Passive Housing

- Mellem Broerne

AD10-Ark12, Bjarne Blindbæk Lausen, June 2009

Title Page

University of Aalborg, Architecture & Design
Master Thesis, Architecture, Spring Semester 2009
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Project period: Feb. 3rd 2009 - Jun. 3rd 2009
Title: Passive Housing - Mellem Broerne
Editions: 4
Page number: 84

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Synopsis

The subject of this project is to design a passive house building complex, at the harbour front in Nørresundby. The building is supposed to have an experimental architectural expression, and at the same time act as a link between the city to the east, and the park to the west.

Summary

This project depicts the process of designing a building complex, containing dwellings, while fulfilling the passive house standard for low energy usage.
The final proposal should have a characteristic appearance, as the local municipalities have a vision of an architectural experimentarium.
The dwellings should meet the needs of different user groups, ranging from inhabitants of three room to four room flats.

During the design phase, different proposals have been tested utilising calculation tools meant for use during the sketching phase.
As the project has moved closer to a final proposal, more precise tools have been used, in order to obtain more reliable results.

The project culminates in the presentation of the final proposal.

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Preface

This Master Thesis in Architecture is composed by Bjarne Blindbæk Lausen at the faculty of Architecture & Design at the University of Aalborg, during the spring semester 2009.
The report is intended to convey the process of the development of a building complex containing dwellings, situated at the harbour front in Nørresundby.
All sources are referred to after the Harvard method, and can be found in the end of the report, along with references to the illustrations. All technical calculations for the final proposal are located on the cd, attached to this report. Additional drawings will likewise be attached to the report.
The report is arranged chronologically, describing the process.

Introduction

During the recent years, the topic of global warming has got an increasing amount of publicity, as it is believed that the rising emission of co2 is the main cause of this phenomenon. In addition to this noble initiative, it is also important to be independent from politically unstable regions, from which we receive much of our energy. The Danish government has responded by defining different classes of low energy buildings, and introduced a gradual aggravation of the standards for energy usage in new buildings. Even though it will take quite a while before the standards are as low as the best it is possible to build today, it is ,naturally, allowed to construct a building, which exceeds the minimal energy efficiency stated in the Danish building code.
Furthermore it is not long ago that the steep rising of the energy prices came to a halt, and it is still possible that the prices would start skyrocketing again.
As a result, it is interesting to take a look at modern building techniques, allowing the construction of low energy housing, which will lower both the co2 emission and the heating cost.
However, to most normal people these houses and technologies are unknown, and furthermore there are prejudices that low energy houses become uninteresting in their expression, because of the requirements that have to be met in order to hold the energy usage low. It is therefore appropriate to build low energy houses of a more experimental character, partly in order to create new, and challenge the existing technologies, partly in order to turn the focus towards low energy building.
This project will be based on the Bolig+ competition, situated at the harbour front of Nørresundby. The very essence of the Bolig+ competition is the idea of low energy housing, focusing on a energy neutral solution, where the energy usage and –gain will nullify each other during the year, resulting in an annual energy usage of zero. In order to achieve such results it is not enough only to use a passive approach, but it will also be necessary to facilitate active energy producing techniques, like for example solar collectors. Actually the project introduction does only dictate the low energy class one standard, and not the passive house standard. This project however, will not focus on the principle of an energy neutral building, but instead concentrate on maximizing the passive techniques in order to minimize the energy usage.
Aalborg Kommune has yet another vision for the project site, where the entire harbour front area between the two bridges is set out to be a new housing area with traditional buildings of high quality, the site for the Bolig+ competition is meant to contain some more experimental architecture. This experimental architecture is new and expressive, creating new uses of buildings, making untraditional use of materials and bold details, enhancing the expression of the building.

Analysis

The Site

The project site is placed on the south facing harbour front of Nørresundby, right to the east of the railroad bridge. The entire stretch between the two bridges is undergoing a massive urban renewal, turning the area that once had an industrial character, into an attractive residential area.

The local area has once before undergone such a massive renewal, as a result of the construction of the Limfjords bridge in the thirties. This means that there is a great amount of funkis buildings, which were constructed in that period, in the area.

The area is dominated by stone materials like concrete, however the most predominant material is bricks, which lends the area a great amount of materiality.

The location on the northern shore of the Limfjord does not only offer a magnificent view of the Limfjord, it does also supply the site with plenty of sunlight, which can be utilized in low energy buildings.

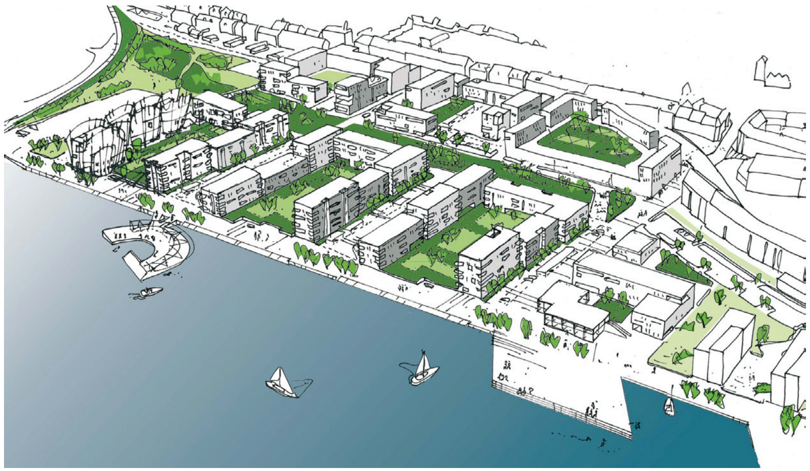
There are on the other hand also certain dangers in building that close to the harbour front, on several occasions the promenade has been flooded, which is a problem that needs to be considered in order to avoid flooded flats on the ground floor.
The dense masterplan can also cause a problem, the area will accommodate a large amount of people while not leaving room for parking spaces. This problem applies both to cars and bicycles. The high density will also inevitably create shade, which can develop into problems for uniform exposure to the sun light.

Context

All the new buildings along the harbour front are held in a rather common approach to architecture, when it comes to the use of materials.
The area is dominated, partly by the funkis buildings from the 1930'ies, partly by the modern buildings facing the Limfjord.
The predominant material is stone, mainly in the form of bricks, giving a warm texture to the buildings and referencing to the past. There is however, also a presence of plaster, concrete and glass, functioning as a proof of the time we live in.
The new buildings are mainly north-south oriented sticks, dominated by large glass facades and balconies towards the south. The other facades seem more closed.
To the west, the railroad bridge acts as a borderline for the project site. On the other side of this separation lies a park facility, which is for the time being the only place in Aalborg, where it is allowed to swim in the Limfjord. Furthermore the promenade going through the area, continues through the green area to the west, and connects to another residential area.

Local Plan

The entire area around the project site used to be an industrial area, but now the entire area is being claimed for urban and residential purposes.
The overall aim of Aalborg kommune, is to create a residential area which has a lot of green elements. This results in a masterplan, where the entire area is divided by a park-like green strip, parallel to the main internal road. Furthermore the building complexes are kept in a u-shape, with a more private green area in the middle.
The buildings facing the Limfjord, open up towards the view of the water, and the harbour front on the Aalborg-side, and it is planned to keep the promenade along the water.



Aalborg Kommunes vision for the harbour front.

To the north, the buildings facing Vestergade, are supposed to correspond to the more urban context, which is the inner city of Nørresundby.

The actual project site, laid out in the local plan, is a part of one of the u-shaped complexes. This means that the building is supposed to be a north-south oriented stick, which does not necessarily comply with the idea of low energy housing, where as large a south oriented facade as possible is preferred.

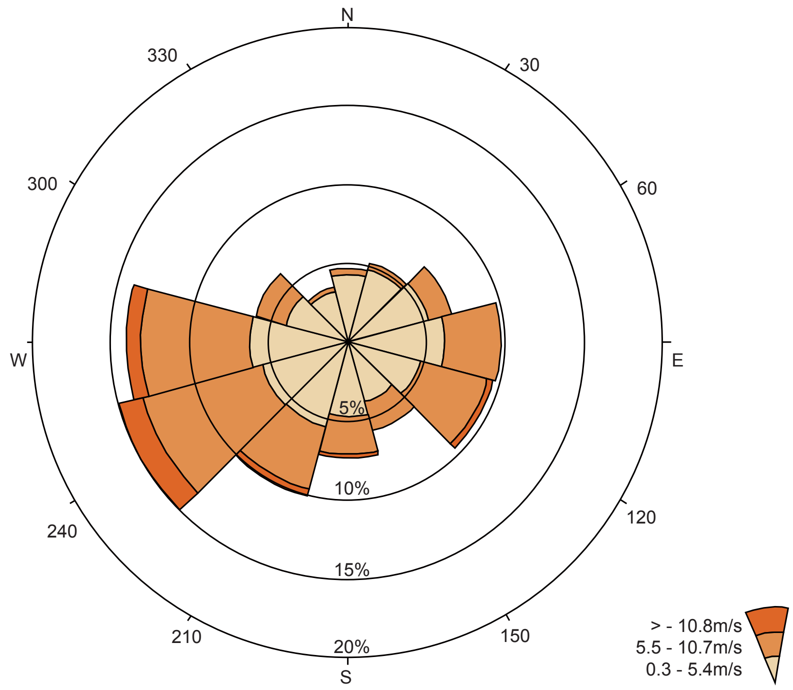
As a part of Aalborg Kommunes vision for the entire area, the project site is meant to contain some more experimental architecture. This experimental architecture is new and expressive, creating new uses of buildings, making untraditional use of materials and bold details, enhancing the expression of the building.
The striking appearance of the building will be further underlined, since it is supposed to rise in ten storeys towards the harbour front, while the northern part of it is allowed to vary between three and six storeys in order to mediate between the tall part and the surrounding buildings.

At the same time the building is supposed to act as the transition between the skyline of the harbour front, the railroad bridge, and the park. (Lokalplan 12-072)


Main Roads
Internal Roads
Promenade
Wild Green Area
Park-like Green Area
Buildings
Project Area
Project Site

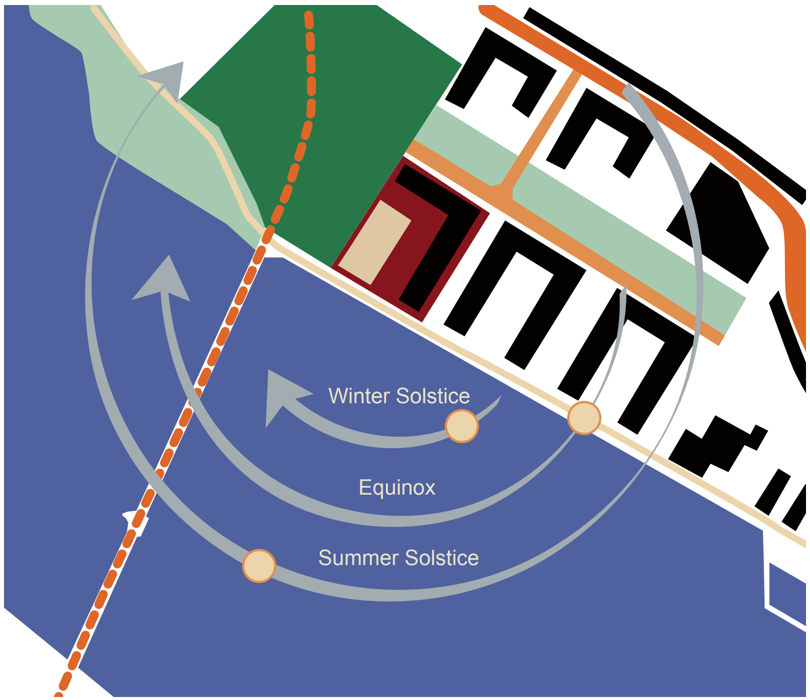
Environment

Aalborgs placement at the Limfjord results in a predominant wind direction from the west, from where the windspeeds are also quite high. If the wind is not coming from the west, it will mostly be coming from the east.
This east-west bound wind direction can possibly be used in conjunction with a natural ventilation system, which could drive the ventilation in the summertime. (DMI 2008)



Mean wind directions for Aalborg

The site is located right next to the Limfjord, so there is practically no obstructions to the south, allowing a great amount of sunshine on the site.
Because of the lower angle of the sun during the wintertime, the sunlight will practically only come to the site from south, whereas in the summer, the site will be lit from the east and west as well.



Sun-paths directions for Aalborg

Summary

There is a great potential for the project site. This applies in terms of quality for the inhabitants of the area, who have access to a view over the Limfjord and different recreational instalments. However there are also a lot of potential for energy optimised building.

A lot of potential does often come along with a lot of visions, and in this case especially the visions of Aalborg Kommune seem to be capable of generating a residential area of high quality.
While a lot of these visions supplement the aims of this project quite good, others do contradict it, and will have to be changed.

For example the project site given in the local plan does only allow for a north-south directed stick building, which is far from optimal for a low energy building. This opens up for a discussion whether the given project site should be changed or not, in order to optimise the orientation towards the sun.

However, the intention of this project is to take up the challenge of creating a low energy building with a unique architectural expression, following up on Aalborg Kommunes vision of an architectural experimentarium.

User Group

The project introduction for the Bolig+ competition defines its own user group. This user group is based on the vision of a flexible system, adapting to virtually every kind of inhabitant constellation, where, for example, a flat for a nuclear family should be able to be turned into two flats for singles.
How interesting this approach to an inhabited space may seem, the implementation of such a system in itself would be enough work for a project of this magnitude. Instead, it has been decided to define a new user group.

Considering the attractive location, the aim with the project is not to create social housing, since it would be unrealistic to believe that such a location would be used for such a purpose.
The aim is not to create luxury flats either, luxury flats are in this case understood as flats that are significantly larger than needed and use unnecessarily expensive materials etc.
This leaves room for a vision of creating high quality flats for the middle class. High quality means a proper use of good materials, carefully designed and implemented details, good functional floor plans etc.

In this project, focus will primarily be put on families seeking the advantages of the parcel house in a high rise building placed in an urban context, thus combining the advantages of city life, with the safety and possibilities of rural life.
The inhabitants in the user group will put a great focus on the outdoor facilities, for example garden facilities that offer safe surroundings where children can play safely.
Another element that these users would benefit of is balconies, providing an outdoor space with a magnificent view in immediate continuation of their flat.
This is quite consistent with Aalborg Kommunes plans for the area, where a lot of garden- and park-like facilities are planned, while there is easy access to Lindholm Strandpark.

Even though the main focus is on families, a family does not necessarily consist of a father, a mother and two children. Family constellations do vary from a single parent with one child, to large families with many children from mixed marriages.
Seen from this perspective, the idea of highly flexible flats from the Bolig+ competition is well thought through. But since this idea is deemed to extensive for this project, this degree of flexibility will be adjusted in the room programme by inclusion of different types of flats appropriate to house most user types.
It is considered that different flat types ranging from three room flats to four room flats, will be appropriate for the chosen user group.

An aspect of the project that is not necessarily consistent with the user group, is the focus on energy efficiency. Even though the role of this aspect is growing more important in every household, it is not in any way expectable that the inhabitants of this project will live a lifestyle in accordance with the low energy standards.
As a consequence, yet another task could be assigned to the architect: to ensure that the building is used in a energy efficient way.
One way to achieve this could be to write a manual, for the correct use of the building.
Another method could be to streamline the design in a way that encourages to a more sustainable lifestyle.
An example for the latter approach can be seen in Bæk & Simonsens project: Grønneparken in Viborg. The project consists of a row house complex, containing 32 flats. The essential part is however the common house, which has been dubbed: The Ecology Central. In this building the users share facilities, such as a common cold store, minimizing the energy usage.

Passive House vs. Low Energy House

Since the oil crisis in the 70s, the demands for maximal energy usage defined in the Danish building regulations have gradually been tightened. In the latest version of the building regulations the normal energy frame has been supplemented with two low energy classes, where low energy class one is the most strict one.
Another approach to low energy is the passive house standard, which was developed mainly in Germany, Austria and Switzerland. This standard is international, and certified by the Passivhaus Institut in Darmstadt, and so it is not part of the Danish building regulations. (Marsh, Larsen, Lauring og Christensen 2006)

The central idea of the passive house standard is to minimize the energy usage for space heating, by defining a maximum usage of 15 kWh/(m²a).
The usual way to achieve this low energy usage is initially through passive technologies, hence the name: passive house. Passive houses do however have a lot of active technologies nowadays, especially in Denmark where it is nearly impossible to attain the passive house standard without a lot of automated controls.
One of these approaches is the use of a high level insulation, which is quite common in all low energy buildings, and since the latest building regulations, also quite common in general. In order to achieve these high levels of insulation, it is inevitable that the paradigm of the outer wall has to be changed, be it because the walls have to be thicker or consist of a different construction, in order to contain the increased amount of insulation material.
Another important aspect of the passive house standard, is the passive heat gains. Instead of equipping the house with radiators and similar heat sources, the passive house finds its primary heat source in the solar radiation and heat gain from inhabitants and domestic appliances.
Insulation and passive heat gains are however not enough to keep a house warm, so passive houses are equipped with a mechanical ventilation system, capable of recovering more than 75% of the heat from the exhaust. Not only does this system save energy, it also ensures that the indoor climate is of a high standard.
The maximal allowed level of primary energy usage is 120 kWh/(m²a), this includes all energy used in the household, including water heating, lighting and appliances. (passiv.de 2007)

The low energy standard defined in the Danish building regulations puts its focus on all energy needed to operate the house, i.e. space heating, heating of water, circulation, ventilation etc., but ignores lighting and appliances.
The standard for a low energy class one building allows a total energy usage of 35+1100/a kWh/(m²a), which seems rather low compared to the passive house stand-

ard of 120 kWh/(m²a), but then again the demands from the building regulations do ignore the energy usage for lighting and appliances, which in general counts for 50% of the energy usage.
The fact that the building regulations considers all energy usage at once, instead of having a dedicated demand for heating, does also make active energy contributions more viable. Solar collectors providing warm water or solar cells generating electricity to run the technical system of the house, will have an impact on the energy frame in a low energy house.

Passive House

Maximal energy usage for space heating:

15 kWh/(m²a)

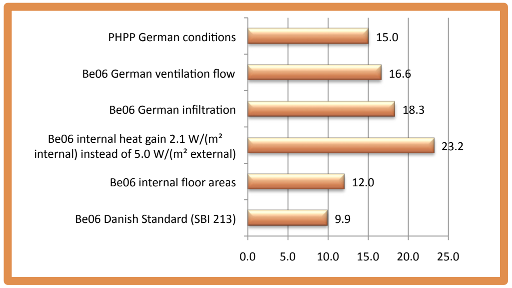
Maximal primary energy usage:

120 kWh/(m²a)

Low Energy Class One

Maximal primary energy usage:

35+1100/a kWh/(m²a)



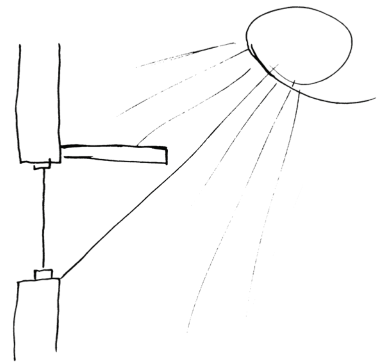
It can be concluded that there are too many differences between the two standards, for them to be directly comparable. This fact is even further emphasized, considering that the passive house standard consequently uses net measures for the area calculations, while the Danish building regulations uses gross areas.
In theory, it is possible to take out certain aspects of each standard, but differences in calculation methods and premises, result in the need for a conversion system.

An exam project at the faculty of engineering in Århus, considering the possibilities to compare the demands from the Danish building regulations with the passive house standard, indicates that achieving the passive house standard is harder than reaching low energy class one. (Ellehauge & Kildemoes 2006) Thus the aim of this project will be to fulfil the passive house standard, since energy usage in a passive house usually will be lower.

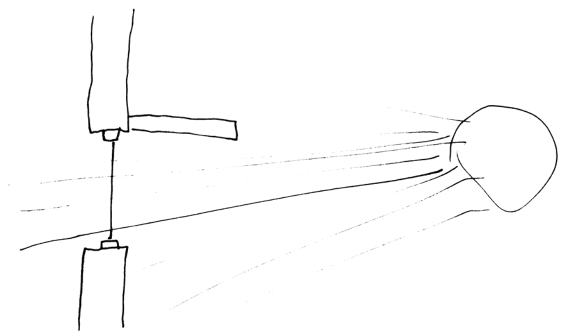
Orientation

The classical approach to low energy housing is to orient the building towards the sun, on the northern hemisphere this means placing large windows facing south, taking advantage of the solar gain in the winter, while the other facades have as few windows as possible, allowing for a greater level of insulation.
This approach may seem logical, but can result in severe problems during summertime, where the solar gain is stronger while it already is warm, and the result is overheating. Ironically it does energy-wise in general “cost” more to cool a building down than it does to heat it, which is why overheating should be avoided.
One way to counteract overheating without active cooling is the use of sunscreens. Because of the path of the sun, its angle is much lower in the winter than in the summer, approximately 10° and 45° respectively. This means that a stationary screen, e.g. a overhang can block most of the sun during summer, while allowing it to pass in the winter. Movable screens are even better, as they can be adjusted to the actual situation. These can be either automatic or manually controlled.

Another problem with the south facing windows is that the great amount of direct light can induce glare, which again can result in great discomfort by the occupants.



Solar shading, blocking the sun during summertime



Solar shading, allowing the sun to pass during wintertime

This problem can of course be reduced with the aforementioned movable shading, but this could also mean that the occupants screen for the sun to avoid glare, and thereby shut out the solar gain that is necessary to keep the energy usage low.

On the other facades the solar gain is neglected by the heat loss, especially on the western and the northern facade. However, according to the previous section, other energy factors like electricity should not be ignored. One of the great consumers of electricity is the artificial lighting, and optimising the natural lighting is a good start at lowering the total energy usage. It seems to be quite a challenge to meet the passive house standard, while still providing an acceptable amount of natural lighting in the north facing parts of the building.

The risk of glare problems is not that distinct in the case of north facing windows, since they will only provide diffuse daylight which will never be strong enough in itself to create glare. A bad geometry will however be able to result in a situation, where the contrast between light and shadow will be strong enough to strain the occupants eyes and thereby causing discomfort.

Indoor Climate

The determination of the indoor climate is based on Cen Report 1752. This tool is used to define certain design criteria, in order to obtain a chosen comfort class.
Since comfort is a subjective term, the criteria given are not absolute, but appear in the form of intervals and percentage of dissatisfied occupants. The higher the comfort class is, the lower the permissible intervals will be, thereby making sure that the percentage of dissatisfied occupants will be as low as possible.

The design criteria take thermal comfort and the indoor air quality into account. Thermal comfort defines aspects such as operational temperature, draught and temperature differences.
The indoor air quality section is used to calculate the required ventilation rate in order to secure a acceptable quality of the air. Furthermore the permissible level of noise from the ventilation system is defined.

For this project the thermal comfort has been set to class B, which is a quite good quality, while it is not so energy demanding as class A.
The design criteria for the different rooms are listed underneath.

The Passive House standard has its own requirements for the indoor air quality, namely a ventilation rate of $30m^3/(h*person)$, and a maximal indoor temperature of 25°C. These are deemed to be approximately identical, to the listed design criteria.

Design Criteria							
	Comfort Class	Operational temperature °C		Permissible mean air velocity m/s		Sound Pressure dB (A)	Ventilation rate h^{-1}
		Summer	Winter	Summer	Winter		
Living room	B	24±1.5	20±1.5	0.2	0.15	35	2.46
Kitchen Dining area	B	22±1.5	18±2.0	0.2	0.15	40	16.41
Bedroom	B	24±1.5	22±1.5	0.2	0.15	30	1.74
Room	B	24±1.5	22±1.5	0.2	0.15	30	1.74
Toilet_Bathroom	C	26±2.0	23±2.5	0.28	0.21	30	1.33

Overall Design Criteria

Living room

Room sizes				
Room height		2.7	m	
Area		96	m^2	
Volume		259.2	m^3	
Number of occupants		5	Occupants	
Thermal comfort	Class - B			
Activity level of occupants		1	met	acc. to CR 1752 table D.1
Clothing insulation	Summer	0.5	clo	acc. to CR 1752 table D.2 og D.3
	Winter	1	clo	acc. to CR 1752 table D.2 og D.3
Operational temperature	Summer	24±1.5	°c	acc. to CR 1752 figure A.2
	Winter	20±1.5	°c	acc. to CR 1752 figure A.2
Desired maximum PPD		10	%	acc. to CR 1752 table A.1
Desired maximum dissatified due to draught		20	%	acc. to CR 1752 table A.1
Permissible mean air velocity	Summer	0.2	m/s	acc. to CR 1752 figure A.3
	Winter	0.15	m/s	acc. to CR 1752 figure A.3
Desired maximum dissatified due to vertical air temperature difference		5	%	acc. to CR 1752 table A.1
Permissible air temperature difference		3	°c	acc. to CR 1752 table A.2
Desired maximum dissatified due to warm or cold floor		10	%	acc. to CR 1752 table A.1
Permissible range of floor temperature		19-29	°c	acc. to CR 1752 table A.3
Desired maximum dissatified due to radiant assymetry		5	%	acc. to CR 1752 table A.1
Permissible radiant temperature assymetry	Warm ceiling	5	°c	acc. to CR 1752 table A.4
	Cold ceiling	14	°c	acc. to CR 1752 table A.4
	Warm wall	23	°c	acc. to CR 1752 table A.4
	Cold wall	10	°c	acc. to CR 1752 table A.4
Indoor air quality				
Ventilation rate required for comfort				
Expected occupancy		0.07	Occupants/m^2	acc. to CR 1752 table A.7
Expected sensory pollution load caused by occupants		2	Olf/occupant	acc. to CR 1752 table A.6
Expected sensory pollution load caused by the building		0.1	Olf/m^2	acc. to CR 1752 table A.8
Total sensory pollution load	G_c	0.24	Olf/m^2	
Desired indoor air quality	$C_{c.i}$	1.4	dp	acc. to CR 1752 table A.5
Outdoor air quality	$C_{c.o}$	0.1	dp	acc. to CR 1752 table A.9
Ventilation effectiveness	ε_v	1		acc. to CR 1752 annex F
Required ventilation rate	$Q_c=10xG_c/(C_{c.i}-C_{c.o})x1/\varepsilon_v$	1.85	l/sxm^2	acc. to CR 1752 equation A.2
Required ventilation rate		2.46	h^{-1}	

Ventilation rate required from a health point of view is ignored since the building has a low pollution load

Permissible A weighted sound pressure level generated and/or transmitted by the ventilation system	35	dB(A)	acc. to CR 1752 table A.10

Design Criteria for Living room

Summary

When designing low energy housing, it is important to keep track of the possibilities and limitations of the chosen approach. In this project, the passive house standard has been chosen as low energy approach.
It is however noted that this approach has a weakness, as it allows for a high usage of primary energy. There has to be taken great care to minimise this energy usage, and create a truly sustainable passive house.

A place where this often fails is in the orientation of the building, where windows are often placed carefully to gain an optimal amount of solar heat, neglecting the need for natural lighting in many rooms.

In this project, it is deemed important to secure a sufficient amount of natural light to all rooms, both from a qualitative and energy saving point of view. Furthermore a more refined experience of the light will be strived for in the kitchen and the living room.

The indoor climate has intentional been defined as a class B. Class A offers a better indoor climate, but does also cost more energy to maintain, and class B does still offer a satisfactory indoor climate.

Vision

Vision

The intention of this project is to unite the idea of a passive house, with the vision of an experimental piece of architecture. The context is full of traditional new projects, characterised by a high quality. This project will not stand behind in terms of quality, but will furthermore advance the development, by introducing a new and expressive architecture.

The project should rise from the character of the project site, and its context, as opposed to certain tendencies where projects are designed on basis of diagrams, and could be placed anywhere.

The project will aim at fulfilling the passive house standard, while still holding the primary energy usage to a minimum. At the same time ensure an adequate level of daylight in the secondary rooms, and an interesting and inspiring lighting of the kitchen and the living room.

Low energy usage is however not enough, as the inhabitants are to spend a lot of time in the dwellings. The indoor climate should also be an important factor, ensuring that the inhabitants will have comfortable conditions in their homes.

The primary users are defined as families, searching for traditional rural qualities like safety and facilities for their children, while still being close to the qualities of urban life. These users will be part of the middle class, leaving out social building and luxury flats.

Design

Design Parameters

In order to move towards a final design, a set of parameters, defining specific goals to fulfil for each proposal, has been formulated.
Each proposal has then in turn been valuated in accordance to the design parameters, and either been adjusted or replaced by another proposal, to ensure that all the parameters are met at an acceptable level.
The design parameters are:

- Solar heat gain
- Natural lighting
- Natural ventilation
- Views
- Balconies

Solar heat gains prove a critical role in the passive house standard, as they are needed to heat the dwellings. As a consequence, the most important aspect of the site, is the orientation, as the layout of the site allows for a north-south oriented stick only.
Thus great attention should be paid to the shape of the building, to allow for these critical solar gains.

As stated before another important factor in the energy usage, is artificial lighting, where up to 50% of the energy usage can be found.
Optimising the windows concerning natural lighting, will have a striking influence on the energy usage, and with todays standard of low energy windows, it should be achievable without exceeding the allowed energy usage for space heating.

In order to keep the primary energy usage low, the mechanical ventilation system can be combined with a natural ventilation system, which will take over during summertime, where a heat recovery unit is no longer needed.
A natural ventilation system does however bring along some demands for the design of the building, both through the geometry of the building envelope in order to

make the system work, and through the internal arrangements in order to ensure an optimal air flow.

The placement next to the Limfjord allows for great views at the water and the Aalborg side, which is regarded as a quality, as residents put an ever growing importance into the aspect of having a view.
Again a great deal of attention should be put into the shaping of the building, as a poor layout would not only shade for the sun, but also block the view.

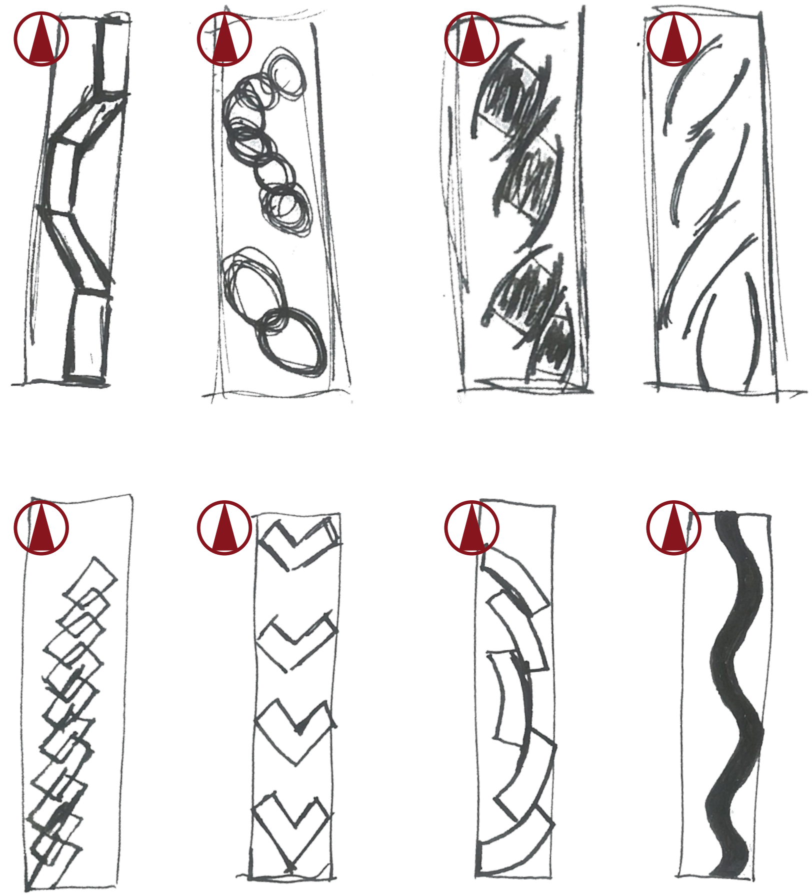
The best way to allow all inhabitants in a high rise building to have a private outdoor space is to include a balcony in each flat.
The balconies should be placed in a way so they get sunlight in the most attractive times of use, during afternoon and evening, and should at the same time provide some degree of shelter against the winds that can occur.

Preliminary designs

The initial sketching phase consisted of several small sketches, depicting an overall building layout. Through these sketches, it was easy to estimate the performance of each proposal in relation to the design parameters.
Most proposals could be ruled out momentarily, during this phase, while some were allowed to be further detailed in order to test whether or not they could be suitable for the project.

Further detailing of a project proposal included primitive 3D models, to acquire a more precise understanding of shading on the structure, and the relation to the context.
Furthermore a floor plan was developed, which was used to investigate the possibilities for natural lighting, natural ventilation, views and the general functionality as a dwelling.
In this stage, the evaluation was still held on a qualitative level. Actual calculations were not initiated before a proposal was chosen for even further investigation.

The proposals from the initial sketching phase either consisted of building-strings, shaped in order to receive the highest level of solar gain, or of several structures placed together to create a building complex.
Virtually all proposals shared the same advantages and disadvantages, which were all related to the project site.



Sketches showing different principles for placement of building volumes

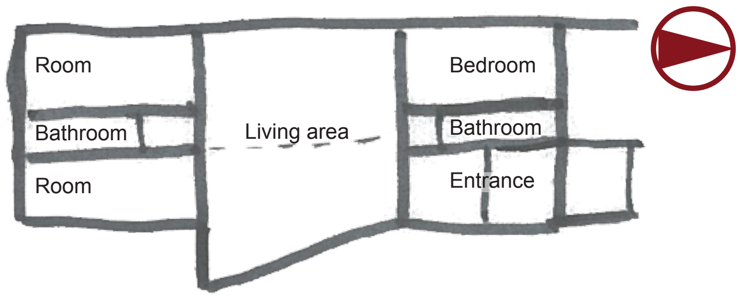
Because of the north-south orientation of the site, the always present problem of the building shading for itself, was applicable to all proposals.
By deliberately designing the structure in a slender shape, it was possible do retain a high efficiency of the natural lighting from the east and the west.
At the same time, the longest facade would be exposed to the predominant winds, which follow an west-east bond direction.
Views would mostly be satisfied as soon as the solar heat gain was solved satisfactory, as the main view is directed towards the south. It is however possible to create an attractive view without directly south facing windows, as the view can be oriented in a south-west/south-east direction.

The conclusion of these early tests was that the best approach would be a line of consecutive masses, displaced to allow as much facade exposed to the south as possible.
Experiments with several independent structures were considered unfavourable, since they did have the problem of shading, while lacking the benefits of lower heat losses due to the bigger surface of the climatic shell.

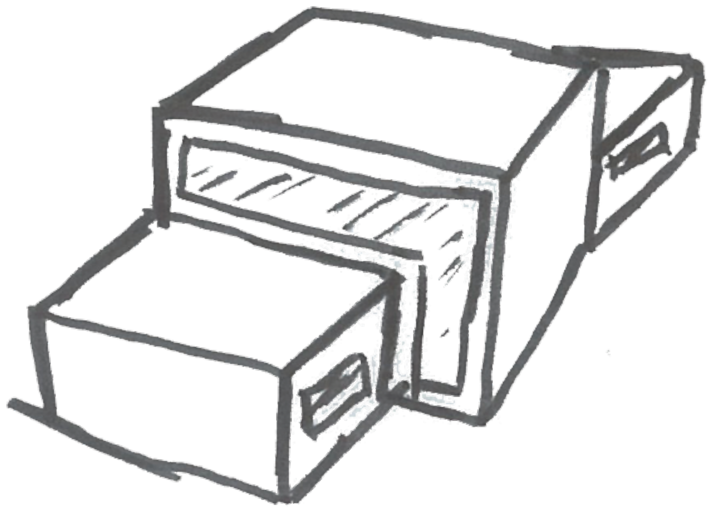
Stackable Units

The essence of this approach was to allow the main living area to stretch from the east to west in order to obtain the maximal amount of natural daylight, while at the same time giving free passage for cross ventilation during the summer.
The bedrooms were placed north and south of the main living area with the bathroom in the middle of the building, as it did not have the same need for daylight.
As an extra spatial quality the living area was double high, where the actual living room was an extra floor above the kitchen featuring a direct connection to the dining area.
This feature also meant that the natural ventilation system could be augmented by using the principle of thermal buoyancy, which works best in high rooms.

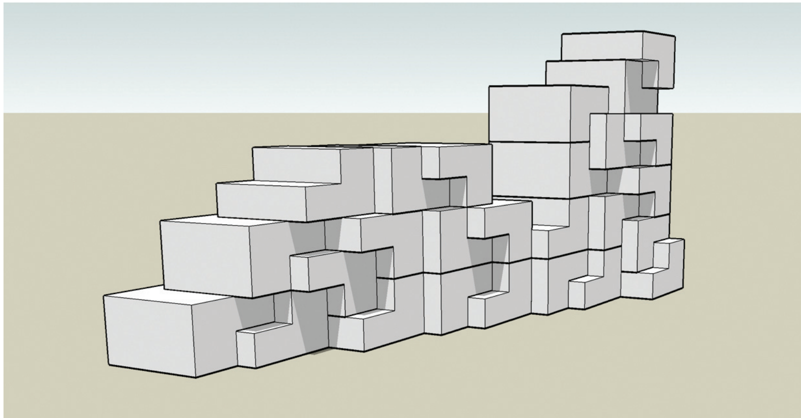
When stacking the units they would shift horizontally and create a jigsaw pattern, where the access shafts would be placed where the units overlapped.
This structure was supposed to build up towards north, meaning that the southern units would be low, close to the water, while the northern units would be placed high, having access to a greater view. This, however, was in direct conflict with Aalborg Kommunes vision of a tower, marking the area.



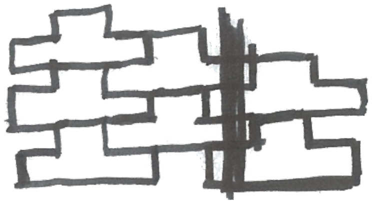
Stackable Unit: Floor Plan


Stackable Unit: Perspective

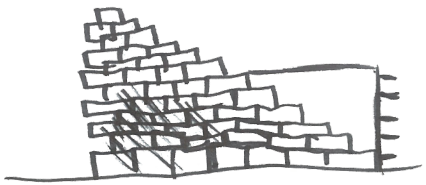
The individual units would also be displaced in the east-west direction to ensure that every flat would get a share of the direct sunlight. It soon became evident that this shifting did not allow enough sun light to pass, before the building started shading for itself. Furthermore, this approach added a lot of surface to the thermal envelope, where energy could be lost.



Volumes shifting horizontally



Stackable Unit: Stacking principle



Stackable Unit: Stacking principle

A quick calculation using the month average tool confirmed this, as the calculation resulted in a unacceptably high energy usage seen in relation to the passive house standard.

Architecturally, the proposal started as an interesting idea where the individual units were clearly marked in the facade, almost like a piece of patchwork. When the units began shifting in and out, this effect started to become a bit to excessive in relation to the context, reminding of the pragmatic wave which is specially popular in the Netherlands.

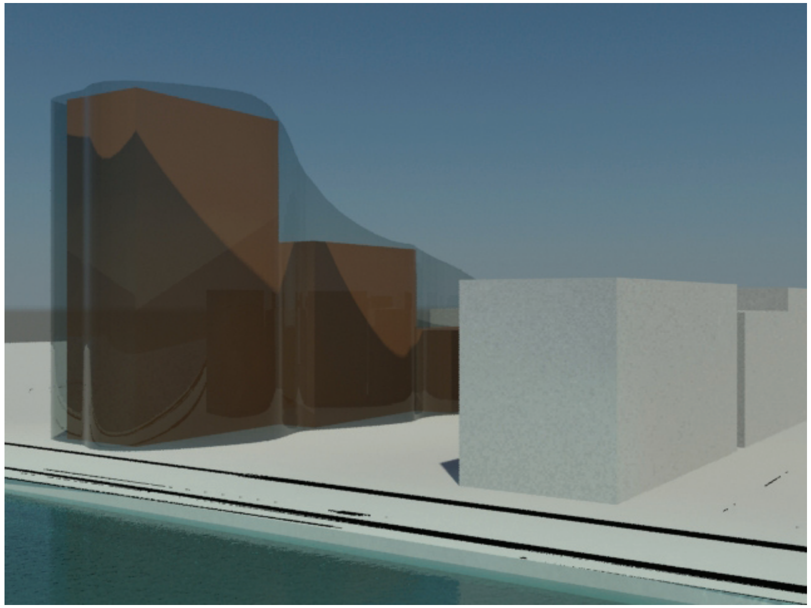
Boxes

Another proposal had three rectangular wooden towers shift in plan, in order to create more south-facing facade. Initially a glass shell surrounded the building, acting as a solar collector during winter, preheating the air, and as a chimney during summer, boosting the effect of natural ventilation.

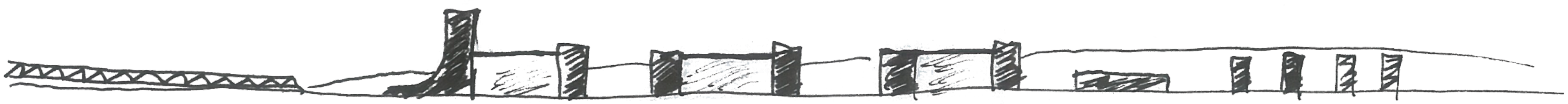
The problems with the shell was that as a common thermal zone linking the flats, it allowed noise to travel from one flat to another.

Also, during summer, it would probably prove quite difficult to avoid overheating, while it would be necessary to penetrate the glass shell in order to get access to outdoor areas like the balconies.

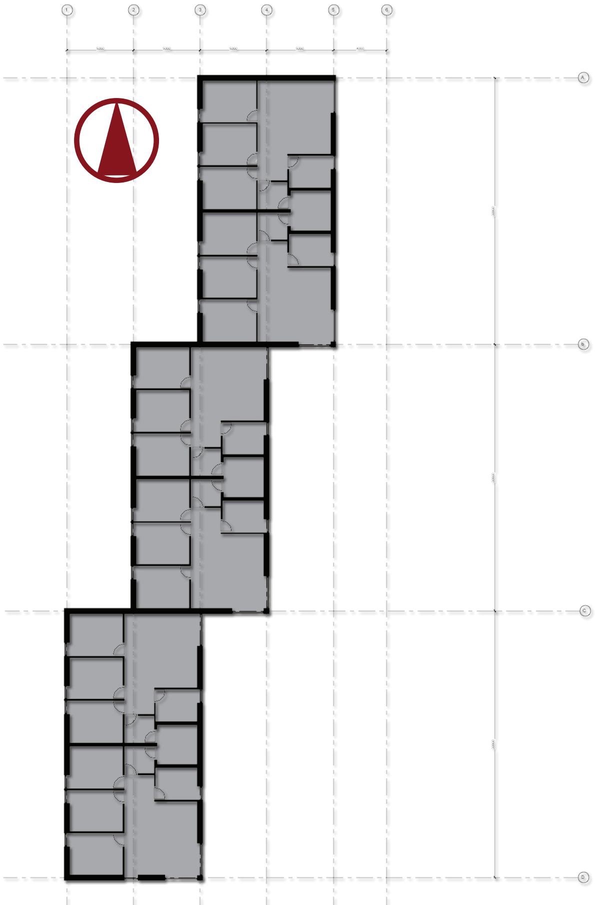
Furthermore it would in general probably be uncomfortable, living inside a glass shell, feeling isolated from the rest of the world.



Boxes in a glass shell



Concept for transition between urban context and park

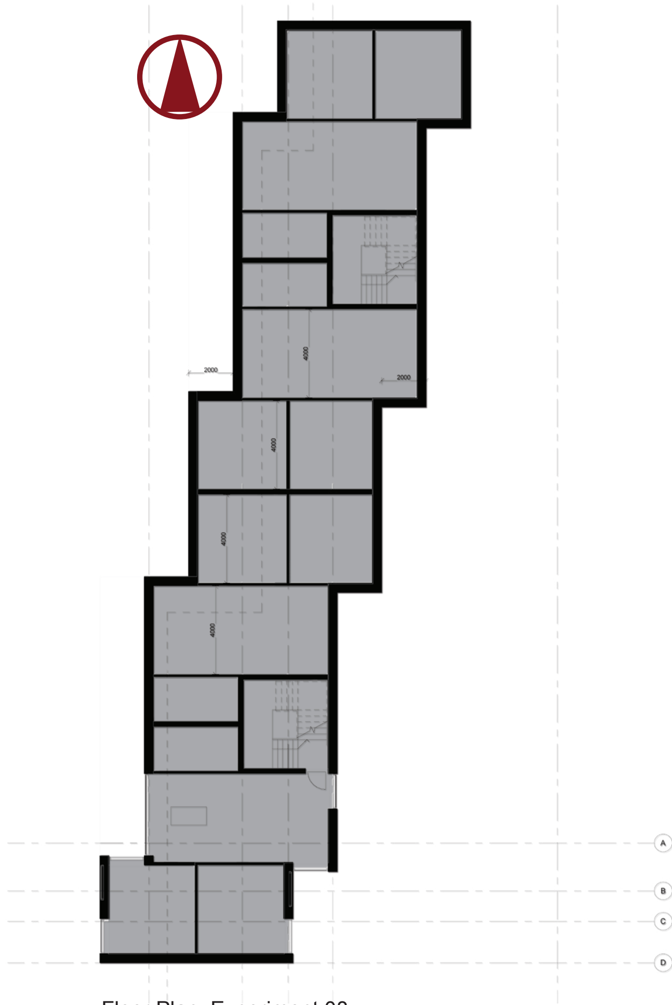


The glass shell was discarded, but the displaced boxes were investigated further, since the idea of a series of wooden boxes, with an almost furniture-like feel placed at the water, seemed like a strong concept. Furthermore the strict shape inspired simple and functional floor plans.

Yet the shown proposal has some problems regarding its floor plan, where the first problem is a inadequate amount of solar heat gain. The three displacements are meant to provide south-facing facades, harvesting the sun, but the displacements are too small, being in total shade soon after midday.
Placing all the bedrooms to the west does not only result in hot bedrooms at nighttime because of the afternoon sun, but would also block for natural lighting of the living room in the afternoon, it would also block for the access to west-facing balconies.
It should however be noted that natural cross ventilation would work properly in this scenario, as the bedrooms will be unused during daytime, and not produce pollution allowing fresh air to enter the living area. During night, when the air is being polluted, the living area is unused, and the polluted air can be extracted that way.

In a further refinement the apparent problems with the floor plan were solved in a series of proposals where the flat was split into two floors, with the kitchen, dining area and living room residing in a double high core, just like in the stackable unit concept.
All the bedrooms were now placed on top of each other, placed opposite the service core containing stairwell and bathrooms.

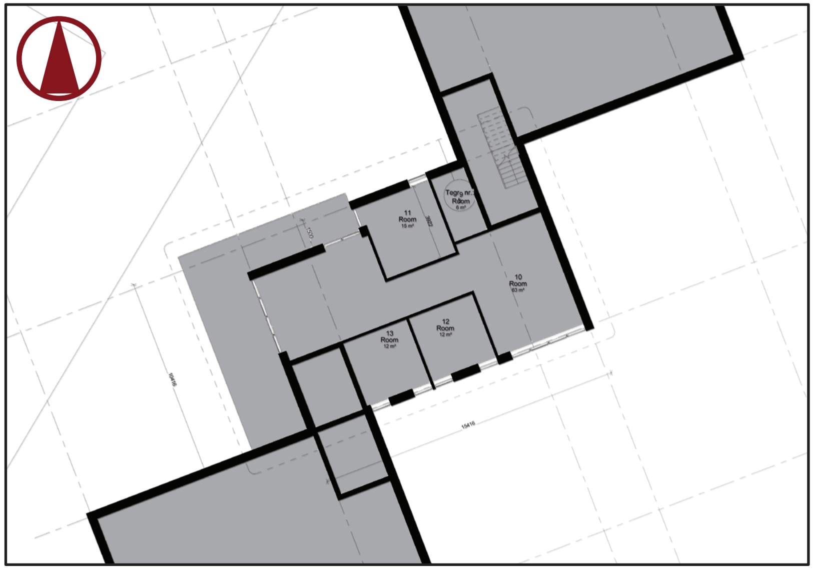

Interior perspective: Experiment 09



Floor Plan: Experiment 08

The floor plan still was not absolutely satisfactory, as the stairwell demanded a lot of floor space as it had to go through both levels of the flat in order to grant access to the next flat. Even worse, the problem with the building shading for itself was still present.

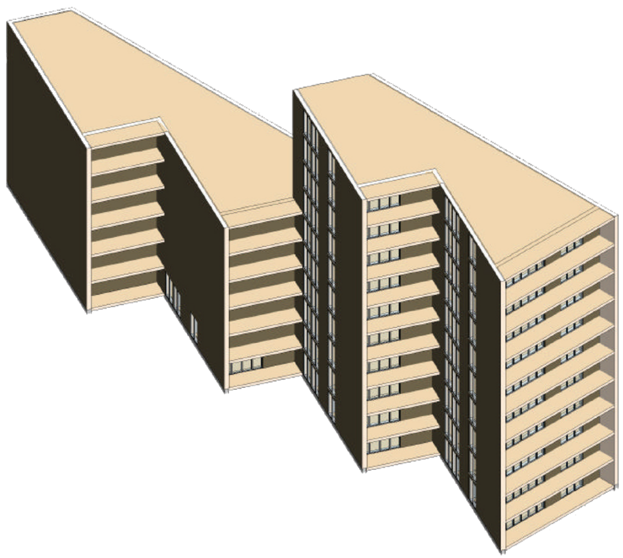
In another proposal the flats were reduced to one storey again, and the floor plan was rotated in an effort to acquire a higher amount of solar heat gain.
The kitchen was placed at the eastern side of the building, which ensured daylight in the morning an at noon, while the living room would benefit from the afternoon and evening sun.
Even though the building was oriented to optimise the solar gain, it still was not enough, as the south-east facade would be in total shade soon after midday, and the western facade would not receive any direct sunlight at all during wintertime.



Floor Plan: Experiment 10

Optimised Volume

In an effort to remedy the shading problems, the east facade was straightened out while leaving the west facade in a jagged shape, allowing the sunlight to enter the building in the afternoon hours.
Like in the previous proposal, each flat was limited to one floor, in order to obtain a simpler, more functional layout of the floor plan.



Perspective: Optimsed Volume

Floor Plan: Optimsed Volume

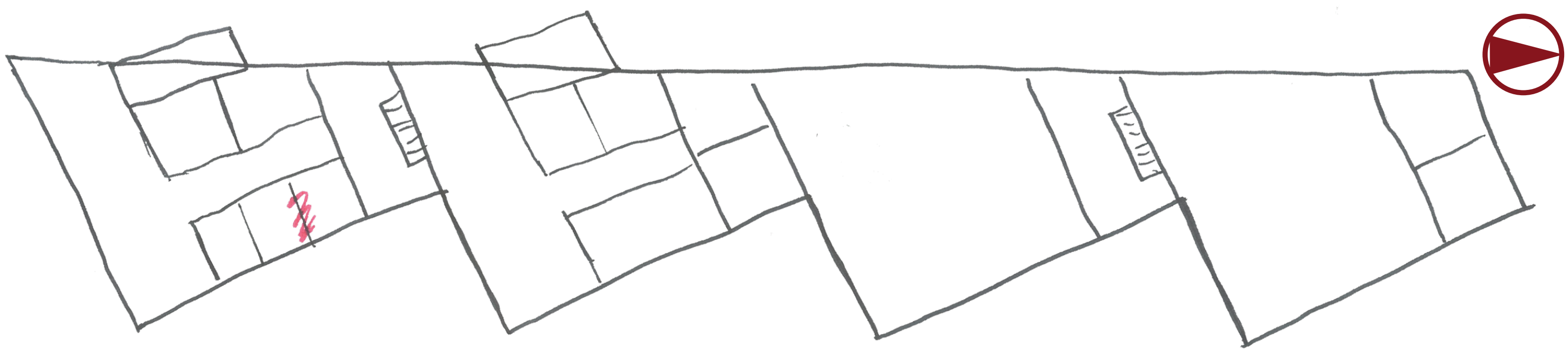
Technically, this proposal worked quite well in most aspects. Experiments using the DiaLux software showed that there was a sufficient amount of daylight in all primary rooms. At the same time the plan solution seemed well suited for natural cross ventilation.
Even though the east facade was relieved of all elements that generated shade, and therefore was receiving solar gain until one o'clock, the western facade did not receive anything at all, since the sun had already set.

Aesthetically the proposal fulfilled the design parameters as there were great opportunities for views, both from the kitchen and the living room, from which there was also access to a south-west facing balcony.

However there was a problem with the rather narrow kitchen area, which was even further emphasised in the shown example, where the entrance cuts off the connection between kitchen and living room.

The problems with the building shading for itself could be solved by mirroring the plan, so the east facade was jagged and the west facade was straight.
This arrangement allowed for plenty of solar heat gain on the east facade, while a high level of natural lighting was maintained on the west facade.

This proposal was chosen for further detailing, as it functioned well, both aesthetically and technically.



Floor Plan: Optimsed Volume

Detailing

Indoor Climate

When the proposal reached a high enough level of detail, it was possible to do some realistic calculations to estimate the indoor temperatures for the individual rooms. The used method can also be used to calculate which ventilation is rate required to achieve a good indoor climate.
The method used is the 24 hour average temperature calculation, which calculates the average temperature over 24 hours and the maximum temperature, based on user input containing geometric data, ventilation rate and internal heat loads.

In this case this tool has been used to investigate wether or not overheating would occur during summertime, as a result of inadequate ventilation or too high solar radiation.
The calculations have therefore been based on the outdoor temperatures from august, as it is assumed to be the warmest month. At the same time, the flats calculated are the southernmost of both types, as they are the ones with respectively the highest solar radiation and the smallest area of exposed facade.

The ventilation rates where initially obtained from the design criteria, which again are based on CR1752. The resulting temperatures where evaluated in accordance with whether or not they fulfilled the demands from the design criteria, and whether the ventilation rate should be adjusted.

The results were all in the permissible range, where the 24 hour average temperature ranged between 22°C and 25°C, and the highest calculated maximum temperature was 26.7°C.

The problem with the 24 hour average temperature calculation is that it is a static calculation, meaning that it depends on average data for the outdoor temperature, which again results in a lower level of precision.
In order to get truly reliable simulations of the indoor climate a more advanced tool, like BSim, is needed. The 24 hour average temperature calculation tool was however never meant to give such a precise result, but is intended as a quick tool to estimate the characteristics of a proposal during the sketching phase.

Natural Ventilation

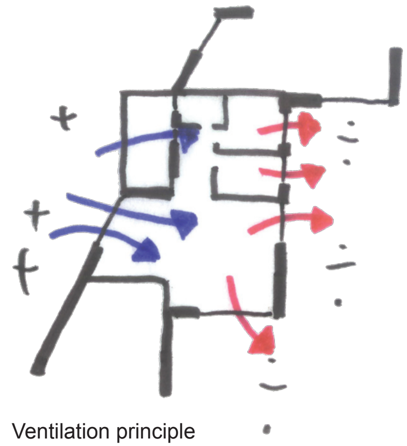
In an effort to reduce the energy usage, it was decided to use natural ventilation during summertime, as it, unlike a mechanical ventilation system, does not require energy to operate.

In general natural ventilation can be driven in three ways: through wind, through thermal buoyancy or through a combination of both.
As thermal buoyancy requires a rather high room height, normally two stories at least, in order to work properly, this principle is not applicable in this project.
Wind driven natural ventilation can either act single sided or as cross ventilation, where cross ventilation is more effective.

The site is well suited for natural ventilation of the cross ventilation type, as the building is oriented so the long east and west facades are exposed to the dominating wind directions, allowing every flat to be cross ventilated.

The effectiveness of the natural ventilation has been calculated using principles from By & Byg Anvisning 202, where the possible air change can be calculated based on information about meteorological characteristics of the site and the ventilation openings.

Single sided ventilation and cross ventilation



Ventilation principle

The result of the calculations, showed that the solution was effective enough to achieve a ventilation rate higher than the needed ventilation rate found through the design criteria and the 24 hour average temperature calculation.

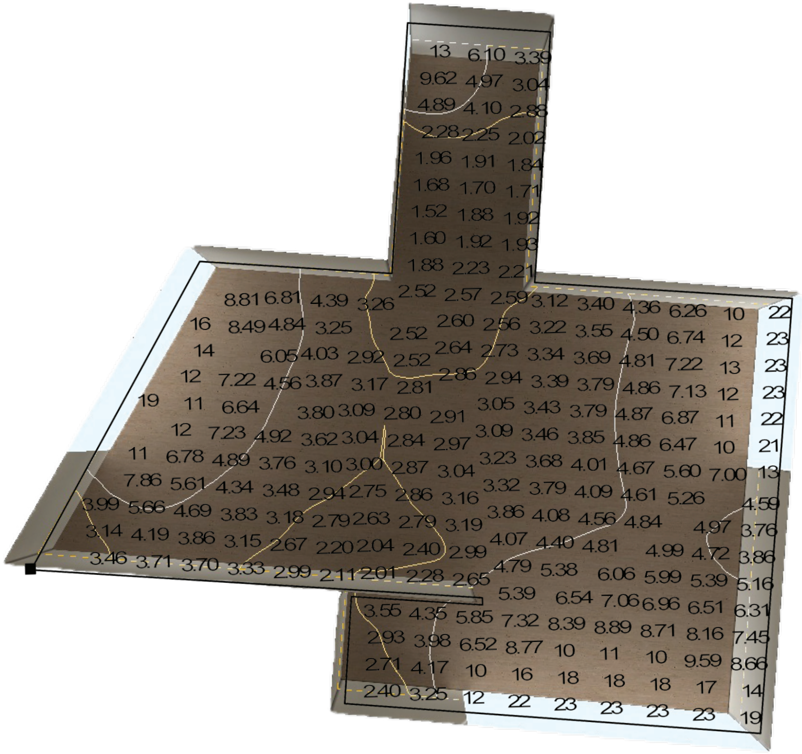
Windows

Initially all windows were intended as a modular system, where every window was one meter wide, reaching from the floor to the ceiling.
This system did cause some problems, mainly in furnishing the rooms, where this kind of window was not optimal. There were also some considerations whether this kind of window would result in too high a heat loss especially on the western facade, where no solar gain can be achieved during wintertime, where it is needed the most.
The consequence of this insight was a new system, where the tall windows were maintained in the kitchen-living area, where the natural lighting was considered specially important. A new system was found for the rest of the rooms, allowing them to be as flexible as possible, while still maintaining a high daylight factor.

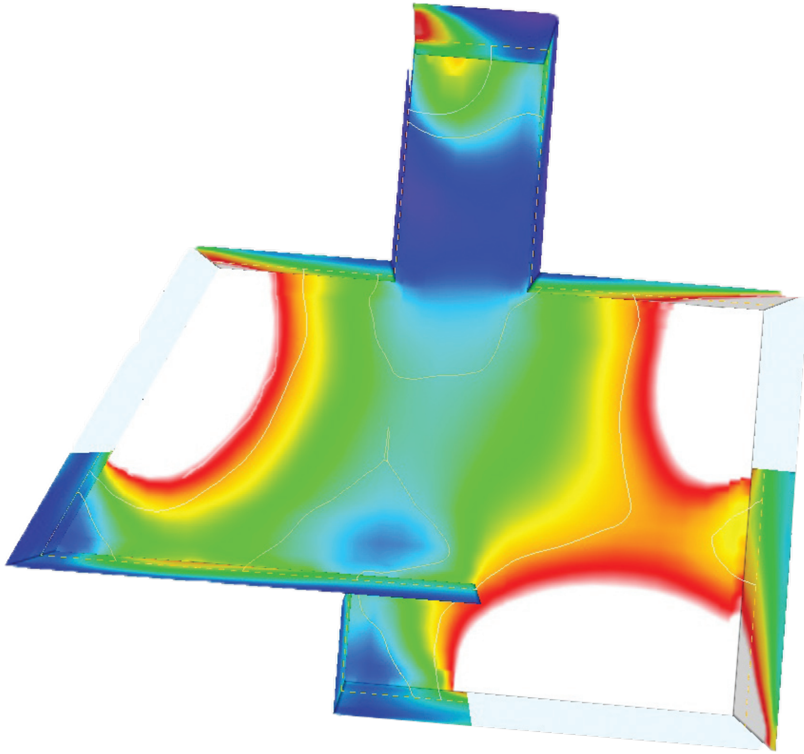
A new sketching phase was started, investigating how different window types would affect the facades. The window types were chosen from the criteria that they allowed the light to enter deep into the building. Therefore, it was important that the windows were placed high.
Parallel to be evaluated on their aesthetic qualities, the windows were tested in DiaLux, where the daylight factor and the daylight distribution could be simulated.


Experiments with windows

The sketching phase resulted in a system similar to the tall windows in the kitchen-living area maintaining the width of one meter, but instead of starting from the floor they started 900mm above the floor, still reaching the ceiling, which was lowered 500mm in relation to the kitchen-living area.
The DiaLux simulations showed that these window types would provide a men daylight factor of five percent or more, where five percent should be considered as a satisfactory level for a well lit room. At the same time the daylight distribution was evaluated during pseudo coloured representations of the rooms, and were likewise deemed satisfactory.



Daylight factor: Type B



Daylight distribution: Type B

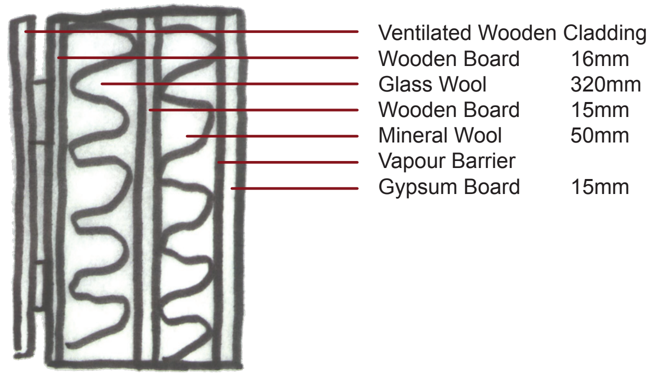
Constructions

One of the most important aspects of a passive house is the need for a high level of insulation, which again results in rather thick walls when using a traditional heavy wall construction based on bricks or concrete. Light wall constructions do not take that much space, and allow for a higher level of insulation.
It can be beneficial to use light wall construction elements for the climatic shell, and move the heavy constructions to the internal walls, so there still will be exposed thermal mass to even out the temperature fluctuations.

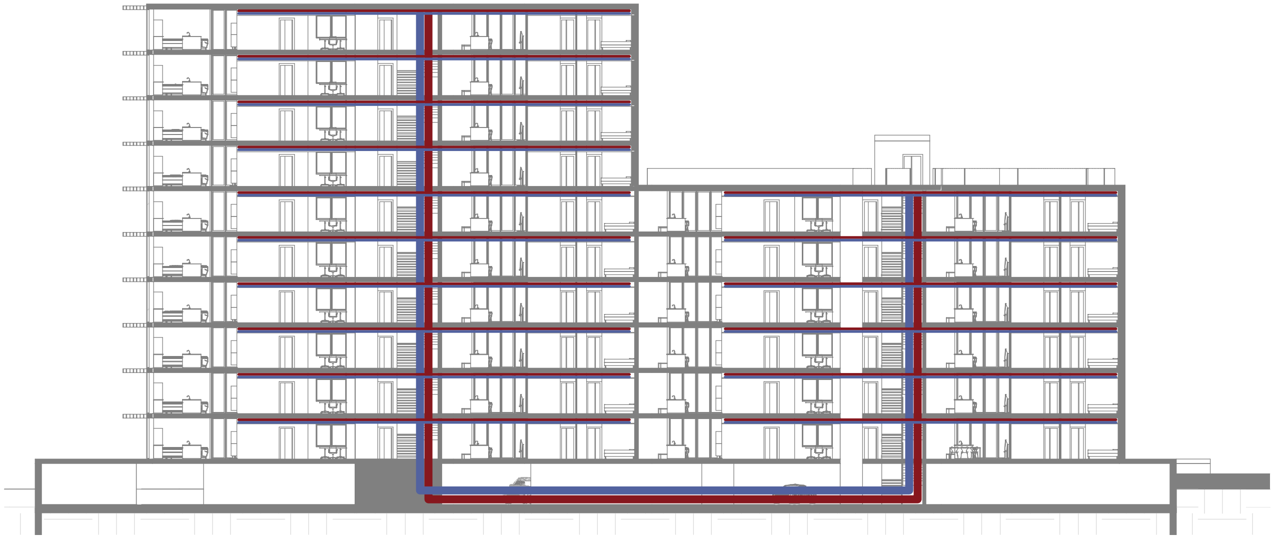
For this project a wooden facade cladding has been selected, partly because of its possibility to maintain a rather thin shape in relation to the amount of insulation, but also because of the aesthetical features, standing clearly out from the rest of the buildings at the harbour front, with its almost furniture like appearance.
The facade is approximately 430mm thick, and features an U-value of 0.09W/m²K.

The other constructions have similar thermal qualities, with U-values ranging form 0.089W/m²K to 0.15W/m²K, while the windows have an U-value of 0.53W/m²K.

In the kitchen-living area the room height is 2.7m, while it is reduced to 2.3m in the rest of the flat. This allows the ventilation ducts and similar supply systems to run behind a suspended ceiling, granting direct access to all rooms, before reaching the kitchen-living are, which can be reached from the end of the suspended ceiling.



Principle of outer wall construction



Principle of mechanical ventilation system

Passive House Verification

The passive house title is not a protected title, which means that every building can be called a passive house. There is however a passive house certification, which is commonly used to get established in the market, and later projects will be executed without certification.
In order to achieve the passive house certification an advisor approved by the Passiv Haus Institut in Darmstadt, has to verify data given in the Passive House Planning Package (PHPP) together with different informations regarding the project.
In this project the calculation tool in the PHPP has been used to verify whether or not the building would be capable of fulfilling the passive house standard.

Because the project is supposed to be heated by district heating, it is unfavourable to use smaller decentral ventilation units, which in all cases would be a too expensive solution. The alternative is to use a central ventilation unit, serving all flats.
This does again cause the passive house calculation to encompass the entire building.

The area of the biggest concern, regarding the calculation, was the problem of the building shading for itself. In the final proposal the south facing part of the jagged facade, were supposed to harvest the energy from the sun, but would be in shade at some time during the afternoon.
This was modelled into the PHPP tool by adding an additional shading, only allowing 30% of the sun light to pass, mimicking the time frame where the facade would receive sunlight.

The calculation showed a energy usage of 12 kWh/(m²a) for space heating, while the primary energy demand was 120 kWh/(m²a) and the infiltration 0.6 h^{-1}, thus fulfilling the passive house standard.

BSim

Even though a building has a low energy usage, it is not enough to leave it like that, it is also necessary to investigate the indoor climate in order to evaluate if it is inhabitable.
The 24 hour average temperature calculation gave a indication of the indoor climate, but it was a approximation as the data used for the calculation were static.
BSim uses a dynamic calculation, based on the Danish Reference Year (dry) which contains the average of hourly values for climatic factors, collected over several years.

BSim was in this project used to verify that overheating would not occur, when using natural ventilation and shading as the only cooling systems.

The simulation showed that there would be 20 hours above 27°C and 60 hours above 26°C, which is inside the acceptable limits stated in DS 474, where the amount of hours above 27°C should not be above 25, and the amount of hours above 26°C should not be above 100.
Simultaneously it could be estimated when this overheating would occur, and these periods were considered to be spread in an acceptable way.

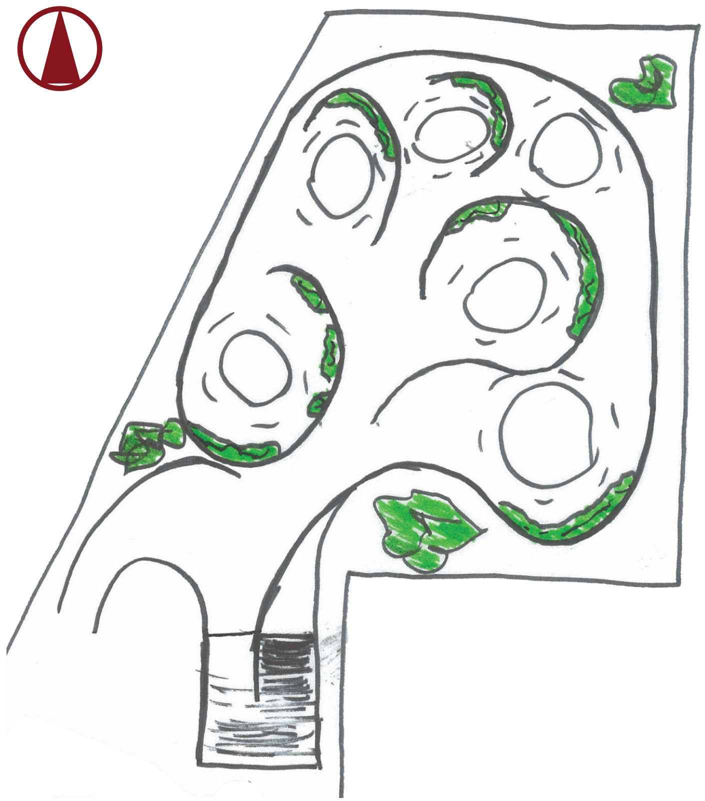
Roof Terrace

In order to grant a common outdoor space, which is still sheltered from the public, a roof terrace was to be included on top of the northern part of the building.
The main purpose of the roof terrace was to provide an outdoor space where it was possible to meet other residents, but there were also practical considerations to be taken, as the roof terrace would be quite exposed to the wind.

The idea was to place this lounge area in the very northern end of the roof, while the southern end of the terrace, next to the tower and the shadow thereof, would contain a service area. This service area should then incorporate functions such as outdoor drying facilities for clothes.
The lounge area was supposed to have a more organic shape as a response to the intended purpose of the area. The shape would then gradually become more stringent as it moved towards the functional character of the service area.

Inspiration for roof terrace

Plan: roof terrace



Plan: roof terrace

Facade

The facade is thought as a wooden cladding of vertical lamellas in natural colours. The facade would continue past the windows in the form of shutters, acting as solar shading, that can be open or closed according to the need for shading.
In order to refine the facade expression, a series of experiments regarding the cladding, and the articulation of the windows and their solar shading.

Quick sketches showing different solutions to these topics were produced and evaluated with the help of reference photos.

It was decided that the initial idea of vertical lamellas covering the entire facade, acting as a living facade, when the shutters open or close according to the use.

The biggest disadvantage of a wooden facade, is the risk of a fire spreading along it.
This problem can either be solved actively, i.e. by dimensioning or using fire-retardant materials, which however usually are poisonous.
Passive systems do not take action before the fire breaks out, an example could be the use of strategically placed sprinklers.
The most dangerous stage of a fire in this kind of houses, is when the windows break and the fire spreads out that way. Which is where sprinklers could make a difference, preventing the fire to reach the facade and spread to the rest of the building.


Inspiration for facade materials

Already in 1998, the wood industry was hoping that a change in the rules regarding wooden facades could be reached.
In North America there is a long tradition of building high-rise buildings with wooden facades, and the experiences from there seem to suggest that it is possible to build this kind of building in a manner that is still safe for the inhabitants.

Experiments with facade claddings

As an alternative to the wooden facade, could be using brickwork as the lamellas, which could be taken for wood when seen at a distance.
When coming close it would lack the materiality, and it would in general have the feel of being fake and dishonest.

Inspiration for shutters

Presentation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10

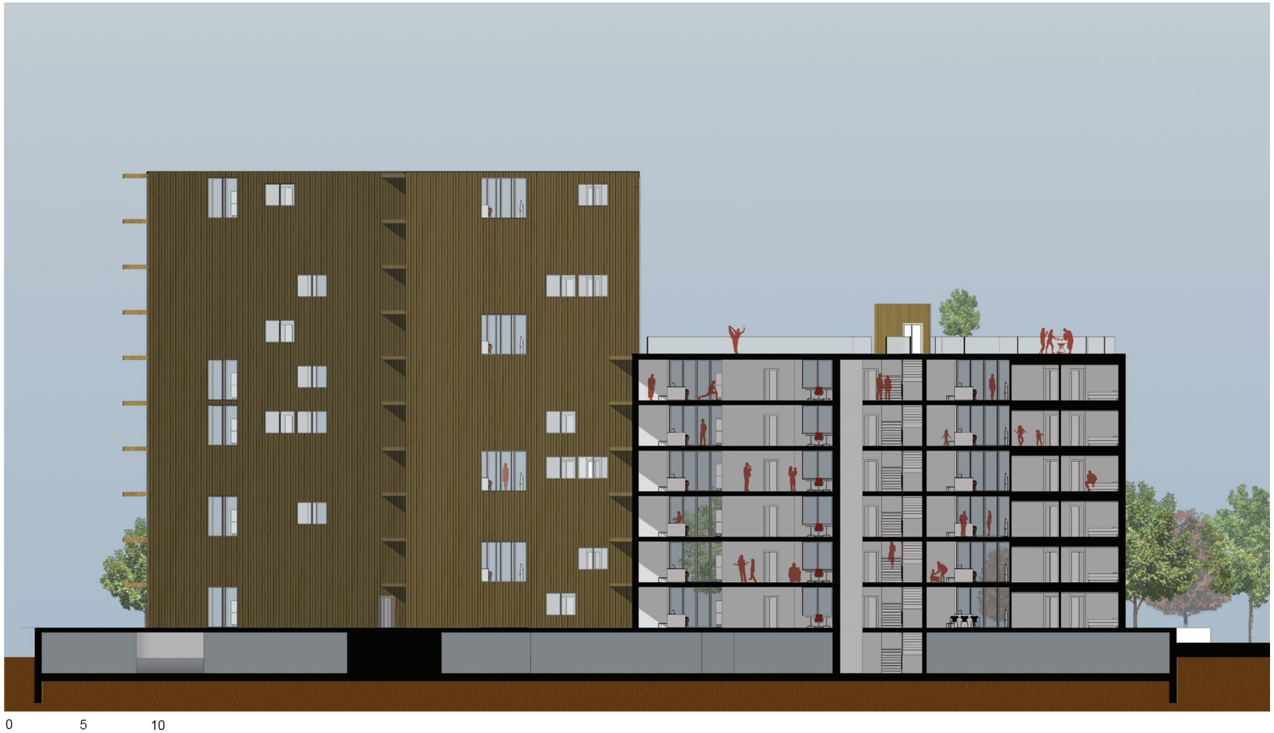
The Building

The building is part of a U-shaped complex, defining a sheltered garden space. The eastern facade, which is facing this common area, is dissolved into a jagged shape, allowing the building to have direct contact to this common area and to the harbour front of Aalborg to the south.
The western facade is straight, lining out the building plot. The balconies placed on this facade are breaking out of the facade, reaching for the park to the west and creating a link between the private outdoor space, and the recreational areas.

The building contains to different flat types, A and B, where Type A is again divided into Type A I and Type A II. The difference is that Type A I is located at the very southern end of the building, and as a consequence has the possibility to provide more windows to the south.
All flat types revolve around the living area, that consists of living room, kitchen and dining area.
This area is bright and spacious, as it has windows to both east, south and west, providing sunlight as well as a direct visual connection in all directions.
The balconies add yet another quality to the flats, allowing the inhabitants to enjoy the view and the fresh air, while still being sheltered by the mass of the building.

Situation Plan 1:500

Floor Plan 1:500



Section AA 1:500

The variable facade, will change its appearance according to climatic factors, or the mood of the inhabitants, who can overrule the automatic system at any time.

This results in a building that is never the same, that will almost have the character of an ever changing sculpture.

South Facade 1:500

West Facade 1:500

East Facade 1:500

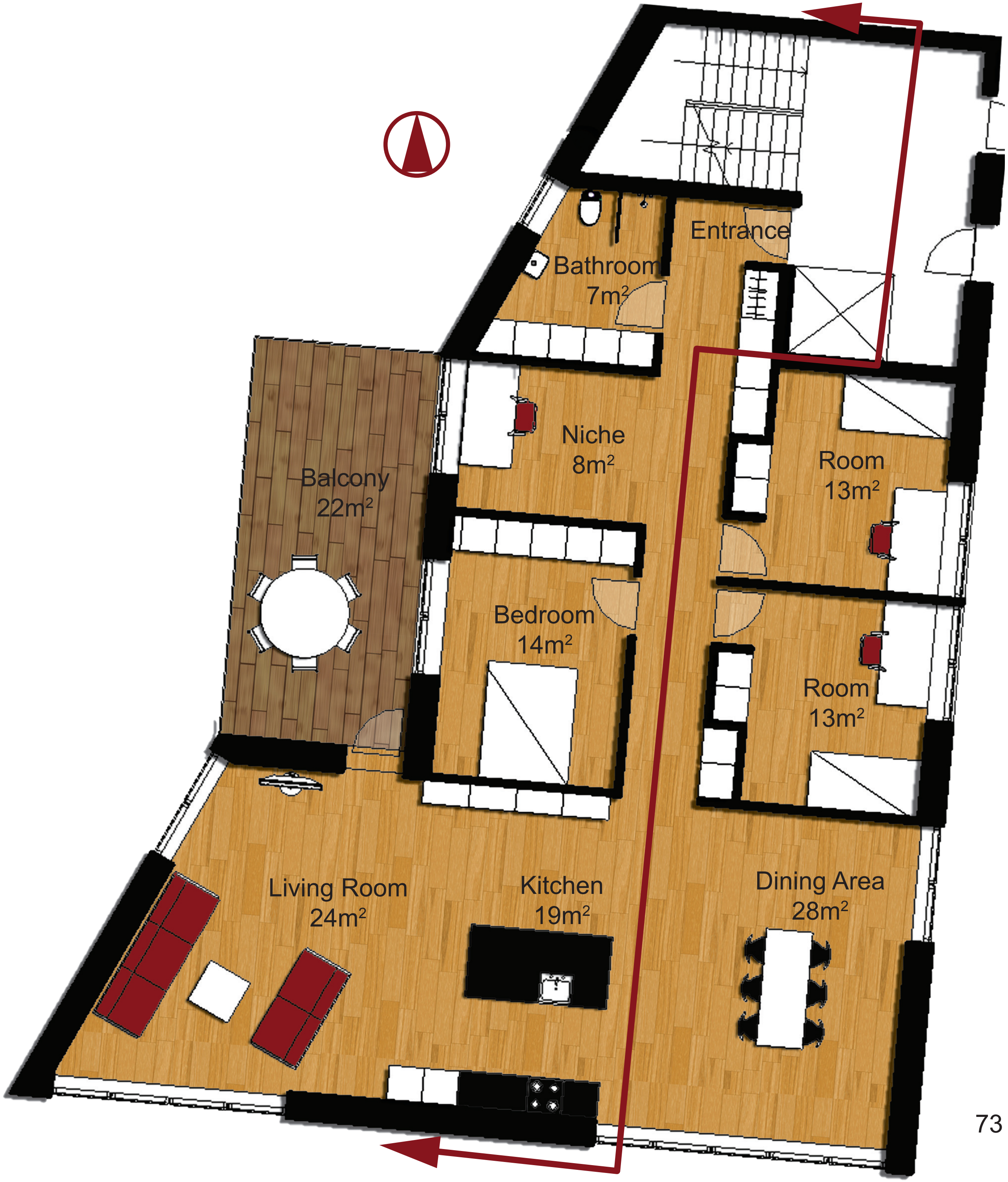
Type A

The Type A flat (the shown flat is of the type A I) is intended for the established family, needing room for the everyday family activities.

Other than the open planned living area, this flat has a bedroom, two smaller rooms and a niche in the hallway. This niche would normally be used as an office, as play area for the children, as a lounge area etc.
If there should be need for more rooms, the niche can easily be converted into a small room, with a light wall construction.

The dining area is placed in the eastern side of the building, where the jagged facade allows daylight to enter from the morning till the early afternoon, whereas the evening sun will illuminate the living room.
From the living room there is also access to the balcony, which also enjoys the benefits of the afternoon sun.

Section Type A I 1:100



Floor Plan Type A I 1:100

Type B

As the Type A flat is for larger families, or similar constellations, Type B is smaller, and aims at young couples moving together, maybe starting a family. Or at other user groups who could benefit of this kind of dwelling.

Just like in Type A, the living area is the central area of this type and as a result, the living area is nearly identical. The dining area is however larger in Type B, as the main entrance is placed in conjunction with it.

In this type, the hallway has been extended, and the niche is now part of the hallway. This is because the user group is assumed to appreciate an open plan solution to a higher degree.

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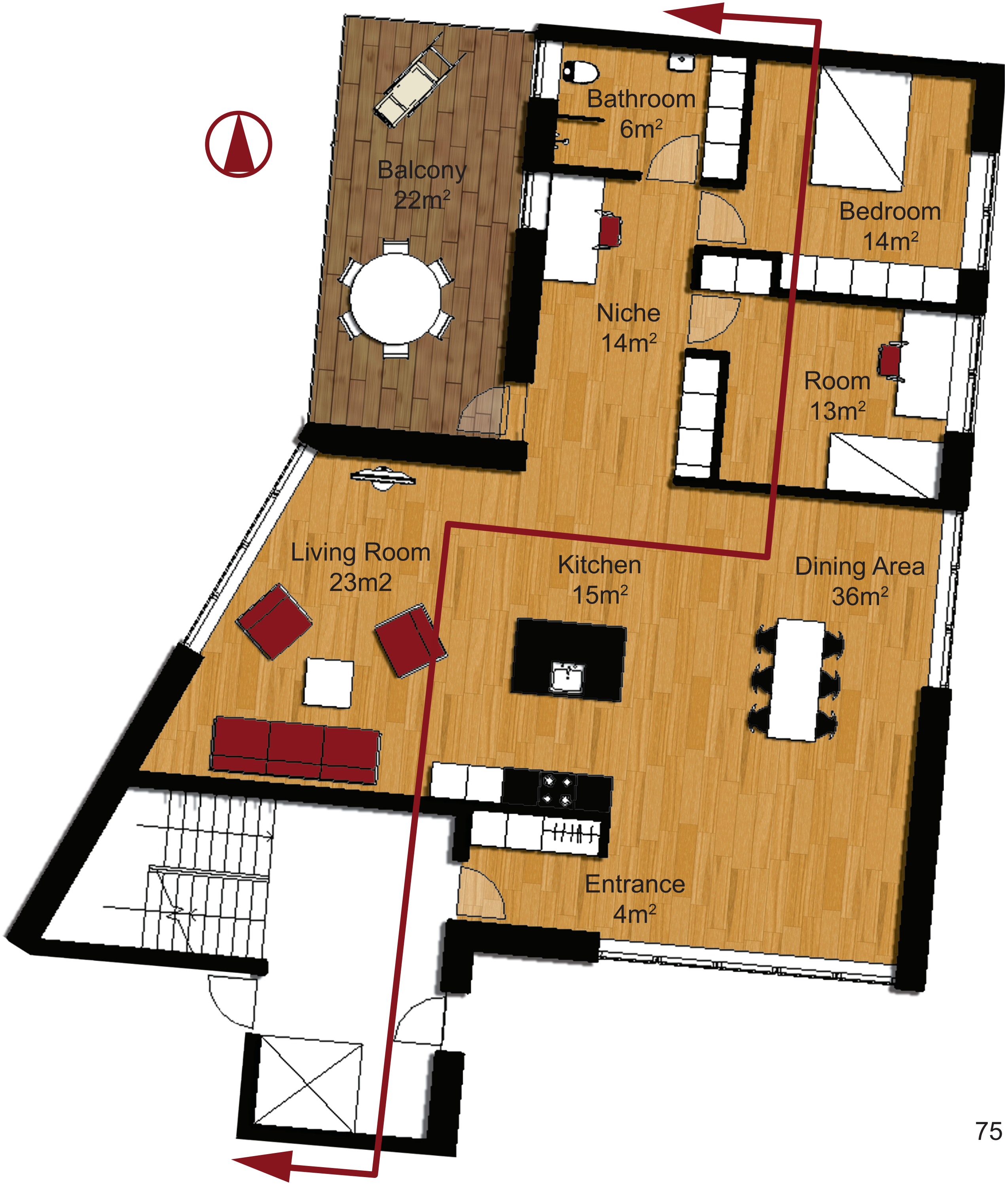
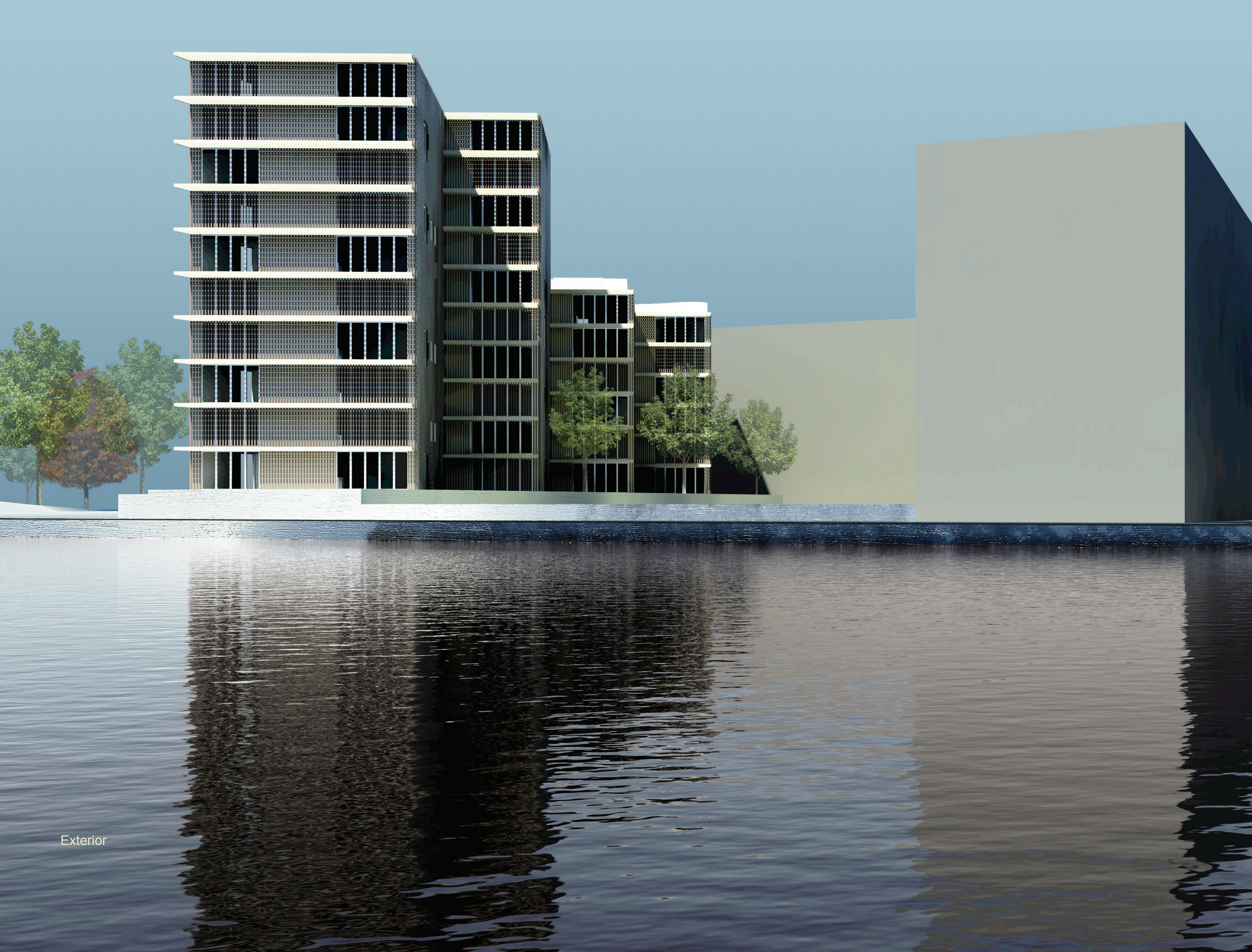
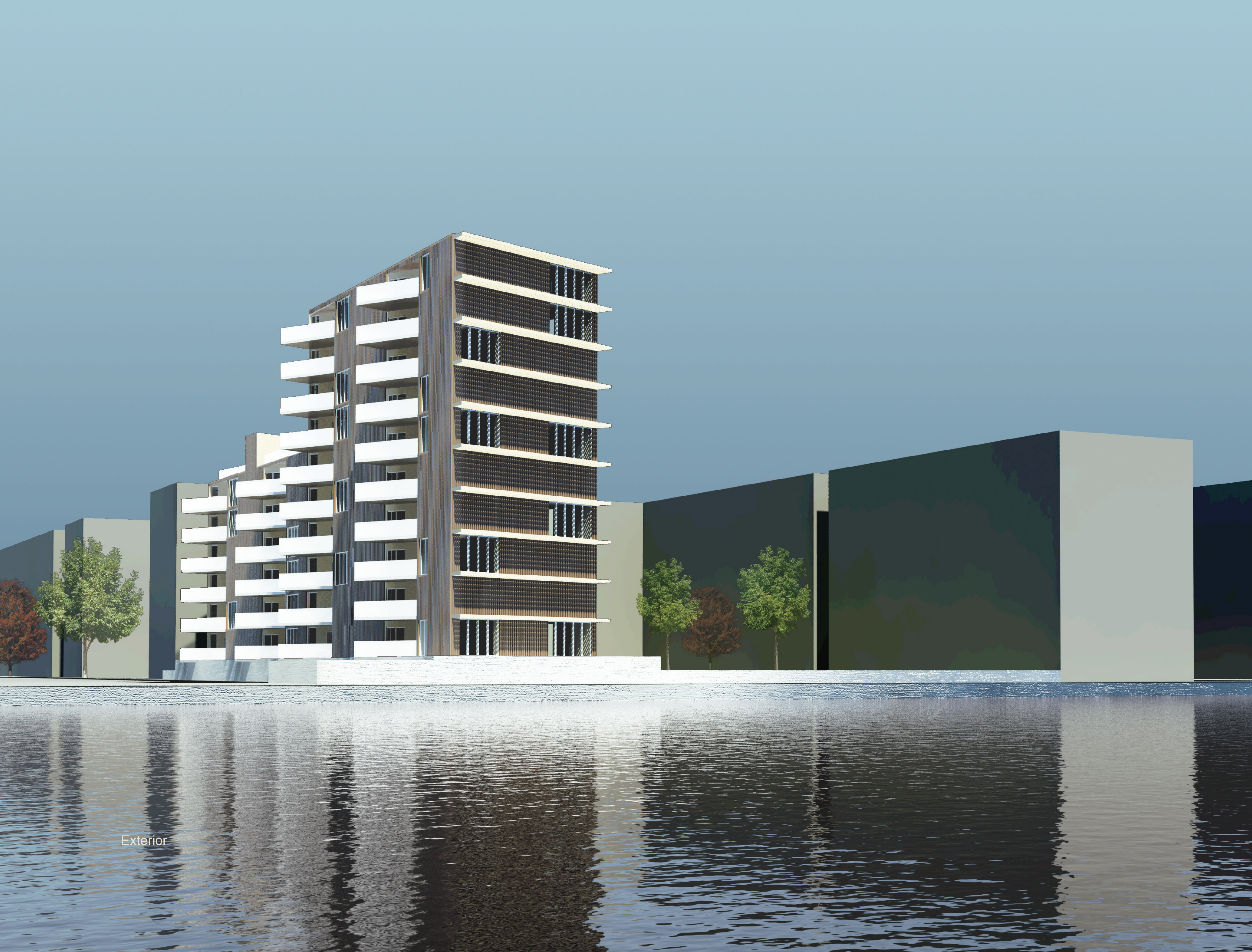
Section Type B 1:100



Floor Plan Type B 1:100

Interior: Type A I


Exterior


Exterior


Roof Terrace

Evaluation

Conclusion

The aim of this project is to build dwellings in an urban context, fulfilling the passive house standard, thus keeping the energy usage low, just as the stamp on the environment.

A lot of considerations have been made in order to reach this goal, mostly considerations of the orientation of the building, where the building plot entailed problems acquiring enough solar heat gain, which is important in passive house design.

Other measures to lower the energy usage, should also be included, when designing low energy buildings. Artificial lighting is considered to be one of the big consumers of energy, why great consideration has been put into the placement and dimensioning of windows, in order to optimise the amount of daylight in the dwellings.
Other than providing daylight and heating, the window placement increases the connection between the dwelling and the common area, between the dwelling and the harbour front across the Limfjord and between the dwelling and the park to the west.

In spite of having a low energy usage, the building has a high level of indoor climatic comfort, ensuring that the qualities of the dwelling are not disturbed by uncomfortably conditions.

The layout of the floor plans satisfies different inhabitants, with different lifestyles and demands. In general each dwelling is rather flexible, with open floor plans and disposable areas, allowing the inhabitants to adapt the dwelling to their lifestyles.

The building itself stands out in a striking way, with its ten storey high, ever changing wooden facade. The combination of natural materials, which are acting as were they alive, and the urban structure of a high rise building, acts as link between the city to the east and the park to the west.
This role as a link, is further underlined as the building opens up to these opposites in two different ways.

Discussion

One of the main concerns of this project, is to break with the prejudice that the passive house standard sets limitations so strict, that it is impossible to create a passive house of a high aesthetical quality.
The characteristics of the site did not make this task easier to achieve, as they added even more limitations.

It can be discussed whether this goal has been accomplished or not, the idea of a living facade giving the building an ever changing expression is one of the main parts of the concept.
This is however a feature which is becoming more and more popular with the rise of the low energy buildings, not only because of its aesthetic qualities, but also because it is often a necessity in order to prevent overheating.
The idea of the living facade should however be interpreted in a different way, as it tells the story of a box, a piece of furniture, that is opened, according to demand.

The 10 storey high wooden boxes, that the south and the east facade remind of, are not exactly a common sight in Denmark. This is because of the risk of the facade catching fire, resulting in a rapid spreading from floor to floor, has caused the authorities to ban wooden facades on high rise buildings.
Experiences from other countries where this kind of construction is allowed, have on the other side triggered the development of techniques to ensure that a fire would not escalate into a catastrophe. The question is whether or not the Danish authorities will change the regulations, in order to allow wooden constructions in high rise buildings.

Finally it can be discussed if it is realistic to assume that a dwelling of this magnitude, in this location, will be allowed to be sold as anything less than a luxury flat.
There is a tendency that dwellings near the water become quite expensive, especially in the cities, even though they do not offer much more than the view to justify this increase in price.
The building cost should not be significantly higher, just because the house is built near the water, but as long as people are willing to pay more for living at the water, the decision to built expensive luxury flats, can not be criticised.

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Illustrations

All illustrations not included in this list are own productions.

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