least two directions from the living area and kitchen. The only rooms in the building are the bathrooms, although some of the dwellings have a window in the bathroom.

All dwellings have a private outdoor area, adding a good quality to all apartments.

As a conclusion, the design criteria for low-energy architecture housing complex is achieved.

Illustration List

Ill. 1-2 http://map.krak.dk/
Ill. 3 http://www.aalborgkommune.dk/images/teknisk/PLANBYG/lokplan/oversigt.html
Ill. 4-11 Own illustration
Ill. 12 http://www.dmi.dk/dmi/index/sog.htm?query=tr99-13 Or DANISH METEOROLOGICAL INSTITUTE TECHNICAL REPORT 99-13
Ill. 13 Sun diagram, lecture v. Tine Ring Hansen 13/3 2009
Ill. 14 Own illustration
Ill. 15 http://www.aalborgkommune.dk
Ill. 16-34 Own illustrations
Ill. 35 http://www.vincenttimber.co.uk/
Ill. 36 http://www.lughertexture.com/
Ill. 37 http://www.realoakfloors.co.uk
Ill. 38-63 Own illustrations

Reference List

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Appendix Be06

Model: Between The Bridges	SBi Beregningskerne 4, 8, 11, 14
Be06 key numbers: Project 2	
Transmission loss, W/m²	
Building envelope excl. of windows and doors	3.9
Energy frame, kWh/m² year	
Low-energy buildings class 1	35.4
Low-energy buildings class 2	50.6
Total energy frame	70.8
Total energy frame, kWh/m² year	
Energy frame in BR, no addition	70.8
Total energy requirement, kWh/m² year	
Energy requirement	33.7
Contribution to energy requirement, kWh/m² year	
Heating	27.8
El. for service of buildings, *2.5	1.3
Excess temperature in rooms	2.8
Net requirement, kWh/m² year	
Room heating	13.9
Domestic hot water	13.8
Cooling	0.0
Selected el. requirements, kWh/m² year	
Heating of domestic hot water	0.2
Heat loss from installations, kWh/m² year	
Output from special sources, kWh/m² year	
Total el. requirement, kWh/m² year	
El. requirement	31.9