spiritual architecture

ma4-ark3 2012

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synopsis

Through the concept *spiritual architecture* the goal was to design a plus energy-apartment building where the apartments would promote spiritual living for the residents. The atmosphere of the dwellings where seen as the main tool in order to achieve this – manifested through the materials, the light, the flow and layout of the apartments and by built-in furniture. The layout of the apartments where chosen in order to promote individualism and to have the opportunity of renting rooms out. The bigger apartments have more than one balcony – giving opportunity of private outdoor area for all of the residents in the apartment. 30% of the façade are windows and all the apartments get lights from all four corners of the world. Due to the shape of the building the temperature and energy frame are lower than in traditional rectangular buildings – and the conditions for cross ventilation is optimized.

preface

This report is documenting the process and the results of the master thesis developed by student ma4-ark3 at Aalborg University, the department for Architecture, Design and Media Technology during the project period of 01.02.12 - 23.05.12.

The report is organised after the phases of the project – starting with the analysis phase, moving on to the sketching and the synthesis phase, while ending with the presentation of the project. The presentation is shown partly in this report and will be supplemented with models at the exam.

The report includes appendices, containing calculations not utilised directly in the project together with input and output values necessary in order to perform different calculations.

The Harvard Style of Referencing Published Material is used throughout the report and all sources are listed in the end of the report.

L.Y. Elvelund

Linda-Yvonne Elvelund

table of content

*a typical Danish apartment -
white and with designer furniture*

introduction & motivation

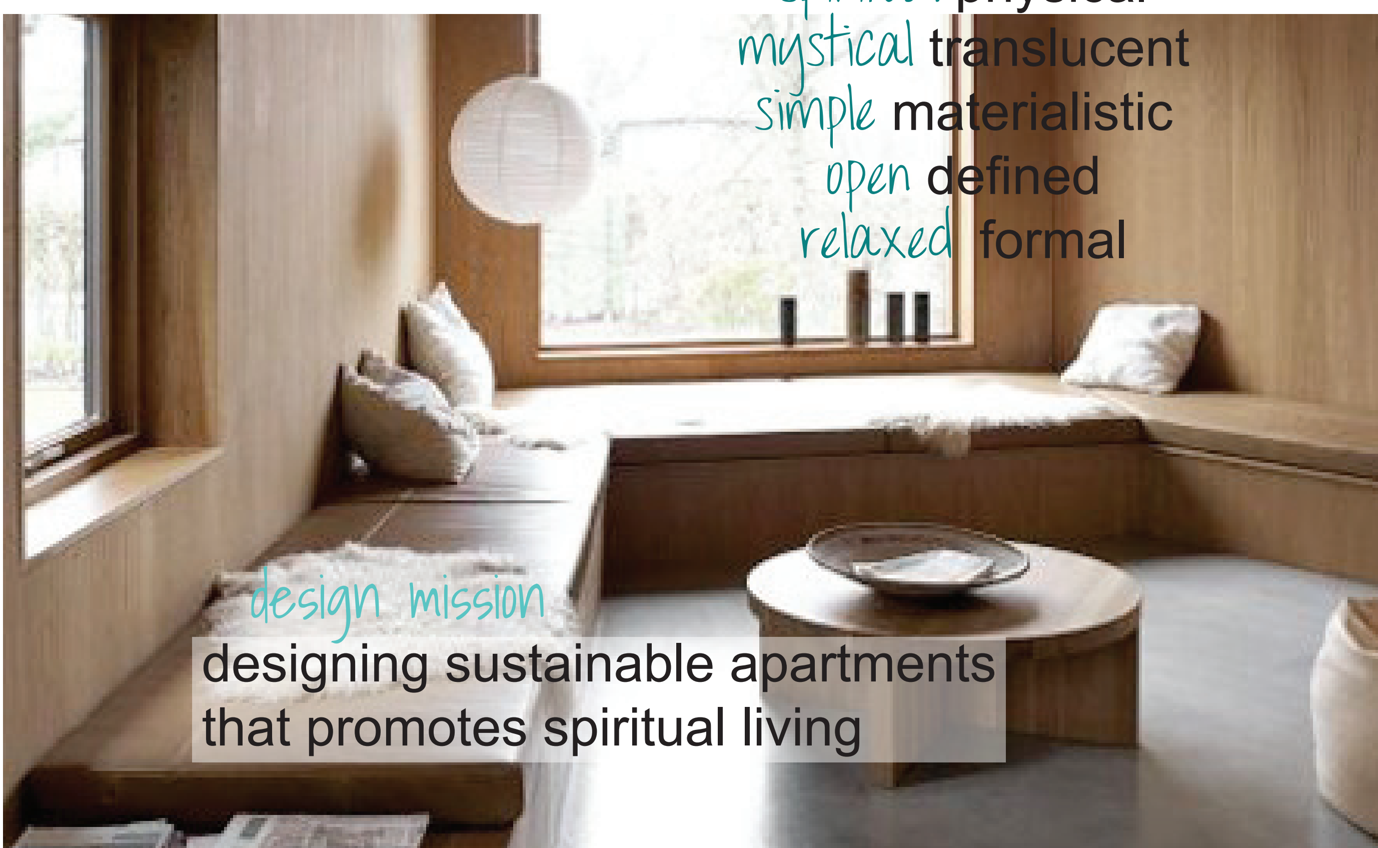
The late-2000s financial crisis, the medias preoccupation with outer beauty, and the fact that more and more people get stressed in their everyday life can all be seen as manifestations of a physical view of life. It seems like a lot of people are more concerned with external matters than what is going on inside of them self - meaning, they are more concerned with the physical aspect of life than the spiritual; they put their body's shallow yearnings in front of their soul's need to develop.

In Scandinavia, there seem to be a mass production of apartments with all white walls. Making a lot of apartment buildings the same regarding the interior materials sends out the notion that all residents are the same, that our individuality is not appreciated. Another impression is that the architects think it is a good idea to make the apartments' interior as neutral as possible, so the occupants can decide for themselves how they want to live by furnishing and decorating. When buying an apartment it is more affordable and the residents are freer to change things they do not like with the apartment - such as tearing down walls to give a better flow of the apartment or redecorating walls to give the home a more suitable atmosphere. In a rental situation they are not as fortunate. Either way, the option of altering ones dwelling after the apartment is already built encourages the occupants to spend both time and money on external matters.

In this project, the goal will be to design apartments where the residents do not feel encouraged to spend time and money on furnishing and decorating the apartment, but where the architecture itself is both an experience and art, and where furniture is part of the architecture. This way, the architecture is meant as a catalyst that encourages the residents to spend time on enriching their internal life instead of their outer life - meaning, the residents get the opportunity of becoming more spiritual than caught up in the physical aspect of life.

*architects Mette and Martin Wienberg's
design of their family home
in Aarhus, Denmark*

warm cold
wood white
spiritual physical
mystical translucent
simple materialistic
open defined
relaxed formal



design mission

designing sustainable apartments
that promotes spiritual living

methods

INTEGRATED DESIGN PROCESS (IDP)

IDP is a design method developed by the department of Architecture & Design at Aalborg University. The method is meant as a contribution in order to help the designer merging the matters of aesthetics, technique and function in the project. According to Knudstrup [2009], the Integrated Design Process is using the professional knowledge and design method from architecture and parameters from engineering in an integrated process.

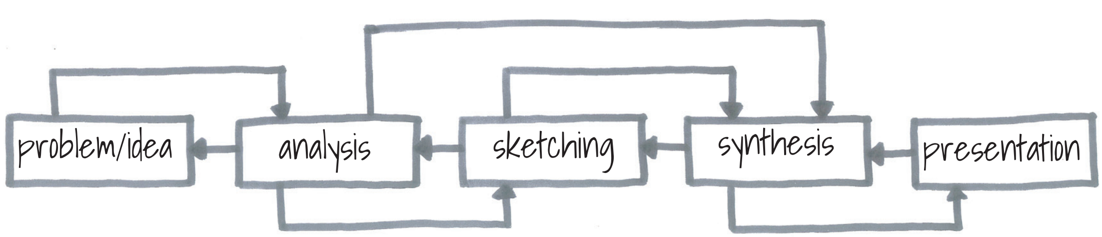
With IDP the project starts with a project idea and then continues through four phases. These phases are part of an iterative process - meaning, several aspects of the project is more likely to be developed simultaneously. The four phases can also be seen as a method of organising the report.

analysis phase

In the first phase, matters regarding topics such as the site, the user groups, and energy and indoor climate are investigated in order to end up with both architectural and technical design parameters that will initiate the sketching phase. Simultaneously, room programs and function diagrams are being developed and a vision is being clarified.

sketching phase

In the next phase the architectural design process is being set off and technical knowledge is being used in order to direct the design in the right direction. The Sketching Phase will usually consist of several solutions to the different problems investigated, and the sketching in this phase is being processed over and over again in order to optimise the design according to the design parameters before the Synthesis Phase starts.



synthesis phase
In this phase, the design is being detailed even more and the building is getting its final design and performance – this is being documented through relevant calculation tools. At this stage the different parameters are merging with the project and creates the final form and expression of the building.

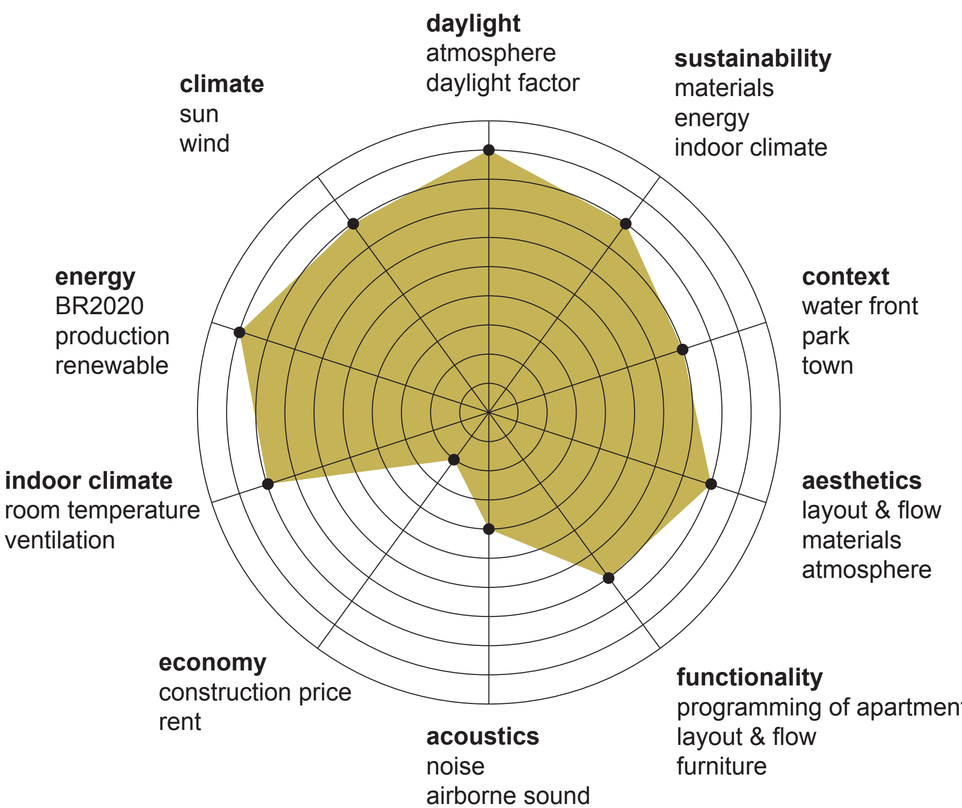
presentation phase
In the projects final phase, the project is being presented through a report, technical drawings and models.

analysis	sketching	synthesis	presentation
TASKS	TASKS	TASKS	TASKS
context analysis definitions expressions layout/flow materials built-in furniture climate /energy	sketching initial calculations	digitalising detailing calculations	dokumentations visualisation calculations report technical drawings
TOOLS	TOOLS	TOOLS	TOOLS
casestudy research studytrip	handsketches 24 Hour Average Be10 models	hand sketches Revit Architecture Velux Daylight Visualizer Be10 BSim	Be10 Revit Architecture BSim Adobe CS5 models

diagram indicating what tasks and tools have been used during each phase of the project

scope

diagram showing how much different topics is emphasised in the project



architect Davor Popadich's design for his family's home on Auckland's North Shore, New Zealand

analysis phase

spiritual architecture

DEFINITION SPIRITUALITY

Being spiritual should not be mistaken with the term of being religious. According to psychiatrists and psychologists as ¬Newton [1994] and Weiss [2004] as human beings we all have a body and a soul. The soul is immortal and the body is mortal, meaning, the soul is the true us. In a body, our task is to develop our soul – to become more spiritual. Becoming spiritual means valuing and possessing qualities as compassion, love, respect, patience, understanding, and responsibility etc. more than physical and external values. People, who seem concerned with what they look like, how much money they have, what they own etc. can be seen as more physical people – their connection to their soul is not that developed. Religion, in all this, can be seen as a tool or a method of becoming more spiritual.

SIMPLE LIVING

Simple Living has its base in the American hippie-culture, and in the beginning it was all about getting back to nature.

Today, Simple Living is a movement that started as a reaction of the stressful everyday life. The goal was to confront the traditional goals and positions that people tend to set for themself and to downsize in ones life in order to get time and energy in return that could be spend on more essential matters. Basically, it is about how to simplify ones external life in order to enrich ones inner life.

The process usually starts with physically tidying up in ones home – when starting in one corner of ones life, it affects other aspects in ones life that again affects other things and so on. The fewer things one own, the less one has to tidy up and clean, and, consequently, the more time and energy can be spent on more precious activities in life. The idea is that the needs for renewal should be covered on other areas than through consumption.

The process of simplifying demands responsibility – responsibility to oneself since one has to figure out for oneself what one likes and do not like to have in ones life or dwelling. A mantra for the Simple Living-followers is to only own what is really needed and what is really loved. To figure out what these things are, it is essential to constantly ask oneself “why” - “why am I doing this”, “why do I own this?”, “why do I need this?” etc. This way one is making conscious choices, which results in one becoming more spiritual. [Berg, 2004, Kvindeguiden, 2012]

PHENOMENOLOGY

In his book “The eyes of the skin” the Finnish architect and architectural theorist Juhani Pallasmaa [2005] emphasizes the importance of experiencing and designing architecture with all five senses. He states, “Significant architecture makes us experience ourselves as complete embodied and spiritual beings” [page 11].

According to Pallasmaa, our technological culture is to blame for the separation of the senses – the eye is seen as the dominating sense since it is the only sense that is fast enough to keep up with the speed in the technological world we are living in today. The problem is that the eye is the organ of distance and separation, whereas touch is the sense of nearness, intimacy and affection - the eye can be seen as focusing more on the physical aspect of life, while touch is the sense that supports spiritual living. In Pallasmaa’s words, vision separates us from the world whereas the other senses unite us with it. Buildings, in all this, are being turned into image products detached from existential depth and sincerity.

architecture
is essentially an extension
of nature
into the man-made dominion,
providing the ground
for perception
and the possibility of
experiencing
and understanding
the world.

In his book, Pallasmaa expresses the significance of shadow in architecture. Shadow is seen as a method of dimming the sharpness of vision – this way depth and distance are made indefinite. This atmosphere makes it easier for people to think clearly. Pallasmaa says “homogenous bright light paralyses the imagination in the same way that homogenisation of space weakens the experience of being, and wipes away the sense of place” [page 46]. Looking at light in only a quantitative matter makes the windows lose their importance as a mediator between two worlds – between closed and open, interiority and exteriority, private and public, shadow and light.

diagrams showing
the plan and the flow of apartments
built at different periods

layout & flow in apartments

One goal in the project is to make the architecture an experience in itself when designing apartments that encourages spiritual living. The aim is that the residents will feel less need to fill the apartment up with designer furniture and art to make the dwelling liveable and homely.

In this project four matters will be investigated in order to accomplish this - the layout and the flow in the apartment, the choice of materials in the apartment, how furniture can be part of the architecture and the light in the rooms. The first two will be analysed on the next few pages, while there will be inspirational pictures of built-in furniture. The light, however, will be analysed during the sketching phase.

LAYOUT & FLOW

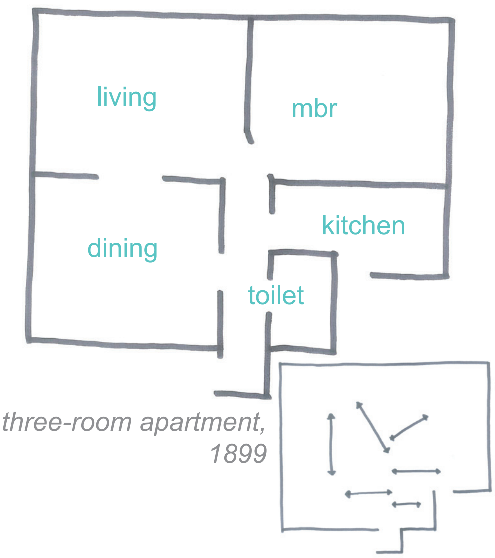
The purpose of this chapter is to show how a typical layout of two-rooms and three-rooms apartments in Denmark has changed the last century. There will also be a couple of case studies of how architects are living in their own dwellings.

After observing apartments for sale over several years, the tendencies seem to be that both in Aalborg and Denmark many people are living in apartments built 50-100 years ago, making this apartment-layout a typical one. The layout of apartments built during these 50 years do not seem to vary much - like there was a mass production of apartments where the rational aspect of constructing was more important than being creative.

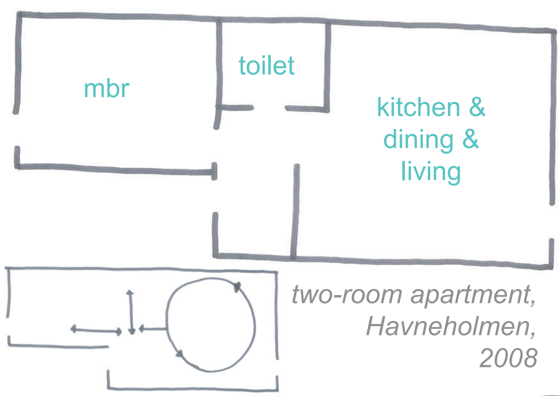
These apartments are characterized by having a hallway from where all the other rooms of the apartment are distributed. This gives a back-forth flow – you have to walk extra distances since the rooms are not directly connected. The flow is very irrational.

In apartments built the last decades this hallway seems to have been replaced with one bigger social room, making possibility of a more circular and free flow. There is still a back-forth flow to the more private rooms.

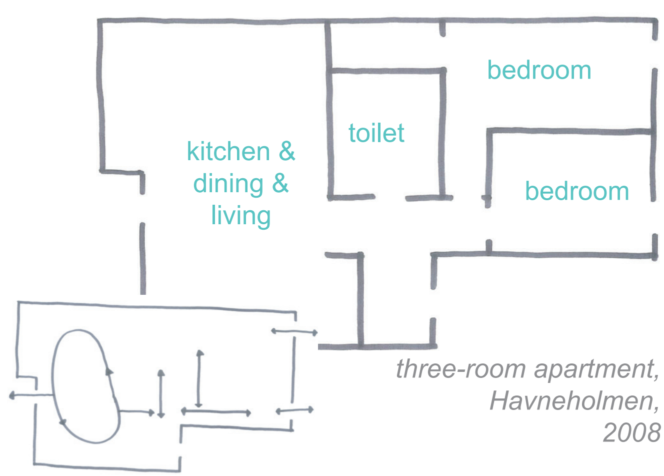
two-room apartment, 1949



three-room apartment, 1899



two-room apartment, Havneholmen, 2008



three-room apartment, Havneholmen, 2008

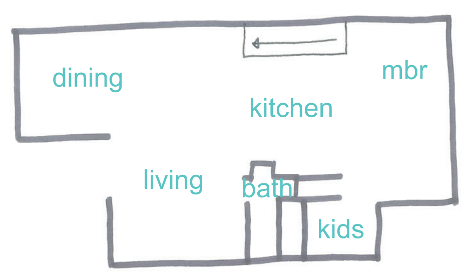
CASE STUDY

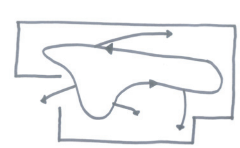
infill in Stokhusgade, 2007
Holscher Arkitekter as

This apartment is characterized by consisting of one big room containing both sleeping, living and cooking facilities. The kids' bedroom is an alcove in connection with the big room and the bathroom is separated from the living area with a glass wall. The apartment is located on the top floor and more than half of the façades are windows from floor to ceiling. The fact that the architect lives here with his wife and three kids makes it a rather groundbreaking way of living.

The flow is very rational since walls when moving from one zone to another do not distract you. This also gives an absence of privacy, especially when there are five people living in this small space.

The owners express that the layout of the open plan dictates the location of the different functions in the apartment and that there are no walls to put things on or place to fill up with things [DR, 2012a].

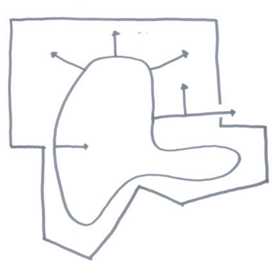


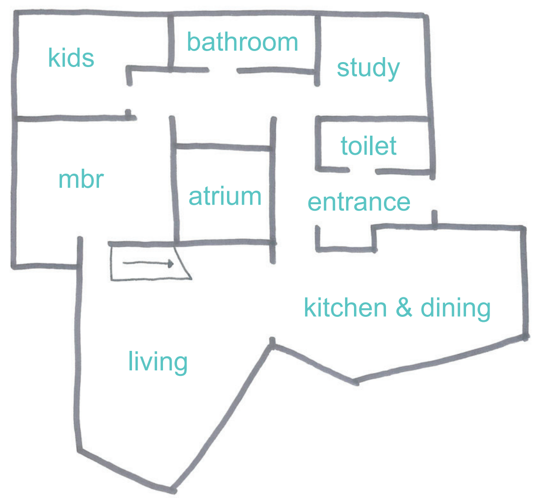


Villa Wienberg, 2008
Wienberg Architects

This is a house that has been extended and now has an atrium in the middle of the house, around which all the other rooms are distributed. The house is also characterized both by the different use of materials in the different rooms – this gives both dynamic in the dwelling and an overview, and by several built-in furniture. The residents state that the fixed furniture is more relaxing than the designer furniture they had before [DR, 2012b].

The flow in this dwelling is more circular – you move through one room to the next. Yet there are more private rooms outside of this circle (kids' bedroom and a study). The house also has a living room on the top floor, which the residents admit is not frequently used since it is not in the natural extension of the rest of the house.





CONCLUSION

One of the wishes in this project is to design plans that are more exciting and mysterious than what is typical. The layout itself should create curiosity with hidden doors and displacements.

The flow between the different rooms should be more open and free. The rooms should not dictate a certain function, but be flexible enough to change according to the residents' individuality and preferences.

materials

The typical Danish apartment with all white walls and bright wooden floors can be seen as a catalyst of wanting to fill the dwelling up with stuff in order to make it homely. The decision of choosing white walls often seem to coexists with the argument of wanting to bring more light into the dwelling, with the reason that this makes the apartment look bigger, or the argument of having an neutral background for the stuff we own. Except for those few hours every now and then, when a room might be lucky enough to bathe in sunlight, the white walls give a room a cold atmosphere. This coldness seem to be one of the reasons people feel the need to furnish and decorate in order to make the place warmer.

The goal in this project is to design apartments where the residents will feel more encouraged in spending time and energy on enriching their inner life. A warm atmosphere is seen as more suitable for this - making wood the obvious building material. In order to both give an honesty throughout the building and to design a sustainable building, wood will be used both in the constructional system, in the exterior and the interior.

MASSIVE WOOD

strength

holz100 is a Austrian patent of a building system in massive wood [wood100, 2012]. As the name indicates, the elements consist of 100% wood. Wooden boards of fir and pine are put together vertically, horizontally and diagonally to create compact construction elements. Wooden dowels penetrate the layers and since the dowels are from a different sort of wood than the boards, the difference in moistures make the dowels swell and get stuck.

Elements consisting of just one material give several benefits. Resistant internal surfaces are created, which give a better air tightness with fewer connections. This means the chances of condensation and mould are minimized. In addition the elements are protected from wind and provide noise insulation.

construction

Massive wood elements can constitute of the entire load bearing system or just part of it. The load bearing system can consist of shear walls and plates, beams and columns, or a combination of these two. [Treteknisk, 2006]

indoor climate

The fact that the holz100-massive wood elements are not glued together, make the elements breath naturally and can take humidity from the air. The condition is that any treatment used on the surface is open to diffusion.

These massive wood elements insulate well without any extra insulation, due to small air pockets created between the layers of the elements. Without extra insulation and since the elements are not glued together, they work well as thermal mass – keeping the dwellings cool in summer and warm in winter. According to lambda-values from holz100norge [2012], an exterior wall with a holz100-element of 400mm will give the U-value 0.138 W/m^{2}K. This is below the Danish Building Regulations requirement for BR2020 of 0.15 W/m^{2}K.

fire

The thickness of the massive elements and the lack of gaps in the elements give the elements a good fire resistance. Tests have showed that holz100 can withstand flames of 900-1000°C for 180 minutes without losing its load bearing capacity and integrity. After 120 minutes the temperature on the opposite surface of the element has only increased 2%. Another fact is the way the layers are connected. With metal nails the nails would heat up and loose their strength. The wooden dowels continue to function during exposure to fire and contributes to the achievement of fire class R60 and R90.

environment

Wood is a sustainable material – it is renewable, it reduces the total CO_2 level and it does not require much energy in its production or transport. Massive wood elements can be recycled or reused as energy. In the matter of recycling elements, the connection between the different elements should be mechanical for easy disassembling.

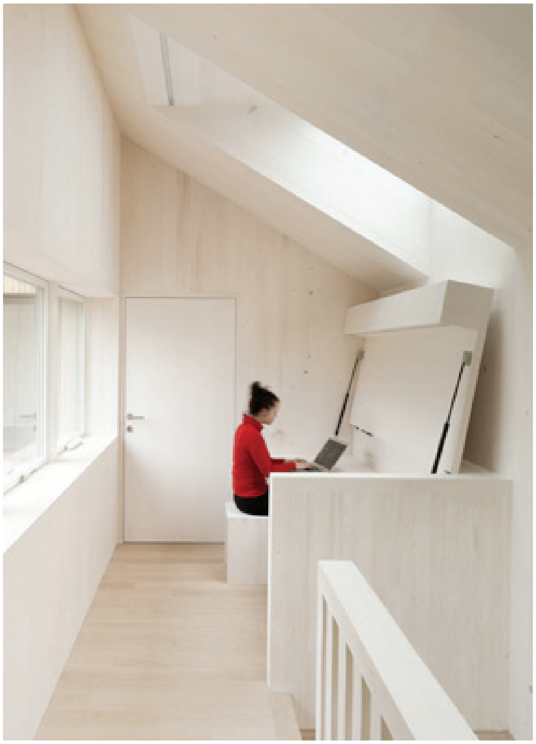
the world's tallest building to be built in wood, barentshouse by reiulf ramstad arkitekter

CONCLUSION

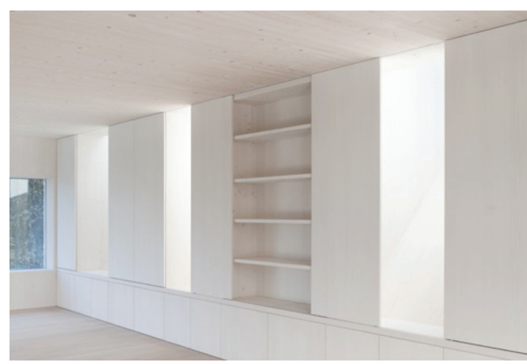
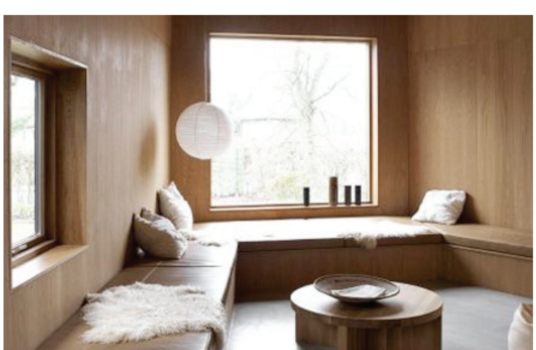
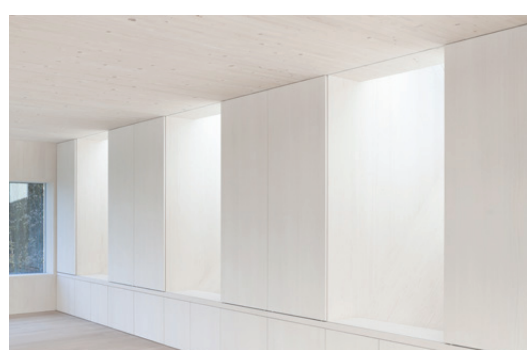
One request is to make the apartments appear mysterious in a way that keeps both the residents and the visitors curious about the place. Another wish is that the apartment should be art in it self. These two things could be manifested through the use of materials, and therefore there should be experimented with different wood and other materials in the interior instead of just choosing massive wood all over.

built-in furniture

When wanting to encourage the residents to focus on internal matters instead of getting caught up with the physical aspect of life, it is important that they have the peace and quiet to do so. Having built-in furniture in the apartments can been seen as one way of giving the apartment a more peaceful expression given that the furniture is merging with the architecture. The built-in furniture should also inspire the residents to not bring too many furniture or too much stuff to the apartments.





the context

Living in a dense city is seen as the most sustainable way of living, therefore the chosen site for this specific project is located at the Nørresundby Harbourfront – more specifically between the two bridges connecting Nørresundby with Aalborg, right next to the fjord and south-southwest of the old market town of Nørresundby. The site is part of an area that used to function as an abattoir. Nowadays, the Harbour Front is characterised by being a new residential area, not yet completed. Immediate to the west, between the site and the railway, there is a plan of a future recreational area. This will be connected to the existing park further west of the railway through the tunnel under the railway. To the east and the immediate north of the site, several residential buildings have been constructed the last few decades; most of them are 5-6 stories.

THE LOCAL PLAN

The fact that the Harbour Front-area is not yet completed as described in the Local Plan [Aalborg Kommune, 2006] means that maps and descriptions of the area in this analysis will not show the actual appearance of how the site looks today. Instead, the vision Aalborg Kommune has of the area has been taken into consideration.

In the Local Plan the site (area B3I) has the status of being a "Architectural Exploratorium", which means the wish for the building(s) on the site is to stand out in the neighbourhood – both when it comes to the building's expression, the use of materials and details.

The different requirements from the Local Plan will be listed in the Design Parameters, but some guidelines are also included in the different analysis of the site in this chapter.

location of the site in Nørresundby
1:10 000


the site
nørresundby
railway bridge
limfjorden
the limfjord bridge
aalborg city


lindholm
strandpark
the site
public green areas
semi-private green areas
blue structures
limfjorden
green structures
1:5 000


the site
pathways
secondary roads
main roads
railway
bridge
infrastructure
1:5 000


the site
block constructions
slab constructions
point constructions
future buildings
building structures
1:5 000


the site
residental buildings
mixed residental and shops
shops etc.
buidling functions
1:5 000

GREEN STRUCTURES

Except for the park west of the railway, the only green public area for the entire Harbour Front will be located immediate west of the site. North of the site is a green area that functions more as decoration than a area to spend any time. Within the (future) block a semi-private green area will also be located.

INFRASTRUCTURE

One of the main characteristics of the site is the close location of the railway.
The main road to the entire Harbour Front is located north of the site with a secondary road distributed west of the building. This road will have a dead end in front of the building, since the Harbour Front is reserved to pedestrians and bicyclist. The axis of the Harbour Front continues as a path through a green area on the western side of the railway.

BUILDING STRUCTURES

Both in the new residential area at the Harbour Front and in the old town, block-formation is the most characteristic building structure. According to the Local Plan, the new blocks should be constructed with openings between so it is possible to get different views into the backyards of the buildings.

BUILDING FUNCTIONS

Residential buildings mainly occupy the Harbour Front. Closer to the city centre the structure varies between occupying residents and shops. The Local Plan request that the southwest part of the site, directly at the Harbour Front, consists of public functions.

site seen from the railway -
surrounded by block formations to the north and the east,
the fjord to the south and the railway to the west

THE SUN

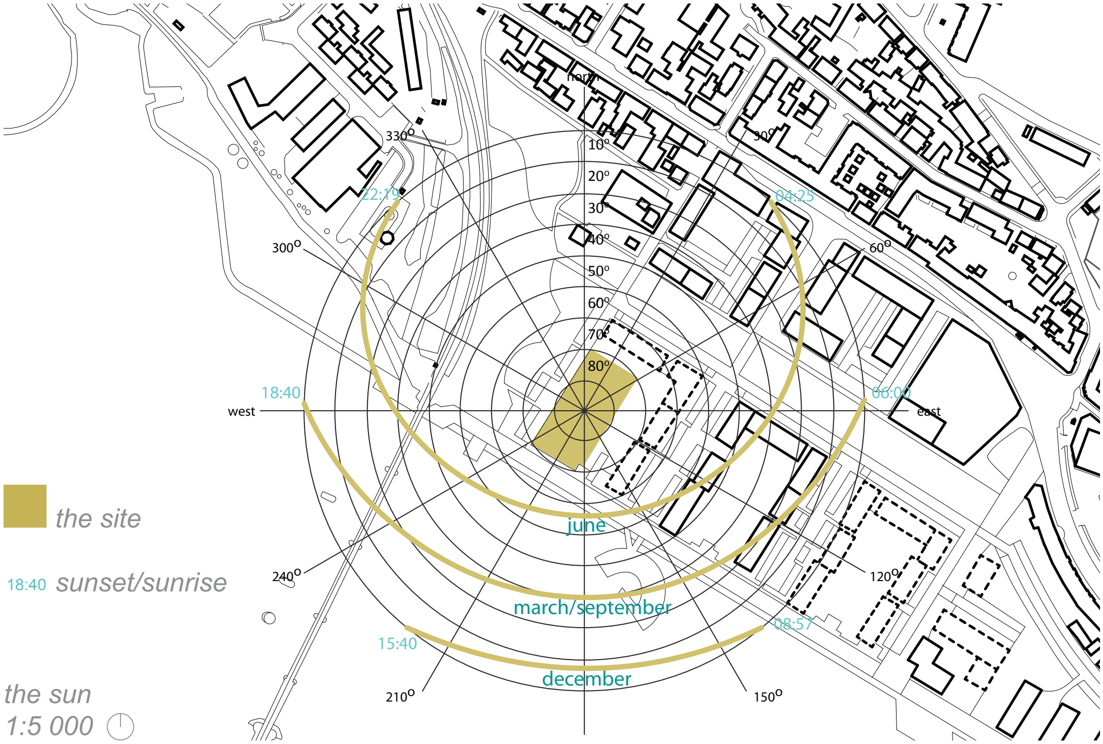
In summer it is possible to get sun on all four sides of the site, in winter only on two sides.

THE WIND

Throughout the year, the strongest and the most wind is coming from west and southwest. In this direction, the site is also unprotected by other buildings or vegetation.

THE SITE

The site is about 2700m^2 and, according to the Local Plan, 30% of this should be outdoor recreational areas. The Local Plan also requests that the view line through the road west of the site should be maintained. To the west and northwest there are views to green areas, to the south and southwest to the fjord. The Local Plan suggests that the building should be up to 10 floors to the south and this way interact with both the big green areas to the west and the railway bridge. On the northern part of the site, however, only 3-6 floors are wanted.



the site

18:40 sunset/sunrise

the sun
1:5 000

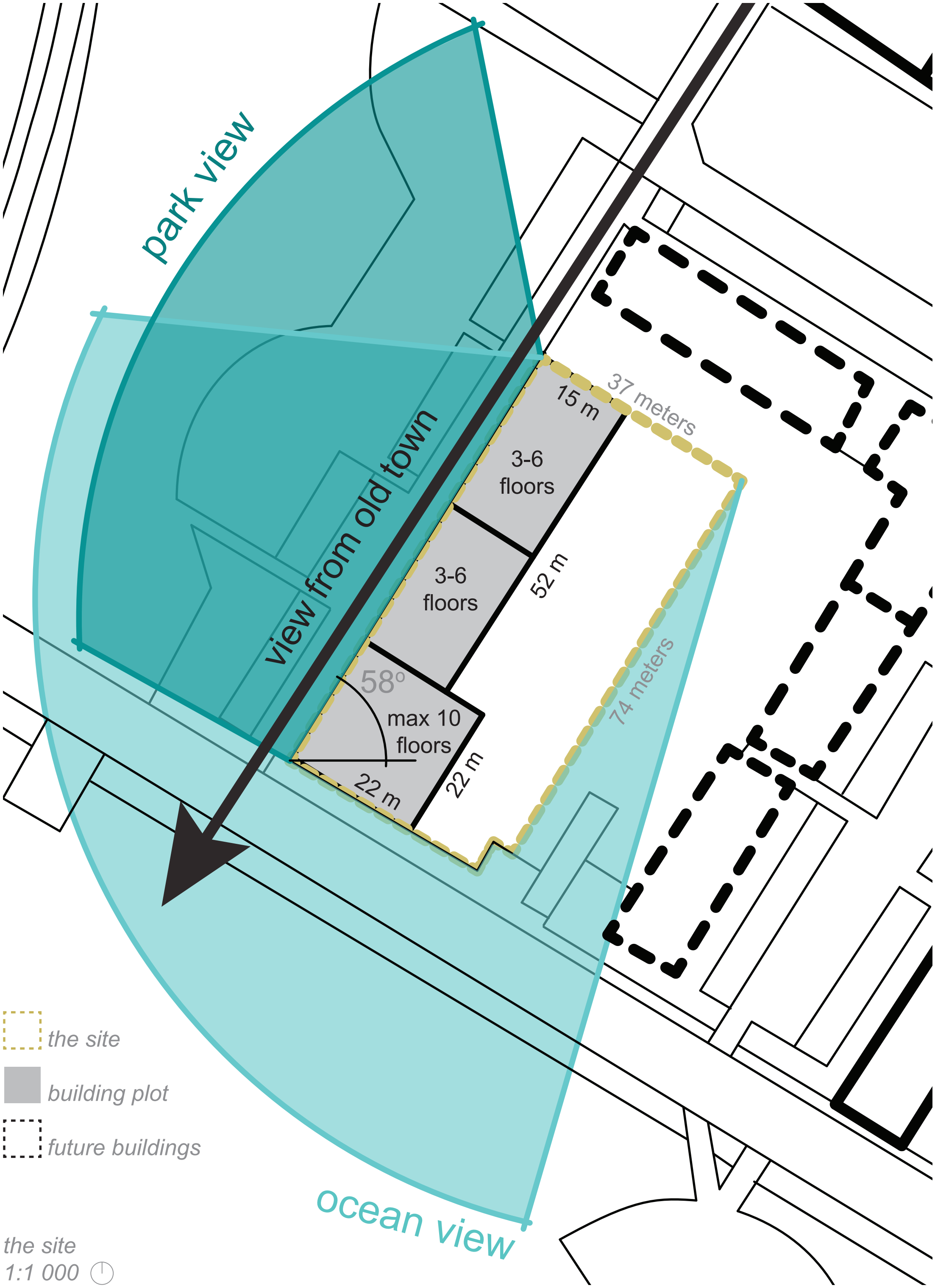
the site

11.0m/s

5.0-11.0m/s

0.2-5.0m/s

the wind
1:5 000



the site
1:1 000

lindholm strandpark -
the park on the west side of the railway

CONCLUSION

The site's location right next to the railway gives it an unspoiled view to Lindholm Strandpark in addition to a spectacular view to the fjord. The meeting point of these two views marks the direction of the strongest wind in the area, which will be significant due to the openness of the site. The view to the fjord is at the same time view to the sun – making it obvious to put outdoor areas in this direction. Both private and semi-private outdoors areas should, however, be protected from the wind but yet give the possibility of the warmth from the sun.

The site's location and rotation gives naturally bigger surface areas to the east and the west – giving shelter from the strong southern sun and reducing heat loss to the north. At the same time, free heat from the sun is not utilized as much as it could be. The west-east orientation gives, on the other hand, good possibilities of cross-ventilation.

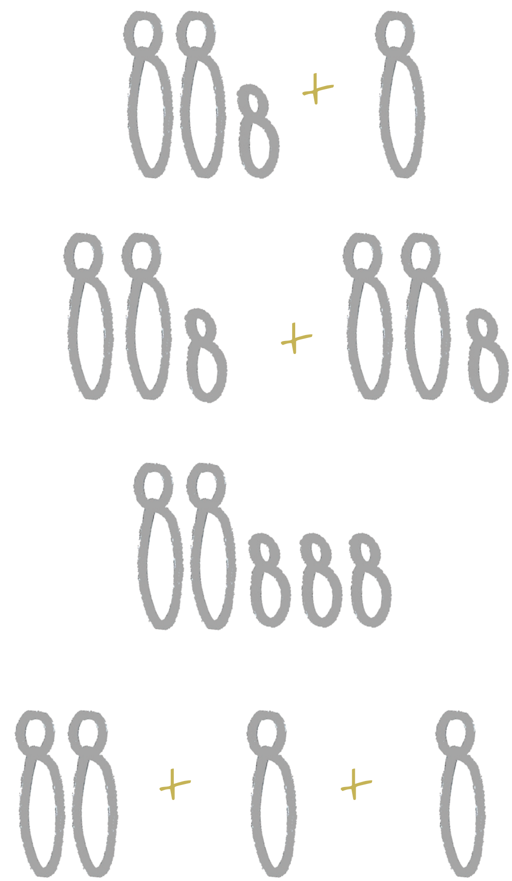
The site is located in the meeting point between the dense city and the more nature-like area to the south and west. Together with the fact that Aalborg Kommune wants the building on this site to have an "Architectural Exploratorium" gives the opportunity of working with, for instance, more natural materials.

target group

The overall target group should be people who seek to simplify their life. The apartments will stand out compared to more traditional apartments and will therefore be suitable for residents that dares to think and act differently – people who are not afraid of trying something new.

In order to support people's individuality there should be different types of apartments – both in size and layout. The idea is to design apartments with 2, 3 or 4 rooms in order to promote living for different types of households. There should also be a possibility to rent rooms out. This way a young couple can rent a big apartment, let out a couple of rooms in a period before taking over the entire apartment again once they have kids. Other possibilities could be for students to live together or couples renting two rooms each and share kitchen, just to mention two examples. When different households are sharing an apartment they all get the opportunity to help each other in the everyday life – this could reduce people's tendencies of getting stressed.

Encouraging people to focus on the softer values in life should give rental apartments rather than apartments for sale. According to Dansk Statistik [2011], in 2011 82% of residents in apartment buildings in Aalborg were renters, which can be interpreted that this is a favourable way of living.



examples of households in the biggest apartments

active house

According to activehouse [2012] an “Active House is a vision of buildings that create healthier and more comfortable lives for their occupants without impacting negatively on the climate”. Further there is a guideline, that there in these buildings should be a balance between energy, indoor climate and environment.

ENERGY

The buildings produce more energy in their lifetime than they consume, meaning they are CO_2 neutral. The energy use only consist of renewable energy, either produced on the building or provided through collective, sustainable energy supply.

In this project, the goal will be to design an apartment building where the energy frame meets the requirements of the low energy class BR2020 described in the Danish Building Regulations [2011]. When the energy use of appliances is added and the energy production is included, the building should be producing more energy than it is consuming.

INDOOR CLIMATE

Active Houses have a healthy and comfortable indoor climate with satisfying supply of daylight and fresh air, and where the materials contribute to a positive impact on comfort and indoor climate.

The Active House is an international definition and there are both qualitative and quantitative requirements for the indoor environment. In this project an indoor climate category according to the DS-CEN-CR 1752 [2001] will be chosen and the requirements from this and the Building Regulations [2011] will be the guidelines in the project.

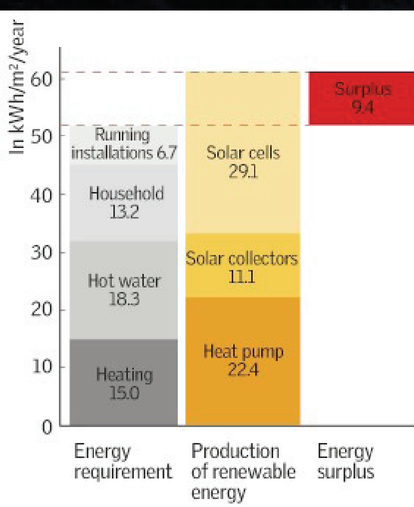
ENVIRONMENT

An Active house interacts positively with its environment. The focus should be put on how building materials and resources are used together with the ecological and cultural context of the site and the region.

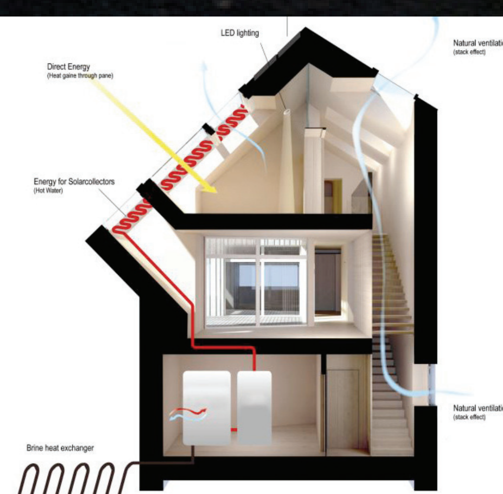
This project will emphasize the importance building materials have both on the indoor climate, the total CO_2 level of the building in its lifetime and on the energy consumption.

The different parameters for energy calculations and the indoor climate required to reach the BR2020-standard are listed in the design parameters.

sunlighthouse, austria
- an active house
developed by the velux group



In kWh/m²/year
60
50
40
30
20
10
0
Running installations 6.7
Household 13.2
Hot water 18.3
Heating 15.0
Solar cells 29.1
Solar collectors 11.1
Heat pump 22.4
Surplus 9.4
Energy requirement
Production of renewable energy
Energy surplus



LED lighting
Natural ventilation
(stack effect)
Direct Energy
(Heat gaine through pane)
Energy for Solarcollectors
(Hot Water)
Natural ventilation
(stack effect)
Brine heat exchanger

design principles

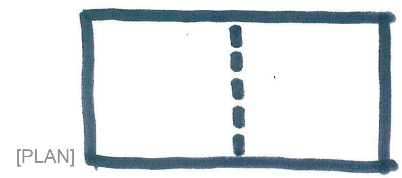
In "Arkitektur og Energi: mod en 2020-lavenergistrategi" Rob Marsh [2011] addresses the importance of uniting a building's summer and winter conditions when designing buildings according to the BR2020.

The development of low energy buildings has resulted in a reduced transmission loss due to better heat insulation and reduced ventilation loss caused by mechanical heat recovery. On the other side, the internal heat contribution has increased – we possess more electrical equipment and heavier constructional systems that can provide thermal mass has been replaced by light weight constructions to give more net area. All in all, overheating has become a bigger problem in low energy houses than the pursuit of reducing the heating requirement. In the energy frame, the heating need represents the largest part, while the electricity usage is the largest part when locking at the total primary energy.

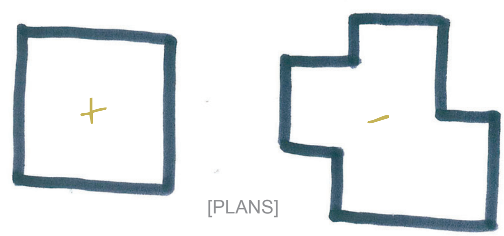
Energy reductions need to be taken into consideration together with a good indoor climate and satisfying daylight conditions – when designing; there should be a symbiosis between transmission loss, solar radiation, heating, overheating and daylight.

Diagrams on the following pages describe design principles for a low energy building - many of them according to Marsh.

transmission loss

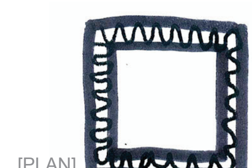


several units put together reduces surface area



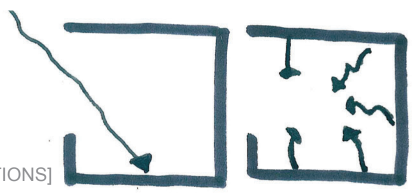
compact buildings reduces transmission loss and heating requirements

the building



high-insulated building envelope reduces the net area of the building

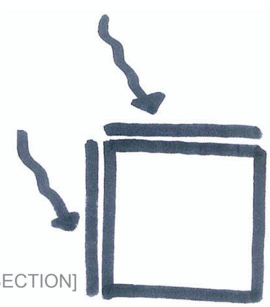
solar radiation



[SECTIONS]

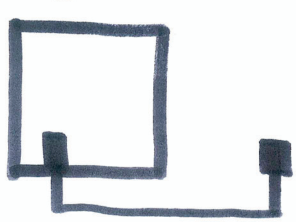
reduce need for high thermal mass

heating



[SECTION]

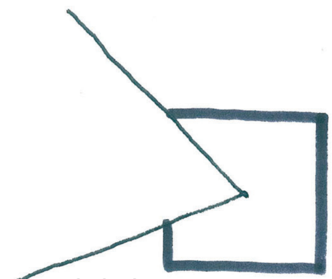
solar cells and panels
to produce electricity and heat



[SECTION]

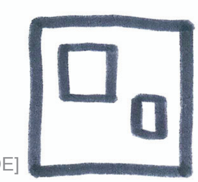
heat pump to heat room
and/or domestic hot water

windows



[SECTION]

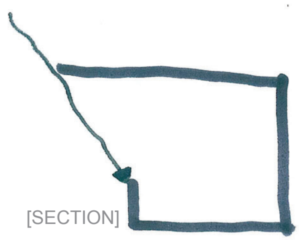
view from windows important



[FACADE]

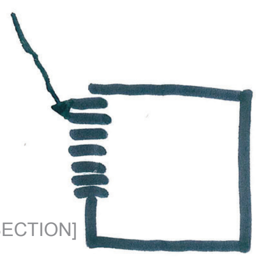
rooms with glass area of 30-50%
of the façade area will minimize
energy consumption
for heating, cooling and lighting

overheating



[SECTION]

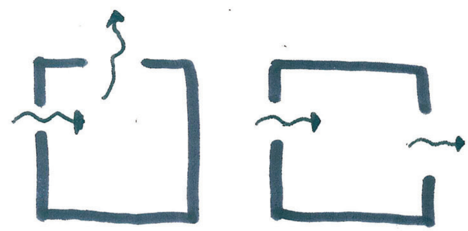
overhang as shading device
most efficient to the south in summer
- can also function as protection
from bad weather



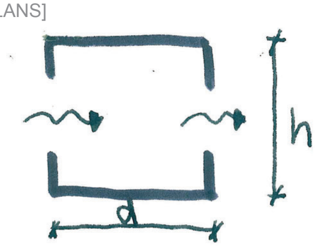
[SECTION]

louvres as shading device
also efficient to the east and the west,
but is blocking some view

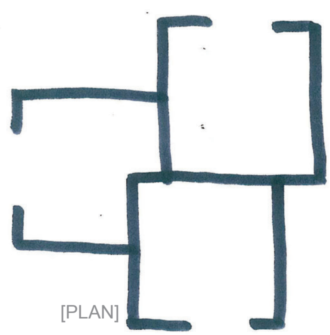
movable, exterior shadings makes it
possible to adjust the daylight
according to its intensity



[PLANS]



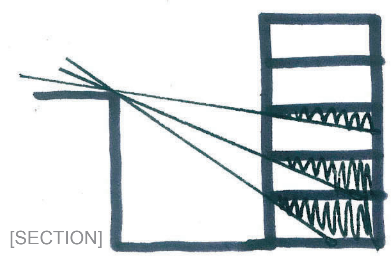
narrow rooms
with generous floor-to-ceiling height
reduces cooling need
with natural ventilation
d = max 5h



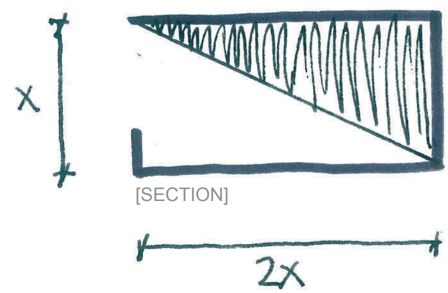
[PLAN]

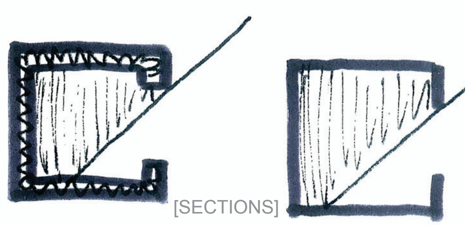
rooms with different orientations
so glass areas are distributed
more evenly prevent overheating

daylight

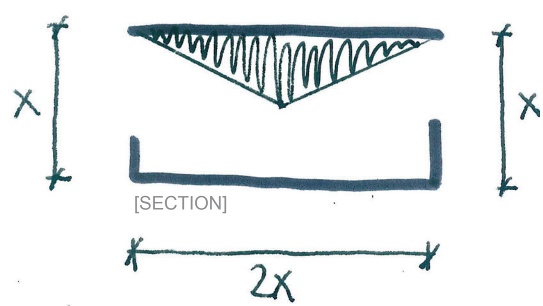


difference in level of daylight from bottom floor to top floor of building





high-insulated building envelope can reduce the daylight



narrow rooms with generous floor-to-ceiling height reduces electricity for lighting

enough light to workplaces when distance from window is twice the height of the window from the floor

windows all the way to the ceiling distribute the daylight further in the room with a more homogenous distribution

room program

The building will consist of apartments with 2, 3 and 4 rooms.

KITCHEN

In the smaller apartments, the kitchen could be part of the entrance-area, while it in the biggest apartments should be a separate room.

BATHROOM & TOILET

The biggest apartments should have an extra toilet in addition to a bathroom or two bathrooms.

ROOMS

The rooms should be of approximate the same size but not have any fixed functions. The residents should decide for themselves where they want to sleep and what should be there living area etc. This also makes it freer to rearrange the apartment over time – and to let out rooms.

TERRACE

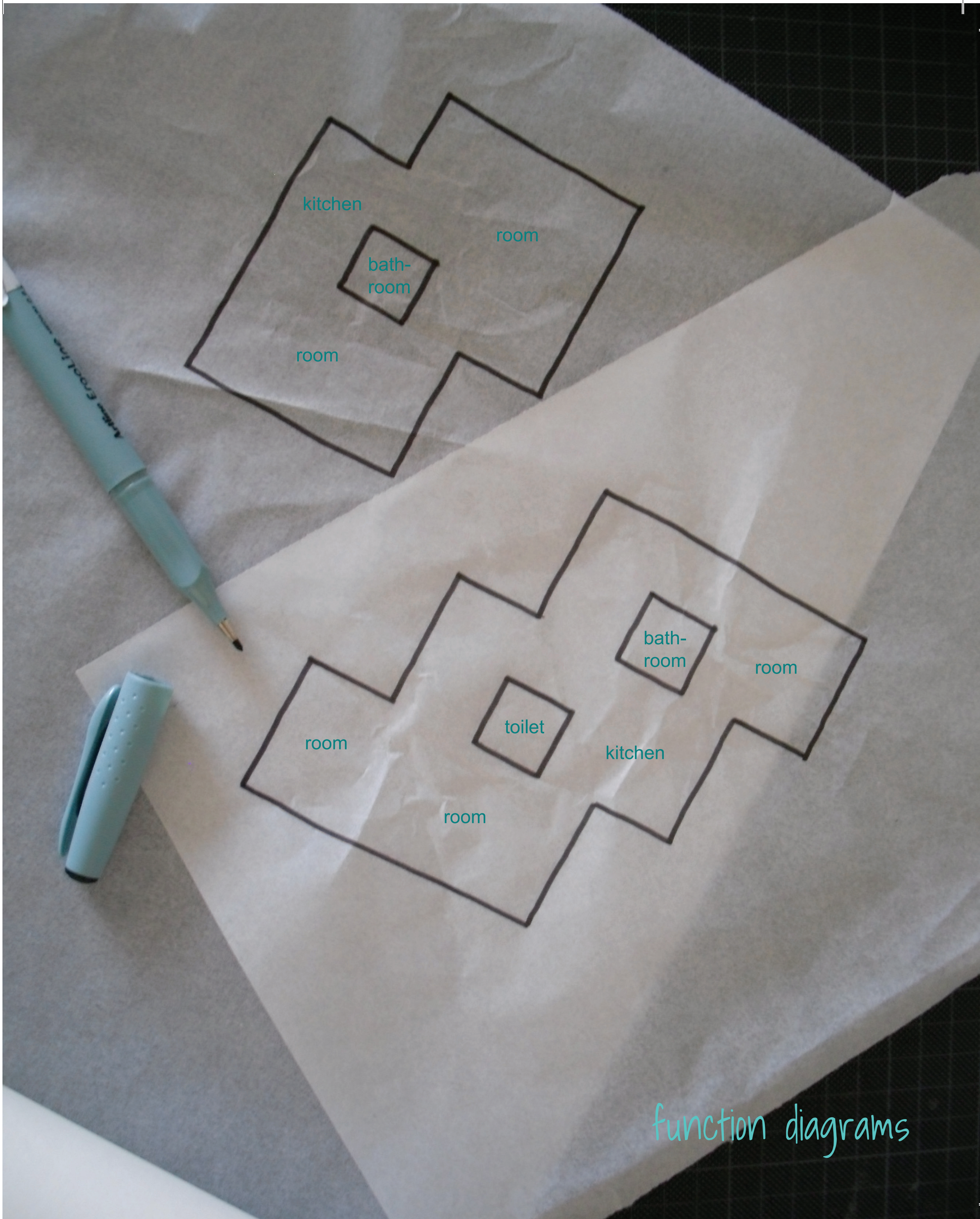
All apartments should have access to private terraces. There should be a possibility to use these even in somewhat bad weather.

STORAGE

There should be extra storage facilities for bigger items outside the apartment - for instance on another floor.

<table>
<tr><th>type of apartment</th><th>room type</th><th>net area</th><th>room height</th><th>daylight</th><th>temperature</th><th>air flow</th></tr>
<tr><td>2 ROOM</td><td rowspan="3">kitchen</td><td>4-6 m²</td><td rowspan="3">max 3.0 m</td><td rowspan="3">3 %</td><td rowspan="6">23-26°C summer

20-24°C winter</td><td rowspan="3">20 l/s</td></tr>
<tr><td>3 ROOM</td><td>4-8 m²</td></tr>
<tr><td>4 ROOM</td><td>10 m²</td></tr>
<tr><td>ALL</td><td>bathroom</td><td>4 m²</td><td>max 2.5 m</td><td>0 %</td><td>15 l/s</td></tr>
<tr><td>3 & 4 ROOM</td><td>toilet</td><td>2 m²</td><td>max 2.5 m</td><td>0 %</td><td>10 l/s</td></tr>
<tr><td>ALL</td><td>room</td><td>10-25 m²</td><td>max 3.0 m</td><td>3%</td><td></td></tr>
<tr><td>ALL</td><td>terrace</td><td>4 m²</td><td></td><td>-</td><td></td><td></td></tr>
<tr><td>ALL</td><td>storage</td><td>3 m²</td><td></td><td>0 %</td><td></td><td></td></tr>
</table>


kitchen
room
bath-
room
room
bath-
room
room
toilet
room
kitchen
room
function diagrams

design parameters

APARTMENTS

• apartments should supports people's individuality – different layout in each apartment
• apartments of different sizes: 2 to 4 room apartments
• apartments should be designed in a way that makes it possible to rent rooms out

ROOMS

• rooms should be flexible to support different use at different times and by different people
• the proportions of the room should be suitable in order to hold different functions
• there should be built-in furniture as part of the architecture
• narrow rooms with high ceiling height to optimize daylight and conditions for natural ventilation

LAYOUT/FLOW

• the layout and the flow of the apartments should contribute to making the architecture an experience in it self
• the flow should be rational, free and flexible yet still make the apartment appear mysterious

MATERIALS

• materials contribute to making the architecture both art and an experience
• different materials to give more dynamic in the apartments
• wood as the main building material – massive wood in load bearing system

CONTEXT

• the building should relate to the existing city and the green areas to the west of the site
• sheltered outdoor area due to the windy site

TARGET GROUP

• people who want to simplify their lives
• different households – individuality should be encouraged
• renters

ENERGY

• the building is an active house
• fulfill energy frame BR2020: 20 kWh/m^2 year
• produce more energy than it consumes
• renewable energy supply

building envelope
- U-value exterior walls: max 0.15 W/m^{2}K
- U-value deck: max 0.10 W/m^{2}K
- U-value roof: max 0.10 W/m^{2}K
- U-value doors: max 0.80 W/m^{2}K – glass doors: 1.00 W/m^{2}K
- transmission loss: 5.7 W for building of 3 floors or more

INDOOR CLIMATE
category B according to DS/CR/CEN 1752

thermal
- summer temperature: 24.5°C +/- 1.5°C
- winter temperature: 22°C +/- 2.0°C
- 26°C not more than 100 hours a year, 27°C maximum 25 hours a year

daylight/windows
- take advantage of view to the fjord and the green areas to the west
- different orientation and shape of windows depending on the rooms function and to prevent overheating
- at least 15% of floor area if the glass' LT-value is above 0.75, or
- daylight factor of 3%
- qualitative light important for the atmosphere

acoustics
- sound class B
- airborne sound: $R'_{w} + C_{50\text{-}3150}$ = 58 dB (between a dwelling and a room outside of the dwelling)
- $L'_{n,w} + C_{I,50\text{-}2500}$ = 48 dB (in rooms and kitchen - from other dwellings and common rooms)

air
- natural ventilation – preferably cross ventilation, in summer
- mechanical ventilation all year
- low polluting building materials
- in kitchen: exhaustion with air flow 20 l/s, in bathroom 15 l/s, toilets 10 l/s
- outdoor air supply: minimum 0.3 l/s per m^2 heated floor space, which gives an air change of 0.5/h


warm cold
wood white
spiritual physical
mystical translucent
simple materialistic
open defined
relaxed formal
main concept

vision

THE APARTMENTS

The vision of the project is to design apartments that stand out compared to typical and traditional apartments. Where a typical apartment can be seen as a result of a rational building process, where the apartments get a rather cold atmosphere due to the notion of making the apartments as neutral as possible in order to appeal to as many people as possible, the apartments in this project will be characterize by their warm atmosphere.

The warm atmosphere should be seen as a way of promoting spiritual living. The concept of spiritual living is seen as a way of making people aware that there are more to life than physical and external matters. The apartments should be a haven where the residents will feel encouraged to downsize both their physical belongings and their activities in order to enter a more peaceful state of mind that will also reduce tendencies of stress. Making the architecture of the apartments an experience in itself should manifest the warm atmosphere.

To support people's individuality there should be different apartments – both in size and layout.

> a piece of architecture
> should not become transparent
> in its utilitarian and rational motives;
> it has to maintain its
> impenetrable secret and mystery
> in order to ignite
> our imagination and emotions.
>
> Juhani Pallasmaa, 2005

THE ROOMS

The design of the rooms should make the residents feel encouraged to withdraw from the physical sphere of life in order to enrich their internal life.
In all the rooms there should be storage facilities to contribute in bringing more peace and quiet to the room.

THE BUILDING

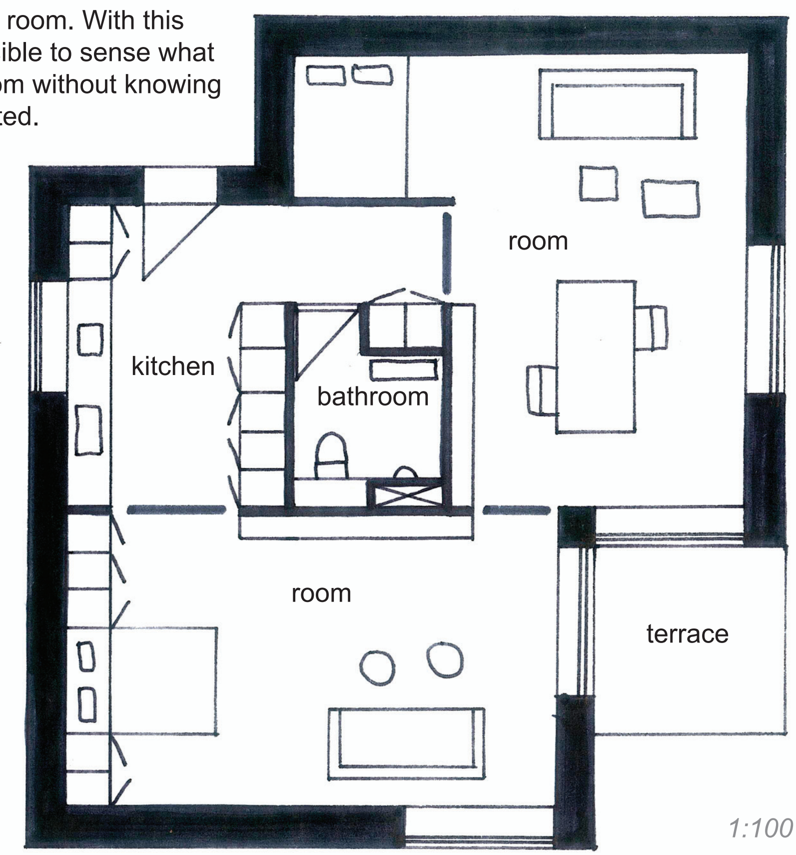
The building should be an active house, meaning it should produce more energy than it consumes in its lifetime and both the energy consumed and produced should be renewable.
There should be private, semi-private and social outdoor areas in addition to indoor common rooms.
The building and the site should act as a fusion between the town of Nørresundby and the fjord and the park south and west of the site.

Rintala Eggersson's prefabricated Boxhome, 2007

sketching phase

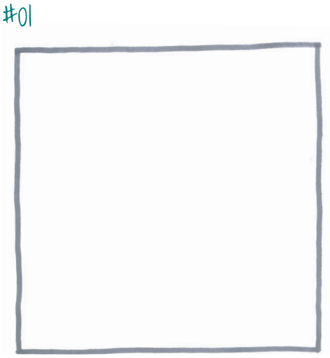
apartments

In order to design apartments that will appear more mysterious than traditional apartments, the starting point was a two-room apartment constructed by intersecting a square and a rectangle. In the intersection a box appears that acts as a room divider, a bathroom and furniture. This creates a space divided in different zones that can interact with each other or be more closed off if the wish is rent out a room. With this box as a divider, it is possible to sense what is going on in the next room without knowing for sure - curiosity is created.



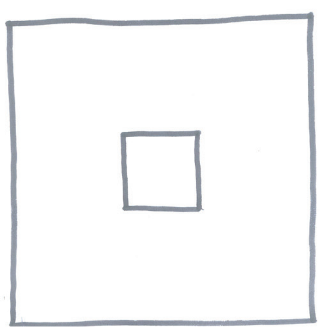
1:100

#01



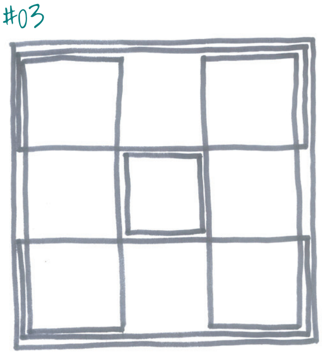
Apartment as one big open room - flexible and rational but misses the requested mystique.

#02



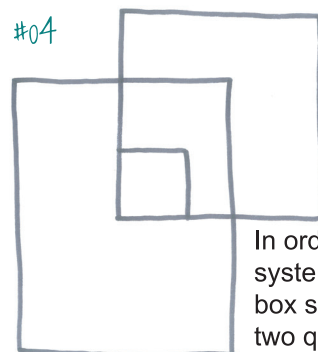
When putting a box into the room zones are differentiated.

#03



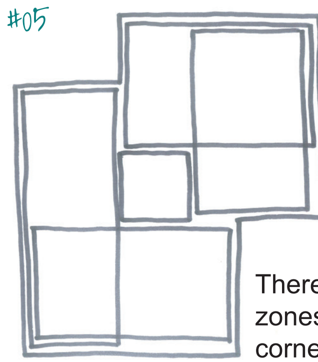
Four zones are created. The corners can belong to two zones – when they are counted twice the space seems bigger than it really is.

#04



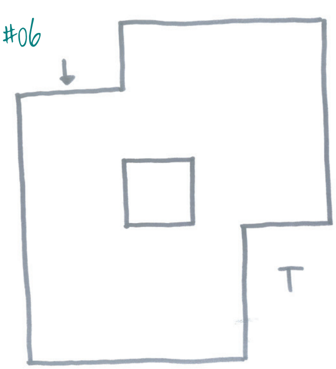
In order to get a system of where the box should be placed, two quadrilaterals are intersected.

#05



There are still four zones - but only two corners.

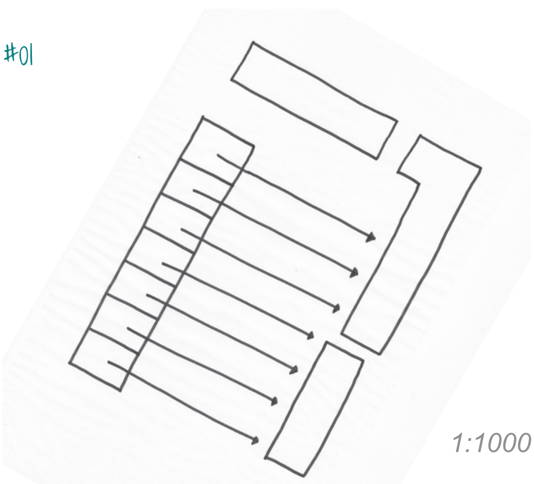
#06



The external corners can determine entrance and terrace to the apartment.

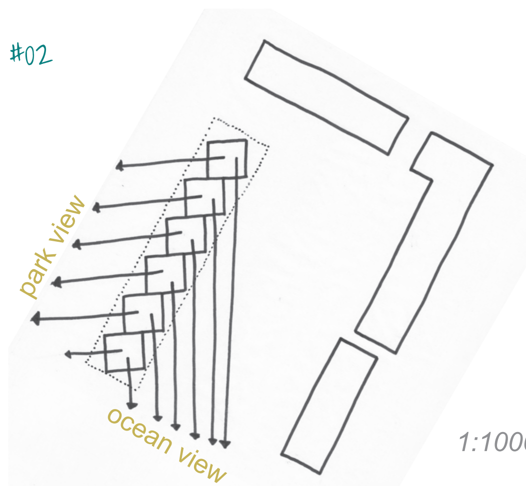
building on site

The site is rotated 32° compared to the north-south axis. This makes it possible to intersect several quadrilaterals and end up with a zigzag-shaped building where apartments get better daylight- and ventilation conditions than a more compact building.



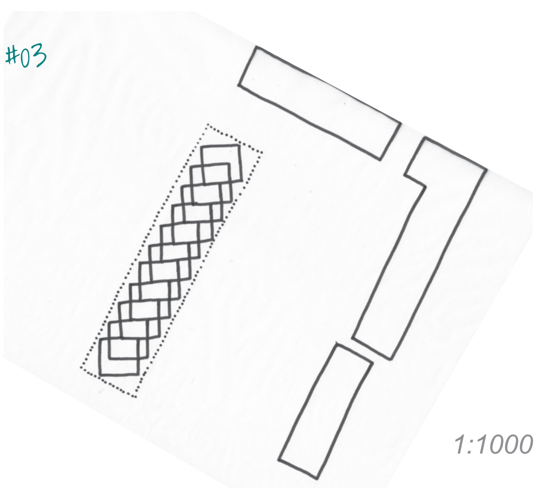
APARTMENTS ORIENTED PARALELL TO THE LINES OF THE SITE

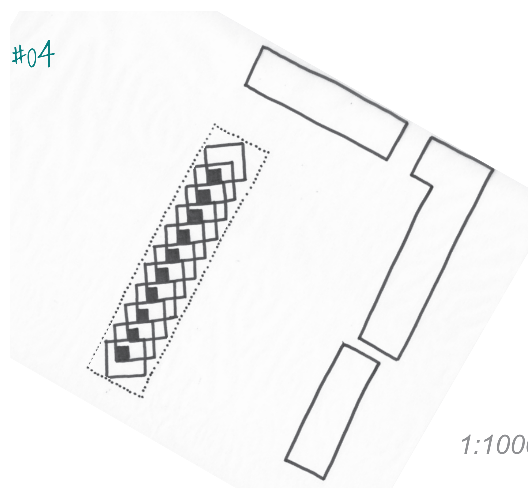
- view directly towards buildings to the east
- daylight only from two directions: SE and NW



APARTMENTS ORIENTED PARALELL TO THE FOUR CORNERS OF THE WORLD

- view to the fjord and the park
- daylight possible from all four directions
- apartment consisting of few, big rooms may cause overheating in apartment





APARTMENTS CREATED WHEN INTERSECTING SEVERAL QUADRILATERALS

• the apartments is being separated into several smaller rooms.
• apartments get daylight from four sides, while rooms in apartments get the possibility of daylight from two perpendicular directions
• cross ventilation in a room is possible when having windows in two directions

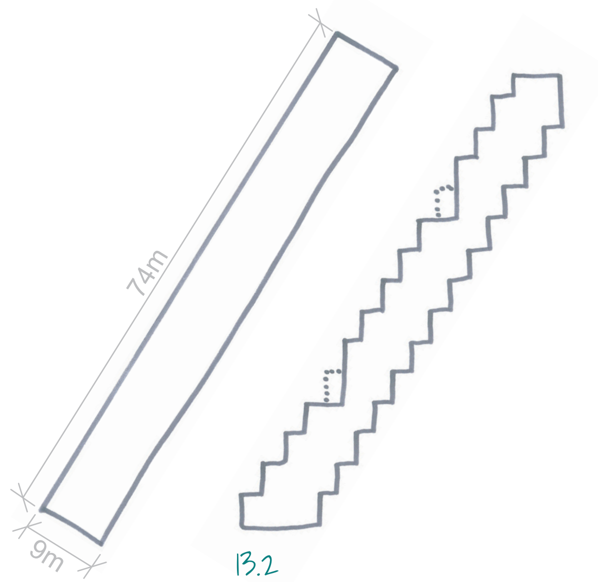
BOXES CREATED IN THE INTERSECTIONS

• the apartments' layout become more mysterious
• apartment consisting of several, smaller rooms gives smaller chance of overheating in apartment

energy frame [be10]

The wish of wanting more mysterious apartments that will give more of an experience for the residents and at the same time provide better conditions for both daylight and ventilation compared to more compact, traditional buildings, gave many surfaces due to the zigzag shape of the building. A Be10-calculation was performed early in the design process in order to compare the building to a more compact one of the same external dimensions. Another purpose of the early calculation was to see what effect different initiatives had on the energy frame, such as changing the height between floors or increasing the window area in the facade. Results are given in the table below.

12.4
kWh/m² year



preconditions:

- 5 floors of apartments
- 6 apartments per floor
- height between floors: 3.0m
- 30% window area of facade area

results:

energy frame for compact building	12.4	
energy frame for designed building	13.2	
• height between floors: 3.2m	27.0	
• 40% window area of facade area	24.5	
• U-values maximum (BR2020)	15.0	
• common hot water tank	17.7	kWh/m² year

input BE10_01

heated floor area	3345	m^2
heat capacity	120	Wh/K m^2
heat supply	district heating	

WALLS, ROOFS, DECKS	area [m^2]	U-value [W/m^2 K]	
walls north	618	0.09	
walls east	891	0.09	
walls south	618	0.09	
walls west	891	0.09	
roof	669	0.05	
ground deck	669	0.06	b=0.07, dim ude: 10°C

WINDOWS	area [m^2]	U-value [W/m^2 K]	Ff	g	shading
windows north	185	0.9	0.86	0.62	
windows east	267	0.9	0.86	0.62	
windows south	185	0.9	0.86	0.62	own building (right, 75°)
windows west	267	0.9	0.86	0.62	own building (left, 56°)

VENTILATION	area [m^2]	q_m winter [l/s m^2]	η_{vgv}	SEL [kJ/m^3]	q_n summer [l/s m^2]
entire building	3345	0.3	0.85	1.5	2.0

INTERNAL HEAT SUPPLY	area [m^2]	persons [W/m^2]	app. [W/m^2]
entire building	3345	1.5	3.5

HEAT DISTRIBUTION PLANT		
supply pipe temp.	70	°C
return pipe temp.	40	°C
type of plant	2	

PUMP		
type	T (time controlled)	
number	1	
P_{nom}	15	W
F_p	0.4	

DOMESTIC HOT WATER		
hot water consumption	250	liters (average for the building)
DHW temperature	55	^oC
number of tanks	30	(one in each apartment)
tank volume	250	liters
supply temperature	60	^oC
el. heating of DHW	no	
heat loss from hot water tank	1.8	W/K
temp. factor	0	

building on site - with apartments

The first layout and distribution of apartments resulted in several narrow rooms with the width of only 2.6 meters in connection with deep rooms of 6.3 meters. Following, the most common rooms in the building is analysed regarding the temperature and the deep room is analysed for daylight.

room temperature [24 hour average]

The excel sheet 24HourAverage is applied in order to analyse six different rooms in the building according to the indoor temperature. The three most common rooms in the building in addition to three different sized rooms located at the southern end of the building are chosen. The rooms are analysed for the summer period, and different measures has been taken into consideration in order to not get a temperature above 30^{o}C – see list to the right.

From the results, the clearest tendency seem to be that smaller rooms give higher temperatures – this is both the fact when the room is located between apartments or at the end of the building.
One purpose of the boxes in the apartments is to create more openness between rooms. When choosing to leave the room open, they will get a bigger volume - resulting in a lower room temperature.

precondition:

#01:
• height of room: 2.7m
• 30% windows of facade area
• air change: 5/h
• infiltration: 0.1/h
• 2 persons in each room - at home 17-07

#02:
• window south replaced by terrace door 1.5x2.1m

#03:
• window area north reduced to 1.0m^2
• window area west reduced to 2.0m^2

#04:
• air change: 10/h

input:

area room	10 m²	18 m²	25 m²	15 m² end	25 m² end	35 m² end
orientation	NW	SE	SE	SE	SEW	SEWN
wall area north	7.0 m²					17.0 m²
wall area east		10.8 m²	10.8 m²	10.8 m²	10.8 m²	17.0 m²
wall area south		7.0 m²	7.0 m²	10.8 m²	17.6 m²	7.0 m²
wall area west	10.8 m²				10.8 m²	6.5 m²
window area north	2.1 m²					5.1 m²
window area east		3.2 m²	3.2 m²	3.2 m²	3.2 m²	5.1 m²
window area south		2.1 m²	2.1 m²	3.2 m²	5.3 m²	2.1 m²
window area west	3.2 m²				3.2 m²	2.0 m²

WINDOWS	U [W/m²K]	g	f_{shadow}	f_{glass}
north + east	0.90	0.62	0.9	0.86
south + west	0.90	0.62	0.7	0.86

result:

10 m²	may	june	july	august	september
#01	28.5 °C	**33.1 °C**	**33.9 °C**	**31.1 °C**	26.5 °C
#03			**30.4 °C**		
#04			28.2 °C		

18 m²	may	june	july	august	september
#01	26.3 °C	**30.1 °C**	**31.0 °C**	29.6 °C	25.7 °C
#02		**31.0 °C**	**31.8 °C**		
#04		26.5 °C	27.4 °C		

25 m²	may	june	july	august	september
#01	23.7 °C	27.7 °C	28.5 °C	27.4 °C	23.5 °C
#02			29.2 °C		

16 m² end	may	june	july	august	september
#01	28.6 °C	**32.3 °C**	**33.1 °C**	**31.8 °C**	27.9 °C
#02		**32.1 °C**	**32.8 °C**	**31.5 °C**	
#04		28.9 °C	29.7 °C	28.7 °C	

25 m² end	may	june	july	august	september
#01	26.8 °C	**30.6 °C**	**31.4 °C**	**30.4 °C**	26.4 °C
#02		29.1 °C	29.9 °C	28.7 °C	

35 m² end	may	june	july	august	september
#01	25.8 °C	29.9 °C	**30.5 °C**	28.7 °C	24.5 °C
#02		**30.3 °C**	**31.0 °C**	29.2 °C	
#03		28.2 °C	29.1 °C		

daylight [velux daylight visualizer]

The deep room of 6.3 meters seem to get a dark and uninviting corner. Through an analysis in Velux Daylight Visualizer the room where compared to solutions where the room west of this were replaced with a winter garden that would be in direct connection with the deep room. At the same time, different window solutions for the east façade and the winter garden were investigated.

preconditions:

In the analysis the deep room is being examined with a terrace door of 2.0x2.1 meters in the south facade. For the solution with winter garden there are folded glass doors between the two rooms - in order to give light in the west end of the deep room and to open up completely between the two rooms during warmer periods.

The goal of the analysis is to find a window solution for both of the rooms, which will provide a daylight factor around 3 for the deep room, yet areas of shadow is created in between the light - in order to dim the sharpness of vision.

WINDOWS EAST

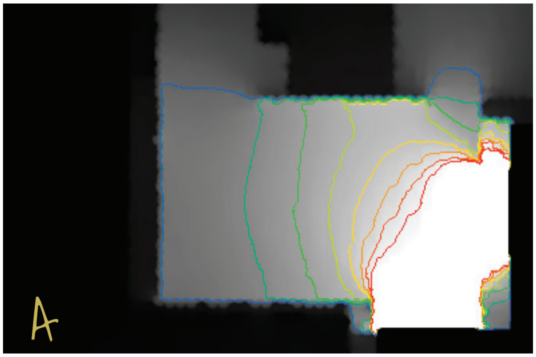
To the east and south, one wish is to create windows it is possible to sit in - with other words, windows with a sill height of 450mm. In addition, one big window seem more inviting compared to having several smaller ones.

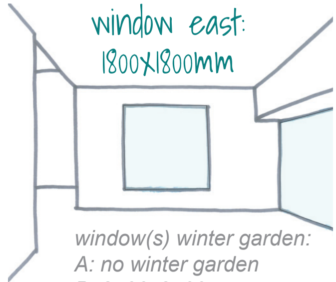
Square shapes expresses intimacy more than rectangular shapes - therefore the smallest window analysed is 1.8x1.8 meters. The fact that windows to the ceiling gives light further into the room is investigated by looking at the effect of both a window of 1.8x2.25m and of 2.25x2.25m.

The forth example analysed consists of an extreme situation with a window from wall to wall - 3.4x2.25m.

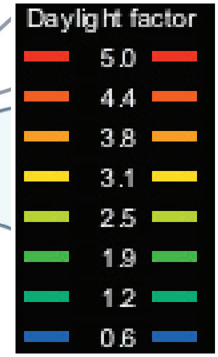
WINDOWS WINTER GARDEN

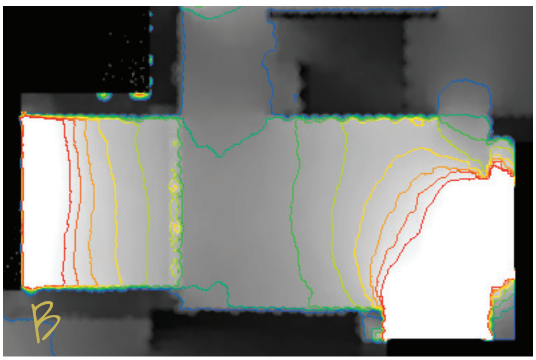
Two different window-solutions where investigated for the winter garden - one where the entire west facade is replaced with glazing, another where the window has the same size as in the east facade. In the latter, there is also a terrace door in the north facade of 1.0x2.1m.

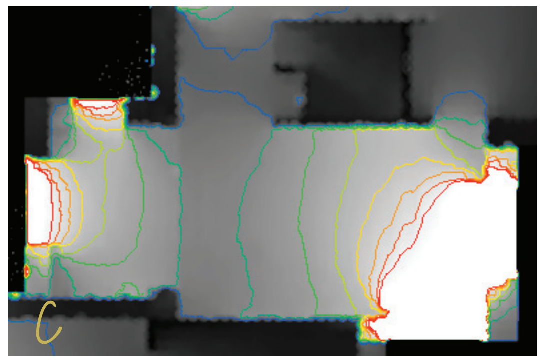


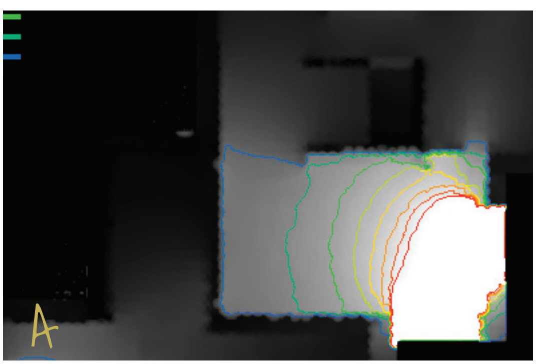


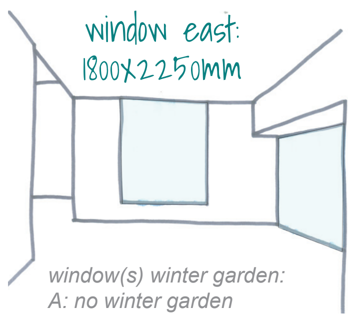
window(s) winter garden:
A: no winter garden
B: 3400x2700mm
C: 1800x1800mm,
sill height: 450mm



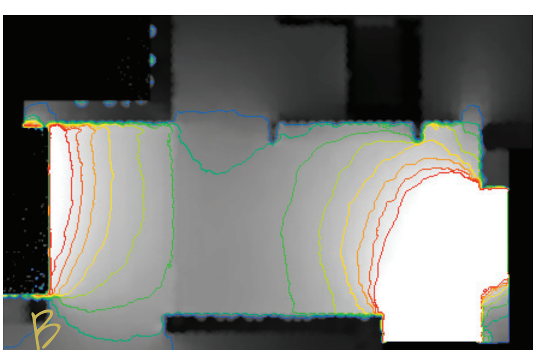


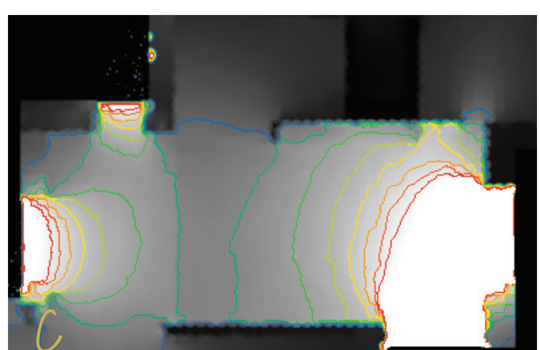


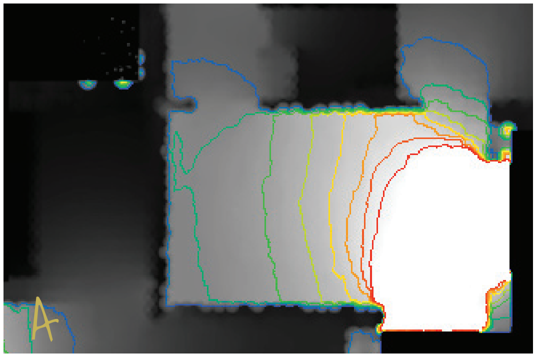


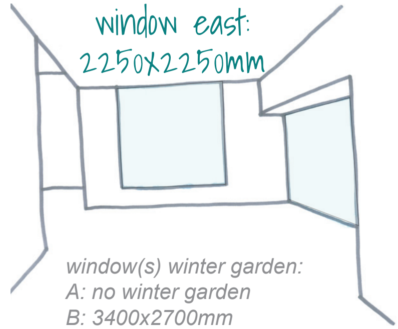


window(s) winter garden:
A: no winter garden
B: 3400x2700mm
C: 1800x2250mm, sill height: 450mm

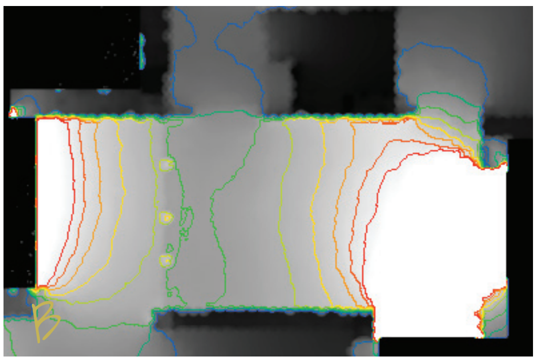


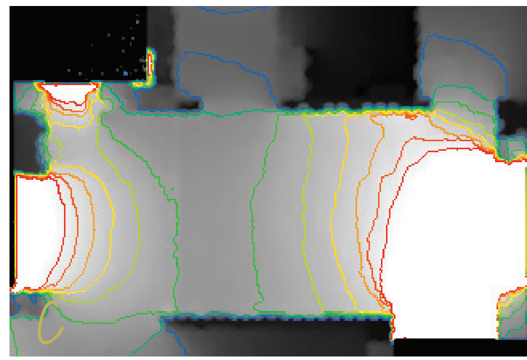


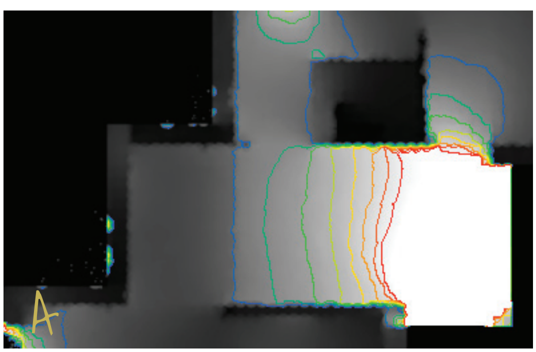


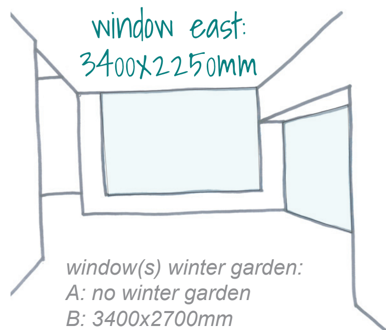


window(s) winter garden:
A: no winter garden
B: 3400x2700mm
C: 2250x2250mm, sill height: 450mm

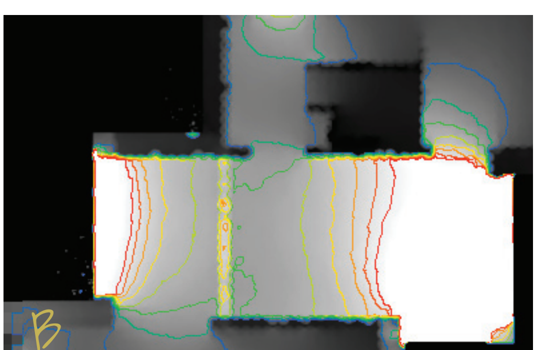


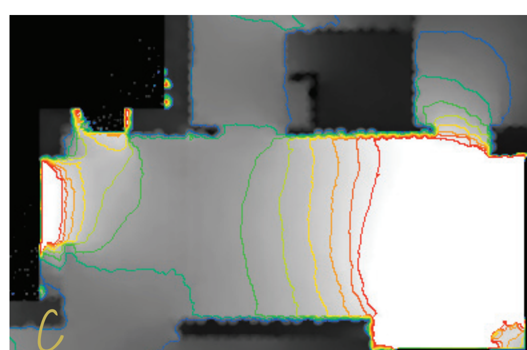






window(s) winter garden:
A: no winter garden
B: 3400x2700mm
C: 1800x1800mm, sill height: 450mm

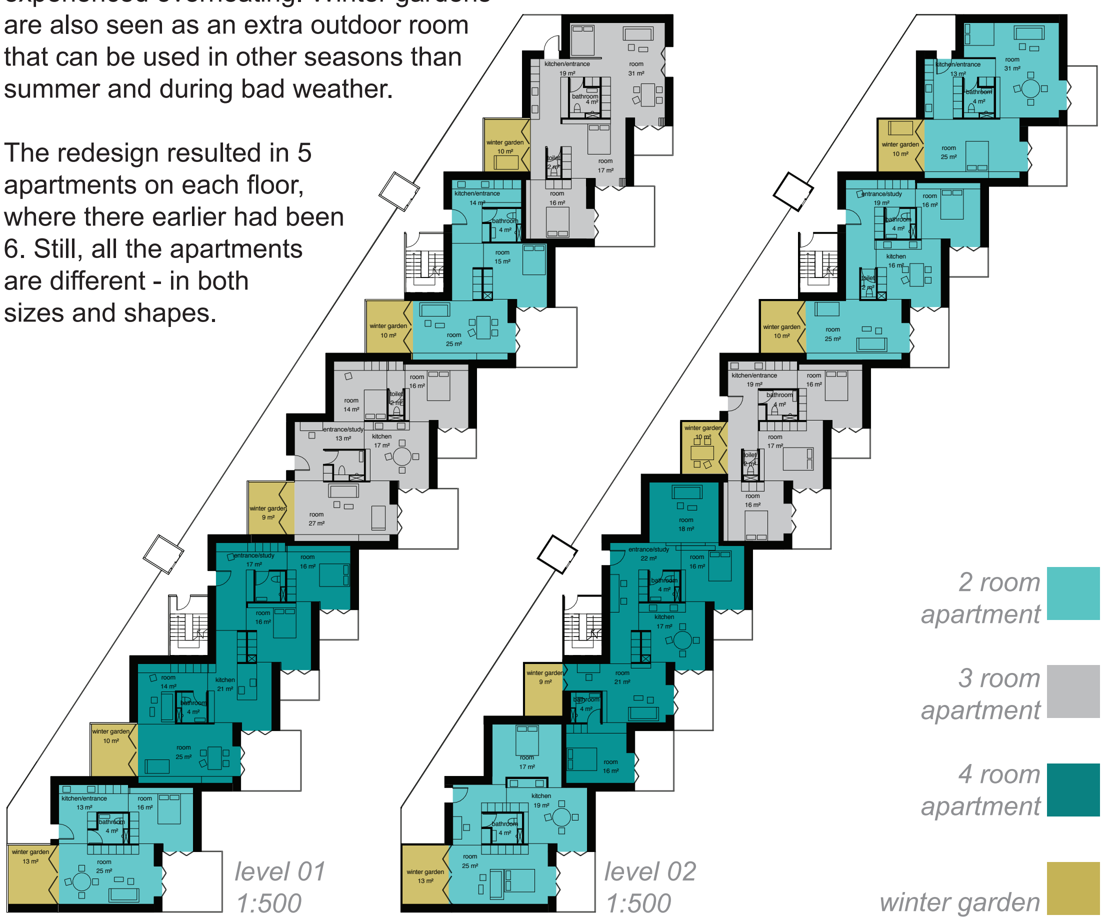


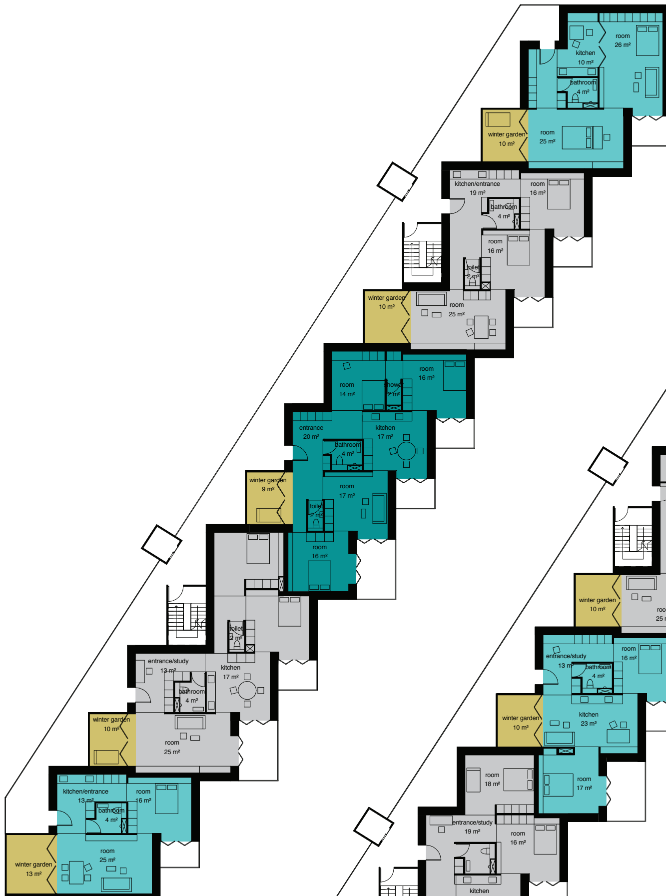


apartments with winter garden

As a result of the analyses in 24 Hour Average and Velux Daylight Visualizer a winter garden is included in all of the apartments in order to give more light through the apartment and to exclude the use of narrow rooms, which easily experienced overheating. Winter gardens are also seen as an extra outdoor room that can be used in other seasons than summer and during bad weather.

The redesign resulted in 5 apartments on each floor, where there earlier had been 6. Still, all the apartments are different - in both sizes and shapes.





level 03
1:500

level 04
1:500

level 05
1:500

energy frame [be10]

The new design of the building with unheated winter gardens and now also a ground floor formed the basis of a new Be10-calculation. The building now has suggested balconies for the east/south facade (see the previous two pages). These will give shadow on the windows below - but this fact is not taken into consideration in this calculation. The effect of the shadow will be analysed later.

precondition:

- 5 floors of apartments + ground floor with common facilities and a café/restaurant
- 5 apartments per floor
- height between floors 3.0m
- 30% window area of facade area, but
- 80% windows café (windows only east and south)
- all windows 1.8x1.8m velfac 200helo 48mm (3-layered)
- infiltration winter (infiltration with a pressure difference of 50Pa):

  q_n = 0.04 + 0.06 * q50 [SBi213 p.59], where
  q50 = 0.5 l/s m2 for BR2020 [BR10 7.2.5.1 stk. 5]
  this gives: q_n = 0.04 + 0.06 * 0.5 = <u>0.07</u>

results:

energy frame for designed building	14.0	
heat	19.7	
room heating	2.6	
excessive in rooms	0.0	
transmission loss	2.5	
total el. consumption	31.9	kWh/m² year

input BE10_02

heated floor area	3420	m^2
heat capacity	120	Wh/K m^2
heat supply	district heating	

WALLS, ROOFS, DECKS	area [m^2]	U-value [W/m^2 K]	
walls north	555	0.09	
walls east	1209	0.09	
walls south	874	0.09	
walls west	669	0.09	
roof	561	0.05	
ground deck	430	0.06	b=0.07, dim ude: 10°C
walls toward unheated rooms north	320	0.09	b=0.07
walls toward unheated rooms west	504	0.09	b=0.07
deck between level 01 and parking	66	0.06	

WINDOWS	area [m^2]	U-value [W/m^2 K]	Ff	g	shading
windows north	129	0.77	0.88	0.5	window opening 1.72%
windows east	383	0.77	0.88	0.5	window opening 1.72%
windows south	287	0.77	0.88	0.5	own building (left, 75°), window opening 1.72%
windows west	156	0.77	0.88	0.5	own building (right, 56°), window opening 1.72%

VENTILATION	area [m^2]	q_m winter [l/s m^2]	η_{vgv}	SEL [kJ/m^3]	q_n summer [l/s m^2]	q_n winter [l/s m^2]
apartment + café	2990	0.3	0.85	1.5	2.0	0.07
common rooms level 00	430				2.0	0.07

3420 *values changed since last Be10-calculation*

INTERNAL HEAT SUPPLY	area [m²]	persons [W/m²]	app. [W/m²]
entire building	3420	1.5	3.5

HEAT DISTRIBUTION PLANT		
supply pipe temp.	70	°C
return pipe temp.	40	°C
type of plant	2	

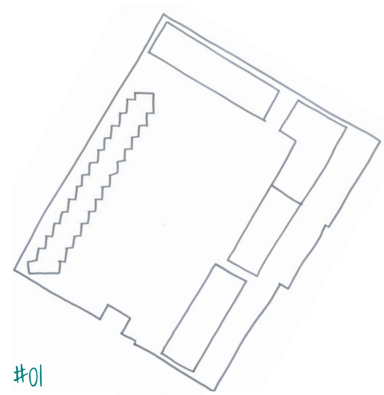
PUMP		
type	T (time controlled)	
number	1	
P_{nom}	15	W
F_p	0.4	

DOMESTIC HOT WATER		
hot water consumption	250	liters (average for the building)
DHW temperature	55	°C
number of tanks	25	(one in each apartment)
tank volume	250	liters
supply temperature	60	°C
el. heating of DHW	no	
heat loss from hot water tank	1.8	W/K
temp. factor	0	

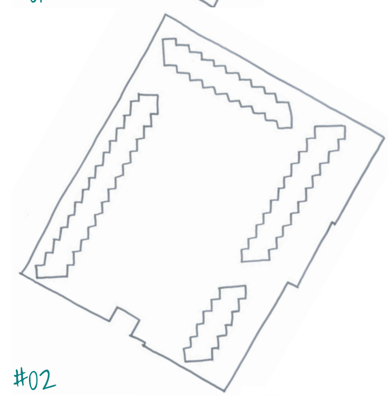
site plan

The building site is today an empty field - the surrounding buildings indicated in the context analysis and developed further to the right are not yet built. In this project, the wish is for the designed building to stand stronger amongst the more traditional concrete buildings at the Harbour Front. Choosing to expand the design of the building to the entire block will give the area a more obvious role as a fusion between the denser town of Nørresundby and the green areas to the west.

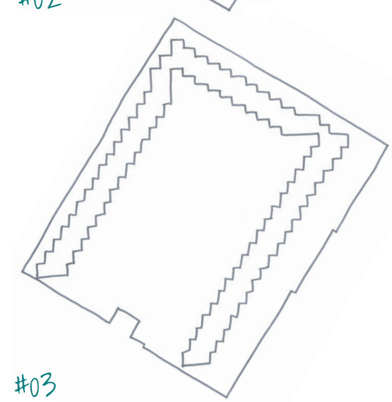
The Harbour Front is a windy and open area - not many people seem to spend time outdoors even on a sunny day. The idea is to close the block in order to create more intimacy in the semiprivate outdoor area between the buildings and at the same time create stronger coherence between the residents in the different parts of the building. It is still possible to enter the backyard from the street side of the building through gates that will be two stories tall.



#01



#02



#03

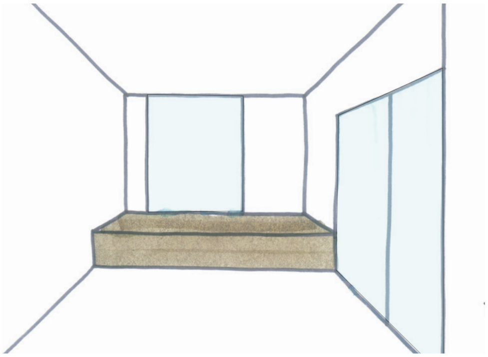
window design winter garden

As a continuation of the first Velux Daylight Visualizer-analysis (pages 61-63), different window solutions for the winter garden were investigated. The wish was to make a relatively sunny room without too much insight. The winter gardens are located in connection with the entrance hallway and the wish was to make the room private - neighbours and visitors should not feel encouraged to look into these windows. Therefore relatively moderate window areas were appreciated.

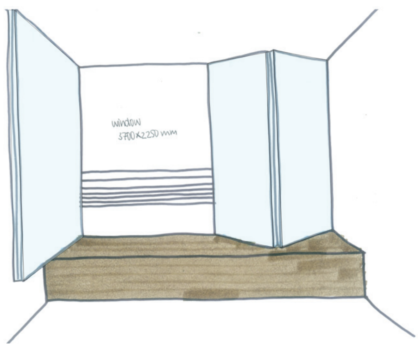
To make the room more open and to get a connection with the outdoor, it seems obvious to have windows/door in both the west and the north facade. To the north there should be a terrace door - giving possibility of a terrace area for the apartment outside the winter garden.

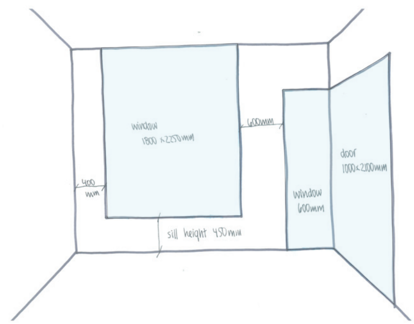
Inside the room, solutions with or without a built-in bench were investigated. Having no bench will make the room more flexible for the residents, especially since the room is only 2.6 meters wide. On the other hand, a built-in bench will give more character to the room - hopefully encouraging people to use the room for relaxation. The bench can both provide seating and storage facilities.

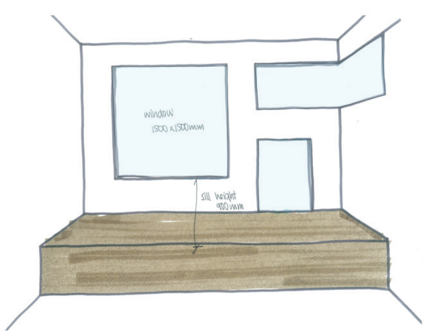
In the chosen solution (below) windows and door are placed in order to get an intimate corner in connection with the built-in bench. This way it is possible to make use of the bench without getting the feeling of being directly on display.

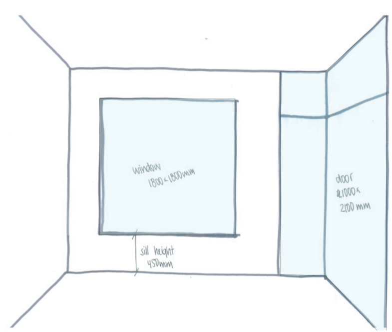


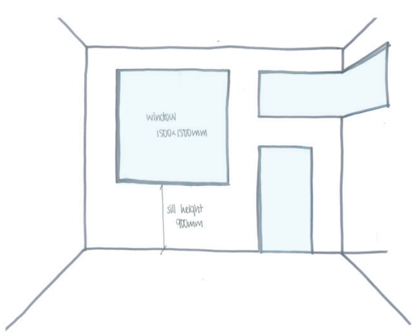
the chosen window/door solution for the winter garden - 1.8x2.25m west and 1.8x2.1m north


window
5700×2250 mm


window
1800×2250mm
600mm
400
mm
sill height 450mm
window
600mm
door
1000×2100mm


window
1500×1500mm
sill height
900mm


window
1800×1800mm
sill height
450mm
door
1000×
2100 mm


window
1500×1500mm
sill height
900mm

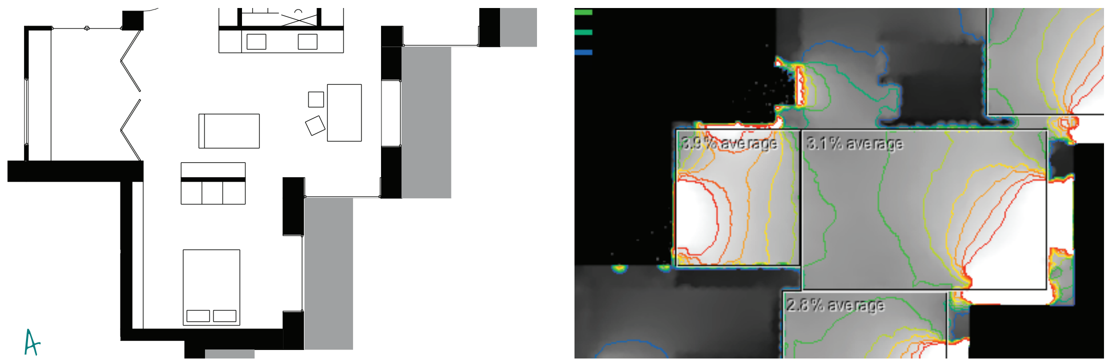
balcony design [velux daylight visualizer]

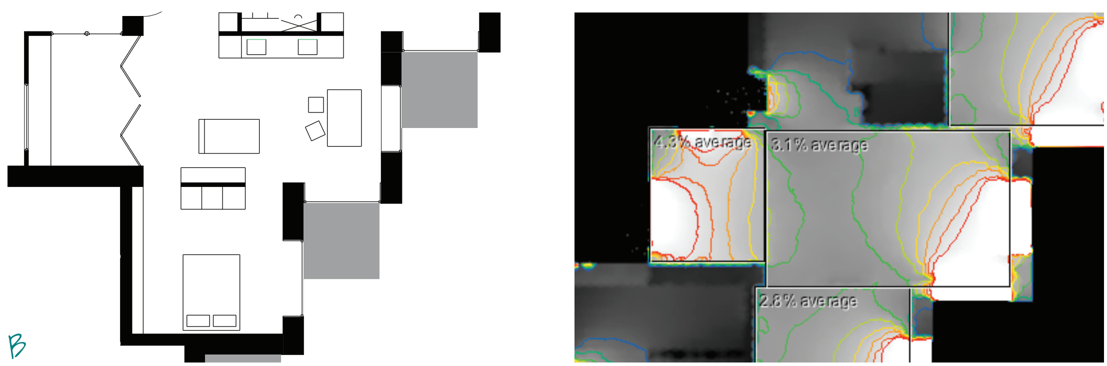
The effect of the shadow from the balconies on the windows is looked into in another Velux Daylight Visualizer-analysis.

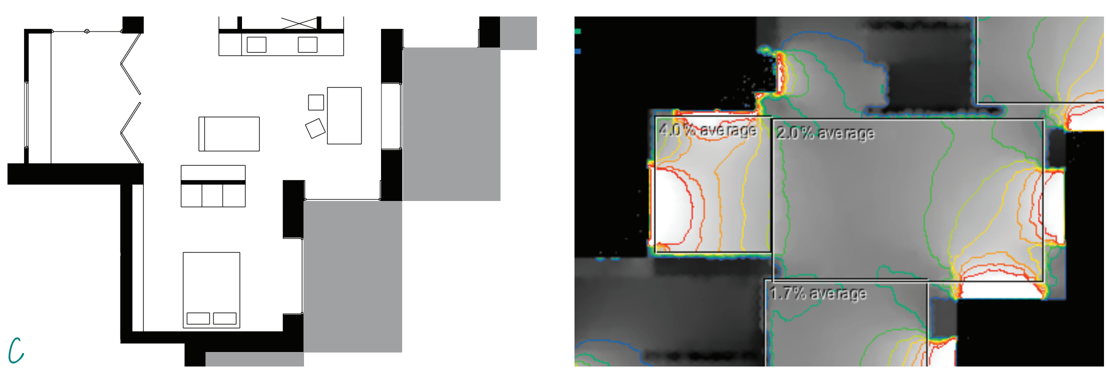
The deep room with a east window of 1.8x1.8 meters and a terrace door to the south of 2.0x2.1 meters is analysed with different balconies above - see list of balconies and results of the analysis to the right. Both the window and the terrace door have gotten a balcony above - in the designed building it will not always be so. Having a balcony over just one of these facade elements will give intermediate values from the table. This is taken into consideration when choosing the final balconies for the building.

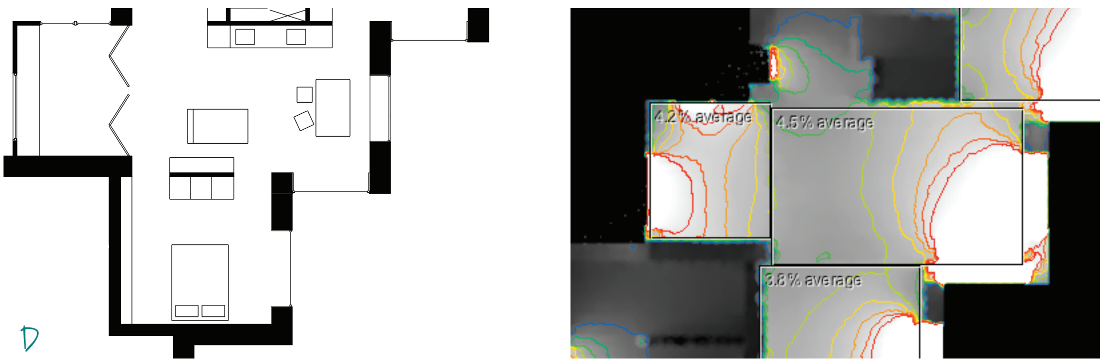
results

size of balconies above windows	DAYLIGHT FACTOR	
	deep room	south room
A: 1.3x4.0m	3.1	2.8
B: 2.0x2.0m	3.1	2.8
C: 2.6x4.0m	2.0	1.7
D: no balconies	4.5	3.8
E: 2.0x2.6m	2.9	2.8
F: triangular balconies	3.0	2.8

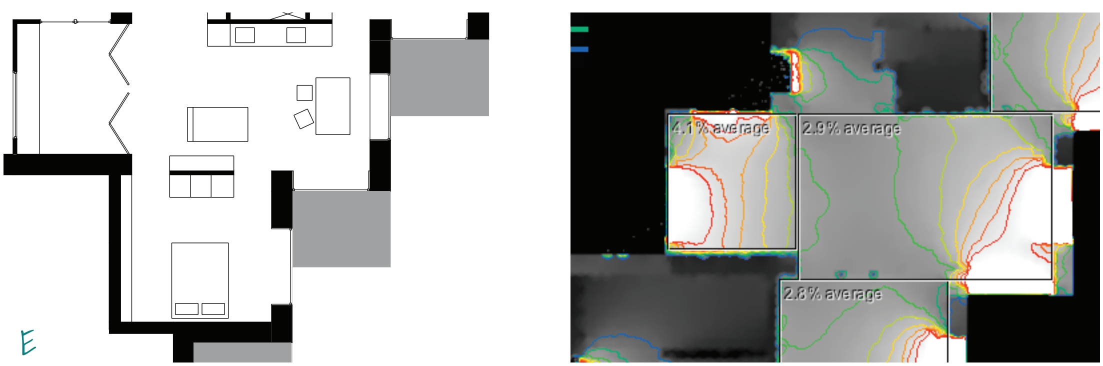

A
3.9% average
3.1% average
2.8% average


B
4.3% average
3.1% average
2.8% average

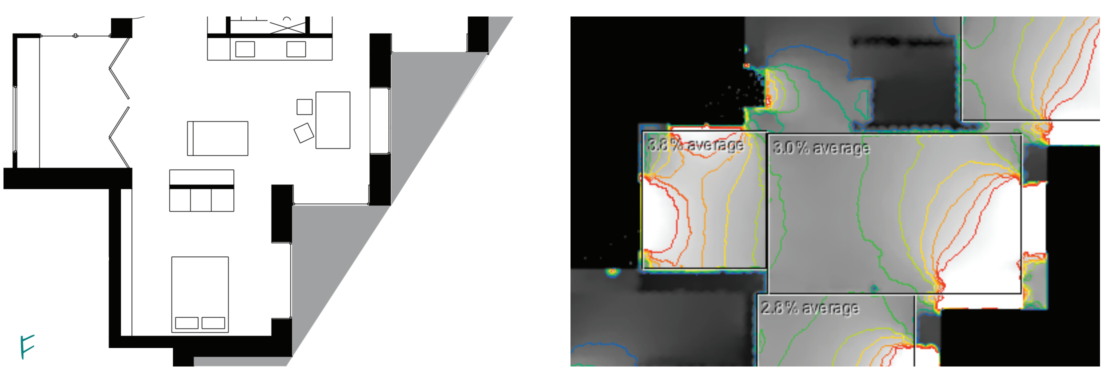

C
4.0% average
2.0% average
1.7% average


4.2% average
4.5% average
3.8% average

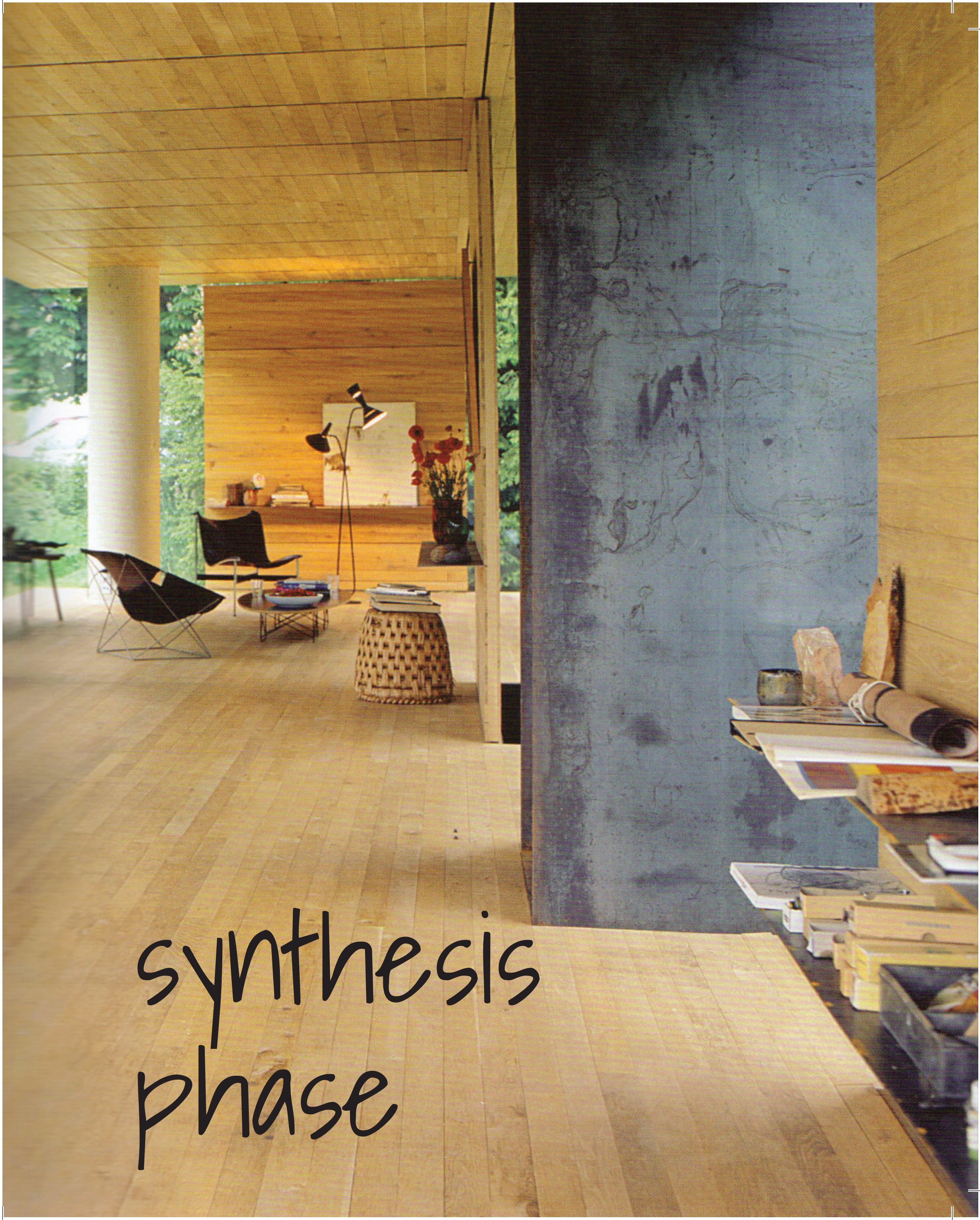
D


4.1% average
2.9% average
2.8% average

E


3.8% average
3.0% average
2.8% average

F



synthesis phase

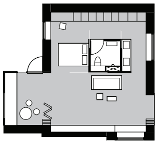
different apartments

The vision of designing apartments that were different in both shapes and sizes resulted in 18 different shapes, 16 different sizes when it comes to area, 1 to 4 room apartments, apartments with ateliers and totally 30 different layouts. The apartments will also be different since the different shapes will result in different numbers of balconies in apartments with same number of rooms – for instance, some 2 room apartments will get only one balcony, others will get two.

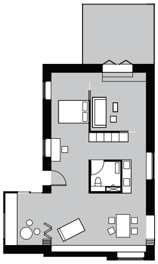
On the following pages diagrams of the different apartments are shown as plans in 1:500 - organised after shape or other similarities. In the presentation phase examples of some of the apartments will be presented.

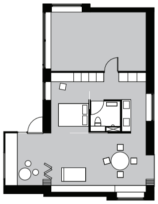
APARTMENTS TO THE NORTH
to the north the building is joined with another building - this gives apartments with less of a zigzag shape than in rest of the building, which again results in having French balconies in order to provide view for the apartments in the building to the north.

01_01
2 rooms
75 m²

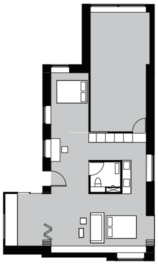


05_01
3 rooms
103 m²

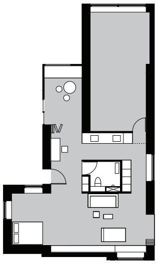




02_01
2 rooms
104 m²



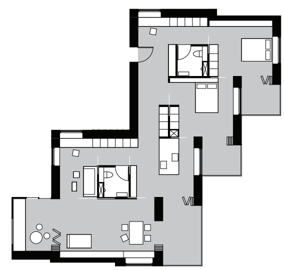
03_01
2 rooms
123 m²



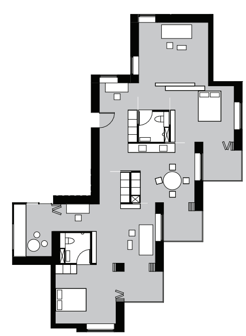
04_01
1 room
123 m²

APARTMENTS WITH ATELIERS
when expanding the building to the north apartments with atelier was integrated in the building in order to take advantage of the northern light

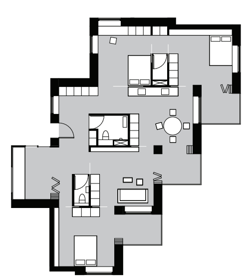
4 ROOM APARTMENTS
there are three 4 room apartments in the building - all different in shapes and sizes



01_05
4 rooms
158 m²

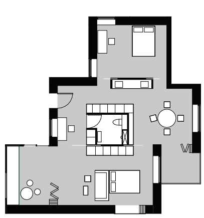


02_05
4 rooms
158 m²

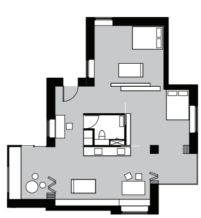


03_04
4 rooms
146 m²

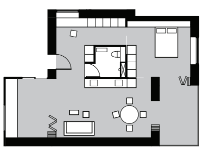
KITCHEN
the relocation of the kitchen often give apartments different layout and number of rooms even though the shape of the apartment is the same



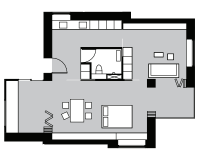
02_06
2 rooms
112 m²



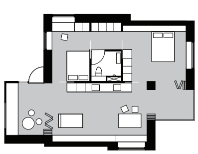
05_04
2/3 rooms
107 m²



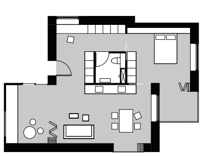
01_06
1/2 room(s)
89 m²



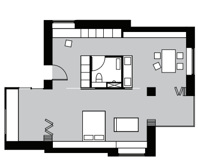
02_02
2 rooms
83 m²



03_02
2/3 rooms
83 m²



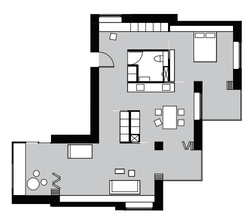
03_06
1/2 room(s)
89 m²



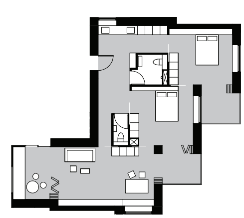
05_02
1 room
83 m²

SMALLEST APARTMENTS
the smallest apartments in the building can be seen as one big open room separated by the box

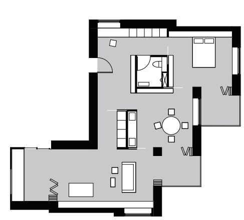
STAIRCASES
apartments next to the staircase get some long, darker corridors, which is utilised as storage space and a study



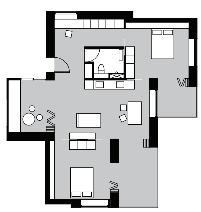
02_03
2 rooms
116 m²



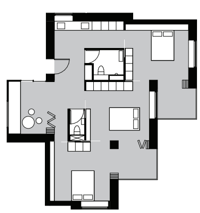
03_03
3 rooms
116 m²



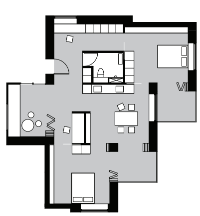
05_05
2 rooms
116 m²



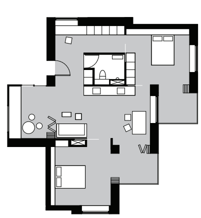
01_02
2/3 rooms
104 m^2



02_04
3 rooms
104 m^2

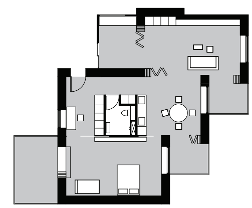


04_02
2/3 rooms
104 m^2

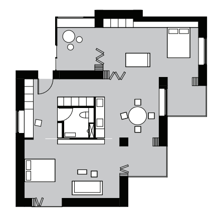


04_04
2/3 rooms
104 m^2

BOX and WALLS
replacing a box with walls, or vice versa, sometimes creates a different layout in apartments of the same shape



04_06
2 rooms
117 m^2

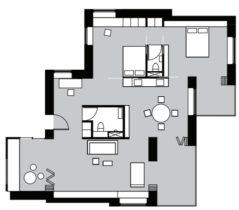


05_06
2 rooms
117 m^2

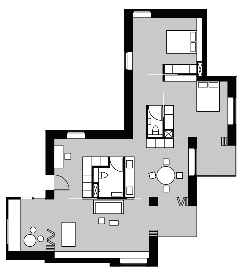
SOUTH END
the top two floors at the south end of the building give opportunity of differencing the same shaped apartment by placing a roof terrace in connection to one of them and a French balcony in the other

3 ROOM APARTMENTS
different shapes and sizes of three room apartments

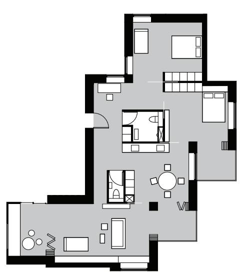
01_04
3 rooms
126 m²



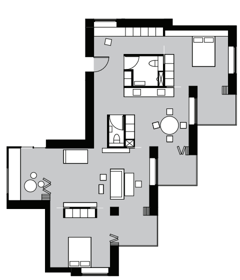
03_05
3 rooms
139 m²



04_05
3 rooms
139 m²

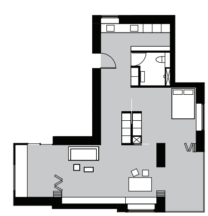


05_03
3 rooms
135 m²

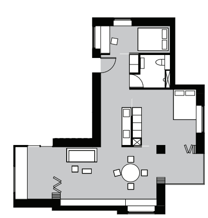


STAIRCASES AND NO BOX
in a couple of apartments next to the staircase it is not possible to walk around the bathroom-box as in the other apartments. even though this feature is replaced by a kitchen and/or storage facilities, the result gives, unfortunately, a rather traditional layout of the apartment

01_03
2 rooms
96 m²



04_03
3 rooms
96 m²



room temperature [bsim]

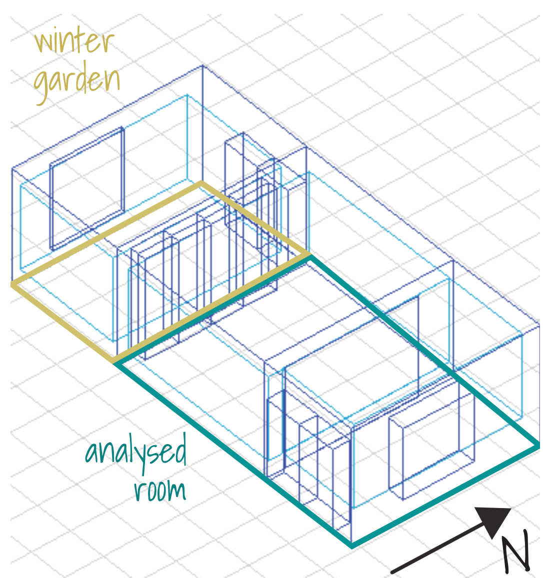
According to the Building Regulations [2011] the room temperature in a room in a dwelling should not be above 26°C more than 100 hours a year or above 27°C more than 25 hours. The deep room is analysed again - this time in BSim in order to reach this goal.

preconditions:

The basis of the analysis is a warm summer day, meaning the heat load for both equipment and lighting is reduced to zero.

The winter garden is located in connection to the analysed room. During summer, the doors between these two rooms will be open - giving opportunity of cross ventilation. This gives a higher ventilation rate due to the higher volume of the two rooms together - something that affects the temperature in a positive way. The mechanical ventilation system will use both the winter garden and the outdoor as air supply. In the analysis values from both of these are noted - the correct number of hours above the 26°C and 27°C will be somewhere in between these two sets.

The airflow rate for thermal design is calculated according to DS-CEN-CR 1752 [2001] - see appendix a. The input value for air supply in BSim is the highest value of this one and the minimum air change requirement of 0.5/h according to BR10 [2011].



When it comes to venting, it is assumed that the windows/ventilation opening is being open all day long during the warmest days - with an air change of 5 times an hour when the residents are at home and 2 times an hour when they are away.

The people profile is chosen from Jensen et al. [2011] - see appendix b. It is assumed that the two people living in this room will spend several hours in the winter garden during summer - lowering the effect on the room analysed.

VENTILATION	requirement	calculated
BR10	0.5/h	
1752		3.08 l/s
BSim	(0.5/h x 35 m^2 x 2.54m) / 3600 s = **0.0124 m^3s**	3.08 l/s / 1000 = 0.0031 m^3s

results:

The first analysis gave too many hours over the dimensioned temperatures. The glazing of the windows to the south was replaced with sun shading glass - this reduced the number of hours below the requirements when the air supply came from the outdoors. The numbers of hours above 27°C is still too high when looking at an intermediate value for the two air supplies. It can be argued that the warmest hours of the day (right after midday) are when the people are usually not at home - either at school, at work or outside enjoying the nice weather. If they are at home it is more likeable they will open all the windows.

results:				air supply ventilation system			
				outdoor		winter garden	
windows south	g	U_g	L_T	h > 26°C	h > 27°C	h > 26°C	h > 27°C
velfac energy	0.55	0.53	0.72	149	81	190	100
velfac sun	0.37	0.55	0.61	90	26	114	42

input systems BSim

SYSTEM	DESCRIPTION	TIMESCHEDULE		
		CONTROL	TIME	
EQUIPMENT	heat load: 0			
HEATING	max power: 1 kW fixed part: 0 part to air: 0,7	floor heat ctrl factor: 1 set point: 22°C max. surf. tmp: 27°C design temp: -12°C min. power: 2,2 kW te min 17°C L=0,3m, Ls=1,5m	heating season (sep - may)	
INFILTRATION	basic air change: 0,098/h (from Be10: 0,07 l/s m²) tmp factor: 0,01/h tmp power: 0,5 s/m/h wind factor: 0,2	full load	all year	
LIGHTING	no lighting			
PEOPLE LOAD	2 people medium activity	100% 18-06 50% 7-8,17 100% 18-19, 23-06 100% 17-06 50% 7-8, 15-16 100% 17-19, 23-06 100% 17-08 50% 9-16 100% 23-08 50% 9-13	mon - thu mon - thu mon - thu fri fri fri sat - sun sat - sun sat - sun sat - sun	okt - apr all year may - sep okt - apr all year may - sep okt - april okt - april may - sep may - sep
VENTILATION	input supply: 0,012 m³/s (from BR10: 0.5/h) pressure rise: 900 Pa total eff.: 0,85 part to air: 0,5 output return: 0,012 m³/s pressure rise: 600Pa total eff.: 0,85 part to air: 0,5 recovery unit max heat rec: 0,85 min heat rec: 0 max cool rec: 0 max moist rec: 0 heating coil: 0,5 kW cooling coil surf temp: 5°C	zone temp ctrl part of nom. flow: 1 min inlet temp: 17°C max inlet temp: 40°C heating set pnt: 22 cooling set pnt: 25	always	
VENTING	solution #01: basic air change: 5/h tmp factor: 0,3/h/K tmp power: 0,5 wind factor: 0,3 s/m/h max air change: 5/h	venting ctrl home set point: 25°C set point CO_2: 600 ppm factor: 1 venting ctrl away set point: 25°C set point CO_2: 600 ppm factor: 0.4	mon - thu may-aug fri may-aug sat- sun may-aug mon - thu may-aug fri may-aug	17-08 15-08 all day 09-16 09-14

constructions and U-values

The U-values of the constructions are calculated according to DS 418 [2002].
The horizontal division has been chosen according to Eriksen and Ejlersen [2003].
The material mentioned first is on the interior side of the construction.

EXTERIOR WALL U_{max} = 0.15 W/m^{2}K (BR2020)

146mm massive wood, holz100 — λ = 0.100 W/mK
265mm insulation, Rockwool Super Flexibatts — λ = 0.034 W/mK
80mm fibreboard — λ = 0.046 W/mK
24mm laths
32mm cladding, larch
547mm

$$U' = \frac{1}{R_{se}+\sum\frac{d}{\lambda}+R_{si}} = \frac{1}{0.04+\frac{0.146}{0.100}+\frac{0.260}{0.034}+\frac{0.080}{0.046}+0.13} = \underline{0.09}\ \mathrm{W/m^2K}$$

GROUND DECK
(less than 2 meters under terrain, toward air) U_{max} = 0.10 W/m^{2}K (BR2020)

100mm reinforced concrete, 2400kg/m^3, 2% steel — λ = 2.640 W/mK
600mm insulation, Rockwool Terrænbatts Erhverv — λ = 0.038 W/mK
700mm

$$U' = \frac{1}{R_{se}+\sum\frac{d}{\lambda}+R_{si}} = \frac{1}{0.04+\frac{0.100}{2.640}+\frac{0.600}{0.038}+0.17} = \underline{0.06}\ \mathrm{W/m^2K}$$

ROOF U_{max} = 0.10 W/m^{2}K (BR2020)

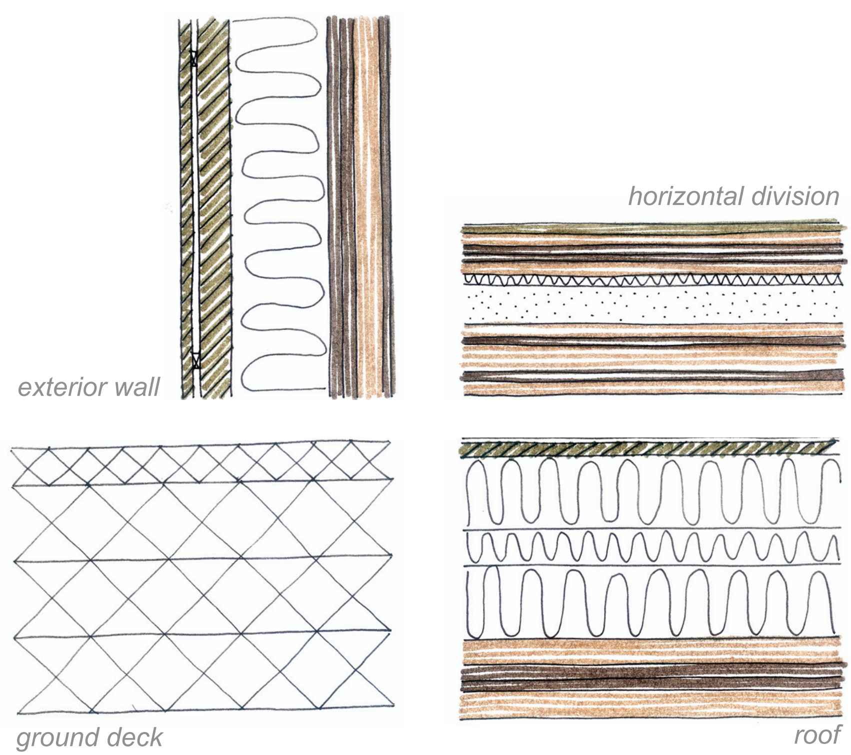
210mm massive wood, holz100 — λ = 0.130 W/mK
195mm insulation, Rockwool Super FlexiBatts — λ = 0.034 W/mK
0.20mm vapour barrier
195mm x2 insulation, Rockwool Super FlexiBatts — λ = 0.034 W/mK
35mm fibreboard — λ = 0.047 W/mK
2.2mm asphalt roofing, Icopal Base 511 PG
2.2mm asphalt roofing, Icopal Base 300G
3.9mm solar cells, Icopal IcoSun Top S
838.5mm

$$U' = \frac{1}{R_{se}+\sum\frac{d}{\lambda}+R_{si}} = \frac{1}{0.04+\frac{0.210}{0.130}+\frac{0.195x3}{0.034}+\frac{0.035}{0.047}+0.10} = \underline{0.05}\ \mathrm{W/m^2K}$$

HORIZONTAL DIVISION

115mm massive wood, holz100
30mm Rockwool Gulvrenoveringsplader
100mm sand
185mm massive wood
430mm

$L_{n,w}+C_{50\text{-}2500}$ = 48 dB,
$R_w+C_{I,50\text{-}3150}$ = 60 dB



energy frame [be10]

After the latest analyses and the expansion of the building to the north, the final window design, window glass and balconies were chosen. From this, yet another Be10-calculation was performed with all the final data except datas conserning the production of energy is taken into consideration. In this calculation, the choice of replacing the district heating with a heat pump is also investigated.

Output values from the final Be10-calculation including production of energy is presented in appandic c.

precondition:

- 5 floors of apartments + ground floor with common facilities and a café/restaurant
- 6 apartments per floor
- height between floors 3.0m
- windows: velfac 200helo 48mm (3-layered), energy, g=0.5
- windows south in apartments: velfac 200helo 48mm (3-layered), sun, g=0.37
- shading from own building (south and west)
- shading from balconies (south/east and west)
- window openings (shadow): 1.72%
- terrace doors: velfac 200helo, 48mm (3-layered), energy, g=0.5, terrace doors
- terrace doors south in apartments: velfac 200helo 48mm (3-layered), sun, g=0.37
- wooden doors: velfac 200helo, 24mm (2-layered), cedar wood
- joints at windows/doors: no transmission loss (windows put on top of insulation)
- under floor heating in apartments
- mechanical ventilation summer

results:

energy frame for designed building	19.5	
heat	21.9	
room heating	4.4	
excessive in rooms	0.0	
transmission loss	2.5	
total el. consumption	34.2	
• heat pump	17.9	kWh/m² year

input BE10_03

heated floor area	3762	m^2
heat capacity	120	Wh/K m^2
heat supply	district heating	

WALLS, ROOFS, DECKS	area [m^2]	U-value [W/m^2 K]	
walls north	571	0.09	
walls east	1354	0.09	
walls south	932	0.09	
walls west	808	0.09	
roof	608	0.05	
ground deck	522	0.06	b=0.07, dim ude: 10°C
walls toward unheated rooms north	368	0.09	b=0.07
walls toward unheated rooms west	572	0.09	b=0.07
floors toward unheated rooms	128	0.06	
roofs toward unheated rooms	128	0.06	

FOUNDATION	area [m^2]	loss [W/mK]	
exterior wall foundation	222	0.1	b=0.07
joints at windows and doors	2336	0	

3762 *values changed since last Be10-calculation*

WINDOWS	#	area [m²]	U-value [W/m² K]	Ff	g	shading
w_N_1.2x1.2m	11	1.44	0.88	0.83	0.5	window opening 1.72%
w_N_1.2x1.8m	5	2.16	0.82	0.85	0.5	w.o. 1.72%
w_N_1.5x0.8m	14	1.20	0.94	0.80	0.5	w.o. 1.72%
w_N_3.7x2.25m	2	8.33	0.70	0.90	0.5	w.o. 1.72%
w_N_2.0x2.25m	1	5.00	0.70	0.90	0.5	w.o. 1.72%
d_N_2.0x2.1 glass	1	4.20	0.81	0.84	0.5	w.o. 1.72%
d_N_1.0x2.1 wood	3	2.10	0.27	0.10	0	
d_N_2.0x2.7m glass	1	5.40	0.78	0.70	0.5	w.o. 1.72%
d_N_1.8x2.1m wood	1	3.60	0.29	0.10	0	
w_E_1.8x1.8m	30	3.24	0.77	0.88	0.5	w.o. 1.72%
w_E_1.8x1.8m	22	3.24	0.77	0.88	0.5	eaves 27.4°
w_E_2.0x2.0m	2	4.00	0.74	0.89	0.5	w.o. 1.72%
d_E_2.0x2.1m glass	14	4.20	0.81	0.84	0.5	w.o. 1.72%
d_E_2.0x2.1m glass	14	4.20	0.81	0.84	0.5	eaves 27.4°, w.o. 1.72%
d_E_3.4x2.7m glass	4	9.18	0.80	0.84	0.5	w.o. 1.72%
d_E_3.4x2.7m glass	6	9.18	0.80	0.84	0.5	eaves 27.4°, w.o. 1.72%
w_S_1.8x1.8m	21	3.24	0.78	0.88	0.37	right 75°, w.o. 1.72%
w_S_1.8x1.8m	7	3.24	0.78	0.88	0.37	e. 34°, r. 75°, w.o. 1.72%
w_S_2.0x2.7m	5	5.40	0.71	0.91	0.55	right 75°, w.o. 1.72%
w_S_2.0x2.7m	2	5.40	0.71	0.91	0.55	e. 34°, r. 75°, w.o. 1.72%
w_S_2.0x2.7m	3	5.40	0.71	0.91	0.55	e. 38.7°, r. 75°, w.o. 1.72%
d_S_2.0x2.1m glass	18	4.20	0.83	0.84	0.37	right 75°, w.o. 1.72%
d_S_2.0x2.1m glass	29	4.20	0.83	0.84	0.37	e. 39.5°, r. 75°, w.o. 1.72%
d_S_2.0x2.7m glass	4	5.40	0.71	0.91	0.55	w.o. 1.72%
w_W_1.2x1.8m	1	2.16	0.82	0.85	0.5	left 56°, w.o. 1.72%
w_W_1.2x1.8m	2	2.16	0.82	0.85	0.5	w.o. 1.72%
w_W_1.2x1.8m	12	2.16	0.82	0.85	0.5	e. 27.4°, l. 56°, w.o. 1.72%
w_W_1.5x0.8m	5	2.16	0.82	0.85	0.5	left 56°, w.o. 1.72%
w_W_1.5x0.8m	1	1.20	0.94	0.80	0.5	left 56°, w.o. 1.72%
w_W_1.5x0.8m	1	1.20	0.94	0.80	0.5	h. 12.5°, e. 27.4°, l. 56°, w.o. 1.72%
w_W_3.7x2.2.5m	1	8.33	0.70	0.90	0.5	w.o. 1.72%
d_W_1.0x2.1m wood	26	2.10	0.27	0.10	0	
d_W_3.4x2.7m glass	28	9.18	0.80	0.84	0.5	e. 12.5°, l. 56°, w.o. 1.72%
d_W_1.8x2.7m glass	1	2.86	0.80	0.84	0.5	w.o. 1.72%

VENTILATION	area	q_m winter	η_{vgv}	SEL	q_m summer	q_n summer	q_n winter
	[m^2]	[l/s m^2]		[kJ/m^3]	[l/s m^2]	[l/s m^2]	[l/s m^2]
apartment + café	3240	0.3	0.85	1.5	0.3	2.0	0.07
common rooms level 00	522					2.0	0.07

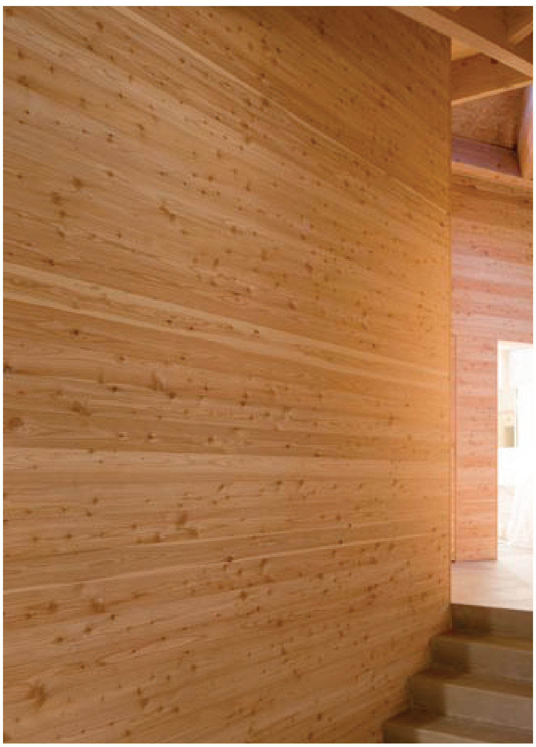
INTERNAL HEAT SUPPLY	area [m^2]	persons [W/m^2]	app. [W/m^2]
entire building	3762	1.5	3.5

HEAT DISTRIBUTION PLANT		
supply pipe temp.	35	°C
return pipe temp.	25	°C
type of plant	2	

PUMP		
type	T	(time controlled)
number	30	(one for each apartment)
P_{nom}	15	W
F_p	0.4	

DOMESTIC HOT WATER		
hot water consumption	250	liters (average for the building)
DHW temperature	55	°C
number of tanks	30	(one in each apartment)
tank volume	250	liters
supply temperature	60	°C
el. heating of DHW	no	
heat loss from hot water tank	1.8	W/K
temp. factor	0	

interior materials



EXTERIOR WALLS,
WALLS BETWEEN APARTMENTS and
CEILINGS

Massive wood will be the most dominating material inside the apartments. The massive wood produced in Scandinavia usually consists of a combination of fir and pine. It gives a warm atmosphere without absorbing too much light.

INTERIOR WALLS

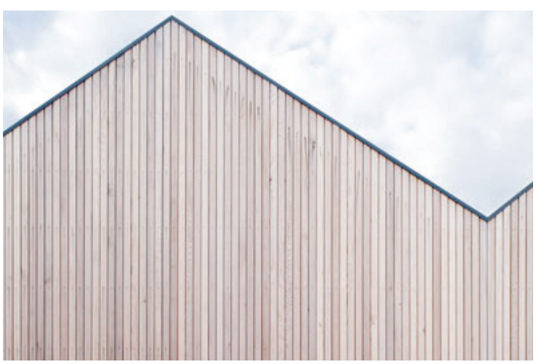
The boxes and other interior walls in the apartments will be covered with plywood and osb in order to differentiate them from the massive wood. The pattern of these two materials can make the wood act as art in itself and the symbiosis with massive wood will create adventure and dynamic in the

FLOORS

apartments.
The idea is to dress one box in plywood and another in osb, where there are more than one. In the smaller apartments only one of the materials will be chosen in order to create a calmer atmosphere.

Wooden floors with under floor heating is chosen in the apartments in order to continue the warm effect of wood and to give continuity in the building.

exterior materials



FACADE

The wish is to make the building look natural and robust - therefore untreated larch is chosen as the facade material. Siberian Larch is one of the most durable on this area and will get a silver colour over time.

In the very exposed and open west facade the idea is to have some shutters that can give both shading from the sun and blocking from the wind. These should be placed outside the railing and some should also include solar cells. The shutters will provide a more dynamic facade to the west since the residents can open and close them, as they prefer.

WINDOWS

Velfac's 3-layered Helo200-windows and terrace doors [Velfac, 2012] are represented in the entire building together with facade doors in cedar wood. The south facades in the apartments have sun-shading glass - the three other directions have energy glass.

SOLAR CELLS

The roof will be covered with Icopal's IcoSun [Icopal, 2012], which is solar cells glued directly on top of a couple of layers of asphalt roofing. This materials is operable at angles between 3-60^{o}, meaning traditional solar cells will be chosen for vertical building parts.

calculations solar cells [be10]

One of the goals of the project is for the building to produce more energy than it consumes - during its lifetime. Before deciding where or how the solar cells should be placed on the building, relevant building elements have been analysed with help from Be10 in order to see the effect of the solar cells with a given orientation, area and slope. Roof, facades and balconies are considered.

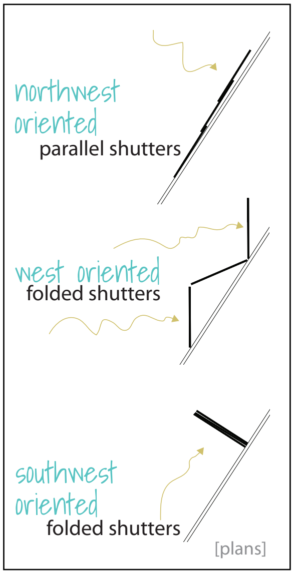
According to the Local Plan [2006] the roof of the building on this site has to be flat. In Be10 solar cells with the slope of 45º is the most optimal. It is therefore analysed what the difference is, when placing solar cells with the slope of 0º versus 45º. With an angle of 45º it is taken into consideration that the area of solar cells will be less than the area of the roof - the cells need to be placed a bit apart in order for the cells not to provide shade on each other.

In the west facade it is looked into the effect of having different types and orientation of shutters, where solar cells is included in one or two out of three shutters. Parallel shutters will give an orientation to the northwest, which is not very optimal. Using folded shutters instead makes it possible to rotate the solar cells toward the sun.

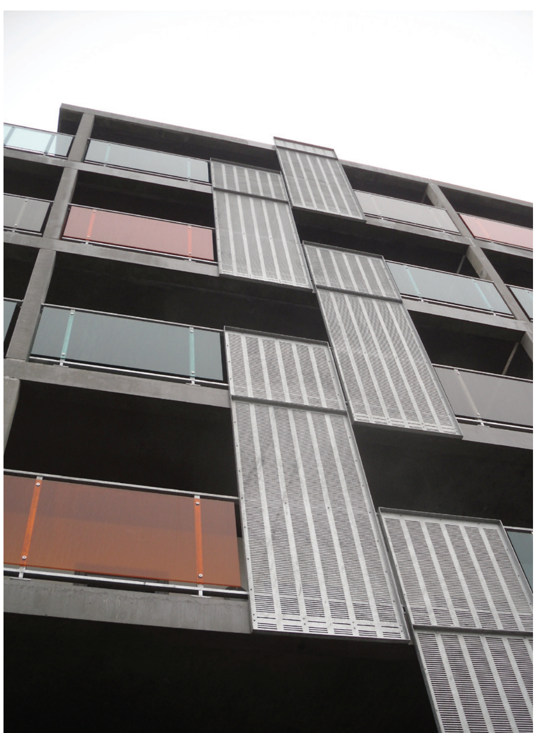
	SOLAR CELLS	area [m²]	slope [º]	production [kWh/m² year]
	south wall	124.3	90	3.5 x 1.8 = **6.3**
	west wall	46.2	90	1.0 x 1.8 = **1.8**
	roof	846.6	0	26.4 x 1.8 = **47.5**
		706.2	45	26.7 x 1.8 = 48.1
	balconies south	128.7	90	3.4 x 1.8 = **6.1**
	balconies east	110.0	90	2.3 x 1.8 = **4.1**
west facade	balconies northwest	275	90	3.8 x 1.8 = 6.8
	balconies west	577.9	90	11.9 x 1.8 = **21.4**
	balconies southwest	288.7	90	7.6 x 1.8 = 13.7

maximum production of energy when solar cells on roof has slope 0º and cells on western facade are oriented west

87.2 kWh/m² year



solar cells solutions
from the building north of the building site -
cells on both south facade
and balconies to the east



final energy frame [be10]

Two of the technical goals of the project are for the building to produce more energy than it consumes and to fulfil the energy requirements of the BR2020 before starting to produce any energy. Both of these matters have been investigated in Be10 and represented in earlier chapters of the report.

The economical aspect of building a low energy building is not taken into considerations in this project. When looking at the calculations of solar cells on the previous pages it seems obvious that it is not beneficial to place solar cells on whatever building element facing the sun. For instance, the east side of the balconies will only have sun during few hours each day and the sun will not be that intense during those hours. It seems more reasonable to skip the solar cells on this façade.

Below, two different calculations have been made. One where the maximum numbers from the solar cell calculation have been taken into consideration - another where there are only solar cells on the roof (placed horizontally), south façade and in shutters in the west façade.

MAXIMUM AREA OF SOLAR CELLS

energy frame BR20 (result Be10 - with heat pump)		17.9	
+ appliances	1.8x25 =	45.0	
- production		87.2	
= final production of energy in active house		24.3	kWh/m^2 year

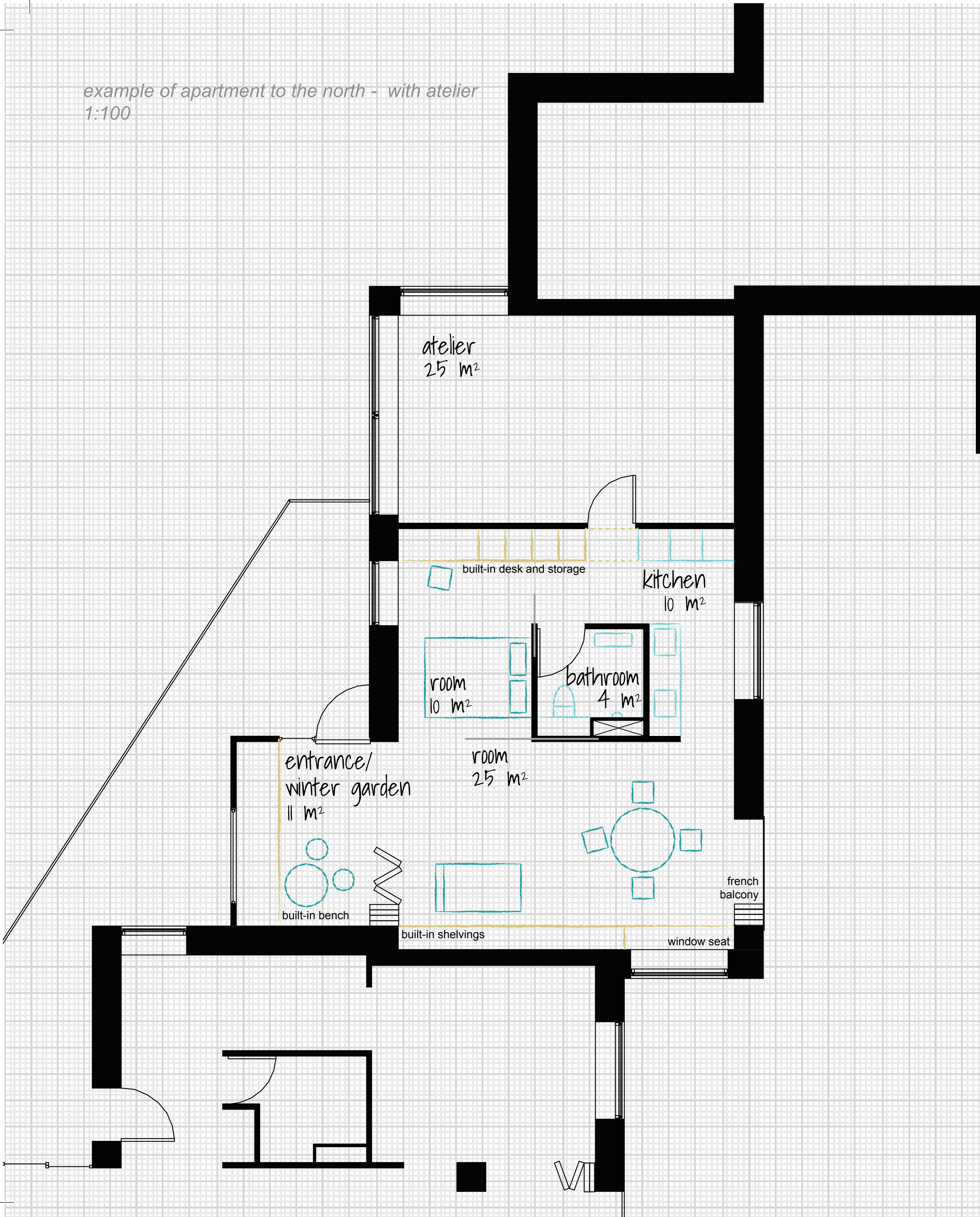
REGULATED AREAS OF SOLAR CELLS

energy frame BR20 (result Be10 - with heat pump)		17.9	
+ appliances	1.8x25 =	45.0	
- production		75.2	
= final production of energy in active house		12.3	kWh/m^2 year

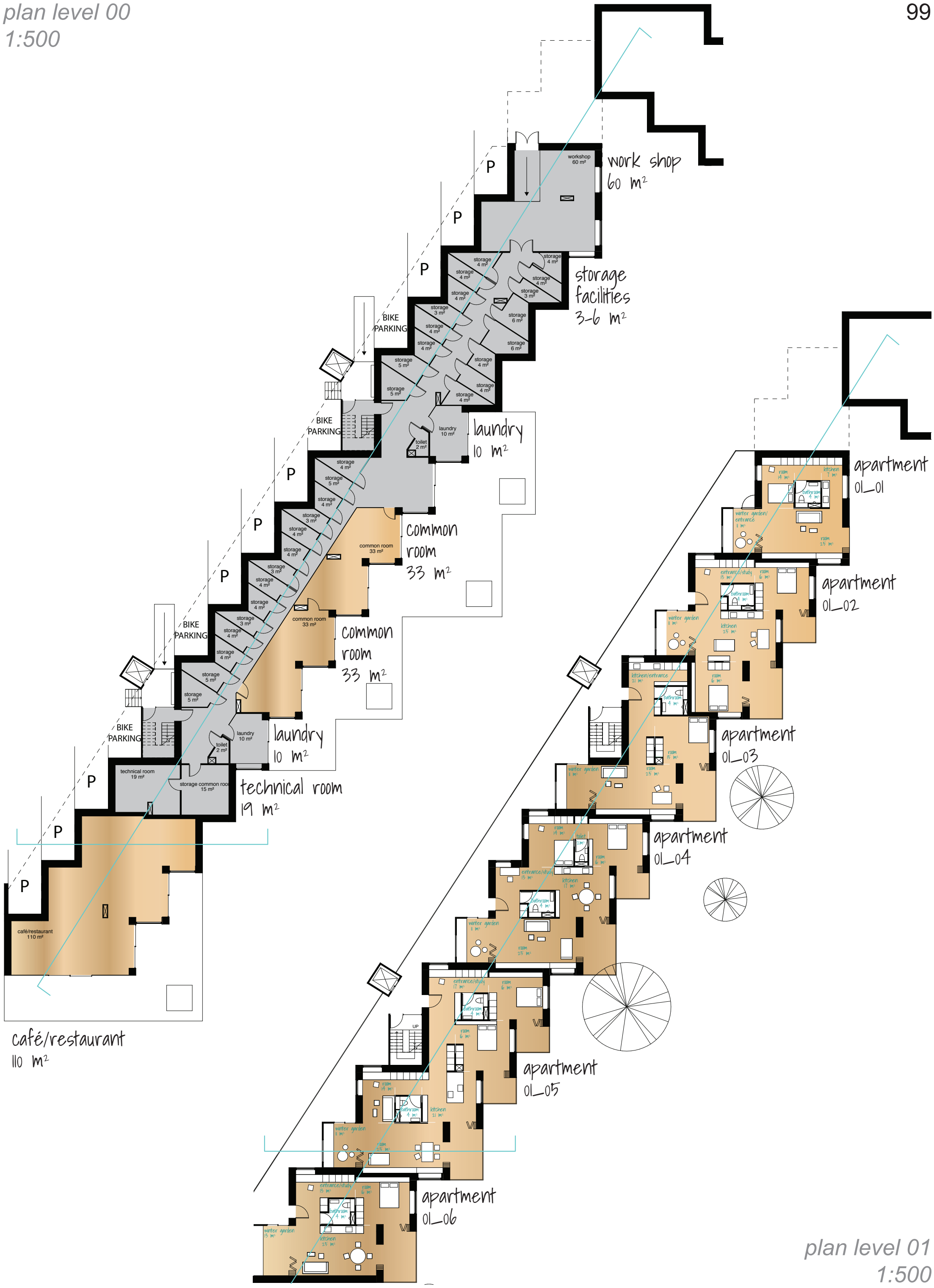
the zigzag shape of the building
in combination with the boxes inside the apartments
give long views that rouses ones curiosity
about what is going on in the other rooms of the apartment


presentation

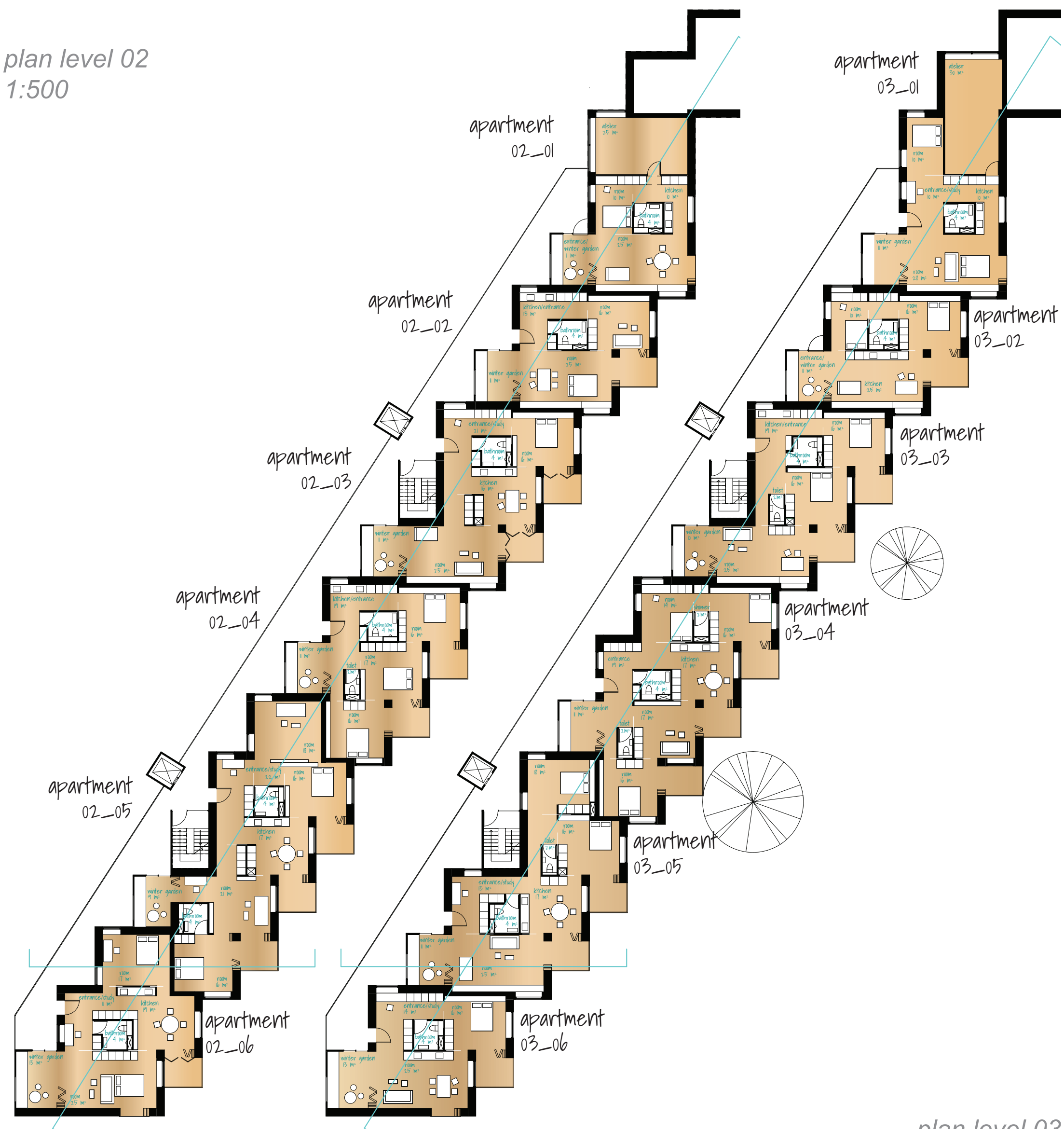
example of apartment to the north - with atelier
1:100



plan level 00
1:500



plan level 01
1:500


plan level 02
1:500
apartment
02_01
apartment
02_02
apartment
02_03
apartment
02_04
apartment
02_05
apartment
02_06
apartment
03_01
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03_03
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03_04
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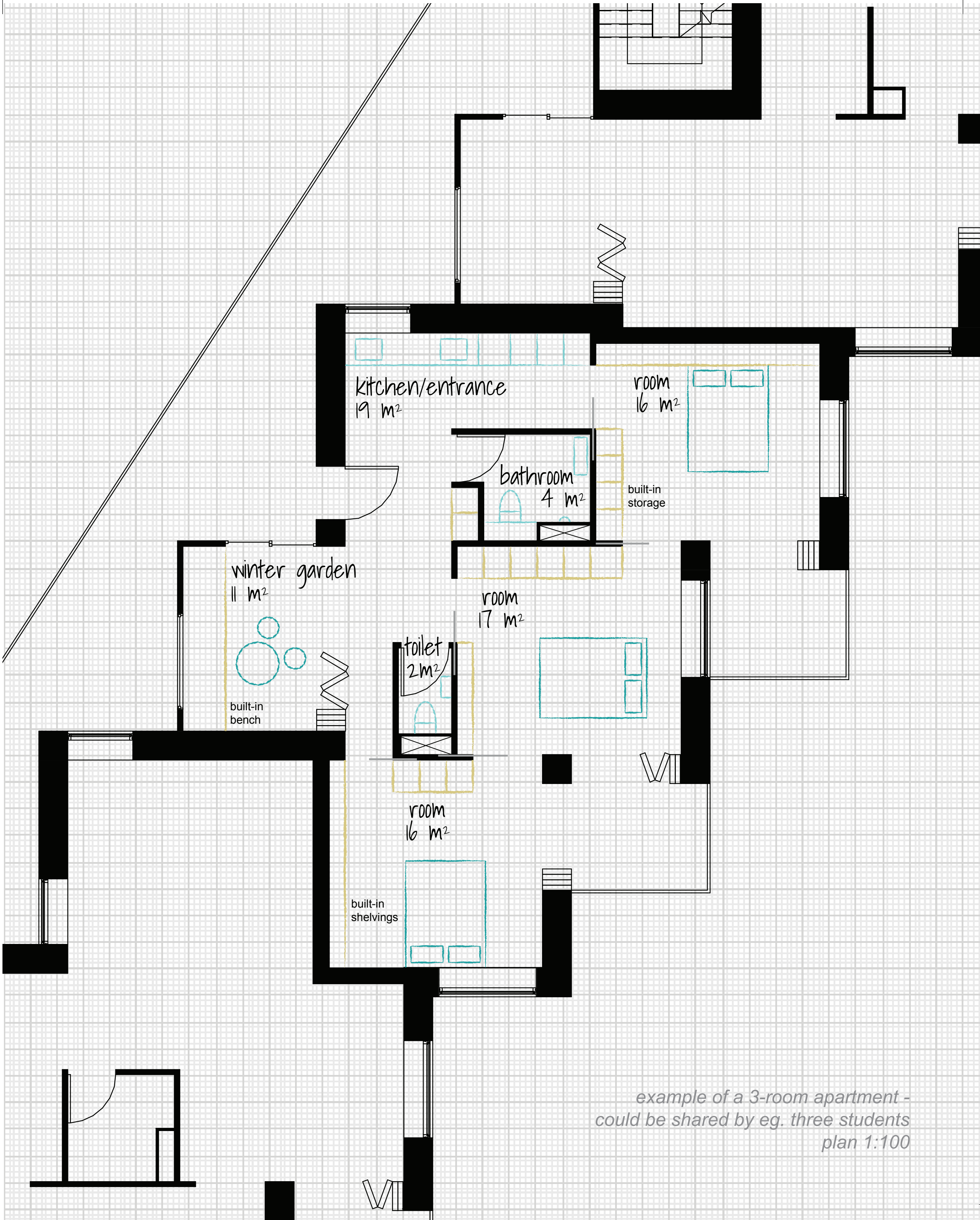
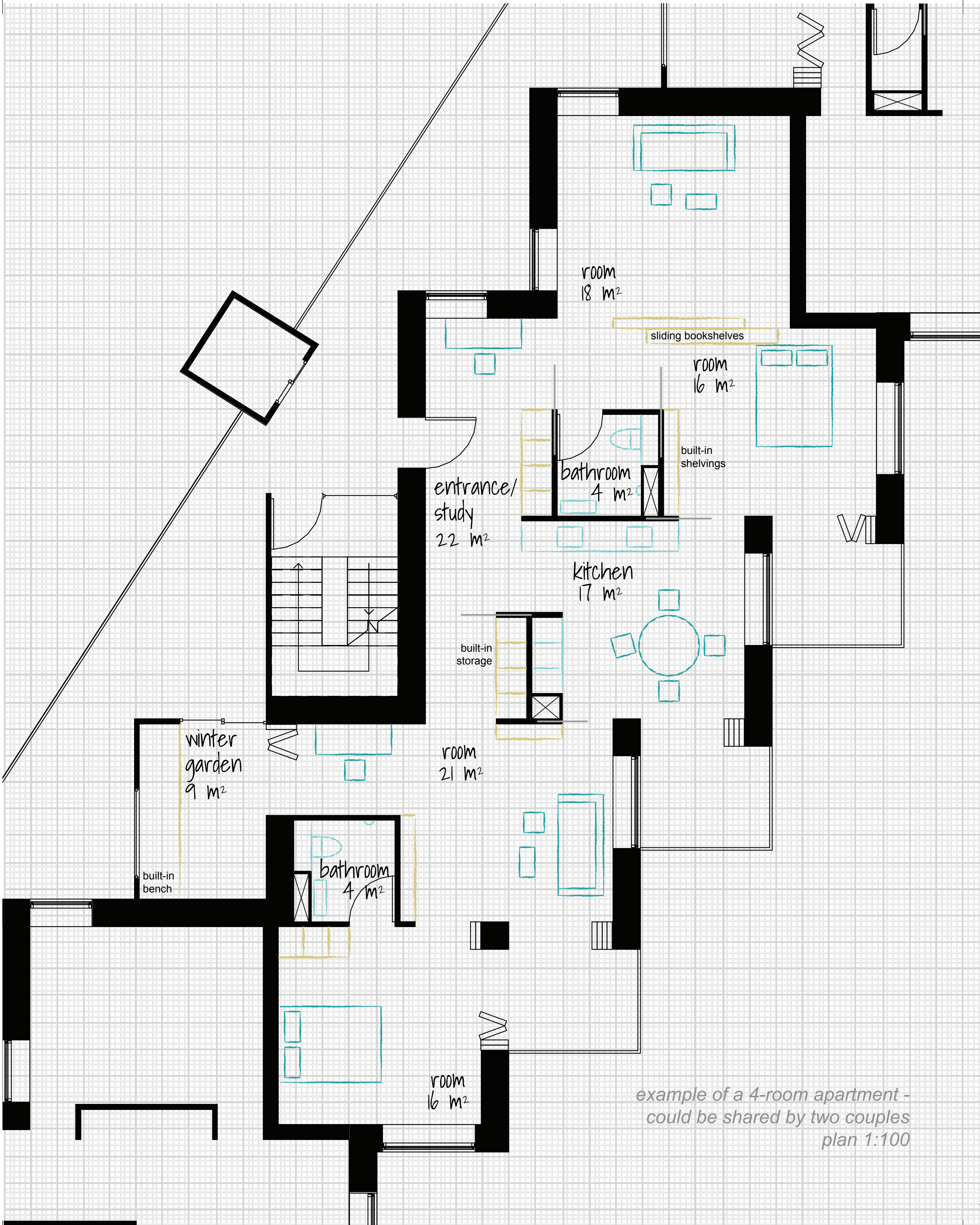
03_05
apartment
03_06
plan level 03
1:500

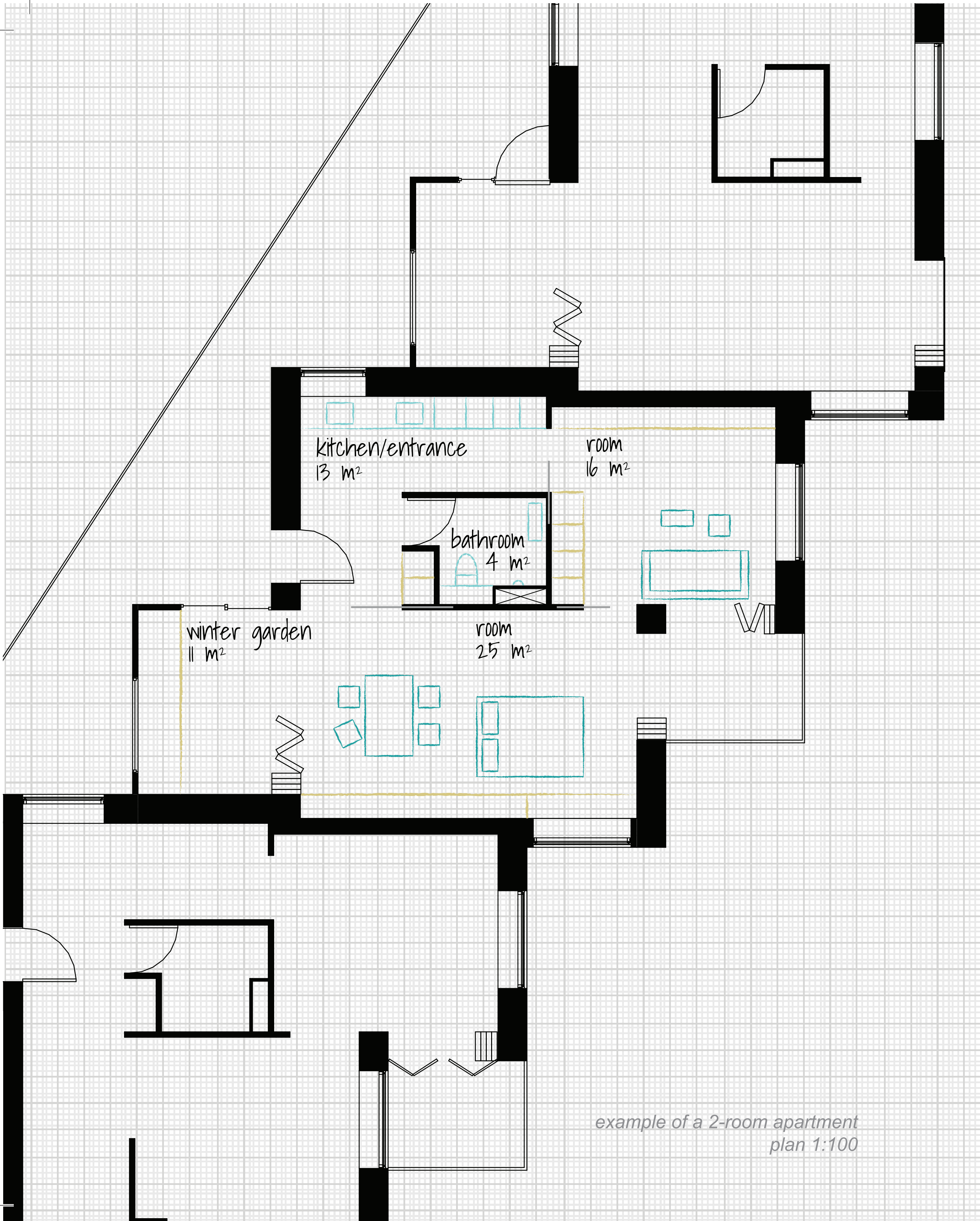


example of a 3-room apartment -
could be shared by eg. three students
plan 1:100

the combination of deep walls and built-in furniture creates the possibility of deep window seating

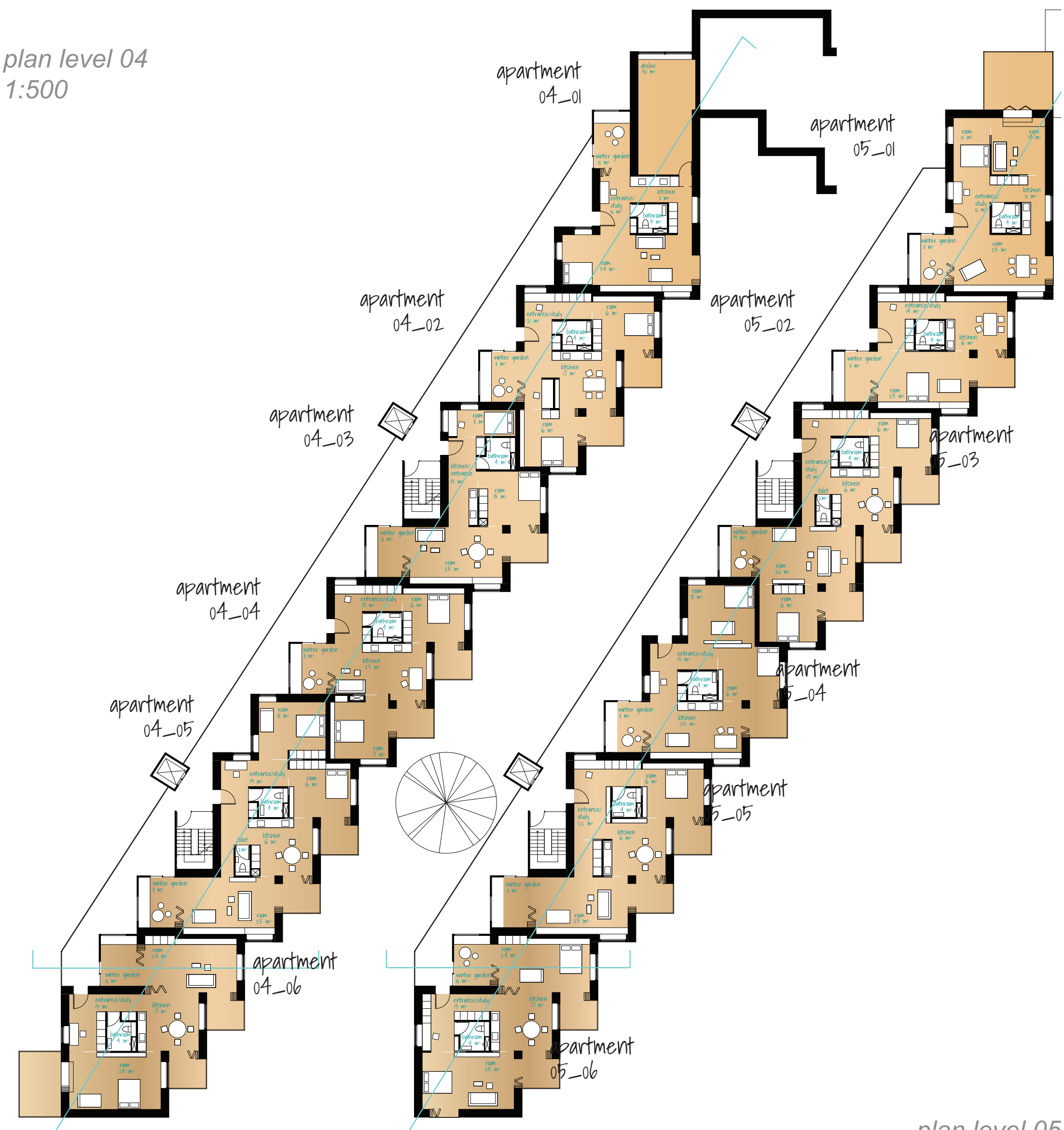


example of a 4-room apartment -
could be shared by two couples
plan 1:100



example of a 2-room apartment
plan 1:100

plan level 04
1:500



plan level 05
1:500

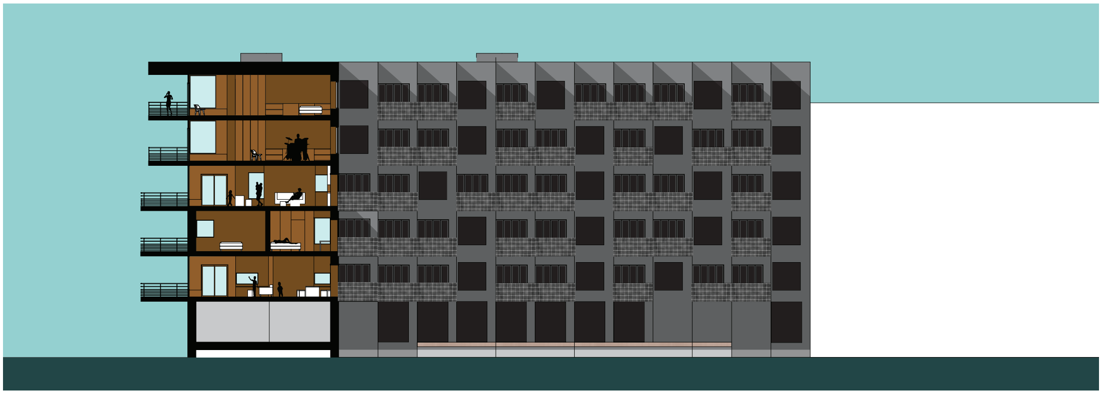
*all the apartments have a winter garden to the west
that provides both viewing and light through the apartment*


east facade
1:500


south facade
1:500


north facade
1:500


west facade
1:500



cross section
1:500

longitudinal section
1:750

site plan
1:1000

conclusion

The main purpose of the project was to design apartments that would promote spiritual living for the residents – these apartments would be located in an active house. The process of merging the softer values of spiritual architecture with harder values required for low energy buildings sometimes created a conflict.

The atmosphere in the apartments was seen as the main driving force during the design process, but when it came to the window design and the consideration of daylight in the rooms, the technical aspects seemed to take over. In order for the residents to get peace and quiet to withdraw and focus on inner values in life it is crucial to reduce the light in the rooms. Working towards an average daylight factor of 3 in the rooms due to the Building Regulations is going against this fact.

The main reason for rotating the building on the site was to orient the view towards the fjord and, of course, take advantage of the suns radiation and light. This resulted in terrace doors of 4 m^2 in the south façade in most of the rooms. Due to the normally thicker exterior walls in low energy buildings there was in addition a wish of making window seats in the east façade. This gave a total window area of 7.5 m^2 in a room of 16 m^2 – giving almost 50% windows of the floor area. In the bigger rooms located in connection with the winter garden the percentage is even higher.

The windows with window seating could undoubtedly be smaller – this would also create more intimacy in both the window and the room itself. In addition to this, a solution could be to replace one big window in the east façade with several smaller. Even if this give negative impact on the energy frame, it would promote softer atmosphere in the rooms. Having different window solution in the southeast oriented rooms would also differentiate the rooms – a window seat could be appropriate in a kitchen but a more intimate and mysterious solution could be chosen for the other rooms.

When the winter garden was introduced the apartments ended up having two entrances in the northwest façade, something that can be seen as a bit of a waste, especially since most of the apartments are rather big. 75% of the apartments are over 100 m^2 – there are even 2 room apartments of this size. Making the winter garden into a windbreak as well could rationalize both the apartments and the entire building – maybe there would be room for more apartments on each floor.

As it is now, the winter garden is usually located in connection with the deepest room of the apartment, which again is located furthest to the south in each apartment. With other words, the winter garden does not contribute to diversity amongst the apartments. Another fact is that both the size of the deep room and the location next to the winter garden can make it obvious to choose this room as a living room. One goal of the apartment design was to create rooms without a certain function – it should be up to the residents how they want to use the different rooms.

The kitchen could be placed in connection with the wind break/winter garden and both rooms should be located more in the middle of the apartment, making this area the distribution area of the apartments. From here, rooms could be located to the north, the south or both – depending on the size of the apartment. Hopefully, this solution could also reduce the corridor area of the apartments, which now seem to take up a lot of useless area.

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all other pictures are the student’s own pictures

Stealth Barn in Norfolk by Carl Turner Architects, 2011

appendix

appendix a - ventilation

Maximum ventilation is calculated according to DS-CEN-CR 1752 [2001]. Required ventilation rate is calculated for all the apartments and airflow rate for thermal design is calculated for all the rooms in the building.

apartments		A1	A2	
# apartments		3	2	
COMFORT				
description				unit
ventilation rate required for comfort	Qc	**1,21**	**1,19**	l/s
sensory pollution load	Gc	0,141	0,139	olf
occupancy		3	3	persons
gross area with winter garden		83	89	m2
gross area without winter garden		73	76	
sensory pollution load caused by occupants		1	1	olf/occupant
sensory pollution load from the building		0,1	0,1	olf/m2
desired perceived indoor air quality	Cc,i	1,4	1,4	dp
perceived outdoor air quality	Cc,0	0,1	0,1	dp
ventilation effectiveness	εγ	0,9	0,9	

REQUIRED VENTILATION RATE

The required ventilation rate for comfort were calculated with help from the annex B.2 and equation (A.2):

$Q_c = 10 \cdot \frac{G_c}{C_{c,i} - C_{c,o}} \cdot \frac{1}{\varepsilon v}$, where

Q_c is the ventilation rate required for comfort [l/s]
G_c is the sensory pollution load [olf]
$C_{c,I}$ is the desired perceived indoor air quality [decipol]
$C_{c,o}$ is the perceived outdoor air quality at air intake [decipol]
εv is ventilation effectiveness

conditions	source
	DS-CEN-EN 1752, equation A.2
0% smokers	DS-CEN-EN 1752, table A.6
new buildings (low-polluting buildings)	DS-CEN-EN 1752, table A.8
category B	DS-CEN-EN 1752, table A.5
in towns, good air quality	DS-CEN-EN 1752, table A.9
displacement ventilation	DS-CEN-EN 1752, annex F

B	C	D1	D2	E1	E2	F	G1	G2	H
1	1	1	1	3	1	1	1	1	1

1,14	**1,15**	**1,15**	**1,25**	**1,22**	**1,22**	**1,12**	**1,2**	**1,18**	**1,14**
0,134	0,134	0,135	0,147	0,143	0,143	0,131	0,141	0,138	0,134
5	4	3	4	4	4	2	4	4	5
158	126	96	96	104	104	75	107	117	158
148	117	86	86	94	94	65	98	104	149
1	1	1	1	1	1	1	1	1	1
0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4
0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9

	I1	I2	J	K	L	M	N	O	P	
	1	1	1	1	1	1	2	1	1	
										unit
	1,18	**1,18**	**1,04**	**1,12**	**1,17**	**1,08**	**1,17**	**1,08**	**1,22**	l/s
	0,138	0,138	0,121	0,131	0,136	0,127	0,137	0,127	0,143	olf
	4	4	2	4	5	3	4	3	4	persons
	116	116	104	139	146	123	117	123	103	m2
	106	106	94	129	137	113	107	113	93	
	1	1	1	1	1	1	1	1	1	olf/occupant
	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	olf/m2
	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	dp
	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	dp
	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	

The airflow rate where calculated according to annex B.1 and B.2.

THERMAL ENVIRONMENT

B1 description

a activity level of occupants

b clothing insulation of occupants

daily wear clothing, summer

daily wear clothing, winter

c optimum temperature

summer

winter

d desired maximum PPD

permissable temperature range

summer

winter

e desired maximum percentage dissatisfied due to draught

permissable mean air velocity

summer

winter

f desired maximum percentage dissatisfied due to vertical air temperature difference

permissable air temperature difference

g desired maximum percentage dissatisfied due to warm or cool floor

permissable range of floor temperature

h desired maximum percentage dissatisfied due to radiant asymmetry

permissable radiant temperature asymmetry

warm ceiling

cool wall

cool ceiling

warm wall

B2

d.1. cooling load

d.2. supply air temperature

d.3. required supply-air flow rate for thermal design

room temperature

difference between room temperature and supply-air temperature

	unit	conditions	source
1,2	met	sedentary activity	DS-CEN-EN 1752, table D.1
0,5	clo	value from earlier semesters	DS-CEN-EN 1752, table D.2
1	clo	value from earlier semesters	DS-CEN-EN 1752, table D.2
1,4			
25 +/- 1,75	°C	category B	DS-CEN-EN 1752, figure A.2
22 +/- 2	°C	category B	DS-CEN-EN 1752, figure A.2
< 10	%	category B	DS-CEN-EN 1752, table A.1
+/-1,5		category B	DS-CEN-EN 1752, figure A.2
+/-2		category B	DS-CEN-EN 1752, figure A.2
< 20	%	category B	DS-CEN-EN 1752, table A.1
0,22	m/s	category B, turbulence intensity 40%	DS-CEN-EN 1752, figure A.3
0,18	m/s	category B, turbulence intensity 40%	DS-CEN-EN 1752, figure A.3
< 5	%	category B	DS-CEN-EN 1752, table A.1
< 2	°C	category B	DS-CEN-EN 1752, table A.2
< 10	%	category B	DS-CEN-EN 1752, table A.1
19-29	°C	category B	DS-CEN-EN 1752, table A.3
< 5	%	category B	DS-CEN-EN 1752, table A.1
< 5	°C	category B	DS-CEN-EN 1752, table A.4
< 10	°C	category B	DS-CEN-EN 1752, table A.4
< 14	°C	category B	DS-CEN-EN 1752, table A.4
< 23	°C	category B	DS-CEN-EN 1752, table A.4
0,75	°C	maksimum temperature summer 26°C, category B	
33	°C	maksimumtemperatur for maksimumsdøgn, july	
0,13	h^-1		
26	°C		DS-CEN-EN 1752, table 1
7	°C		SBi 202, table 6.1

rooms

	description				
	net area	m2	7	8	9
	ceiling height	m	2,54	2,54	2,54
	volume	m3	17,78	20,32	22,86
required supply-air flow rate for thermal design		l/s	0,64	0,73	0,82

10	11	13	14	15	16	17	18	19	20	21
2,54	2,54	2,54	2,54	2,54	2,54	2,54	2,54	2,54	2,54	2,54
25,4	27,94	33,02	35,56	38,1	40,64	43,18	45,72	48,26	50,8	53,34
0,91	1,00	1,18	1,27	1,36	1,45	1,54	1,63	1,72	1,81	1,91

22	23	24	25	26	27	28	29	34
2,54	2,54	2,54	2,54	2,54	2,54	2,54	2,54	2,54
55,88	58,42	60,96	63,5	66,04	68,58	71,12	73,66	86,36
2,00	2,09	2,18	2,27	2,36	2,45	2,54	2,63	3,08

appendix b - people profile

The input for people profile in BSim has been chosen according to Jensen et al. [2001] - table with 2 persons is given below.

2 personer

Time/dag	Mandag	Tirsdag	Onsdag	Torsdag	Fredag	Lørdag	Søndag	Middel
1	2	2	2	2	2	2	2	
2	2	2	2	2	2	2	2	
3	2	2	2	2	2	2	2	
4	2	2	2	2	2	2	2	
5	2	2	2	2	2	2	2	
6	2	2	2	2	2	2	2	
7	1	1	1	1	1	2	2	
8	1	1	1	1	1	2	2	
9						1	1	
10						1	1	
11						1	1	
12						1	1	
13						1	1	
14						1	1	
15					1	1	1	
16					1	1	1	
17	1	1	1	1	2	2	2	
18	2	2	2	2	2	2	2	
19	2	2	2	2	2	2	2	
20	2	2	2	2	2	2	2	
21	2	2	2	2	2	2	2	
22	2	2	2	2	2	2	2	
23	2	2	2	2	2	2	2	
24	2	2	2	2	2	2	2	
Benyttet [timer]	16	16	16	16	18	24	24	18,6
Ubenyttet [timer]	8	8	8	8	6	0	0	5,4
Persontimer [timer]	29	29	29	29	32	40	40	16,3

Tabel 2: Ugeprofil for personbelastning for 2 personer i en bolig.

appendix c - be10

The following is results from the final Be10 calculation - the effects of both heat pump and solar cells are included.

Model: 12_110512_with heat pump													**SBi Beregningskerne 6, 11, 11, 24**
Be10 results: 110512_new glass south													
Energy requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. for service of buildings	1,75	-2,18	-7,36	-14,25	-20,84	-21,01	-20,41	-17,22	-10,09	-4,36	-0,64	2,51	-114,10
Excess temperature in rooms	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total energy requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
BR 2010	4,36	-5,45	-18,39	-35,62	-52,11	-52,53	-51,01	-43,04	-25,23	-10,90	-1,59	6,27	-285,25
kWh/m²	1,2	-1,4	-4,9	-9,5	-13,9	-14,0	-13,6	-11,4	-6,7	-2,9	-0,4	1,7	-75,8
Low energy 2015	4,36	-5,45	-18,39	-35,62	-52,11	-52,53	-51,01	-43,04	-25,23	-10,90	-1,59	6,27	-285,25
kWh/m²	1,2	-1,4	-4,9	-9,5	-13,9	-14,0	-13,6	-11,4	-6,7	-2,9	-0,4	1,7	-75,8
Buildings 2020	3,14	-3,92	-13,24	-25,65	-37,52	-37,82	-36,73	-30,99	-18,17	-7,85	-1,15	4,51	-205,38
kWh/m²	0,8	-1,0	-3,5	-6,8	-10,0	-10,1	-9,8	-8,2	-4,8	-2,1	-0,3	1,2	-54,6
Heat requirement. External supply to building													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Gas radiators	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Gas water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement. External supply to building. Building service													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central heating plant	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic hot water	0	-0	0	0	0	0	0	0	0	0	0	0	0

Ventilation plant	1085	980	1085	1050	1085	1050	1085	1085	1050	1085	1050	1085	12772
Boiler/district heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat pump	3727	2496	1943	1772	1672	1494	1416	1384	1556	1800	1911	3467	24639
Solar heat	0	0	0	0	0	0	0	0	0	0	0	0	0
Room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Local el. water heaters	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for building service	4812	3475	3028	2822	2757	2544	2501	2469	2606	2884	2961	4552	37411
kWh/m²	1,3	0,9	0,8	0,8	0,7	0,7	0,7	0,7	0,7	0,8	0,8	1,2	9,9
El. requirement. External supply to building. Other el. consumption													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Other lighting	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment	9796	8848	9796	9480	9796	9480	9796	9796	9480	9796	9480	9796	115343
Total for other	9796	8848	9796	9480	9796	9480	9796	9796	9480	9796	9480	9796	115343
kWh/m²	2,6	2,4	2,6	2,5	2,6	2,5	2,6	2,6	2,5	2,6	2,5	2,6	30,7
El. requirement. External supply to building. Total el. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
The building	14608	12324	12824	12302	12553	12024	12297	12265	12086	12681	12441	14348	152754
Solar cell performance	3066	5656	10383	17070	23599	23557	22907	19684	12700	7246	3599	2045	151511
Wind mill performance	0	0	0	0	0	0	0	0	0	0	0	0	0
Resulting el. requirement	1746	-2180	-7355	-14248	-20842	-21013	-20406	-17215	-10094	-4361	-638	2507	-114100
El. for heating MWh	3727 Jan	2496 Feb	1943 Mar	1772 Apr	1672 May	1494 Jun	1416 Jul	1384 Aug	1556 Sep	1800 Oct	1911 Nov	3467 Dec	24639 Year
In rooms	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
Heat coil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Pipe loss	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
Total, kWh/m²	1,9	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	1,7	4,4
Room heating, Fulfilment of heat requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Solar heating plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
El. heating of rooms	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El-VF in ventilation plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wood stoves etc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
Domestic hot water, Hot-water requirement													
m³	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total consumption	79,9	72,1	79,9	77,3	79,9	77,3	79,9	79,9	77,3	79,9	77,3	79,9	940,5
Domestic hot water, Supply													
m³	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central heating plant	79,9	72,1	79,9	77,3	79,9	77,3	79,9	79,9	77,3	79,9	77,3	79,9	940,5
Local el. heaters	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Local gas heaters	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	79,9	72,1	79,9	77,3	79,9	77,3	79,9	79,9	77,3	79,9	77,3	79,9	940,5
Domestic hot water, Heating requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central water container	4,19	3,79	4,19	4,06	4,19	4,06	4,19	4,19	4,06	4,19	4,06	4,19	49,38
Local el. heater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Local gas heater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heating total	4,19	3,79	4,19	4,06	4,19	4,06	4,19	4,19	4,06	4,19	4,06	4,19	49,38
Loss central water container	1,41	1,27	1,41	1,36	1,41	1,36	1,41	1,41	1,36	1,41	1,36	1,41	16,56
Loss connection pipes for DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Domestic hot water, pipe loss	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Loss local el. water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Loss local. gas water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total loss	1,41	1,27	1,41	1,36	1,41	1,36	1,41	1,41	1,36	1,41	1,36	1,41	16,56
Total	5,60	5,06	5,60	5,42	5,60	5,42	5,60	5,60	5,42	5,60	5,42	5,60	65,93
kWh/m²	1,5	1,3	1,5	1,4	1,5	1,4	1,5	1,5	1,4	1,5	1,4	1,5	17,5
Domestic hot water, Fulfilment of heating requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Solar heating plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	5,60	5,06	5,60	5,42	5,60	5,42	5,60	5,60	5,42	5,60	5,42	5,60	65,93
El. heating of central water container	0,00	-0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. tracing of DHW pipes	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local el. water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local gas heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	5,60	5,06	5,60	5,42	5,60	5,42	5,60	5,60	5,42	5,60	5,42	5,60	65,93
Direct room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement in hot-water discharge plant													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El. heating of central water container	0	-0	0	0	0	0	0	0	0	0	0	0	0
El. tracing of DHW pipes	0	0	0	0	0	0	0	0	0	0	0	0	0
Charging pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Circulating pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	-0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	-0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement in ventilation plant													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heat coils	0	0	0	0	0	0	0	0	0	0	0	0	0
Ventilators	1085	980	1085	1050	1085	1050	1085	1085	1050	1085	1050	1085	12772
Total	1085	980	1085	1050	1085	1050	1085	1085	1050	1085	1050	1085	12772
kWh/m²	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	3,4
Boiler/district heating exchanger, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Consumption	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Utilizable heat loss	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Efficiency	0	0	0	0	0	0	0	0	0	0	0	0	0
Boiler/district heating exchanger, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Burner, kWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Automatics, kWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Heat pump, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance, Room heating	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
Performance, DHW	5,60	5,06	5,60	5,42	5,60	5,42	5,60	5,60	5,42	5,60	5,42	5,60	65,93
Total	12,56	7,78	5,60	5,42	5,60	5,42	5,60	5,60	5,42	5,60	5,77	11,96	82,33
Contribution ratio, room heating	1,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	1,00	
Contribution ratio, DHW	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	
Heat pump, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El. requirement, room heating	1752	697	0	0	0	0	0	0	0	0	77	1524	4050
El. requirement, stand-by room heating	11	10	11	11	11	11	11	11	11	11	11	11	131
El. requirement, DHW	1964	1788	1932	1762	1661	1483	1405	1373	1545	1788	1823	1932	20458
El. requirement, stand-by DHW	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3727	2496	1943	1772	1672	1494	1416	1384	1556	1800	1911	3467	24639
kWh/m²	1,0	0,7	0,5	0,5	0,4	0,4	0,4	0,4	0,4	0,5	0,5	0,9	6,5
Solar heating plant, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance, Room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contribution ratio, room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Contribution ratio, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Solar heating plant, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Automatics	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement for lighting. Included in the building's performance													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
General during service life	0	0	0	0	0	0	0	0	0	0	0	0	0
General stand-by when not in service	0	0	0	0	0	0	0	0	0	0	0	0	0
Working lights in service life	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement for lighting. Other lighting													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
During service	0	0	0	0	0	0	0	0	0	0	0	0	0
Night consumption	0	0	0	0	0	0	0	0	0	0	0	0	0
Basement car parkings	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement for epuipment													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Equipment	9796	8848	9796	9480	9796	9480	9796	9796	9480	9796	9480	9796	115343
Night consumption, equipment	0	0	0	0	0	0	0	0	0	0	0	0	0
Special equipment during service	0	0	0	0	0	0	0	0	0	0	0	0	0
Special equipment always	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	9796	8848	9796	9480	9796	9480	9796	9796	9480	9796	9480	9796	115343
kWh/m²	2,6	2,4	2,6	2,5	2,6	2,5	2,6	2,6	2,5	2,6	2,5	2,6	30,7

Solar cells and wind mills

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total el. requirement	14608	12324	12824	12302	12553	12024	12297	12265	12086	12681	12441	14348	152754
Solar cells	3066	5656	10383	17070	23599	23557	22907	19684	12700	7246	3599	2045	151511
Wind mills	0	0	0	0	0	0	0	0	0	0	0	0	0
Total performance	3066	5656	10383	17070	23599	23557	22907	19684	12700	7246	3599	2045	151511
Balance	-11542	-6668	-2441	4767	11046	11533	10610	7419	614	-5435	-8843	-12303	-1243
Surplus	0	0	0	4767	11046	11533	10610	7419	614	0	0	0	45988
Adjustment of performance	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar cells, included	3066	5656	10383	17070	23599	23557	22907	19684	12700	7246	3599	2045	151511
kWh/m²	0,8	1,5	2,8	4,5	6,3	6,3	6,1	5,2	3,4	1,9	1,0	0,5	40,3
Wind mills, included	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Net heating requirement in rooms

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heat loss	28,74	26,59	25,66	19,54	12,20	6,78	5,05	5,33	10,18	15,28	20,62	25,94	201,90
Incident solar radiation	6,43	10,31	16,73	24,68	31,45	30,63	30,12	26,71	19,98	12,51	6,87	4,22	220,63
Total supplement	21,83	24,22	32,13	39,58	46,85	45,53	45,52	42,11	34,88	27,91	21,78	19,62	401,96
Relative supplement	0,76	0,91	1,25	2,03	3,84	6,71	9,02	7,90	3,43	1,83	1,06	0,76	
Utilization factor	1,00	0,98	0,79	0,49	0,26	0,15	0,11	0,13	0,29	0,55	0,92	1,00	0,56
Part of month with heating	1,00	0,93	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,50	1,00	
Heating requirement	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
Heating in ventilating heat surface	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Net. room heating	6,96	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	6,36	16,39
Total, kWh/m²	1,9	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	1,7	4,4

Solar shield, forced vent., night vent. and cooling

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Solar shield, red. factor	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	
Forcing, share	0,00	0,19	0,48	0,83	0,98	1,00	1,00	1,00	0,96	0,73	0,27	0,00	
Night ventilation, share	0,00	0,00	0,00	0,00	0,00	0,21	0,26	0,22	0,00	0,00	0,00	0,00	
Mechanical cooling, share	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	

Mean ventilation. Sum of natural and mechanical ventilation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
m³/s	1,24	2,27	3,89	5,83	6,65	6,76	6,77	6,76	6,53	5,27	2,76	1,24	
l/s m²	0,33	0,60	1,03	1,55	1,77	1,80	1,80	1,80	1,74	1,40	0,73	0,33	

Share of time at 26,0 °C room temperature or above

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Time sha<re	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Mechanical cooling, net

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
MWh	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Total heat loss, W/m²

Heat loss	11,9												
Ventilation without HRV in winter	12,7												
Total	24,6												
Ventilation with HRV in winter	4,2												
Total	16,1												