LUFTKASTEL

4MScARK9 2012 - Line Hoff & Lea Maria Klaaborg - AD:MT, AAU

“

DOES YOUR MINDSET OR YOUR BELONGINGS DEFINE YOUR LIFE ?

”

LUFTKASTEL

is a 10th semester master thesis project in Architectural Design.

Developed in the spring semester 2012 from the 1st of February to the 23nd of May at the department of AD:MT, Aalborg University by

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The project was supervised by Claus Bonderup, architect and professor.

and with technical support from Peter V. Nielsen, engineer and professor.

You are holding *one* of 6 copies
and if you flip to the last page
you will find that it contains 131 pages.

Thanks to Poul Henning Kirkegaard, Frank Brøndum from Cembrit A/S and Knud Andreassen for technical guidance.

SYNOPSIS

Målet med denne opgave var at redefinere de tætte byers traditionelle boligform med en en-persons minimalbolig, der indeholder få, essentielle funktioner, og passer til en bruger, som på alle måder udnytter de mange kvaliteter byen tilbyder.

Boligens kubiske ydre form sat sammen med dens rektangulære invendige rum, skaber et mellemrum, hvori samtlige af boligens funktioner er placeret. Funktionerne pakkes ud alt efter, hvilket rum man ønsker at skabe. På samme måde har man mulighed for at pakke alt væk, og derved opnå et nøgent rum, hvor der er plads til at dyrke ensomheden og nyde stilheden.

Kompaktheden fra boligen overføres ligeledes til den urbane sammensætning, hvor de mange små boliger klynger sig i en selvbærende forgrenende struktur, svævende over byens flade tage. Boligernes placering samt adgangsveje og trapper, bevæger sig i mellem hinanden i hvad der umiddelbart synes som et tilfældigt system, men i virkeligheden er et stramt strukturelt princip, dog med stor flexibilitet.

Udnyttelsen af den bymæssige tæthed kan både have miljømæssige-, sociale- og økonomiske fordele, og ikke mindst åbne op for nye boformer der matcher samfundets situationer. Boligens indeklima opfylder 2020 kravene og med integrerede solceller er det ligeledes lykkedes at gøre boligkomplekset selvforsynende med energi.

Resultatet er en ultra kompakt, konceptuel, funktionel og humoristisk et-rums-bolig i en spændende urban struktur, der imødekommer et samfundsmæssigt behov, men også lægger op til debat om hvordan vi skal bo, når alt hvad vi har brug for findes lige uden for døren.

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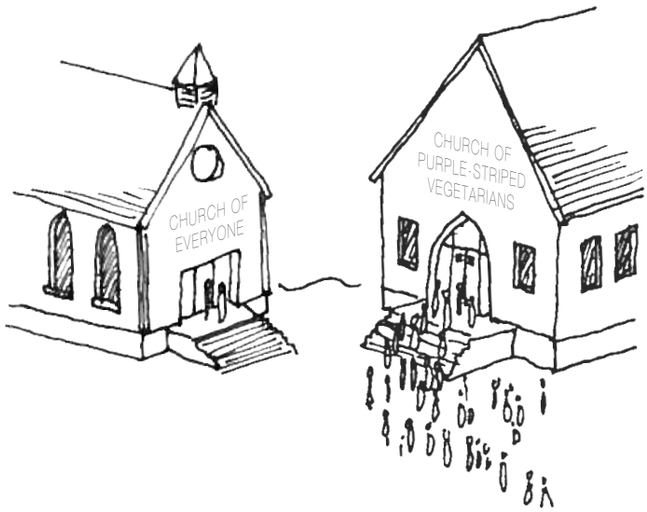


[Frederick, 2007]

TECHNICAL FOCUS

Our primary technical approach is energy and indoor climate - and we wish to reach the new low-energy building class 2020. This will mean that the energy consumption does not exceed 20 kWh/m2 per year. After reaching the 2020 demands, we will aim to reach 0 kWh/m2 per year, which means a completely self-sufficient dwelling complex, energywise. One of the actions to accomplish this task will be an integration of both solar shading and solar cells in the design.

In addition, we have chosen to look into the structural principles in an urban scale, despite our technical focus being energy and indoor climate. The construction happened to be a mayor issue, which is why we decided to place additional attention to this.

COMPOSITION

This report serves to account for the final semester in our master program. The overall theme, minimal dwelling, has been chosen based on what we have considered a relevant topic for both the society and our responsibility as architects. Finally, it is of own interest as well as a result of a reflection of our own lifestyles.

The report is layed out chronological for the reader. The design phase is not a seperate chapter as we have sketched from the very first day - parallel to analysing and investigating. Along the way, spreads with the title "What If…" will be presented. They are to serve the reader with an idea of some of our thoughts through the process. Thoughts that in some cases seem utopic but still have a relation to our final product in either mindset, design or urban idea. Most of these "What If's" are results of case studies or experiments.

Our handling of the project has been very practical, meaning that we have had "hands on" all the way through, prioritising experiments, touching materials and building real scale rather than theoretical documentation, despite the fact that we have studied a number of theorists and done a lot of case studying. This is because we, in this thesis, are very engaged to working with the finish to ensure a high level of detailing in a strong concept. In the same way, we wish to present the strong concept through an extremely plain report, which explains the super minimalistic style both in explanations, presentation and graphics.

MOTIVATION

As full-time students, we are used to live in a small space, on a tight budget - and simple, with a few belongings. That is how we like it.

Sometimes, whenever we have weeks off between semesters. Or if the possibility for an internship occurs, we travel. We go places, we meet people, we experience cultures. We fill our luggage with memories, but not the physical ones. The more we travel, the better we get at reducing what is in our backpacks. The more we travel, the more we want to travel. It is a drug.

By using ourselves as target group, we can design to a user group that is similar to us in state of mind. A state of mind that is getting more common among people in our generation. It is more easy – and normal - to travel, study abroad, expand social networks and switch workplaces than it was in our parent's generation. We do not spend as much time at home in our dwellings, and we use the city and its facilities a lot. Our dwelling has become more a refuge than the focal point of our existence.

We think that there is a market for a dwelling that suits the lifestyle that we live without being a student dorm. A small space should not only be for students. A base, a home, *a minimal dwelling* that supports a simple lifestyle. A place we can crawl into and collect energy for tomorrow, after spending the whole day in the city. A place to practice loneliness. Simply.

GOALS

Instead of creating a problem statement to cover the entire purpose for this master thesis project, we will insted create a list of goals. Goals that are both personal and very specific for the project theme. The goals for our thesis is to:

- Make an experimental and visionary project with a redefinition of traditional city dwellings.

- Design an inexpensive dwelling.

- Create debate about societal and architectural development.

- Combine aesthetic architectural sense with ingenious solutions, constructional comprehension and technical optimisation - to underline our skills obtained through this specific education.

- Get into details of the design.

- Use experimentations and drawings as a main developing factor in the design process.

- Present our project through a simple report.

- Draw, draw, draw.

DEFINITION

This thesis concerns a minimal space for living. The minimal dwelling is not to be confused with minimalism – that is more an architectural reference to the new constructional possibilities that came with Mies van der Rohe's Barcelona Pavilion in 1929 or an expression for an interior design style that is ruled by the amount of visible objects or colors rather than the size of the room.

For us, the minimal dwelling takes place in the dense city in close connection with the already existing city dwellings. It is a private space in a large public city. The minimal dwelling is a dwelling which is optimised to hold the essential within a small space, and the concept has a fine balance between architectural qualities and maximum funtionality. Spaces must be flexible.

Through this project, different methods will be used for analysis and design development. In order to cover all the fields that this education prescribes, methods range from architectural experiments over academic theory to the use of technical tools.

DESIGN PROCESS & DEVELOPMENT

The design process has been continual with sketches and design ideas following the different analysis. The iterations has been so many that it can be interpret as a linear continuous process.

The synthesis phase was highly characterised by a lot of practical work with a sudden focus on minor design adjustments to meet own requirements to cheap, delicate solutions.

Further descriptions of theoretical studies, experiments etc. are to be found in appendix.

ANALYSING AND DESIGNING →

Analysis, experiments, theoretical studies, case studies, sketches, idea generation, modifications, models, decisions

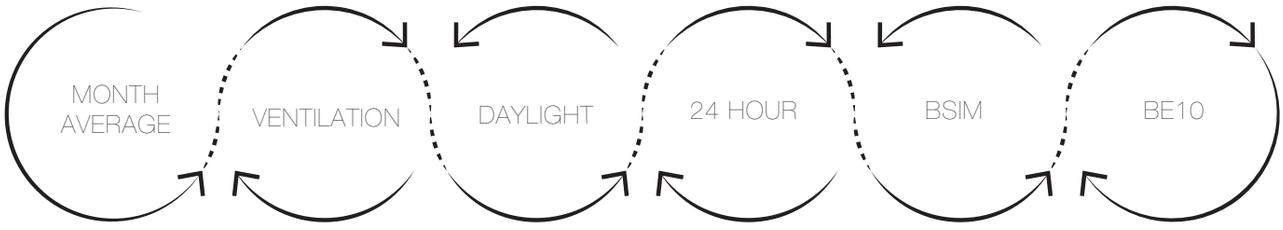
SYNTHESIS AND PRESENTATION →

Building, detailing, adjustments, documentation, formalia

TECHNICAL TOOLS

The integrated design process is the main method used for designing architecture at this school and will be used to help combining the architectural aspects of a building, such as expression, aesthetics, functionality, proportions and tactility with engineering aspects, like energy consumption, indoor climate, technology and construction.

Part of the integrated design process is to integrate technical tools to develop and optimise design solutions. Following tools can be used for following purposes in an iterative process;



Testing typology and optimising volumes and form.

Calculate the ventilation rate for mechanical ventilation.

Testing daylight to optimise light effect, window sizes and shading.

Determing possible overheating.

Simulating indoor environment.

Calculation of energy frame.

THEORETICAL STUDIES

When designing a compact space, it is necessary to be aware of its functionality. Storage, multi functional surfaces and furniture are essential in order to maximise the utilization of few squaremeters. There is, though, need for a very fine balance between the functional features and the more emotional experience in a building. To uphold a high architectural quality, the aesthetic details must not be forgotten. Those details determine the atmospheres in a space.

Thus, to ensure a good minimal space, we need to especially be aware of both the functional and emotional settings.

The architects and theorists who have had an impact in this project - in differents categories are Adolf Loos, Le Corbusier, Peter Zumthor and Andrea Palladio.

The studied theories are regarded background knowledge and will therefore not be listed in this report, but has nonetheless been a very important aspect in the work and development of creating a beautiful room (a summary of the theories is to be found in appendix 2).

As a point of departure we will presume that the increased interest for living in the city is an ongoing tendency and caused by the city's many offers and the dense-living benefits. Therefore, living in the dense city will be our scope for this thesis.

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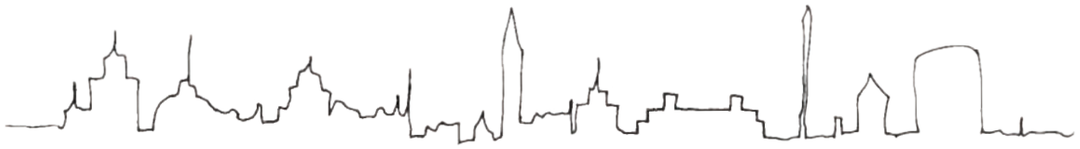


A GREAT CITY IS ONE WHERE PEOPLE WANT TO GO OUT OF THEIR HOMES

[Gehl, 2010]

"

SUS****ABILITY

Many parametres affect the livability in a city, but once these parametres are fulfilled, they also need to last and adapt into the development of our future.

That is sustainability.

But that single word is not uniform; it covers so many fields and overlapping issues that work together. All the topics, though, are related to either environmental, economical, social or political-institutional fields.

When designing a building, we typically focus on environment, society and economy. But we also want to be critical as "sustainability" has become a mainstream word and people get tricked by a word that seems to cover all the promises of a perfect world.

Why not ask questions like:

"Is a 200m2 one-person dwelling 'sustainable' just because the roof has been showered with the newest solar cell technology?"

(Our critical stance on the article "Self-built single-dwelling" [Selvbygget singlebolig, 2011]).

There are many aspects of sustainablity and instead of using it as an undefined term, we will define economic, social and environmental sustainability according to the architecture in this specific project to aim for an equally exciting dwelling and city.

ECONOMY

Inexpensive dwellings are always in great demand. In this project, we want to create a low-cost dwelling without comprimising architectural quality. This can be done by reducing costs on materials; chose local and strong materials with durability and some that require minimum maintainance. Reduce squaremetres, hence materials and keep all appliances and installations simple and few. The building method will also affect the economy so a system or even prefabrication under good circumstances can reduce the total price.

Reducing the dwelling's physical frames and encouraging its inhabitants to benefit from the city, can possibly also have a positive effect on the city's economy and create money flow and work spaces.

"In this project, we want to create a low-cost dwelling without comprimising architectural quality."

SOCIETY

When designing a home where inhabitants are centre of rotation, you still need to consider the surrounding environment and its people. The society plays a big part of 'living' in any kind of dwelling. A good society may be hard to define. Yet we find the same cities among the top 10 livable cities in the world every year. Common to the parametres of these good cities are to meet basic needs for food, shelter, education, work, income, safe living and working. They ensure that the benefits of development are distributed fairly across society and that cultural and biological heritage are preserved. Physical and mental settings are important and education and creativity should be promoted along with democracy and conviviality, participation and involvement.

We believe that these factors could be supported by the way we live and dwell. Therefore, the way we want to approach and improve a good society is that we wish to encourage the advantages of an open mindset, a good community and a livable city. We propose more usage of the city; more interaction and human relations, leaving our dwellings as refuges with the basic functions of living.

"We propose more usage of the city and its qualities; more interaction and human relations, leaving our dwellings as refuges with the basic functions of living."

ENVIRONMENT

"The overall environmental aspects are area and ressource consumption, and less transport because the public functions are concentrated in the city. Environmental pros for the specific dwelling are less surface area which means less material use and lower energy consumption, plus shared installation and construction elements."

A compact city has environmental advantages, but it is important not to comprimise architectural and spatial qualities. The overall environmental aspects are area and ressource consumption, and less transport because the public functions are concentrated in the city. Environmental pros for the specific dwelling are less surface area which means less material use and lower energy consumption, plus shared installation and construction elements. The city can also be too compact if daylight, spatial qualities, green outdoor areas and wind conditions are given a low priority. Sustainable buildings are depending on these parameters, so it is important to find a good balance between compact and spatial qualitites.

USERS

"As a dedicated backpacker, I have reduced my belongings to a minimum in order to always be free to travel. For me, this lifestyle is a continuous hunt for new experiences and great memories."

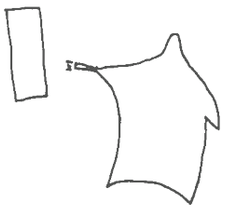
"It is a perfect refuge in my intense everyday life. The naked room lets me do whatever I wish to do whether it is staring out the window or practice my ballet."

"I just graduated and I am now in the search for a job. I am not sure where I will live in a year from now and I want to be able to move to another city if the right job comes up."

"I have a gorgeous house in the countryside, but sometimes I wish I had a small place in the vibrating city so I could take advantage of all its offers."

"I just wanted a place with not too many obligations."

"A young dude like me just wants a place to crash for the night. I am not really home much as I spend a lot of time at school or in the city."



"I am an artist and I am tired of expensive studios without light. All I want is a few squaremetres where I can put up my canvas and let the natural daylight fill the room. Still, I want to be in the city where all the fun happens and I cannot imagine having a studio on the west coast."

"To be honest, I don't really have a lot of money... but I think I deserve to live in the city like everyone else."

"I love hanging out here with a couple of friends before we go out. We always eat pizza on the floor and there is never a huge pile of dishes to clean when I come home late"

"I work in the city 4 days a week and with long nights and sudden meetings, it is really nice to have a second home close to work, so I don't have to commute 3 hours a day."

"I have always been the goofy guy in my network of friends and I finally found a unique flat to reflect my personality. Fun and mystique kinda."

"I simply don't need more space for living..."

A city that every year is among the top 10 on "Most Livable Cities" list is:

COPENHAGEN

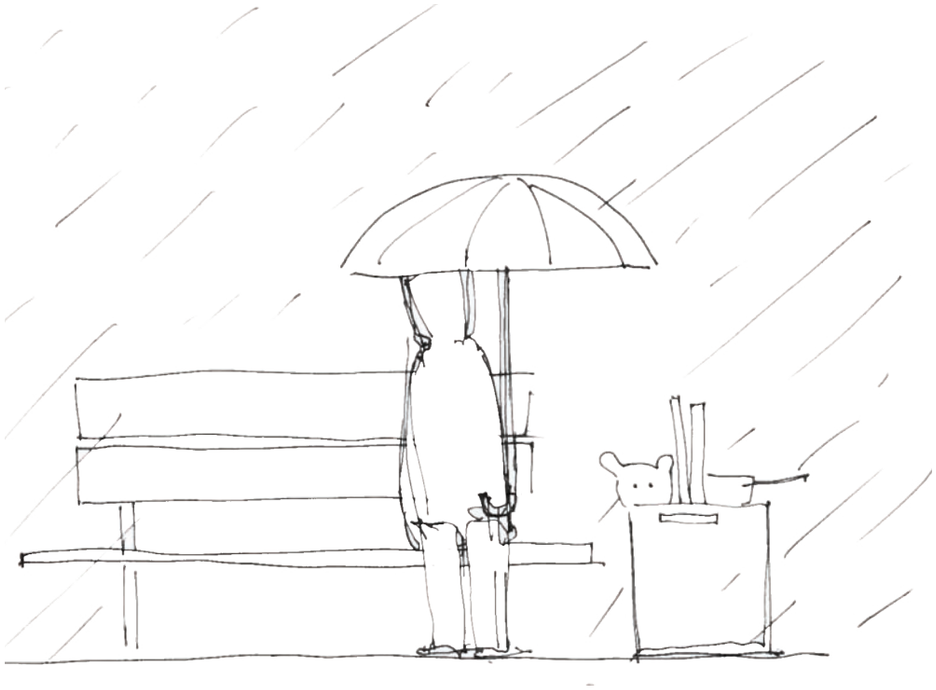
Our capital rates high because it complies with many of the criterias defining a good city according to the human ressource consulting firm, Mercer. Among the 39 criterias, some of the most important are safety, education, hygiene, health care, culture, environment, recreation, political-economic stability and public transportation.

Living in Copenhagen is desired by many but there is not enough vacant homes and those who are available are often expensive and even overpriced. To maintain the human diversity in the dense city, it should be everyone's right to live there.

Right now, it takes an average of 6,8 month from someone decides to search for a rental apartment in Copenhagen until they are actually offered a place.

Let us attack Copenhagen!

Copenhagen need more dwellings…

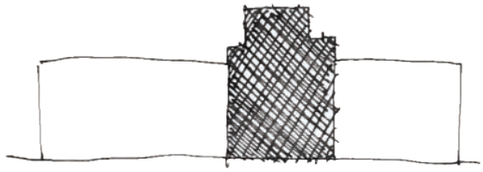


…and we need more:

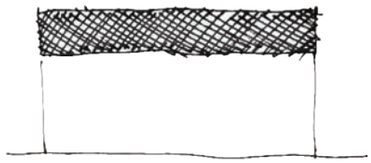
DENSITY

(ACTUALLY DENSER DENSITY)

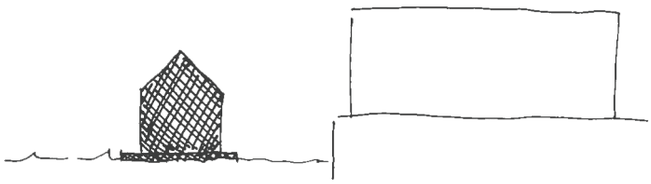
Increasing density in already dense cities can be done in various ways.



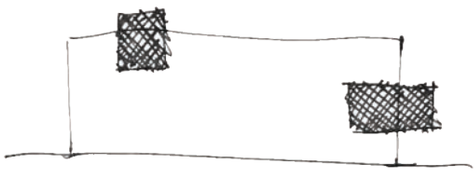
We could take advantage of the holes in the city blocks with infil housing projects.



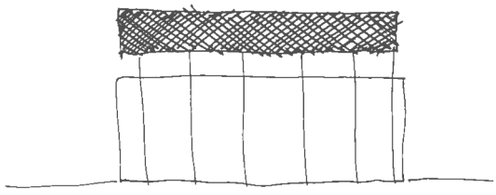
We could extend entire city blocks vertically and add additional stories to existing buildings.



We could build more homes on the water along habourfronts. Boat houses are aslo popular and add life to physical edges.



We could create parasitic add-on architecture, that could grow on existing buildings.

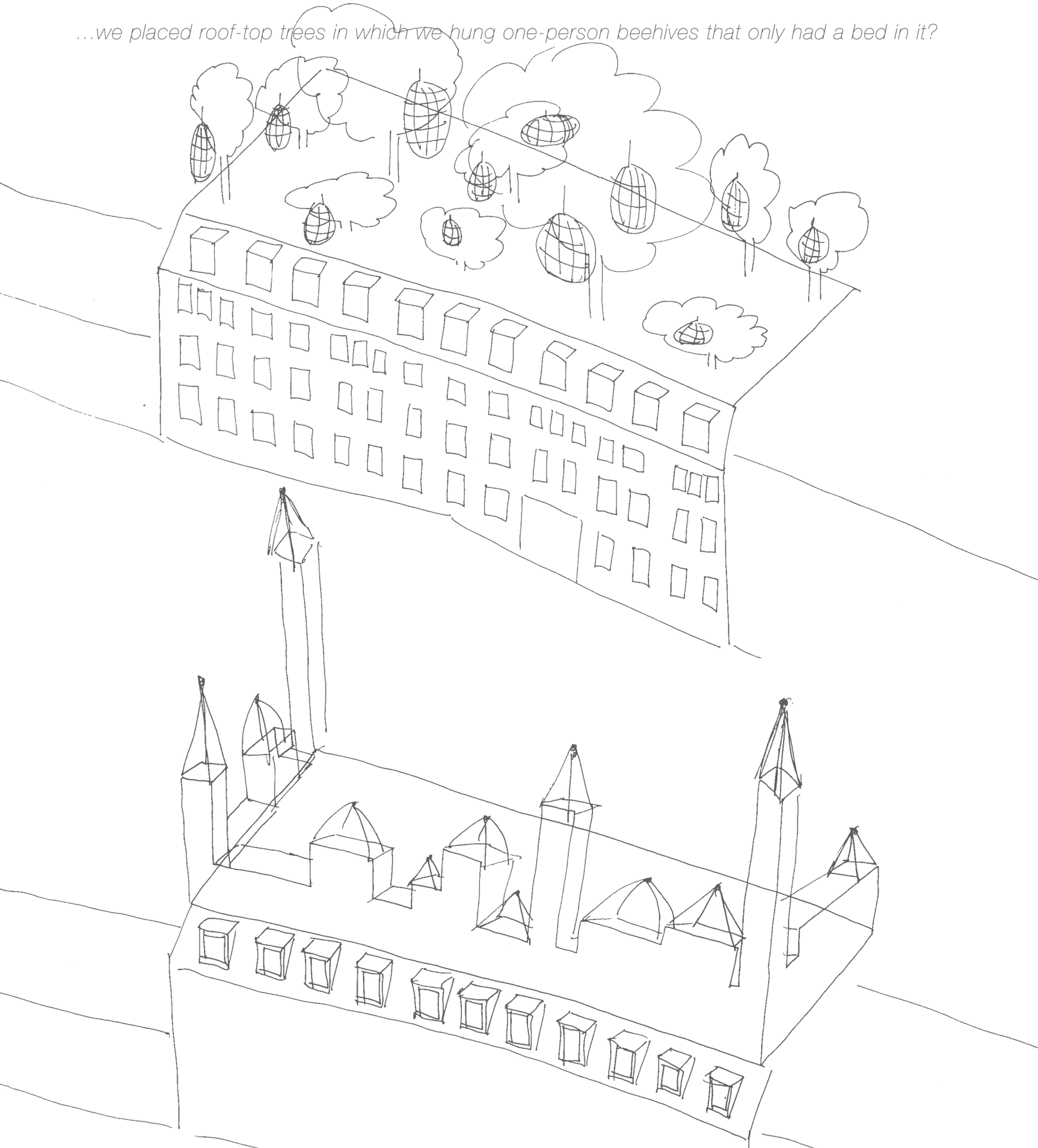


We could create architecture detached from any existing structure, and let it form in the city gaps or in a complete new layer.

WHAT IF...

...we decided to put a small tower apartment on every corner on every house in inner Copenhagen?

...we placed roof-top trees in which we hung one-person beehives that only had a bed in it?



...we put additional stories in the shape of old castles where each house has a unique view?

SITE & REGISTRATION

Though Copenhagen is neither Tokyo, New York or Rio - it is still a metropol. A lively city with a high standard of living, well known for its history and happy people. Copenhagen is taking a direction into a round-the-clock city where more and more shops and restaurants have extended opening hours to accommodate the demands from the growing amount of awake citizens. Copenhagen is therefore an interesting city. It is a city with a potential and a city we can relate to.

We are not in the search for an empty building site. Instead, we want to find a spot that has potential for urban development to increase density like mentioned earlier. One of the spots that is both placed in a very vivid neighborhood and also has a lot of flat roofs for the potential of expanding or adding is the area around Købmagergade, to see the chosen site on a map, see appendix 3.

KØBMAGERGADE 44

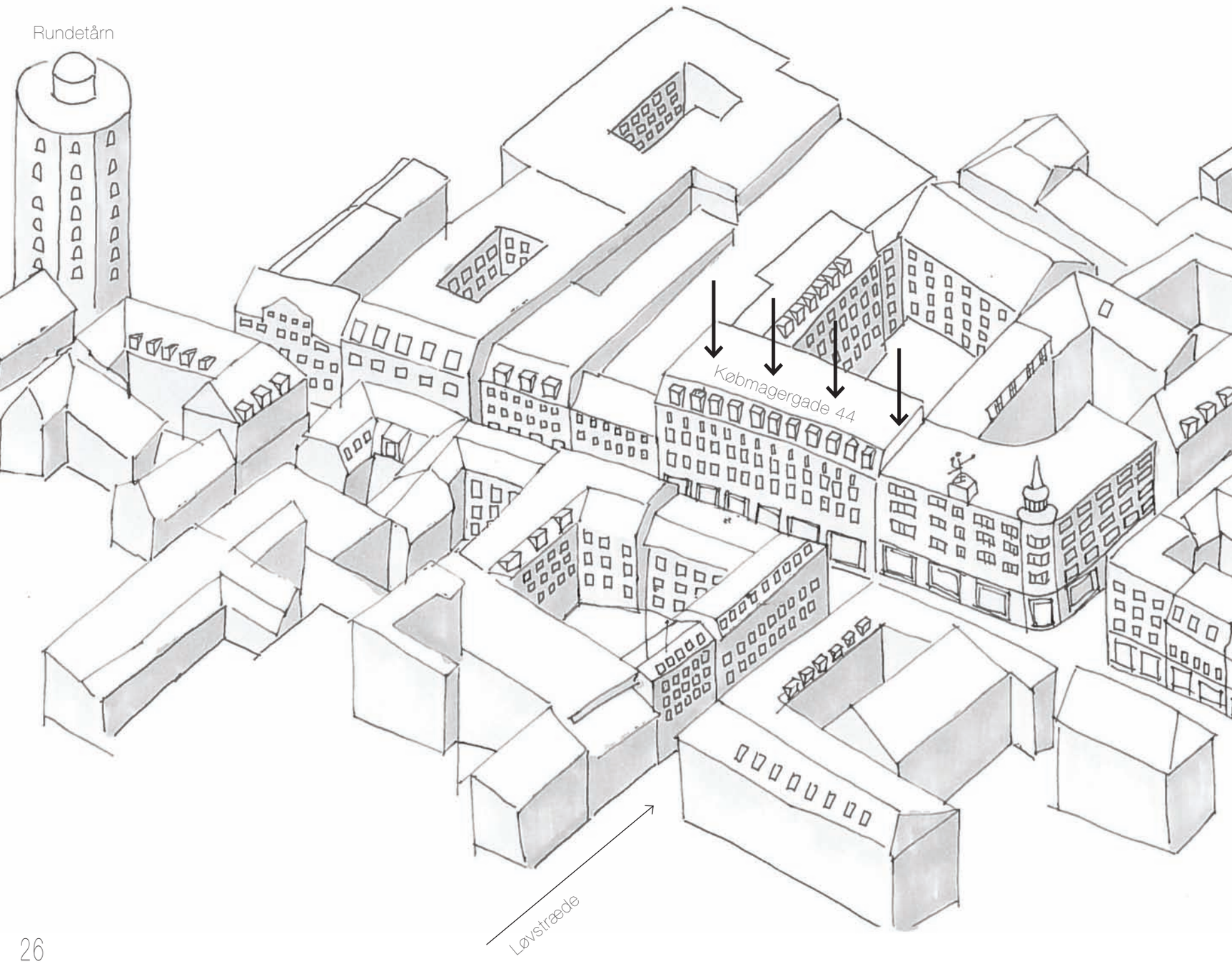
Købmagergade is one of the most important pedestrian streets in inner city, leading from the traffic centre of Nørreport Station all the way to the famous shopping street Strøget. More importantly is the street's most significant attraction Rundetårn. From here, visitors have a splendid view over Copenhagen. A historic site that both attracts local and tourists.

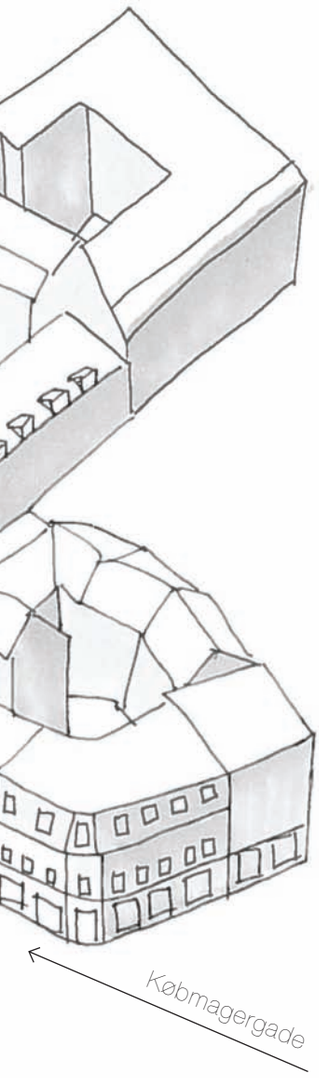
Not only does Købmagergade have a central placement - it is also in close connection with both public transport hubs, important historic sites, restaurants and nightlife, and last but not least public spaces and offers, like parks, plazas and libraries.

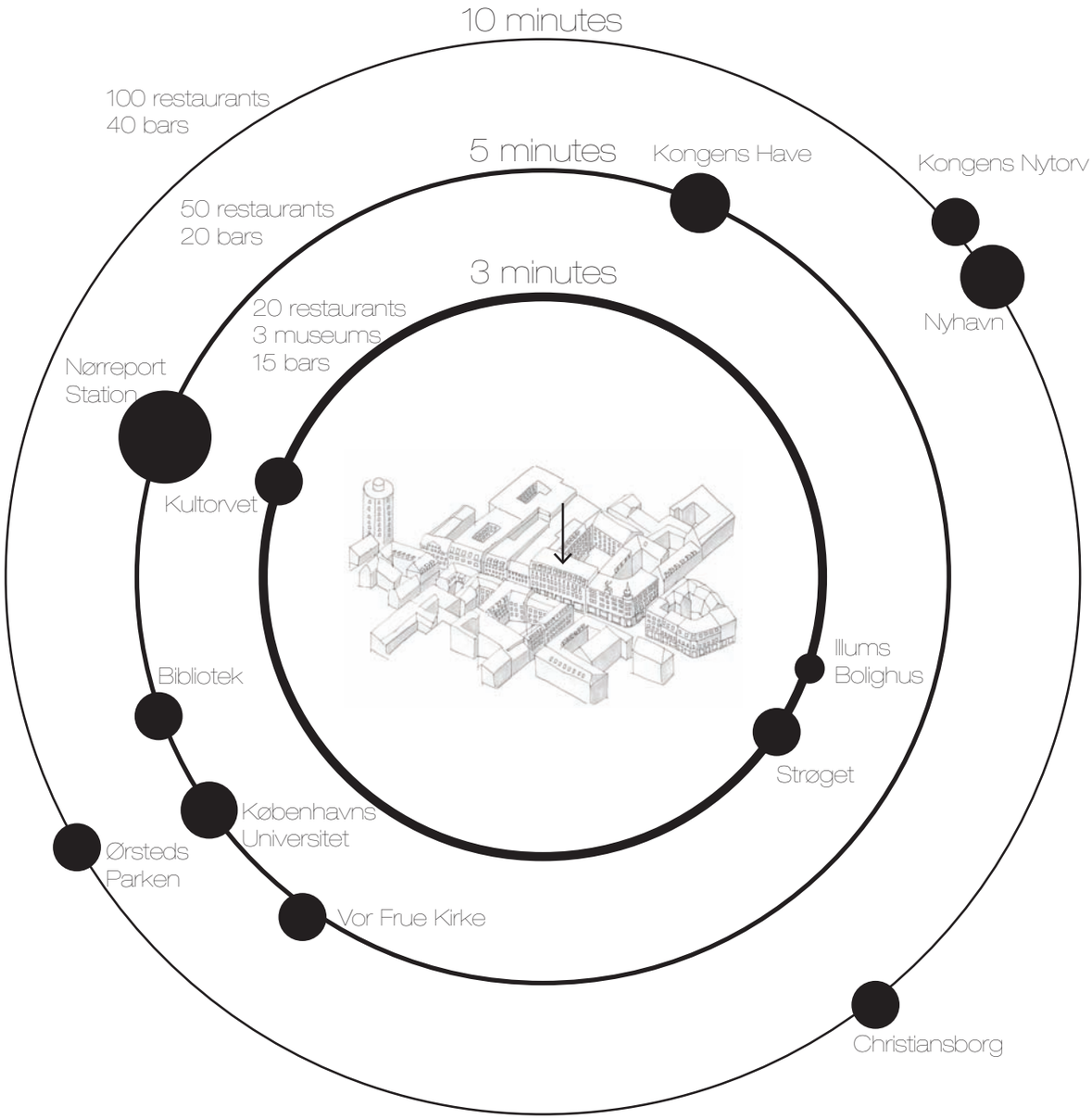
We have chosen to design and only detail dwellings on top of Købmagergade 44, because of the extraordinary building which has a focus, from the view at Rundetårn and stands out with its height and red bricks.

The university of theology is placed in the building with shops in ground level. The backyard is huge and has bicycle parking and a few benches.

The diagram to the right shows an approximation of some of the more important offers within 3, 5 and 10 minutes of walking from the chosen site, Købmagergade 44. It is clear that this area has everything you could wish for with a maximum of 10 minutes of walking.




Købmagergade


10 minutes
100 restaurants
40 bars
5 minutes
50 restaurants
20 bars
3 minutes
20 restaurants
3 museums
15 bars
Kongens Have
Kongens Nytorv
Nyhavn
Nørreport
Station
Kultorvet
Bibliotek
Illums
Bolighus
Strøget
Københavns
Universitet
Ørsteds
Parken
Vor Frue Kirke
Christiansborg

VIEW FROM RUNDETÅRN

FRONT

... FACADE OF KØBMAGERGADE 44

The front facade is characterised by its reds bricks, the rectangular windows and their white frames. The ornamentation is kept to a minimum but with few geometrical shapes. Photos in appendix 9.

BACK

... FACADE OF KØBMAGERGADE 44

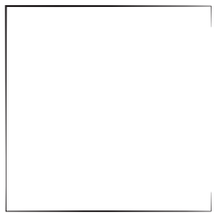
The back facade is far more plain than the front. Windows are large - some with many divisions and some with none. The facade reminds very much of a New York City facade without fire escapes. Photos in appendix 9.

DESIGNING FOR ENERGY

As described before, the dense city gives us advantages for a sustainable dwelling. The aim is to reach building class 2020 with 20 kWh/m2 per year in energy consumption. While designing, initiatives can be done to reduce the energy consumption, some of the implementations are listed below.

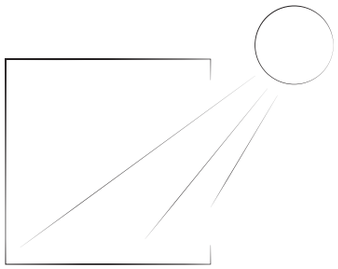
ORIENTATION

Orientation is crucial to take advantage of the conditions around the site. South, north, east and west plus the landscape around determine wind, solar and shadow conditions. [Energi+Arkitektur, 2011, p. 18].



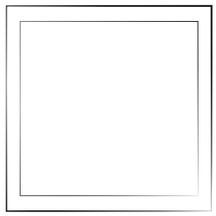
HEAT ACCUMULATION

Heat accumulation is a strategy which stores the solar heat into a heavy material (stone, concrete, bricks) placed inside the dwelling. During the day the heavy material is heated up and during night it slowly releases the heat, a good principle instead of using mechanical heating [Energi+Arkitektur, 2011, p. 23].



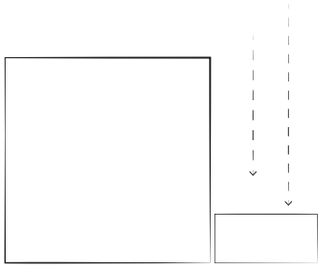
BUILDING FRAME

A keyword is compact, the more compact, the less surface-area and less transmission loss. Low U-values and air tight construction also have a big impact.



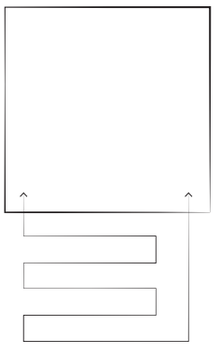
RAIN WATER COLLECTION

A tank in the building or next to can have the function of collecting rainwater, so it can be used for toilet water, to wash clothes or to water plants. It is an easy green way to save money.



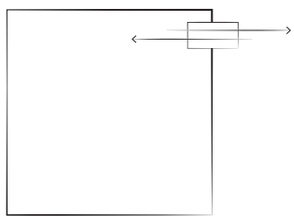
GEOTHERMAL HEAT

The earth has a constant temperature of 8 to 10 degrees, where tubes can be buried into the earth and stock the heat through water or air, which is running through the tubes and into the dwelling afterwards. This can be used for heating or domestic hot water [jordvarme.dk].



HEAT RECOVERY

Heat recovery Is used in mechanical ventilation and takes advantage of the warm exhaust air to heat up the cold supply air. It is important that supply and exhaust are placed next to each other. It is a cheap way to warm up the fresh (and cold) air [Heiselberg, 2006, p.31].



To compare the listed initiatives to what we can use in a dwelling placed on top of a roof in central Copenhagen, orientation, building frame and heat recovery is a must. It can easily be implemented and is therefore number one priority. Geothermal heat is a too expensive method to use, when the building is placed so far away from the ground. Heat accumulation requires heavy materials, which is something we will try to avoid, so it can be a light structure. Rain water collection requires big tanks to store the water in, which needs to be implemented in the design from the start.

SOLAR ENERGY

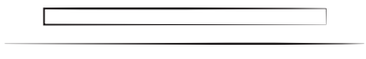
To reach building class 2020, it is crucial to look at different methods to create energy by using the sun radiation. Two alternatives have been studied, which is solar thermal collectors and solar cells. To read about solar thermal collectors see appendix 10.

Solar cells, also called photovoltaic (PV), are a way to generate energy by converting solar radiation into electricity. Solar cells are an investment, it is more expensive than solar collectors, but the technology gets more and more efficient and cheaper in a fast development. There are two types of solar cells, crystalline and amorphous. To read about crystalline solar cells, see appendix 10.

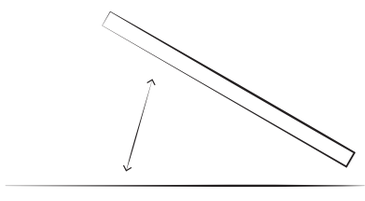
Amorphous solar cells are thin film placed on for example glass. This is the cheapest solution, but only has efficiency around 4-9% and a short durability. Despite that, the amorphous solar cells are less sensitive opposite temperature changes, they are plain dark grey or brown and use less energy in production, plus it can take good advantage of small solar radiation, better than crystalline solar cells. It is the type of solar cell which has a huge potential in development, and can become the leading method [Solceller+Arkitektur, pp. 110-117].

The slope of the solar cells is also very important to take as much advantage of the solar radiation as possible. 15 degrees to 60 degrees in a position of south, southWest, southEast is the best position.

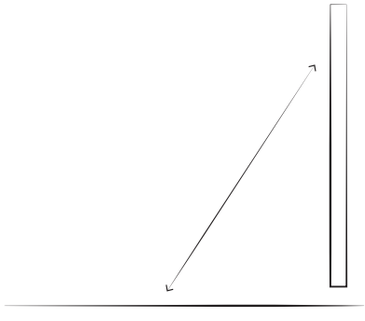
Pros and cons for solar collectors and solar cells are pointed out to make a decision on what to integrate in the designing phase. To take a decision the economic aspect is also taken in consideration. The dwellings are small, so it would be too expensive and too overwhelming to have both methods implemented. The solar collectors are only to be used for heating, which is not the only necessary function. Electricity to appliances is also crucial to make the dwelling independent, so we need solar cells to produce the energy. The question is if we need crystalline or amorphous. With the economy in mind the amorphous solar cells have many positive qualities compared to the price. Plus there is need for more testing of the method, to development. The amorphous solar cells are selected in this project.



0 degree slope gives 999 kWh/m2



30 degree slope gives 1152 kWh/m2



90 degree slope gives 892 kWh/m2

INDOOR CLIMATE

The indoor climate will be studied compared to what the requirements from BR10 and DS are, and what kind of principles we can use to optimise. To study the criterias for a good indoor climate, the dwelling is placed in category II; *normal level of expectation and should be used for new buildings and renovations* [DS 15251, p.13].

In general, the subject can be divided into two themes; the atmospheric comfort and the thermal comfort.

ATMOSPHERIC COMFORT

The atmospheric comfort is described as the perceived air quality, pollution, dust, smell and equipment inside the dwelling. Indoor air Quality (IAQ) is an important headline in the atmospheric comfort, it tells us about the sensory pollution and CO2 concentration. The CO2 level must not exceed 700 PPM above the outside concentration [DS1752, p.27].

THERMAL COMFORT

Thermal comfort is about temperature, overheating, types of windows, shading, draught and cooling, which can be influenced by clothing, activity, air velocity and humidity. Ventilation and shading are crucial to avoid the overheating.

MAX 100 H OF 26 DEGREES
MAX 25 H OF 27 DEGREES

To fulfill the requirements, the dwelling should not have more than 20% dissatisfaction. For residential buildings the minimum temperature in the winter season is 20 degrees, if the temperature gets lower, heating is needed. The maximum temperature in the summer season is 26 degrees, if it gets higher, there is need for cooling [DS15251, p. 25]. There is room for deviation, maximum 100 hours can exceed 26 degrees and 25 hours can exceed 27 degrees [BR10, 2011, 7.2.1 stk.13].

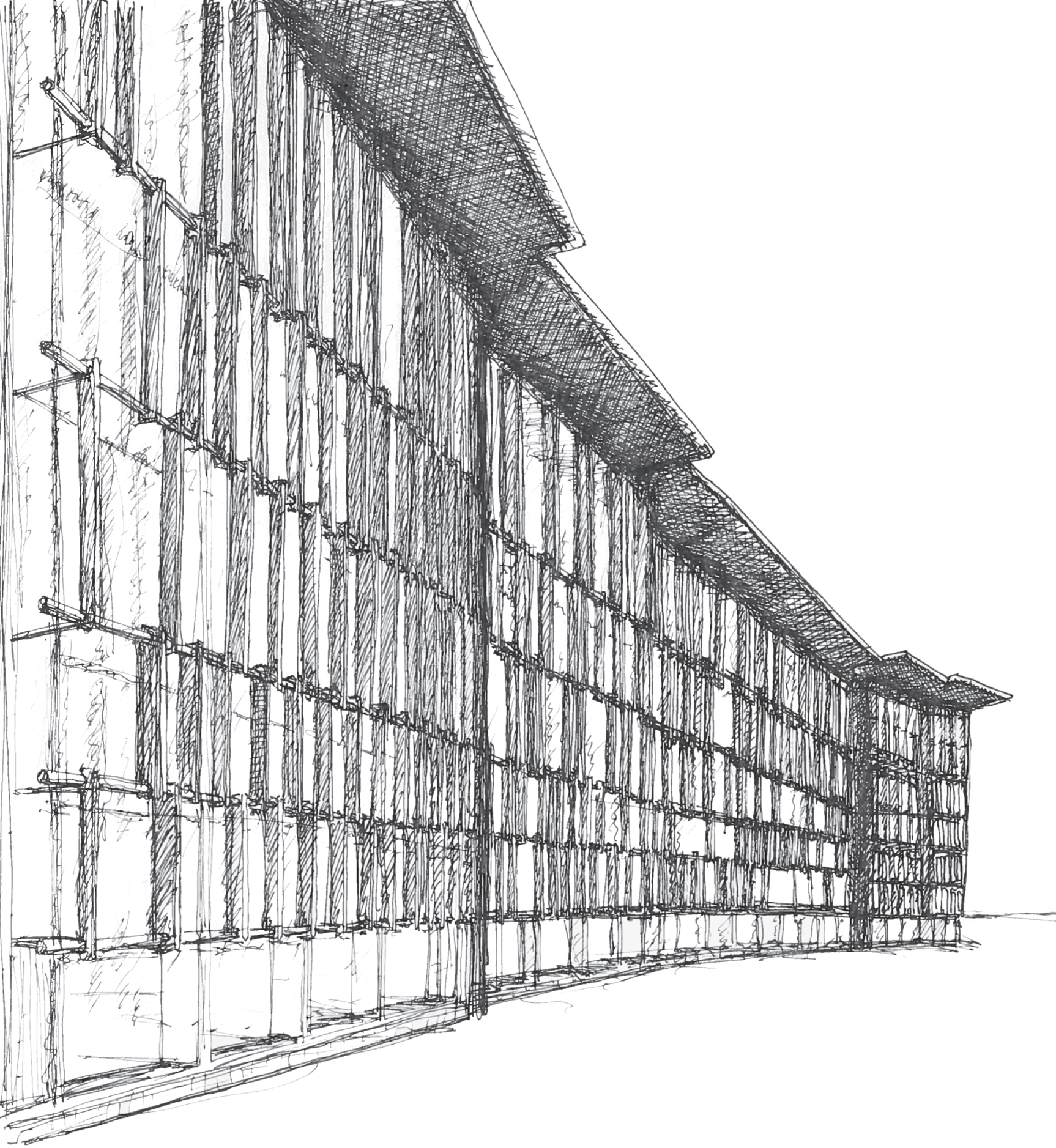
VENTILATION

Natural and mechanical ventilation strategies are very important for the thermal and atmospheric comfort. To get a satisfying indoor climate, hybrid ventilation is chosen, which is a mix between natural and mechanical ventilation. We want to use the natural ventilation during the summer months, but in the winter periods, mechanical is needed, which is why the hybrid ventilation is chosen. It is to reduce the energy consumption during the summer, where the mechanical ventilation is turned off. This ventilation method is easy to use with the high summer temperatures and natural ventilation. To read about natural ventilation strategies see appendix 10.

MECHANICAL VENTILATION

Mechanical ventilation is used during the winter to control the Indoor Air Quality (IAQ), where polluted air can be a problem, because we spend so much time indoor. It can also work as the main heating system. There are two types of mechanical systems, mixed ventilation and displacement ventilation. Mixed ventilation has a stabile air change, new air is blown into the room, mixes with the polluted air inside and changes the air slowly. This method is good for avoiding draught, which can be the case in displacement ventilation. Mixed ventilation is used in this project to avoid draught, to get a more constant air change and because of the few change of people in the dwelling. Supply and exhaust need to be next to each other to use heat recovery, which is a plus with mixing ventilation.

Requirements are needed to integrate a good mechanical ventilation system. Air heating must not be the only heating supply. Air supply for dwellings should be at least 0,3 l/s per m2. Exhaustion in the bathroom 15 l/s and exhaustion separate toilet 10 l/s [BR10, 2011]. No cooling is a goal we want to fulfill, and can easily be done in a climate like Scandinavia. Other methods must be used to compensate for the mechanical cooling ventilation.



DAYLIGHT

The daylight factor tells us the ratio of luminance at a given indoor point compared to direct and indirectly received light from the sun, where BR10 sets a minimum requirement for a daylight factor at 2% in all rooms. In this project we will try to set a minimum daylight factor at 5% in the main rooms (living room, workspace) and 2% in the secondary rooms (bedroom, kitchen). To read more about the DF see appendix 10.

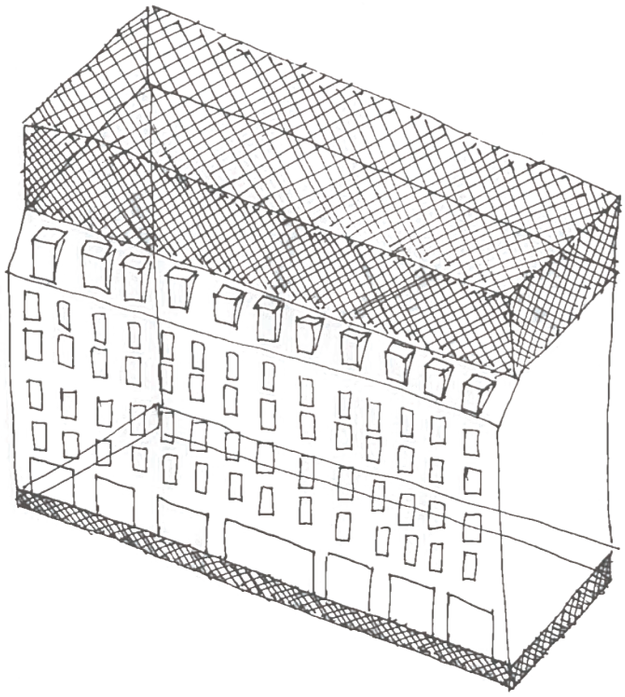
SHADING

In the winter time we need as much solar radiation through the windows as we can get, therefore it can be benefitting designing big openings to the south. But in the summertime these openings will be the reason for overheating. Shading is therefore necessary to avoid overheating. Different shading types are studied to investigate different designs of shading, only Aarhus Bymuseum is described in the next section, as the most important and relevant case.

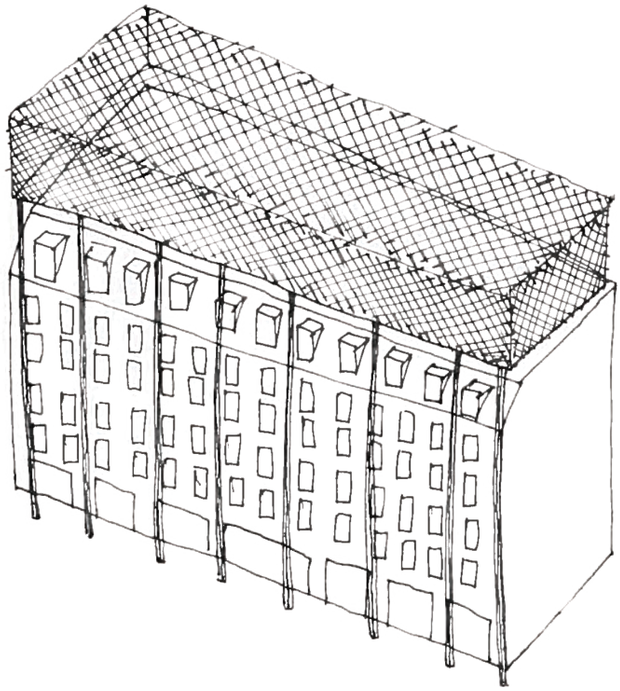
The extension (2005) of Aarhus Bymuseum is designed by Exners Architects. To avoid overheating, shading in form of horizontal bands with vertical larch wood lamellas, covers a big glass facade. This example of shading is studied to find out what and why it captured our attention. This type of shading is all about material and form in a combination. The light larch wood together with glass creates a calm harmony which compliments each other. Shading can often be very dominating on big glass facades and it can lead to a separation between facade and shading, this is an exception. The shading is a part of the facade, without dominating too much (see sketch to the left). The overall harmony and expression the shading has, is a goal to strive for.

URBAN CONSTRUCTION

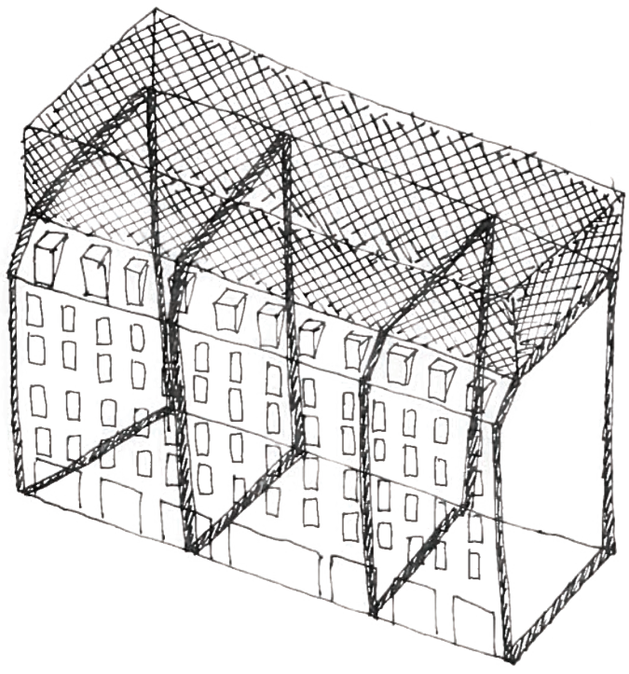
When designing on top of another building, there are different construction principles which integrates the building underneath in different ways. Three methods have been studied and compared to architectural expression and integration.



We could make the dwelling complex as a light structure with materials like light wood, plastic profiles or facades, fibre glass as interior, facade or profiles. The principle contains a careful analysis of Købmagergade 44, where the load capacity is calculated for the material, in this case concrete. The expectations for this method is, that most of the building can take the extra load of a new top floor, but it is often the foundation which needs to be reinforced.



Another principle could be a seperate individual construction, with no relation to Købmagergade 44. Columns would support the dwelling complex, going from the ground level and 4 stories up. This principle makes the dwelling complex independant, which means it easily can be placed elsewhere without a careful analysis of the building underneath.



If Købmagergade 44 has a low load capacity and the design of the dwelling complex do not allow columns to be visible, a third principle can be used. It contains an analysis of Købmagergade 44's bearing concrete wall as in the first example, and then the walls are reinforced with small cracks filled up with carbon fibre adjusted to how much extra load it should carry. The principle is very often used, though it seems like a big action.

WHAT KIND OF DWELLING

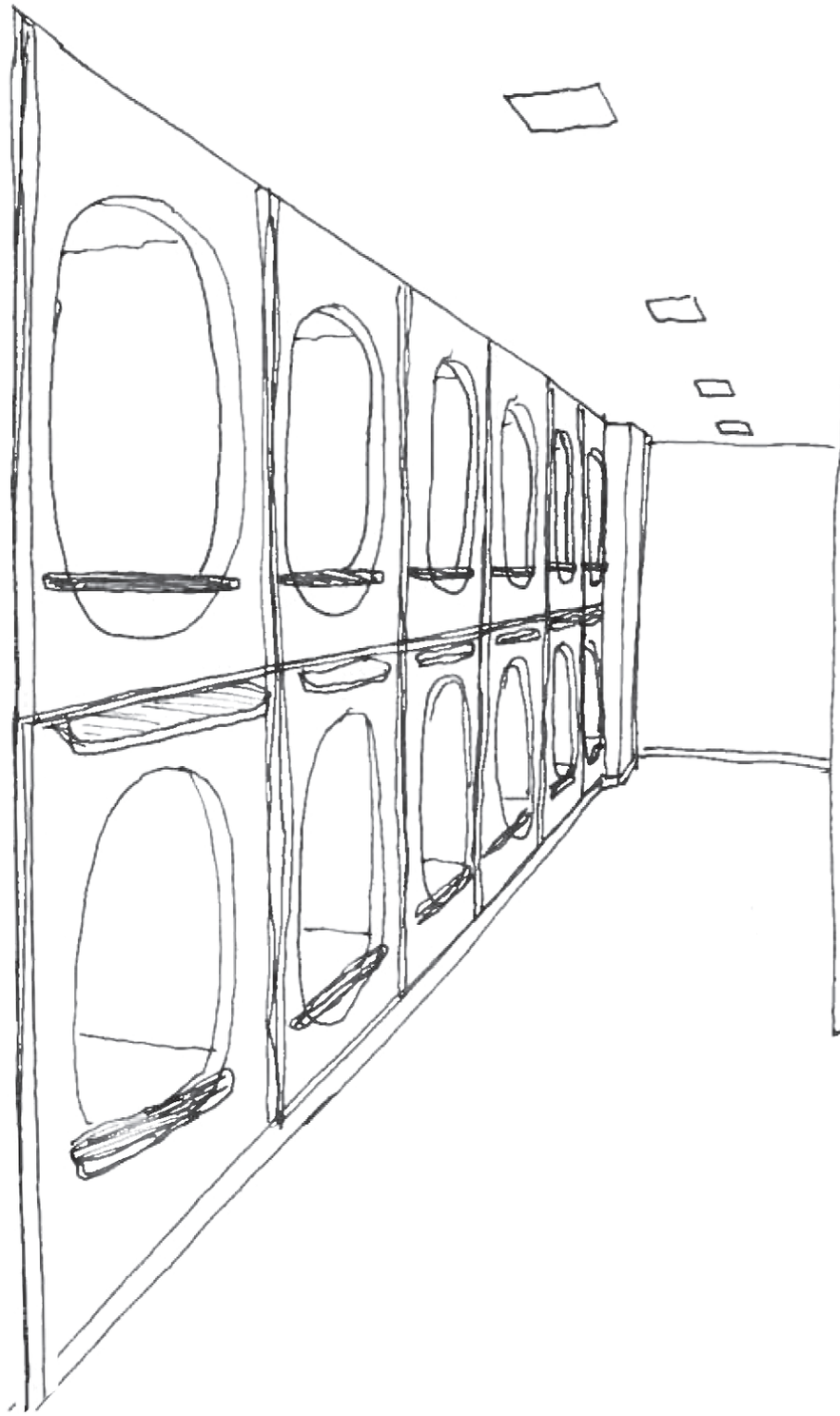
COMPLY WITH THE ISSUE OF LIVING IN A CITY SO GREAT THAT YOU WANT TO BE OUTSIDE?

Based on our focus, with the chosen site and user group, we think there is a good reason to question the general way of living in Copenhagen. Though there are many one-room apartments, it is common for a lot of people to live in large apartments. Many of them are shares or owned, and often expensive. To uphold diversity, there should be rental alternatives. Alternatives proposing an alternative lifestyle.

To sum up, we want to propose a new way of living in the city; a minimal one-person dwelling with the essential functions. The user is expected to enjoy a simple and flexible lifestyle, and should be good in taking advantages of the city's qualities. The dwelling itself should be functional and cheap but with fun and interesting details. Flexibility is highly important and finally, we want to create a refuge-home with great settings for enjoying loneliness.

CASES

The idea generation and design development of the dwelling goes through an experimental and investigating process, that will be described next. Each relevant studied case or experiment will be very shortly presentated with an emphasis on the most essencial information along with a sketch. Many of the studied cases will result in a generation of a conceptual idea for the project. These will be presented along the way and act as process presentation.



"...capsules suggest that you don't really need much but a bed and a shower when you do everything else out in the city..."

JAPANESE CAPSULES

The Japanese capsule hotels really propose a different way of acommodating people in the city. Although they are primarily used temporary, capsules suggest that you don't really need much but a bed and a shared shower when you do everything else out in the city - a thought that is very interesting for this project. Our dwelling should be more private and fit more into a Danish context with the less busy city - meaning that the extreme efficiency of the capsule hotels, both in concept and choice of material, would probably be unattractive and seem unnecessary to a dwelling in Copenhagen.

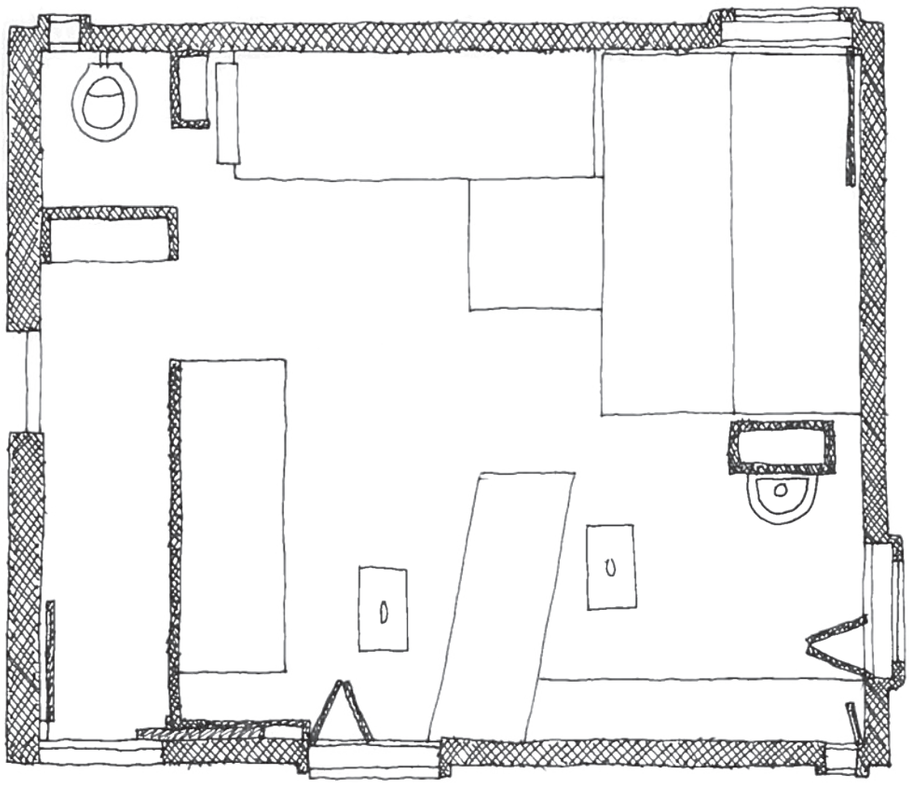
"...inspired by a desire to reduce life to its barest essentials and thereby to find a spiritual purity associated with simplicity"

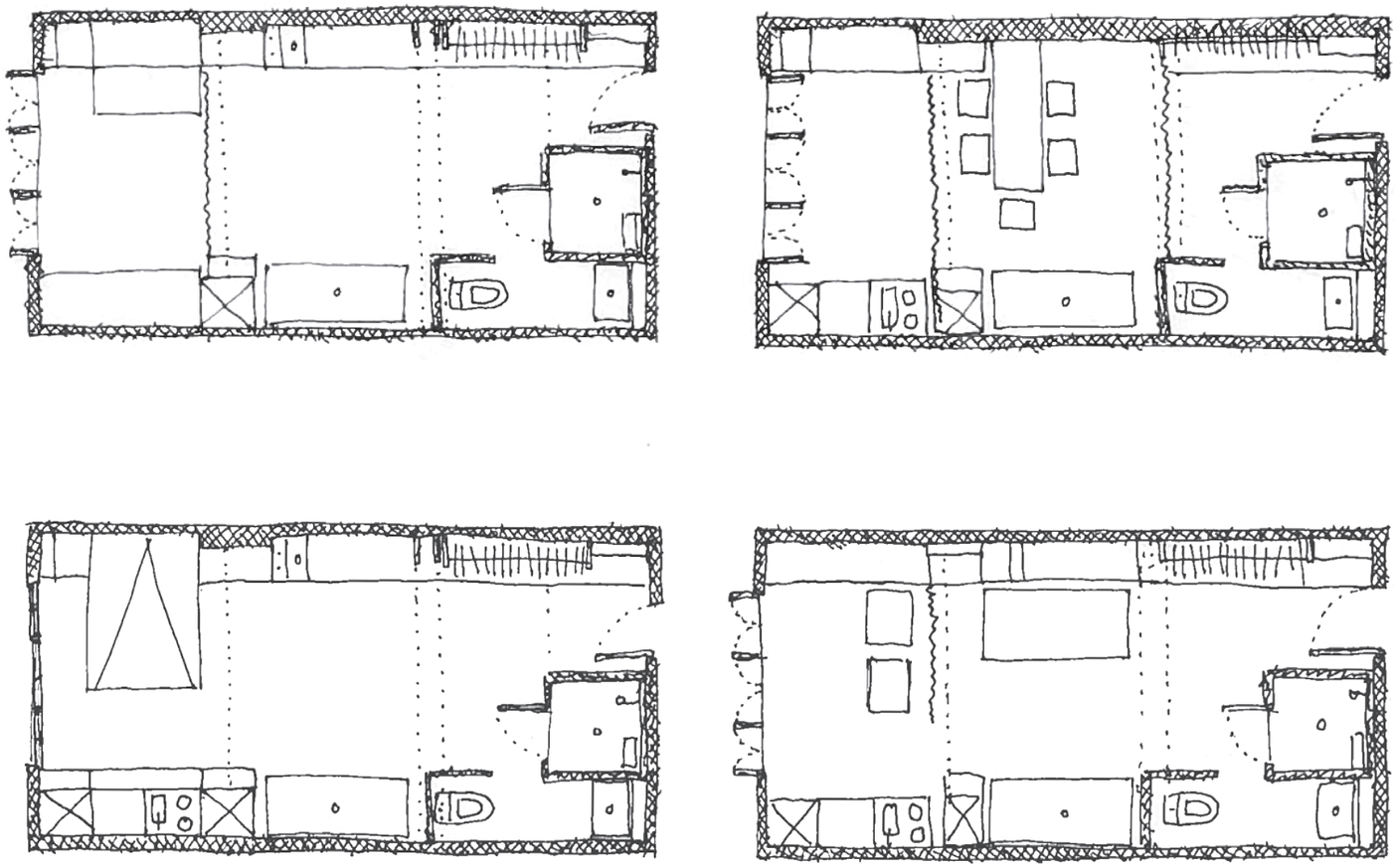
Le Cabanon is a 3,66m x 3,66m residence designed by Le Corbusier in 1952 and placed close to the Mediterranean in France.

The dwelling is designed after the measurements from The Modulor, which is Le Corbusier's measurements based on the dimensions of a body. The dwelling has three small windows, and a mirror is placed in front of one of the windows to spread the light into the dwelling. Even if it is small, there is room enough to have a bed, working space, zink, toilet and storage, plus the entrance and toilet are hided.

Le Corbusier has designed a minimal dwelling, solved with different floor-to-ceiling height, several areas and multifunctional furnitures. It is a dwelling for escape, build for his wife, but maybe he just needed a place, which could be a slave for The Modulor [Unwin, 2010, s.95].

CORBUSIER'S LE CABANON





"...A central placed movable wall makes it possible to transform the 36 squaremetre large apartment into a total of 28 combinations, depending on what functions you want to use..."

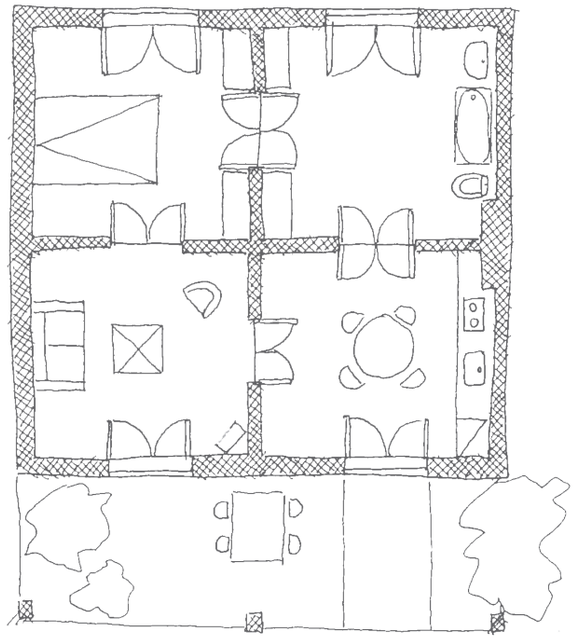
GARY CHANG'S HONG KONG APARTMENT

In ultra dense Hong Kong, architect and interior designer Gary Chang has built his one-room apartment into a multi-functional transformable live-machine. A central placed movable wall makes it possible to transform the 36 square meter large apartment into a total of 28 combinations, depending on what functions you want to use. The solution is smart and fun, but the finish is complicated and expensive, and does not really propose a simple lifestyle. The apartment can do everything that can be done in a normal sized apartment and is therefore not suggesting the inhabitant to benefit from the city.

TAGE LYNEBORG'S CROSS PLAN

"...Et særligt eksperiment er korsplanen med fire ligeværdige rum forbundet med glasfløjdøre! Den plan udfordrer beboeren til stillingtagen og reaktion! Bygningen fremstår arkitektonisk i en provokerende minimalisme..."

[Tage Lyneborg]

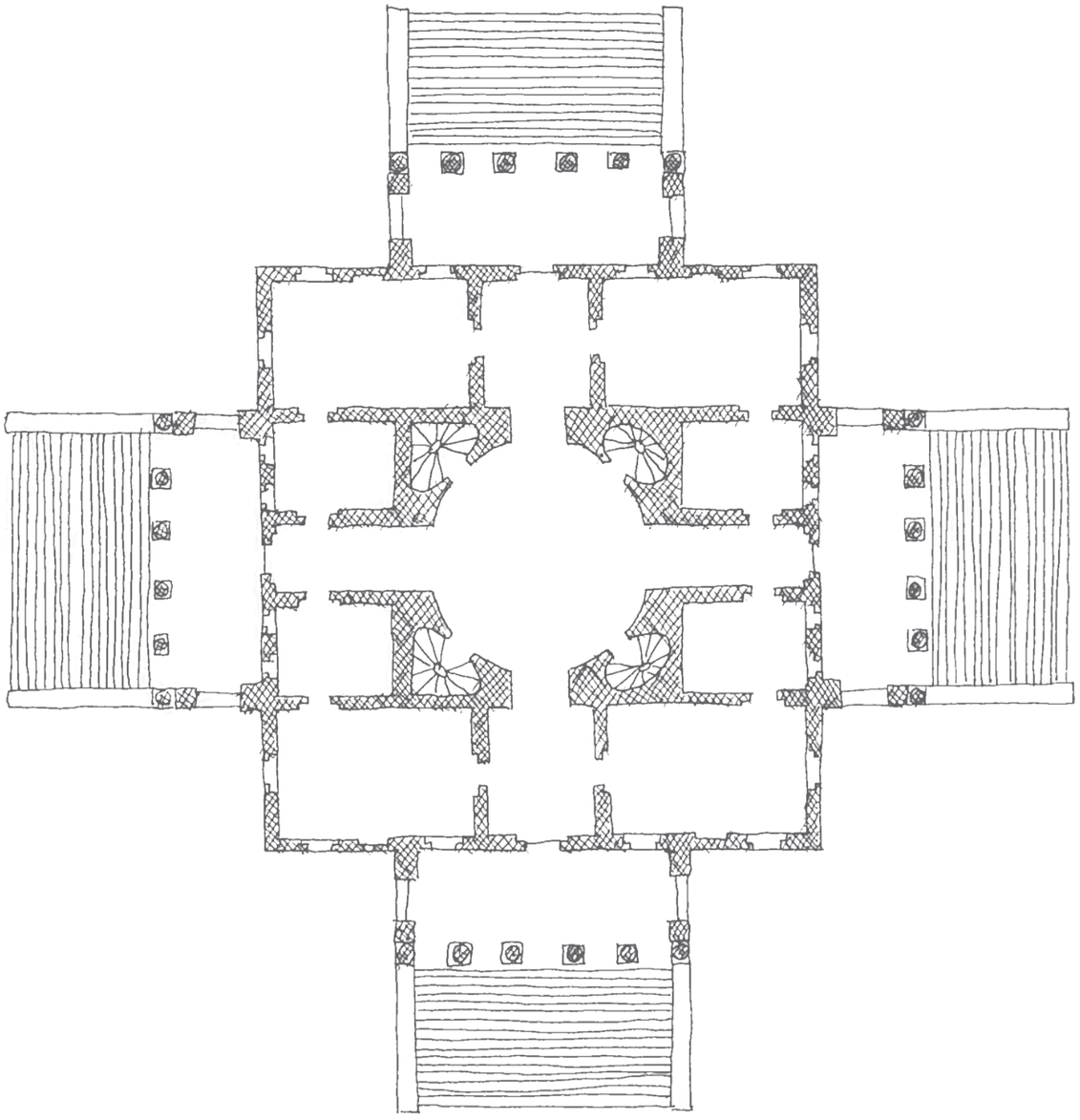


What is interesting in Tage Lyneborg's cross plan, is that there is no hieraki in between rooms which challenges its inhabitant to decide how to take use of spaces that are not necessarily shaped and layed out in the way we know them. An interesting dwelling with a level of flexibily that could be taken even further.

PROPORTIONS, PALLADIO

AND THE RULE OF THE GOLDEN MEANS

Andrea Palladio is always to admire. His work with rooms and proportions back in the years 1550-1570 has almost created a common stance among architects for what makes a beautiful room. In his Villa Rotonda he worked with symmetry, and room plans were systematically divided in sections matching the rule of the golden section. The golden section -or the golden means- is based on the Fibonacci sequence of numbers, known from nature.



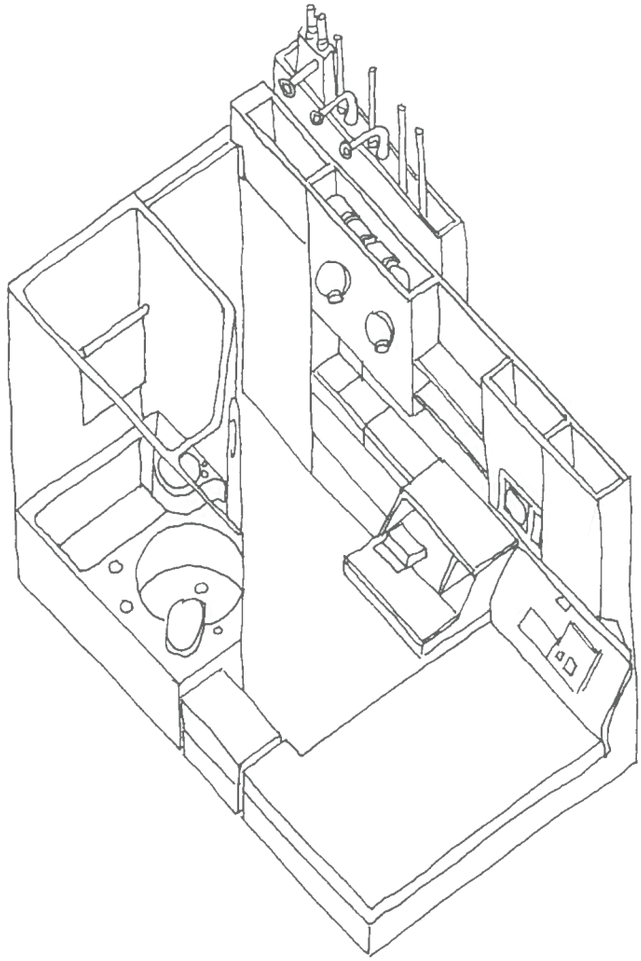
"If with a flat ceiling, the height from the floor to the ceiling must be equal to their breadth; and the rooms above must be a sixth part less in height than those below"
[Palladio, 1570, p. 28]

When the architect Kisho Kurokawa walked into Humboldt University in Berlin and saw the famous quote by Karl Marx in the entrance hall: "Philosophers have only interpreted the world in various ways; the point is to change it!", he gave a shout: "That's what I've been doing my whole life!"

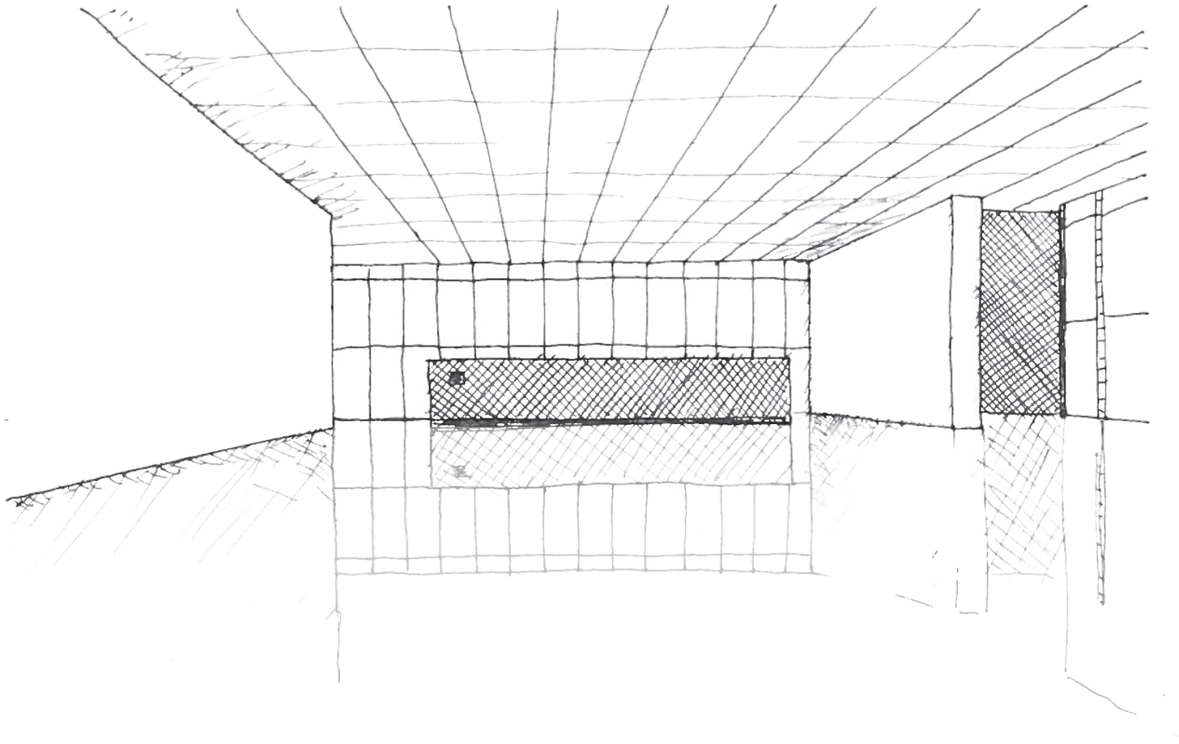
[Schmal, 2005]

NAKAGIN

Nakagin Capsule Tower in Tokyo is the world's first realised example of capsule architecture, and though it is in a bad state of disrepair, the building is still in use today. The two large interconnecting concrete towers hold 140 prefabricated dwelling modules. Units were originally targeted young busy salesmen and meassures 2,3m x 3,8m x 2,1m - but with the opportunity to connect and combine several in order to enlarge the apartment. This never happened though, because the issue with the dwelling was not really its compactness. One unit has all you need. All appliances and cabinets are built into one wall and holds both kitchen stove, fridge, TV, and a bathroom about the size of a airplane lavatory. Over the bed is a large circular window. The interior has a glossy plastic look and the design screams 'temporality' but nonetheless stands a great example of "a powerful reminder of paths not taken, of the possibility of worlds shaped by different sets of values" [Ouroussoff, 2009]. The lack of sensoric and architectural quality in especially the interior, and the eagerness to fit everything into the dwelling instead of focusing on the 'essence' of compact living, could be the reason, that this form of living never really got its breakthrough.



"...Not only should a space be a description of zones, nor only a practical organization of volumes, plans and shapes - it is also an aesthetic composition and a narrative with emotional and tactile character..."



"ATMOSPHERES" ACCORDING TO PETER ZUMTHOR

Peter Zumthor's delicate conduct of sensoric qualities in architecture, makes him interesting when arguing that tactility is extremely important in compact spaces. In Zumtor's lecture "Atmospheres" from 2003, he described how materials and their compatibility is a major parametre when expressing a space. He also argues that a space has both a sound, a temperature and a tension and that there should be placed great attention to working with this. We discovered, for example, how the reflection in the finish of a material can have an amazing impact on a space.

SUMMARY

The capsule taught us that many ***people do enjoy the city*** and don't have big expectations to how they spend the hours when their eyes are closed.

Le Corbusier learned us about the ***functionality and beauty of a refuge***.

Gary Chang inspired us to challenge the fun and ***transformable one-room apartment*** with functional interior.

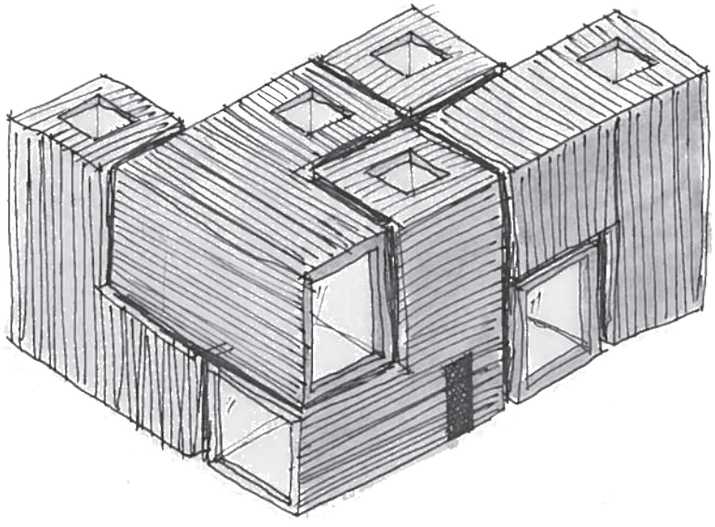
Tage Lyneborg ***challenged*** the well-known in the division of rooms in a dwelling.

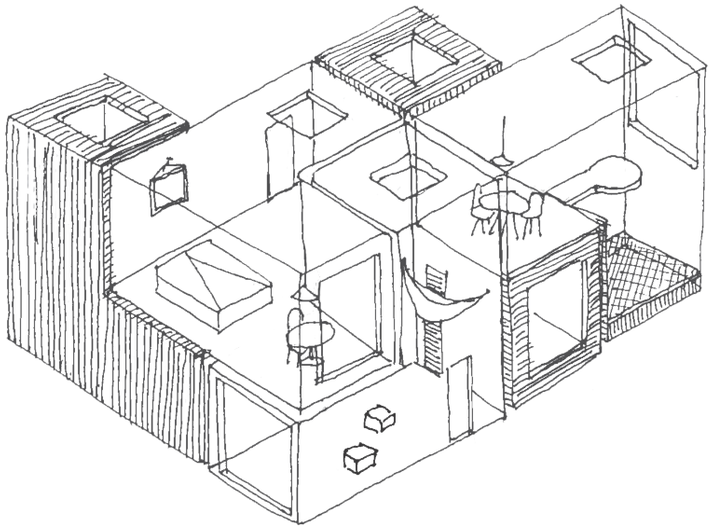
Palladio proved that the ***golden section could create beautiful rooms***.

The Nakagin capsules showed us how ***living in less than 10 square meters is possible***.

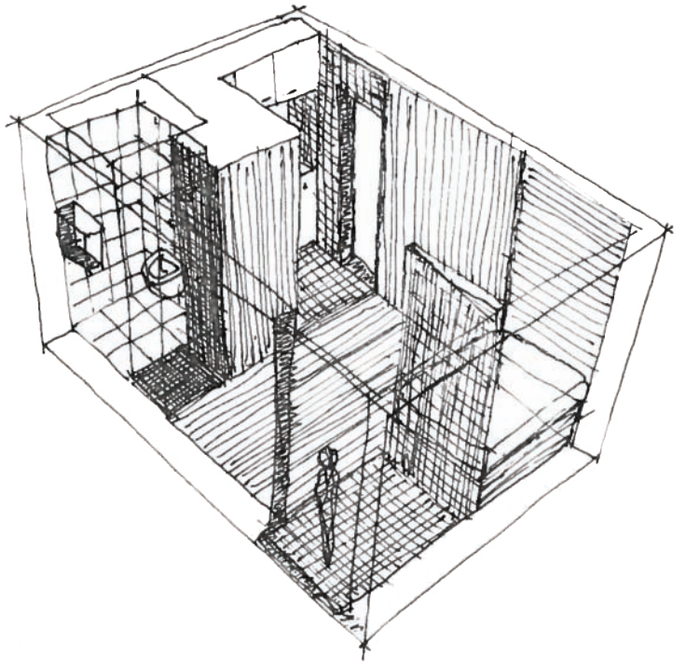
Peter Zumthor reminded us the ***importance of sensoric qualities*** in architecture.

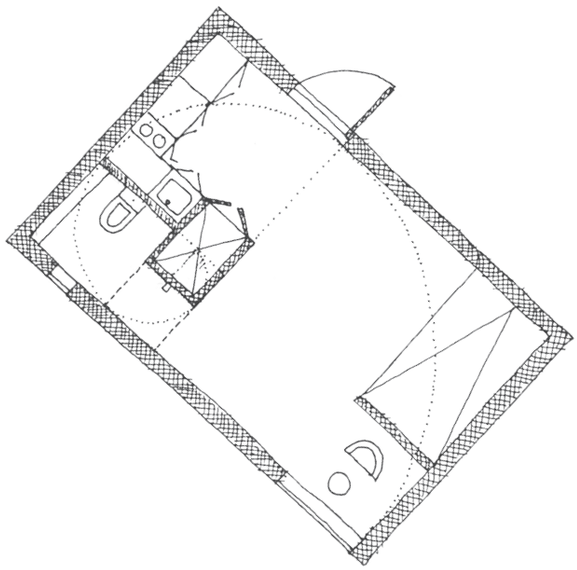
WHAT IF...



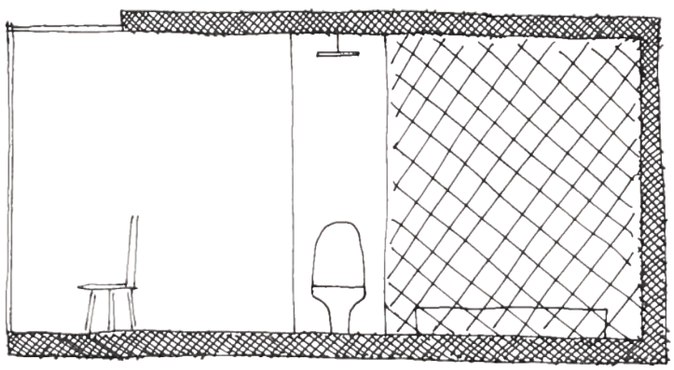


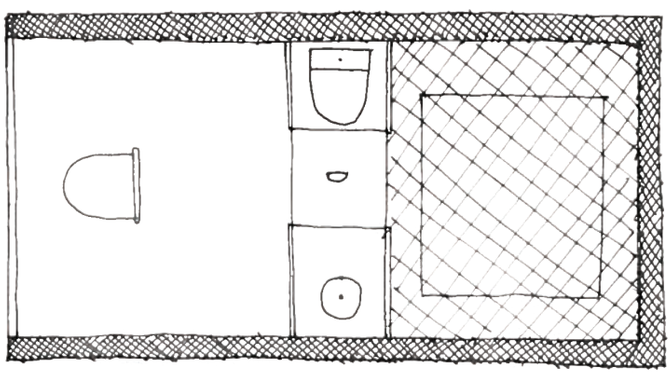
...you chosed your dwelling depending on what kind of refuge you wished for? For example, if you knew that you would mostly need your apartment for sleeping in it... Or maybe your refuge was only for playing piano or painting? Or dancing or jumping with skip-rope? Each dwelling would form after a function and cluster together invisibly in compact constallations, densifying the city.





…the division of rooms in the floor plan and the interior flow pattern was layed out in a very direct interpretation of the golden section in a dwelling?





…the dwelling was strongly divided into a dark and a light zone?

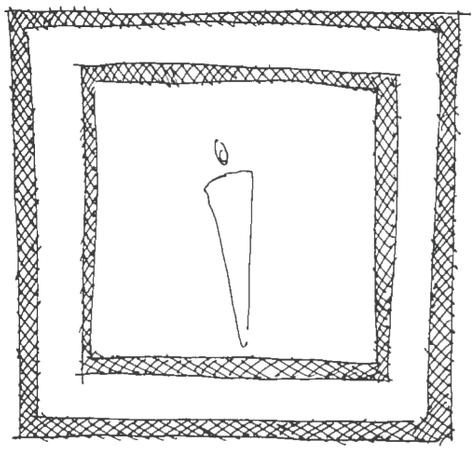
HOW DOES THE DWELLING

TAKE SHAPE FROM ALL THESE STUDIES? HOW WILL IT WORK DESIGN- AND FUNCTION WISE?

Inspired by case studies and experiments, we now see the possibility of creating a small space that is not only compact in its size but also proposes another lifestyle that can be enjoyed by the simple pleasure of a beautiful room.

THE WANTED LONELINESS

When spending a lot of time in the city, a place to hide, relax and process all the impressions of the day, can be pleasurable. Whether one prefers to relax with meditation in a completely soundproof dwelling or unwind his mind to loud rock music, we are determined that the citizen's home should be a place for them to pursue mental tranquility and deserved loneliness. A room with no disturbances.

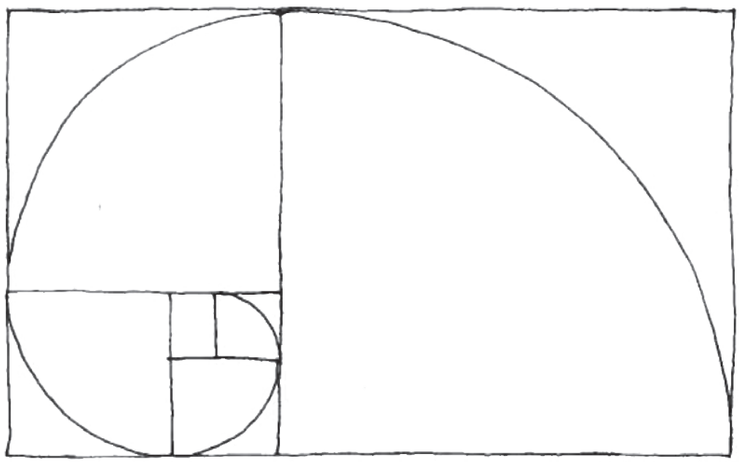


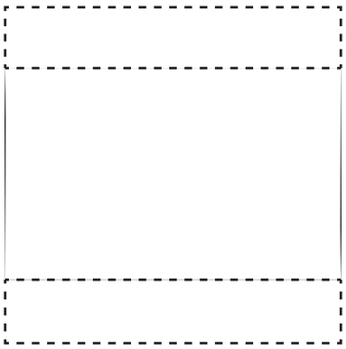
WHAT WOULD IT BE LIKE TO LIVE IN A CUBE?

Like the yolk in a cubic egg...? A cubic room would have a room height defined by the dimensions of the floor or reverse. That alone, could seem irrational, but giving the dweller a posibility to place himself in the very centre of a shape, has an immediate alluring comfort. A cubic room would however lack of orientation unless something in the room defines a clear direction. Regarding the exterior form, a cubic form could on the other hand have advantages. The simple cube is easy to stack and combine and could easily be put into system. A system for exterior composition could have economical and aesthetic benefits. We like the cube.

AND THEN WE TRIED DESIGNING THE SENSE OF A ROOM WITH PROPORTIONS OF THE GOLDEN SECTION

As part of studying Andrea Palladio, we made experiments with room sizes defined by the golden section ratio, meaning that if a room was 1 unit wide, it would be 1,62 unit long. This, of course, is not synonymous with a beautiful room - but we saw the possibilities of a simple, naked room and how the relation of proportions alone could create a feeling of well-being. The naked room would provide the wanted flexibility in the dwelling and add the luxuriant feature of having a 'hobby room' - even in a compact space. We also found, that there was much more orientation with this form, and that we tended to turn ourselves with direction towards the narrow ends, allowing more floor space in front of us, clear. The golden section started to become a design tool when dimensioning our room, and we defined a minimum room height that thereby dictated the short side that again led to a minimum lenght of the long wall in the room. The measures seemed great! For more about the experiments, see appendix 4.





A FUNCTIONAL GAP

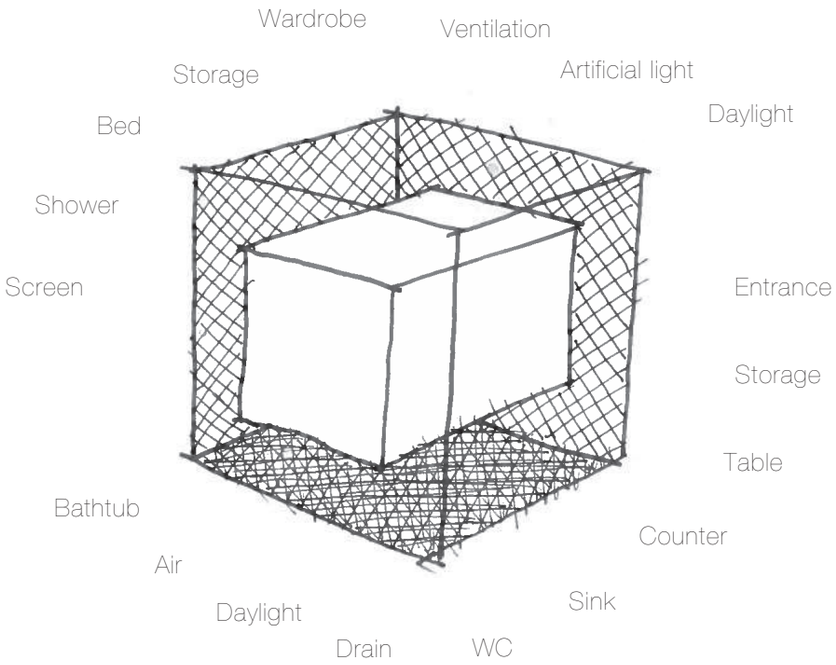
But then what? We really liked the room we had formed from the rule of the golden means - but we also found the idea of a cubic exterior form that could be put into system, and ultimately have an iconic appearance with many orientations, very attracting. Therefore, we tried putting these two shapes together, and learned immediately, that the gap between them had amazing possibilities. In this gap, we could pack away all the dwelling's functions, appliances and installations - and leave us with the desired option of a naked, flexible room.

THE FUNCTIONAL CONCEPT

Thinking the dwelling as a one-person dwelling gives further possibilities in how functions can be thought and placed. For example, an important argument for the overall concept is:

"As only one person uses the dwelling, there is no need for more than one function in use at a time. For instance, you would not really need a 'bedroom' and a 'dining room' at the same time, when living alone. However, the toilet and bathroom should always be accessible."

Another aspect on the one-person city apartment is that we expect the inhabitant to be an active, benefiting citizen, and therefore, the functions of the dwelling should be essential.



THE ESSENCE OF LIVING

THE INTERIOR TACTILITY

"...our sense of smell is perhaps the most reliable. Real wood is a living material and as such in its successive live an object or piece of furniture it continues to breathe and emanate scent. Wood is not only a material, but also an "essence" that changes according to quality, seasoning, humidity of the air and exposure to the sun. Perfumers and cabinet makers know this. Wood has an extraordinary scent that belongs to the identity of a brand more that the shape of its products. The smell of a wardrobe or a table stays impressed in our olfactory memory some hundred times more than its form. Wood breathes and we breathe it, and that's why our relationship to it os more intimate than with any other material...

...To us, the scent of wood is home living, refuge, because we trust it so much as to use it even for the barrels of the best wines and utensils of fine cooking."

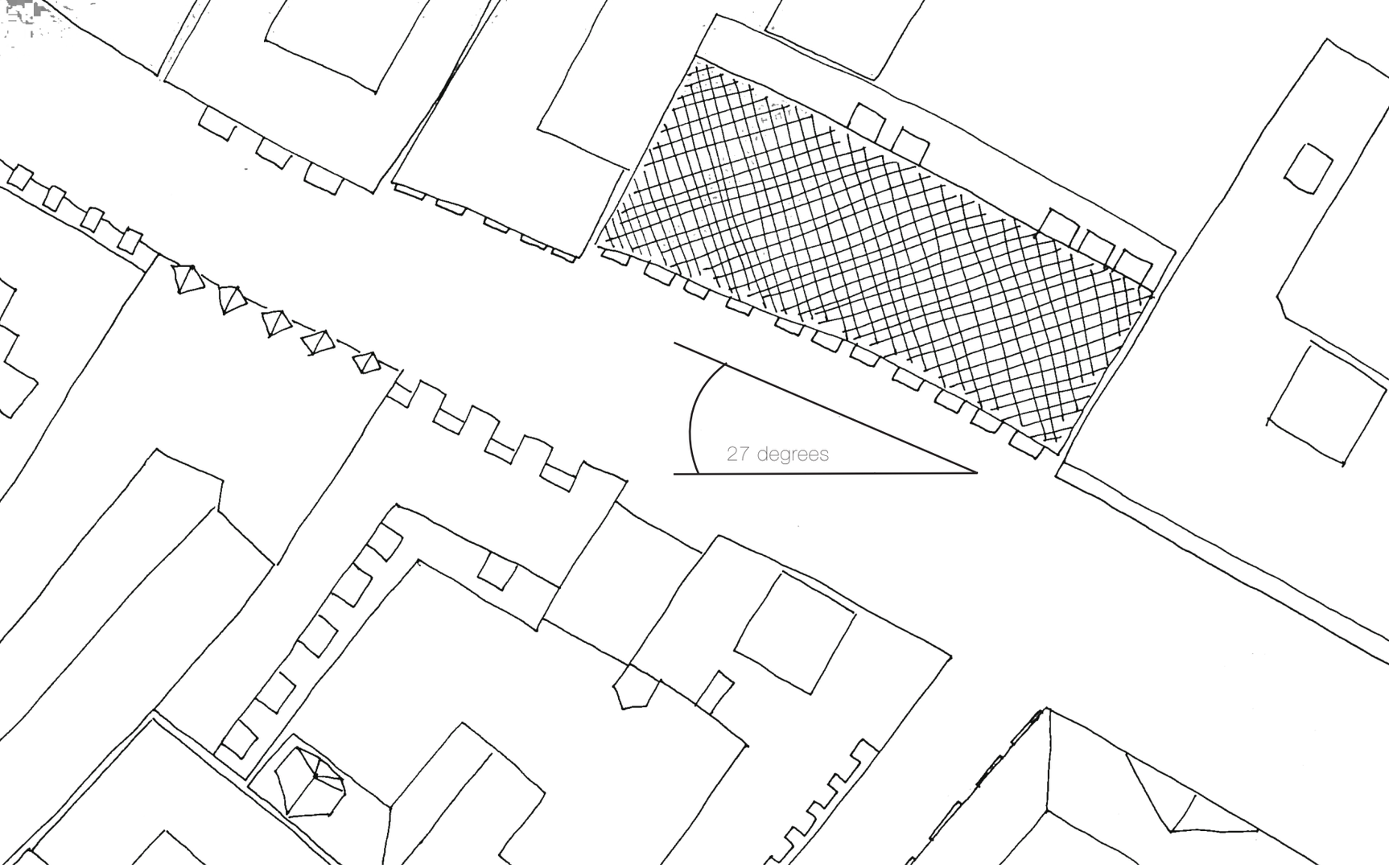
[Domus, 2011]

OPENINGS

We propose that the entire end wall, opposite the entrance, should be a window to allow much daylight and benefit from passive solar energy as well as to create hieraki and orientation. To soften this up, we chose to place another smaller window - a light crack above the door.

SYMBIOSIS

The architectural and conceptual mindset is presented and we will start processing the design with an engineering approach in order to reach a symbiosis between fields. This means that we will refine the design to meet the demands for the energy class and optimize conditions for daylight, ventilation and construction. All the way through the project, we have used technical tools to determine weaknesses in shapes, read appendix 10 (Month Average and 24 Hour spreadsheet). This means that following pages should be considered extended use of technical tools.

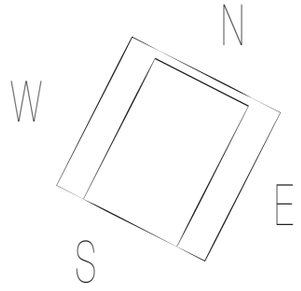


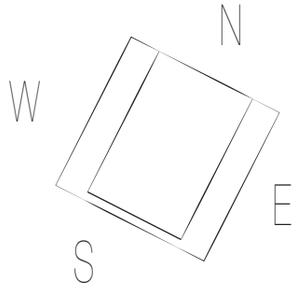
INDOOR CLIMATE

A good indoor environment is essential for general comfort, and the determinating factors like daylight and ventilation should be carefully considered. Small spaces have the potential of low energy consumption and quick heating from solar gains - but a small space is also in the high-risk group for overheating. Therefore, as a design tool, we will simulate different scenarios. The different simulations will take their point of departure as worst case scenarios, so as the very first step, we have to determine the orientations of the dwellings.

The existing building on Købmagergade 44 is angled 27 degrees and we chose the new structure of dwelling units to follow the underlying orientation. Though this will result in orientations towards either southwest, northwest, northeast and southeast, they will be interpret as south, west, north and east. The simulations, however, will be done with exact angles according to the sun path.

To simulate the indoor climate, two different orientations of dwellings are chosen to represents the two extremes. First, DWELLING 1 with an orientation towards south (SW) and second DWELLING 2 with an orientation towards north (NE).





ATMOSPHERIC AND THERMAL COMFORT

In the analysis, the parameters for a good atmospheric comfort were described. But how are the parameters achieved? It is chosen to use hybrid ventilation, where mecanical ventilation is used in January, February, March, April, May, September, October, November and December. Natural ventilation is used in June, July and August.

A minimum ventilation rate needs to be calculated for the Perceived Air Quality (PAQ) and CO2 level, so it can be certain that during all year, both categories are at an acceptable level. During summer it is rarely an issue to set a minimum, because the ventilation rate is automatically high caused we want to avoid overheating, but during winter it is good to set a minimum rate.

PERCEIVED AIR QUALITY

Parameters:
Qc: Required ventilation rate (l/s)
Gc: Sensory pollution (Olf)
Cc,i: Desired perceived indoor air quality (dp)
Cc,o: Perceived outdoor air quality (dp)
Ev: Ventilation effectiveness
A: Area (m2)
a: Pollution constant

Qc = 10 * ((Gc+(a*A)) / (Cci-Cco) * (1 / Ev)
Qc = 16 l/s = 57,61 m3/h = 0,81 h-1 = 0,93 l/s m2

CO2 LEVEL

Parameters:
n: Air change (h-1)
q: Total infused amount of CO2 pollution (l/h)
Q: Pemissible CO2 level (ppm)
C: CO2 concentration in outdoor air (ppm)
V: Volume air (m3)

n = (q x 103) / ((Q-C) x V)
n = 0,38 h-1

In a comparison between the PAQ ventilation rate and the CO2 level ventilation rate, the highest one is chosen, so both can be fullfilled. 16 l/s (PAQ) is higher than 0,3 l/s (BR10), which is minimum requirements. So 0,93 l/s m2 is used to set the ventilation rate in Bsim and Be10 as minimum. See the calculation spreadsheets on the CD for more details.

VAV OR CAV?

In the analysis mixed ventilation was chosen for the dwelling to get a more constant air change without draught. The dwelling is a small room, so there is not space for 'dead' areas with draught. A CAV system is chosen over a VAV system. Mixing ventilation depends on a constant air volume, so the air is changed gradually. CAV is also cheaper to purchase.

MECHANICAL VENTILATION OR FLOOR HEATING AS MAIN HEATING SYSTEM?

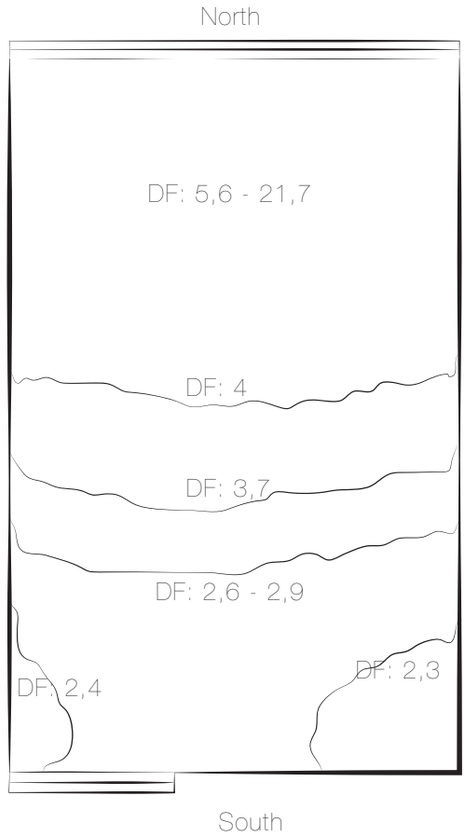
As mentioned earlier in the analysis under mechanical ventilation, it is not acceptable to use mechanical ventilation for heating as the only heating source according to building class 2020. In this project we strive to fulfill the 2020 demands, but for this parameter the argumentation is stronger if we only use mechanical ventilation for heating. When the dwelling is so little it is a big investment to integrate floor heating, when we have the mechanical ventilation installed regardless, it is suitable to use what already is integrated. It can be more expensive to heat with air than water, which is why the 2020 demands requires another type of heating. With air the reaction to temperature change happends quicker, which is an advantage. To be certain in our decission and argumentation, it is discussed in the 'energy frame'-chapter as well.

WHAT IS PROS AND CONS WITH A SMALL ROOM COMPARED TO VENTILATION?

A small volume reacts quicker to adjustments, especially when it comes to temperature adjustments. Natural ventilation openings are designed, in this project, mainly from an architectural point of view and tested in Bsim, which calculates the ventilation rate compared to the size of the openings. Because the dwelling is small, there is need for a lot of ventilation during summer, or else it is quickly overheated. An advantage is, that the room temperature reacts quickly to an open window and cools down in no time. The design of the dwelling included a large amount of windows and from the beginning the sizes of the window openings were big, because we expected high natural ventilation rate.

DAYLIGHT

When the dwelling only consist of one room, it is crucial to get enough daylight, so the perception of the room is positive. With Bsim and Velux Daylight Visualizer, the daylight factor (DF) is calculated in worst case scenario for the dwelling facing north (DWELLING 2). The daylight has been a big design factor and integrated from the start, so the results were expected. The design criteria was to get a DF on 5% or over in at least half of the room and not under 2% near the entrance. The illustration below shows the inner rectangular room with the DF results.



WHAT KIND OF URBAN

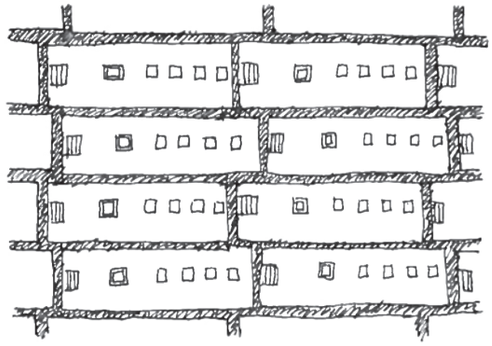
COMPOSITION AND EXPRESSION SHOULD THESE CUBES HAVE?

The wish for the urban expression is to make a composition of dwellings that is not limited within its own form. Therefore, the structure needs to be flexible in some way. The repetition of the geometrical cube, gives us an opportunity to create different orientations within the same structural system, without really changing the form expression. The bearing construction should accommodate this with a balance between system and flexibility.

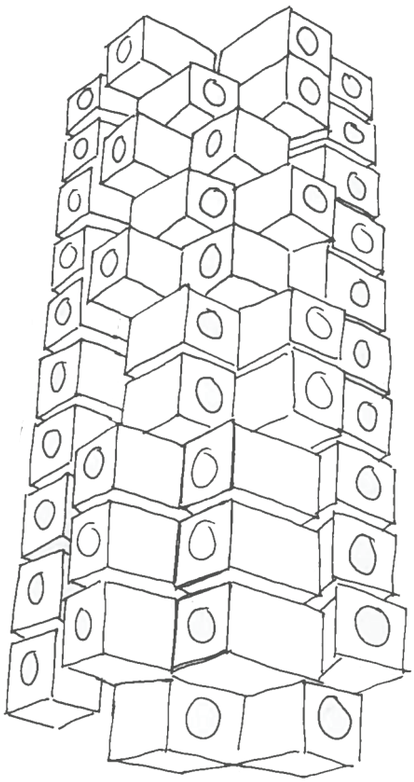
To sum up, we want to create an expression of invisible organized randomness. The composition of dwellings should be able to grow - both vertically and horizontally, and should branch out on adjacent rooftops, across streets and water. Densifying the city is an important issue for us, so despite its ramification, the structure should also be compact to a certain point where the cube still is an independant form.

JAPANESE METABOLISM

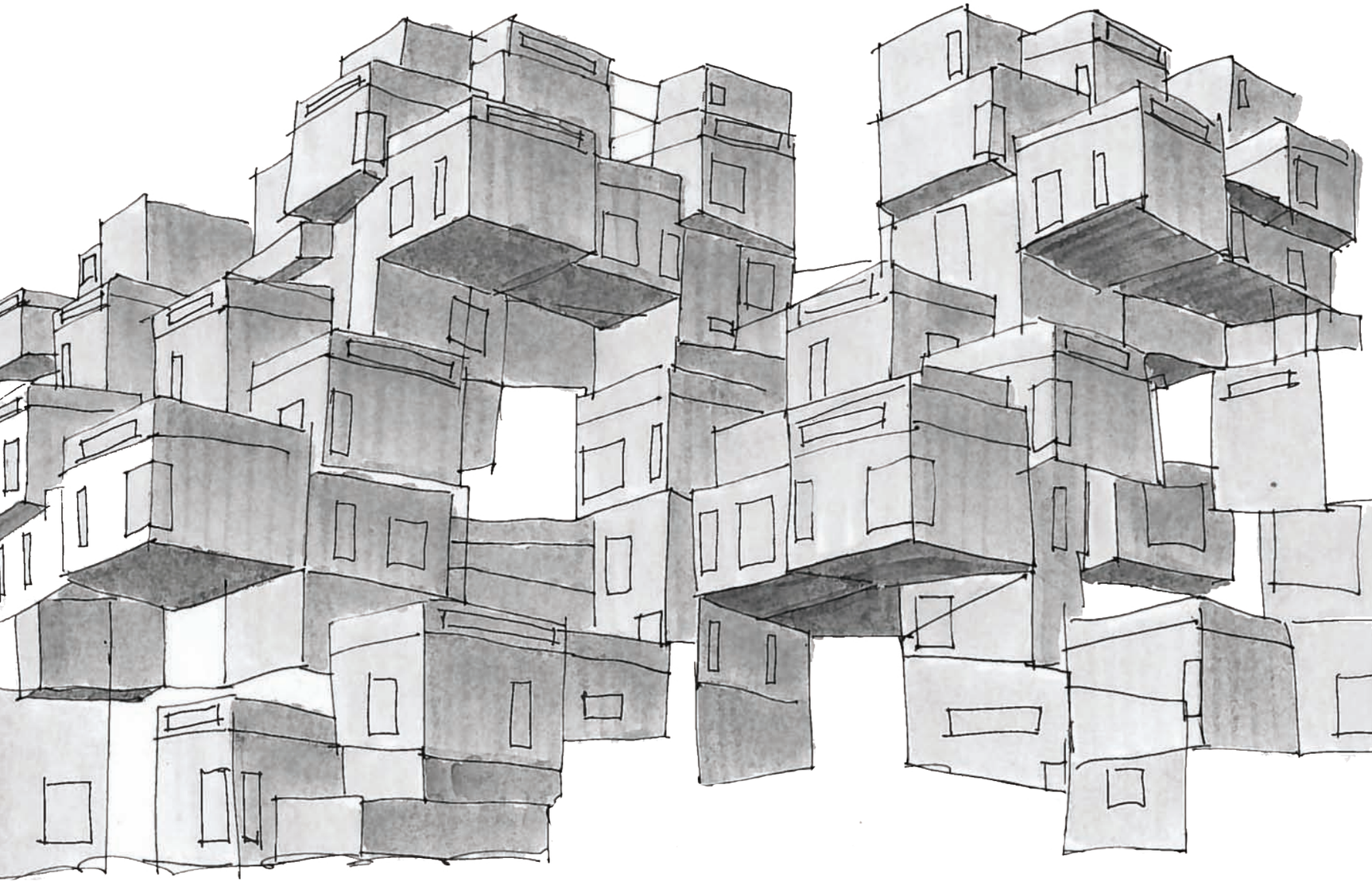
Japanese "Metabolism" was the result of joined forces between architects and designers in the post-war Japan, in the late 1950s. The movement was mostly involved with housing issues and visions for inhabiting cities through large scale structures that were flexible and expandable - and in some ways simulated the process of organic growth. According to this group of designers and architects, the traditional fixed form and ways of thinking 'function' were old-fashioned. They seeked a new way of perceiving cultural ideals.



NAKAGIN
(AGAIN)



The Nakagin Capsule Tower was the first example of Japanese metabolistic architecture. Their way of proposing living in replacable units made it into a shape of a high rise with the possibilty of growing only vertical. The units can be replaced if necessary but that has actually never happened. The structure is very compact and the interpretation of ramification is very abstract.



HABITAT 67

Habitat 67 is a large housing complex in Montreal, Canada, and started out as an experimental master thesis project by architect Moshe Safdie. An idea that was later chosen to be realized through the Expo 67. The 354 prefabricated concrete units are arranged in various combinations and some of the units are combined, making the complex consist of a total of 148 dwellings and every single one of them had at least one private terrace. With this, Safdie tried to integrate the benefits of suburban living and thereby attract those users. The entire project was believed to illustrate and encourage a new lifestyle for dense cities all over the world - a reaction that was caused by the increasing city settlement. However, the project site is in an old port site and not exactly the dense city. One of Safdie's major goals for the project was to create affordable housing, but the price of 900.000 kr per unit made his vision fail. However, the project has not only been criticised but very much rewarded as a success because it redefined and experimented with urban living [Interview with Safdie, 1997].

SUMMARY

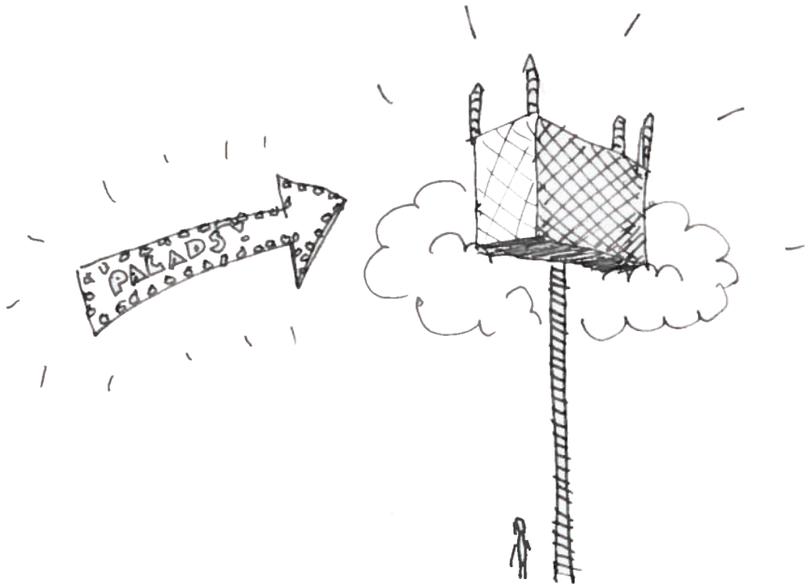
The Japanese metabolists urged to break with the traditional housing means through ***compact, large scale, flexible, expandable structures***.

Nakagin was extremely compact with many units, and the ***option of replacing units made it flexible***, though the expansion of dwellings only occured vertically.

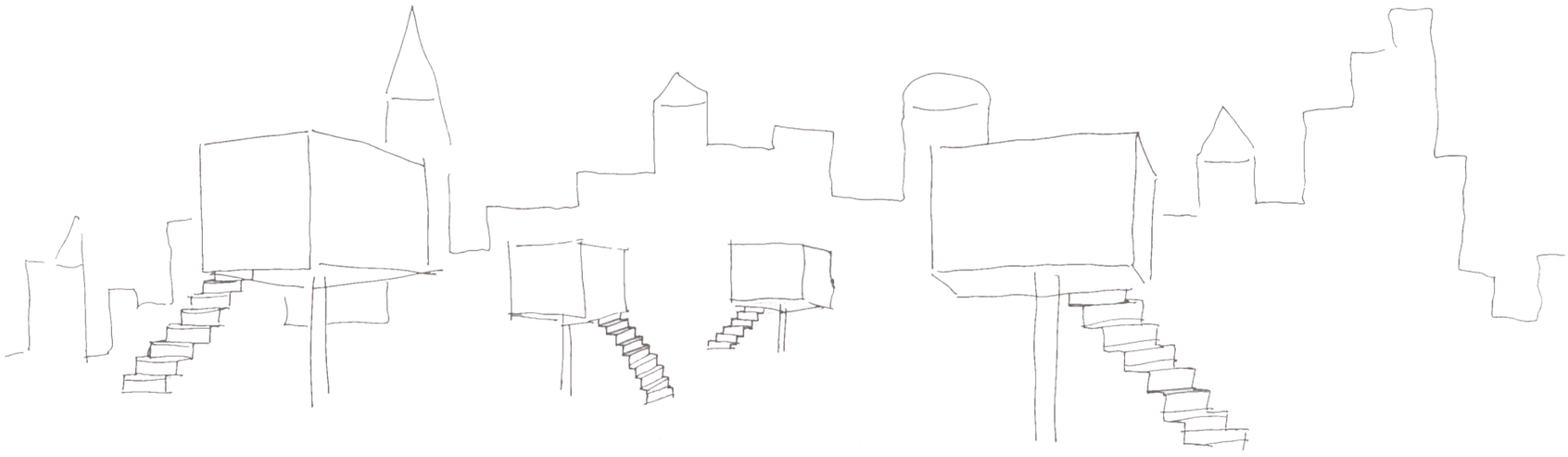
In the Habitat 67 project, the ***urban expression is diverse and exciting***, though units are the same shape.

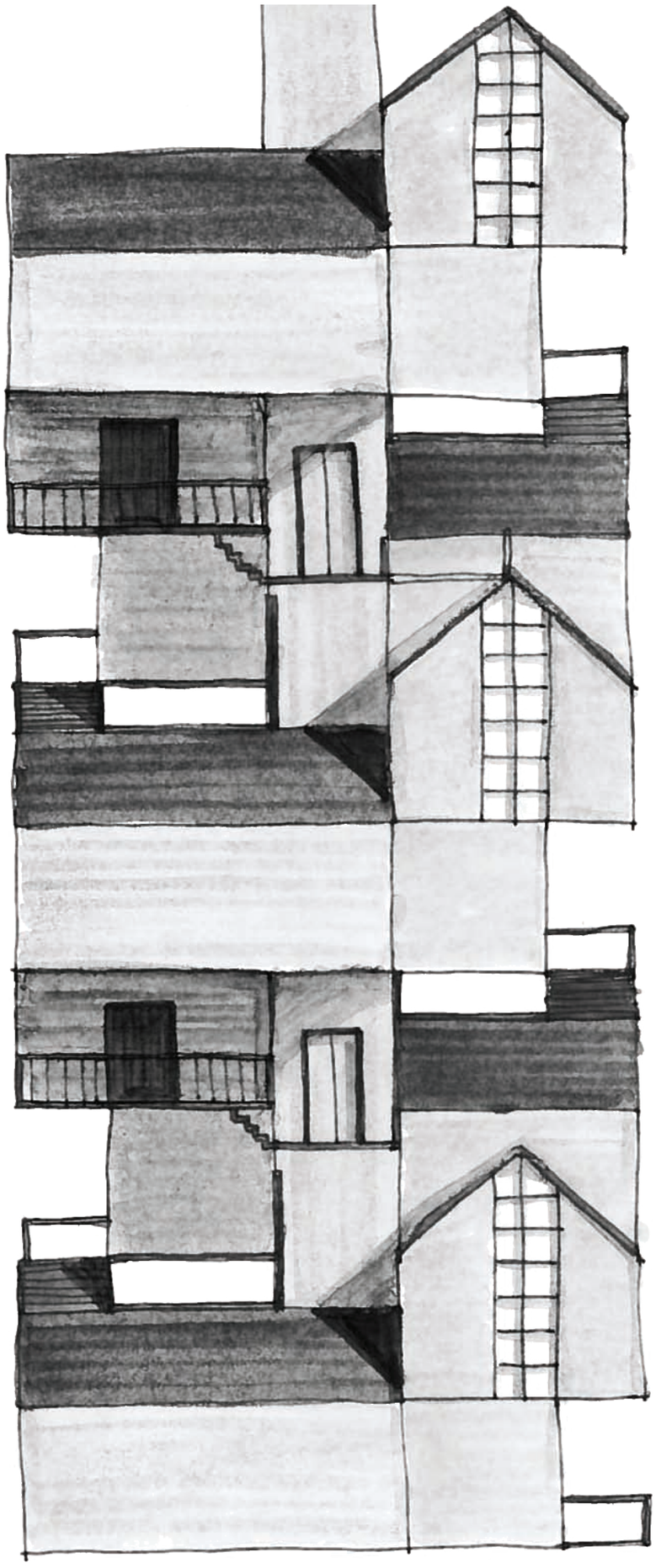
WHAT IF...

...The dwellings were raised up in the air on a column? It could be a very isolated castle!

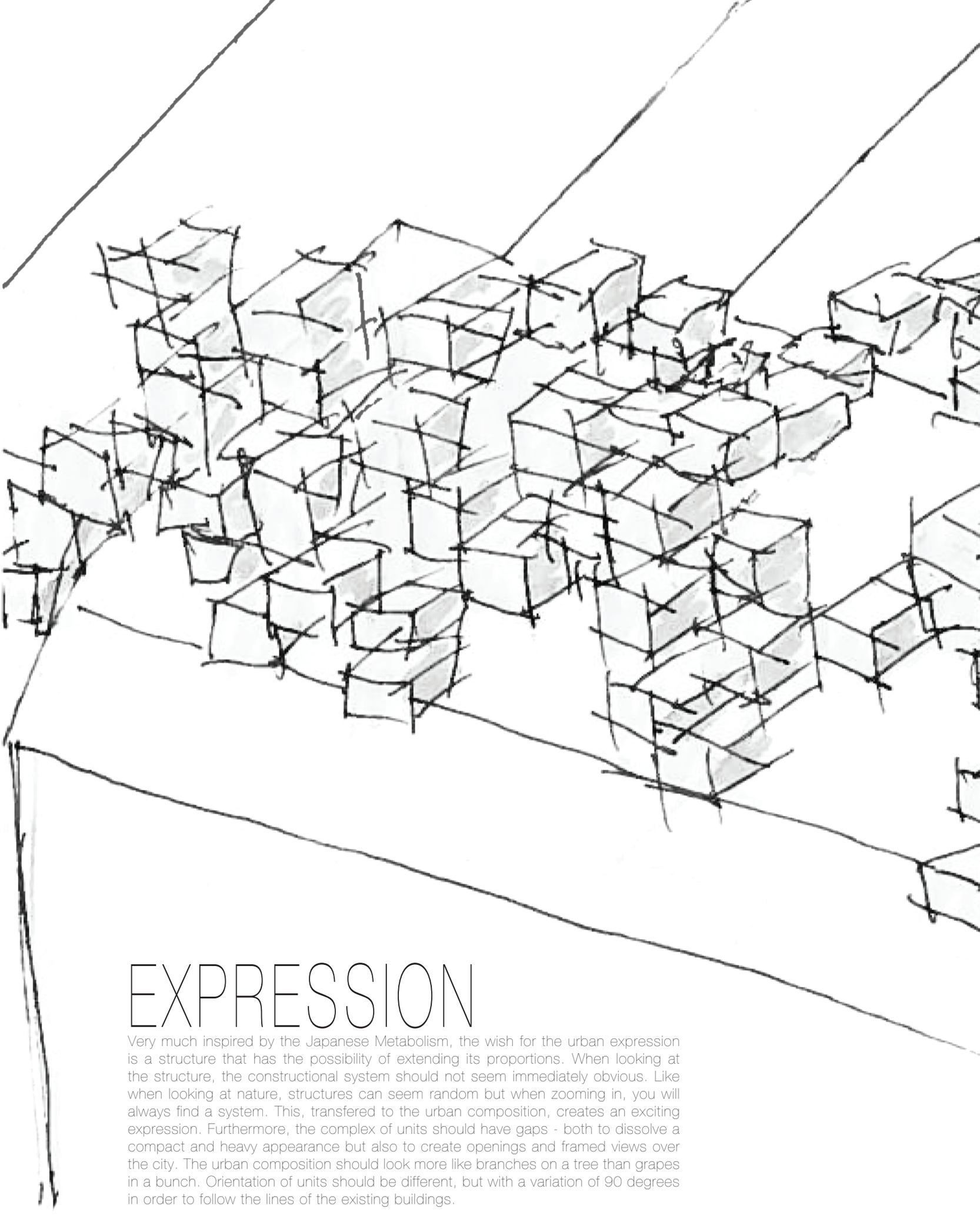


...it together would create small castles in the sky on top of the roof? The stairs connected to every unit, is the only entrance and exit, and when the user was home, he could remove the staircase as a symbol of: Do not disturb.



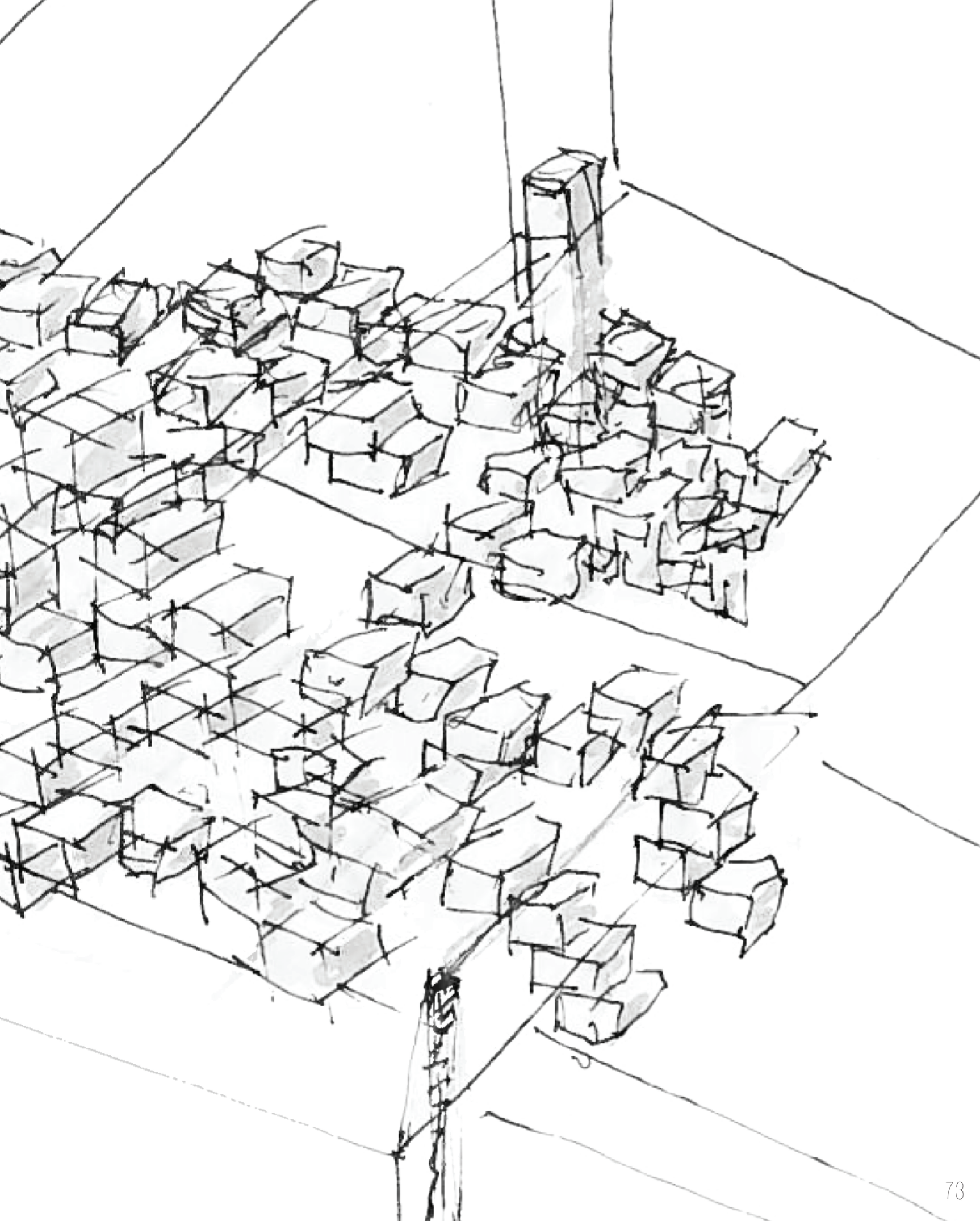


…All the dwellings were stacked, used each other as shading with a central elevator?



EXPRESSION

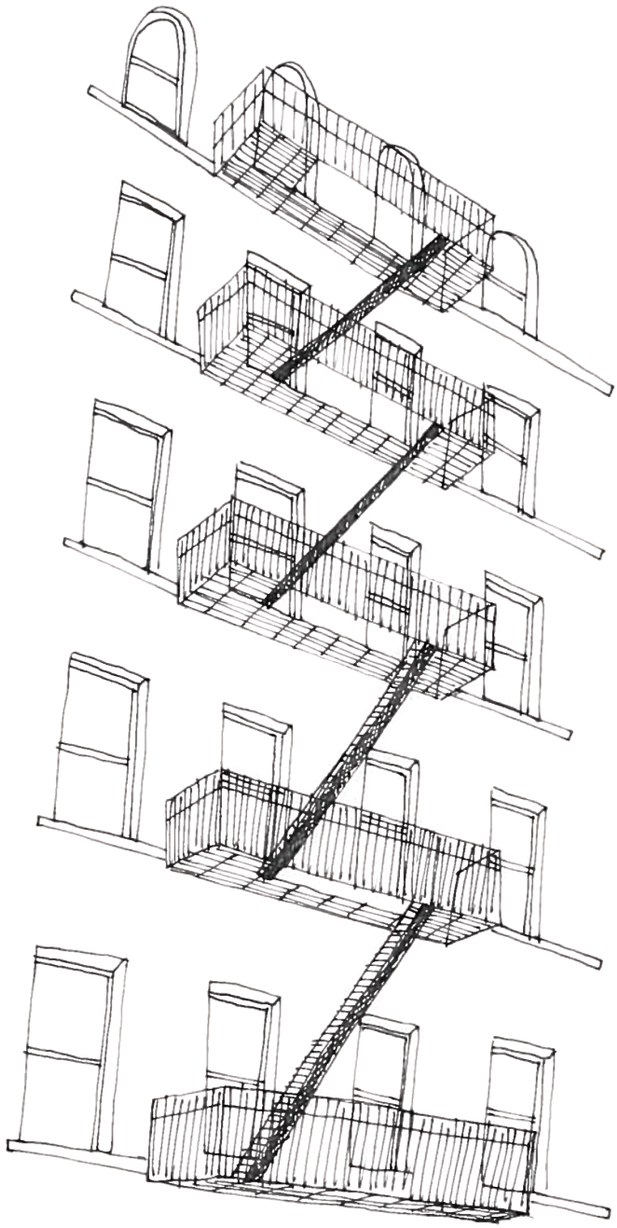
Very much inspired by the Japanese Metabolism, the wish for the urban expression is a structure that has the possibility of extending its proportions. When looking at the structure, the constructional system should not seem immediately obvious. Like when looking at nature, structures can seem random but when zooming in, you will always find a system. This, transfered to the urban composition, creates an exciting expression. Furthermore, the complex of units should have gaps - both to dissolve a compact and heavy appearance but also to create openings and framed views over the city. The urban composition should look more like branches on a tree than grapes in a bunch. Orientation of units should be different, but with a variation of 90 degrees in order to follow the lines of the existing buildings.



ACCESSIBILITY

The arrival to the housing complex is very important for the perception of it. Because of its placement, an elevator and stairs are of course necessities. The elevator is placed in the backyard up against the facade. You arrive via Købmagergade and find your way into the backyard, where the elevator is to the right. Next to the elevator, fire staircases are placed in case of emergency. The staircase is added up against the facade, like the elevator, as a light transparent steel structure.

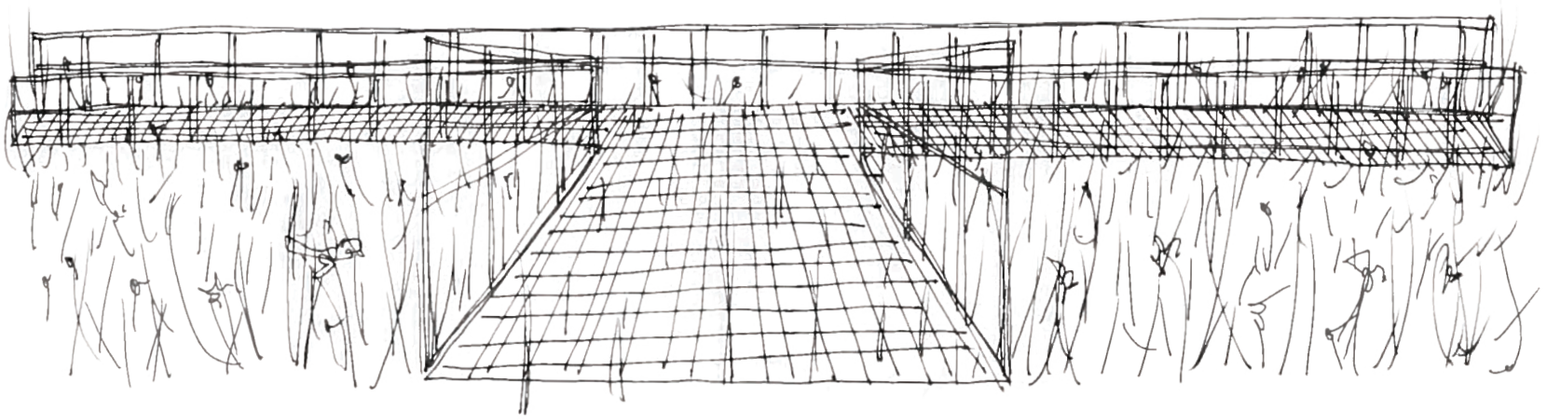
You access the roof in the middle of all the dwelling units. Floating paths made of steel moves around and in between the units. The paths and stairs are dimensioned after BR10 3.2.2, as common access paths. Plus there is a maximum distance to the exit staircase of 25 meters.



New York's fire escapes has been a big inspiration for the design of the stairs and paths. The light steel structure which delicately moves up the facade, is an expression to strive for. Reference photos of elevator and staircases can be seen in appendix 8.

GREEN ROOF

On top of the roof of Købmagergade 44 and under the dwelling complex, a green carpet will take shape. This is because of its many advantages for the city and environment, but also to work as a beautiful carpet below the hovering units in order to soften up the steel structure and the industrial prefab expression. The green roof will consist of long grasses that can grow through the steel grid in the acces paths. A green roof weights around 50 kg/m2 and has qualities like improving air quality, reducing the expenses for heating and cooling in the subjacent building, handling of rainwater, noise reduction and of course the beauty of recreational spaces in the cities many layers. Further explanation of the advantages and technical details are to be found in appendix 7. Reference photo of how the walkway could work in combination with a green roof is to be found in appendix 8.



BALCONIES

To create diversity and to benefit from some of the open spaces in front of windows and on top of other units' roofs, balconies or french balconies will be embodied in the design. Both the dwellings with and without balconies will have a pivot glass door as a part of the window. The balconies will, due to the thickness of the floor, be placed lower than the floor height inside the dwelling, but this will be solved with a couple of stairs. The railing of the balconies will be a steel frame with steel wires to uphold a high level of transparency and leave the cubes as the thorough, visible and undisturbed shapes of the complex.

MATERIALS

When chosing exterior materials, we contacted Cembrit which is a large local retailer of facade materials and building boards. We wanted an extended knowledge in the materials' potential as well as discussing the project with a constructor. During the meeting, we found two different types of facade elements that we thought were adequate for the architecture. Following is a comparison and selection of those two materials.

Cembrit PLAN is a cheap fiber concrete, meets all requirements, is always in stock and has a texture that can be compared to slate. It looks good in combination with solar cells, the material creates a gradual transition between them because of the dark color they both have. The combination between a dark grey on the outside and a light plywood on the inside makes a good contrast and compliments each other well. PLAN can get patina in form of faded white stains. Among the roof surfaces at Købmagergade, PLAN would blend in and be an integrated part of the view from Rundetårn. See pictures of the material in appendix 9.

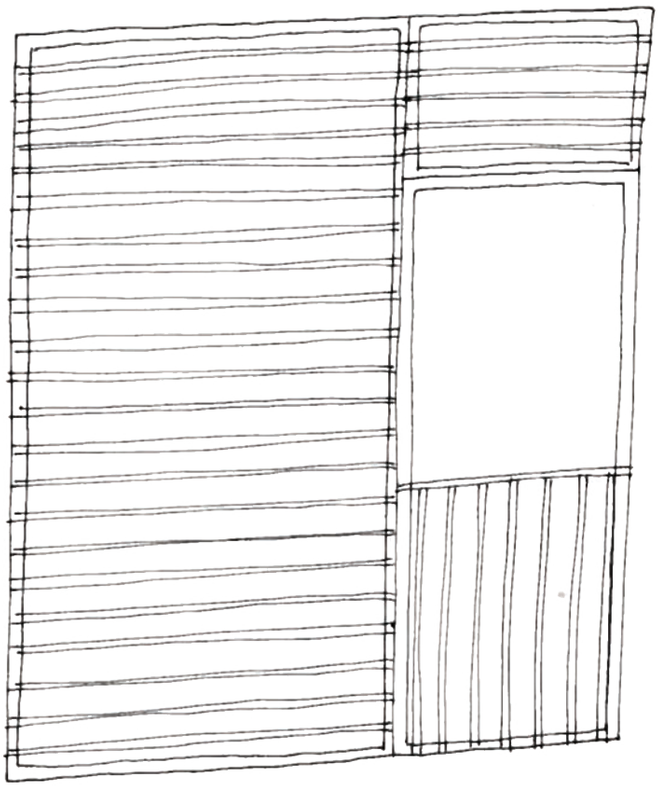
Cembrit Fiberline is a fibre glass composite with a light transparent look and visible fibres. It has a soft green glow which in the city can be compared to the green cobber roofs. The material is innovative, new and can be effective energywise, though it is not verified with calculations since it is only a rainscreen. Nonetheless, Fiberline's domicile has experiences a radical reducement in energy after replacing their facades with Fiberline. The material needs no maintenance and has a long lifetime. However, it is very expensive - around four to five times as expensive as PLAN. From Rundetårn, the dwellings would be easier to notice among all the roof surfaces because of the light color, but the urban composition is eye-cathing anyway and does not really need the material to make up for that. See pictures of the materials in appendix 9.

Considering economy and the integration of solar cells, mades us chose Cembrit PLAN for the facade cladding.

SHADING

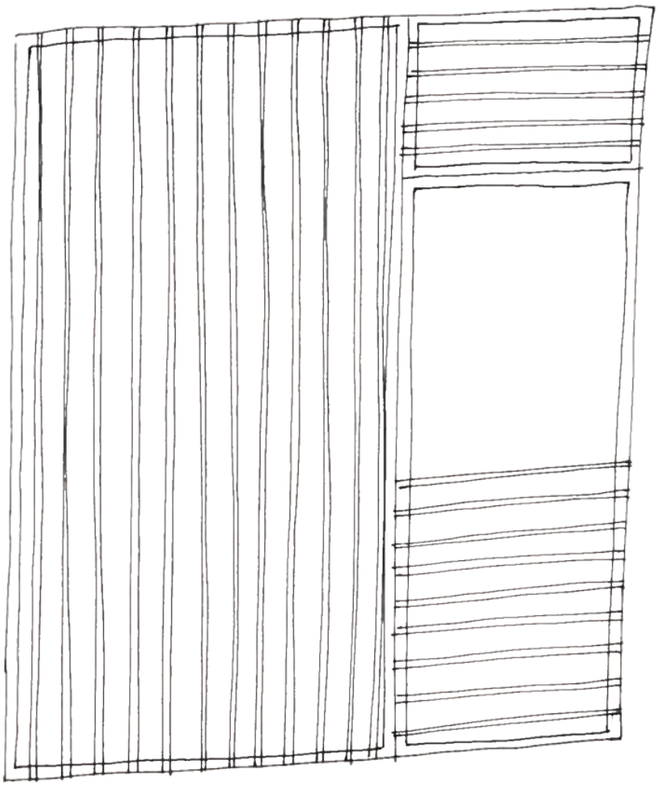
Depending on the orientation of the unit, dwellings to the south, west and east will have shading to avoid overheating. During summer the sun sets high which is the critical radiation for overheating. During winter the sun sets low, which is the radiation we want to take advantage of. The different radiation angles are reflected in the design of the integrated shading.

SHADING ON SOUTH ORIENTED DWELLING



The shading is horisontal which will bring shade when the sun sets high and during winter when the sun sets low, we can take advantage of it.

SHADING ON EAST AND WEST ORIENTED DWELLING



The shading is vertical which will let the sun in during morning and evening, but will shade against the sun radiation from South.

OVERHEATING

With the big window facade, overheating is an important factor to be aware of. 24 hour spreadsheet is used during the sketching and designing phase and Bsim is afterwards used to simulate the indoor climate during the detailing phase. See appendix 10 for more information.

DWELLING 1

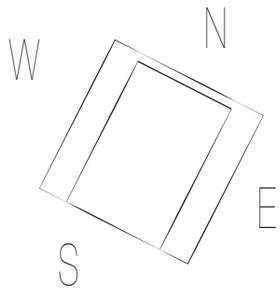
The two parameters which are adjusted to avoid overheating in BSim are the amount of solar shading and natural ventilation. During the three critical summer months, the shading coefficient is set to low (0,15) to give a good amount of shading for the southern windows. During the winter months the shading coefficient is set to higher (0,5) to let the sun in and heat the dwelling during the day.

The ventilation rate during summer, is set to a maximum on 5 h-1, to avoid draught at any time. The window openings are defined and the program ventilate compared to what is needed. During the three summer months the ventilation rate is not very stabil, but is calculated to be between 1,9 and 2,5 h-1, which is much lower than 5 h-1. During the rest of the year, the ventilation rate for the mechanical system is stabil at 1,4 h-1. In general the rate is a little high during summer and winter, but since we have one small room, we couldn't expect otherwise.

The CO2-level is also accepted with 574 ppm in average, which is under 1050 ppm as required in CR1752 (Tabel A.9). Though, if the user has friends comming over for a visit, which is not very often and therefore not calculated with, the CO2-level could be an issue to investigate further.

At first iteration, during the winter months, there was a lot of hours below 20 degrees. The problem was a mistake of materials and insulation thickness. It is extremely important to have good exterior walls, so we can trap the little amount of heat from the sun during the winter, which also will benefit on the energy consumption.

Overall, the demand concerning maximum 100 hours over 26 degrees is fulfilled with only 42 hours. A maximum of 25 hours over 27 degrees is fulfilled with 10 hours. The average operative temperature during all year is 22,6 degrees, which is an exceptable level and shows that the overheating problem has been solved. See appendix 11.

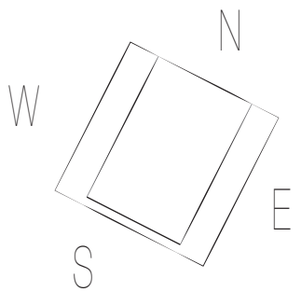


DWELLING 2

The goal was to model DWELLING 2 in BSim, to investigate how much we would have to change from DWELLING 1 to get good results. The issue here was the amount of hours below 20 degrees, which in this model was innumerable amount of days. It was expected that heating would be the parameter to investigate, to get better results. Earlier, during the chapter 'Indoor Climate', it was decided only to use mechanical ventilation for heating. During the summer months there was not hours below 20 degrees, so it was a matter of adjusting the ventilation system, and increase the maximum inlet temperature. This adjustment, of course, has an impact on the energy consumtion, which will be discussed in the section 'Energy frame'.

During summer, the ventilation rate is a little lower than in DWELLING 1, which was expected. The rate is bewteen 2 and 2,4 h-1, a little more stabil, which makes sence, because the dwelling doesn't have direct sunlight during the day. The mechanical ventilation rate is the same compared to DWELLING 1, 1,4 h-1, and stabil during all 9 months.

Compared to overheating hours, DWELLING 2 has 21 hours over 26 degrees and 2 hours over 27 degrees. It is a better result than in DWELLING 1, which also was expected. The amount of hours below 20 degrees is 0 and the average operative temperature during all year is 22,4 degrees. To see the results in a diagram see appendix 11.



WHY ARE DWELLING 1 AND 2 NOT MORE DIFFERENT?

As expected there was a difference between overheating and hours below 20 degrees between the two dwellings, but all in all it wasn't an enormous difference. The mechanical ventilation system only needed 5 degrees higher setpoint for maximum temperature inlet in DWELLING 2. It came as a little surprise the amount of overheating hours in DWELLING 2, just because there is not direct sunligth, which means the dwelling is influenced a lot by the outdoor temperature. The facade coating can maybe have an impact on that, because the material has the same qualities as a rain/wind jacket on a human body. It traps the heat inside the body/dwelling and warms it.

A detailing of the dwelling complex is restricted to only 22 dwellings, all placed on Købmagergade 44's roof. All calculation concerning solar cells, energy frame and construction are only based on these 22 dwellings. As well as all the drawings in the drawing folder. Though the vision for the project is that the structure is limitless and can expand, as mensioned before and presented in the presentation.

SOLAR ENERGY

The amount of solar cells are first estimated from an architectural point of view. The solar cells should enhance the cubic form and contribute to reach building class 2020.

The solar cells are placed to the SE, S and SW. Each different oriented solar cell has been calculated to see how much kWh it can produce compared to efficiency [Solceller i byggeriet, 2000]

SW

A. Area / 40.5m2
B. Efficiency / 10%
C. kWpeak / 4.05 kW
D. Systemfactor / 0.75
E. Solar radiation / 841(SW, 90degrees)

Performance a year / 2555 kWh

S

A. Area / 81m2
B. Efficiency / 10%
C. kWpeak / 8.1 kW
D. Systemfactor / 0.75
E. Solar radiation / 892(S, 90degrees)

Performance a year / 5419 kWh

SE

A. Area / 60.75m2
B. Efficiency / 10%
C. kWpeak / 6.075 kW
D. Systemfactor / 0.75
E. Solar radiation / 833(SE, 90degrees)

Performance a year / 3795 kWh
See the CD for calculation spreadsheet.

The results are used in Be10 to calculate the energy consumption. Together, the solar cells can produce:

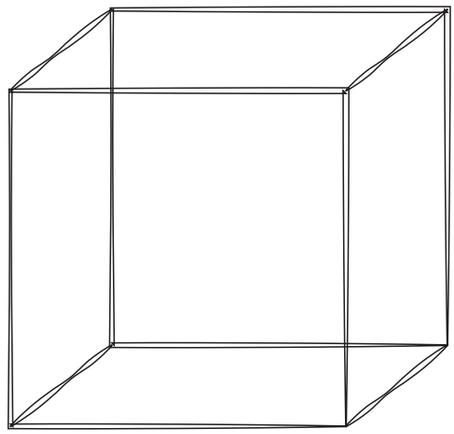
11769 kWh

STRUCTURE

The urban composition should hover above the city supported by a separate steel construction that holds the dwellings and lifts them from the underlying building. This principle is chosen to make the dwelling complex independant from the underlying building. It is also a way to make people in ground level be aware of the architecture. Columns will catch and direct your eyes to look up.

The steel structure forms as a 3 dimensional grid in which the units sit in. Based on calculations and wish for expression, girders and stanchions in the grid are distributed with a 2000 mm space.

The dimensions of the columns which support the whole structure have a big influence on the expression of the building. Therefore we found it necessary to calculate how many columns were necessary to hold the structure, see appendix 12 for calculations. The calculations results in 9 columns on each side of the building, 18 columns together, with a dimension of 150mm x 150mm. See drawings of the dimensioned columns in the drawing folder in 1:200 (drawing #5 to #12).



CONSTRUCTION

The construction of the dwelling is a cubic steel frame. This is to use the same material as the bearing structure of the dwelling complex. There will be a wooden framework in between the steel structure, which will repeat beams with a 600mm distance and also will be reflected in the interior composition where the plywood sheating will fit these measures. The facade cladding is fixed to the wooden frame. 600mm x 600mm is a standard measure, which will not only to save materials, but also fit standard interior elements. Further detailing is to be found in the drawing folder (drawing #1, #2, #3).

ENERGY FRAME

As mentioned before the goal is to reach the Building class 2020. In Be10 the energy frame for the whole complex, 22 dwellings, is calculated to reach the building class 2015 without solar cells and then building class 2020 with solar cells. The final results show an energy consumption of -2,7 kWh/m2 year, which means we have reached the goal.

The northern oriented dwellings are the reason why it wasn't possible to reach the building class 2020 without solar cells, the window areas to the north are too big. But in the design phase we decided that the northern oriented dwellings have so many qualities, that it was okay to only fulfill the building class 2015 without solar cells. In the early design phase, where we decided the dwellings should be individual units both visually and functionally it was also critical compared to reach building class 2020. The design creates a lot of surface area, which already was tested in the Month average to have a negative impact. So taken that in consideration, it is good to reach the building class 2015 without solar cells. See appendix 11 for the listed results and the CD.

Next, DWELLING 1 and 2 was calculated in Be10 to investigate the difference in energy consumption. The expectations were that DWELLING 2 used more energy for heating than DWELLING 1. DWELLING 1 should go below 0 kwh/m2 year with solar cells and DWELLING 2 over. The expectations were correct. DWELLING 1 has an energy consumption of -4,3 kWh/m2 year and DWELLING 2 on 7,9 kWh/m2 year. So together, where all 22 dwellings work as one unit the goals can be reached. DWELLING 1 gives to DWELLING 2 so it in the end come together as zero. To see the listed results see appendix 11.

COULD WE GO LOWER THAN 0 KWH/M2 YEAR?

lit would be a comprimise with the design, expression and functions of the dwellings to strive for better results. The units could be placed closely together, side by side, and oriented to the south all of them. But in this project the design and function overrule the energy frame. It is important to have diversity, and therefore the dwellings are oriented differently. It is important to express individuality and a difference in form, compared to the normal block which dominates Copenhagen, and therefore it creates a lot of surface area.

MECHANICAL VENTILATION OR FLOOR HEATING AS MAIN HEATING SYSTEM?

The results are positive, and fulfill the requirements, so to use the mechanical ventilation system as the only heating system doesn't conduct us from good results.

ECONOMY

The economy is probably the most influential factor in the building industry. Without money, there is no building, and money has the power to control architecture or control the results of what should have been architecture. It has therefore been a goal to reduce costs in the design instead of reducing the architecture in the end.

With a m2 price at 5.000 is the ultimative goal to strive for. But taken into consideration that we are building on top of a roof in Copenhagen centrum the goal seems hard to strive for.

The dwelling is small, means less materials, but it does not make it cheap. To get some help we asked contractor Knud Andreassen to estimate a price.

For materials only, without the toilet, shower, bathtub, sink, facing and ventilation system, but with mountings and screws for the whole dwelling it would be approximately 125.000 kr. The insulation was the most expensive part and also a high class insulation from Rockwool. We chose this insulation to get a tight and solid building frame to minimize the energy consumption.

It is a big window facade, and the windows are from Pro Tec which has a collection called Pro Tec 7 Multi, very energy optimised three layer windows with a low U-value. They will cost approximately 50.000 kr.

Facing materials would be approximately 400 kr/m2 for the Cembrit PLAN, which is inclusive mounting bracket. We have 100 m2 facade in average to cover which gives 43.600 kr.

Knud estimated working hours to be 400 hours.

All in all for only the dwelling, it would cost around 125.000 + 50.000 + 40.000 = 215.000 + working hours.

We could get better prices when it is all in all 22 dwellings and not only one. Solar cells are also going to fill up some facades, which means less external cladding material.

12.181 kr pr m2 is the price and then working hours on top of that. It is 7.000 kr more than we had hoped for. Anyways, it is a price, which most housing buildings would cost now a days.

PRESEN

NTATION

INTRODUCTION

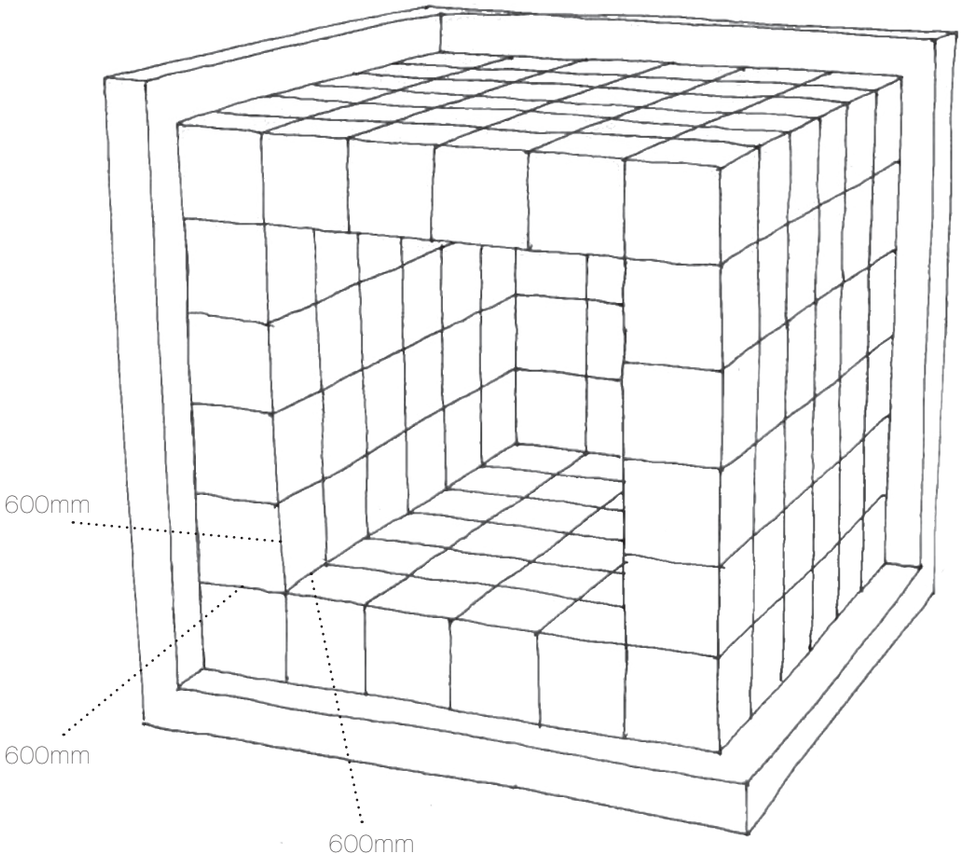
Through analysis, case studies and a consistent design phase, the dwelling developed. Dimensions evolved through architectural experiments on minimal spaces, proportions from geometry and mathematics - and a layout of the Danish modular measures in order to minimize waste in production and thereby reduce costs. The gap between exterior wall and inner room is 600 mm - the dimension of a Danish building module.

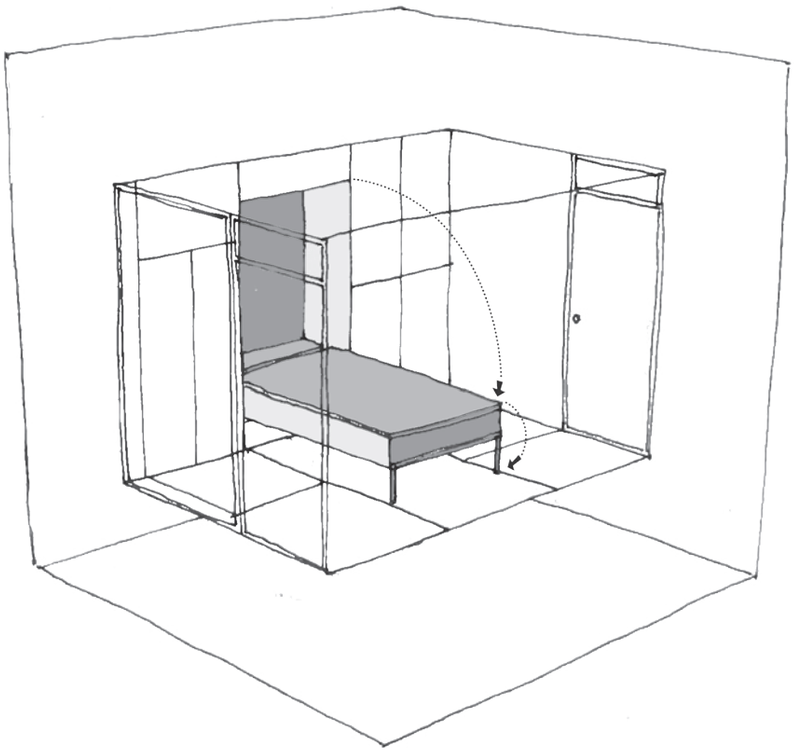
In the same way, the exterior dimensions fit in the same grid, and facade cladding can be repeated without interruptions or waste of material.

The inner room is still dimensioned from the rule of the golden means as the initial intention, while the exterior shape is a cube.

On the following pages, functions, atmosphere and urban composition will be presented.

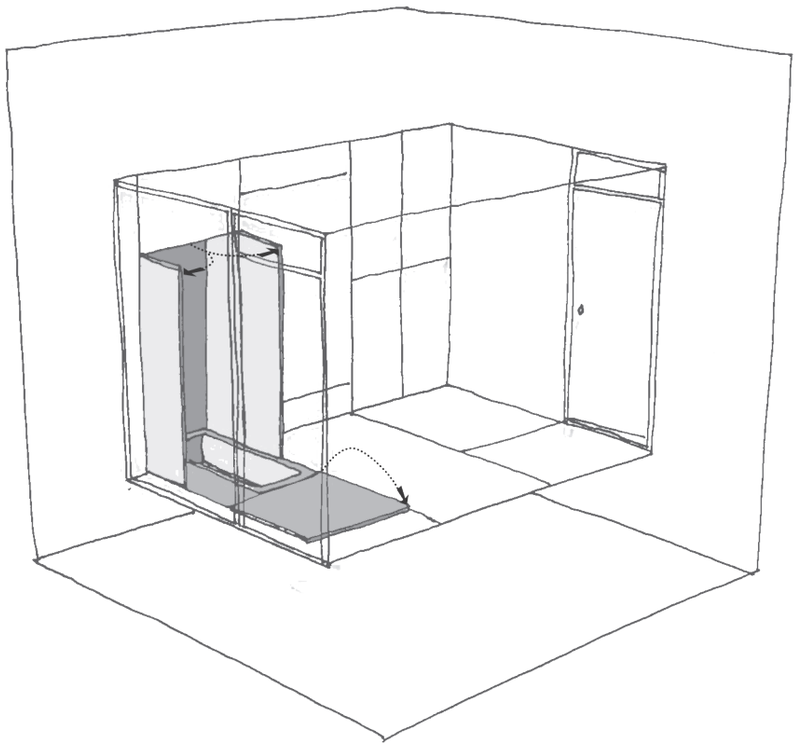
The dwelling measures 4,2m x 4,2m x 4,2m, meaning a 17,64 m2 large footprint. The inner room measures no more than 8,64 m2. For accurate dimensions, see drawing #1 - #3 in the drawing folder.


600mm
600mm
600mm



BED

The bed is an important part of our day cycle and most people spend 1/3 of their life in it. That is also why the bed is placed in the middle of the room with access space all the way around it. The bed is a so-called murphy bed that hides in the wall when not in use. It is 1200 mm wide and 2000 mm long, with a 300 mm thick mattress, leaving an extra 300 mm in the wall for bed linnen, book shelves, alarm clock etc.

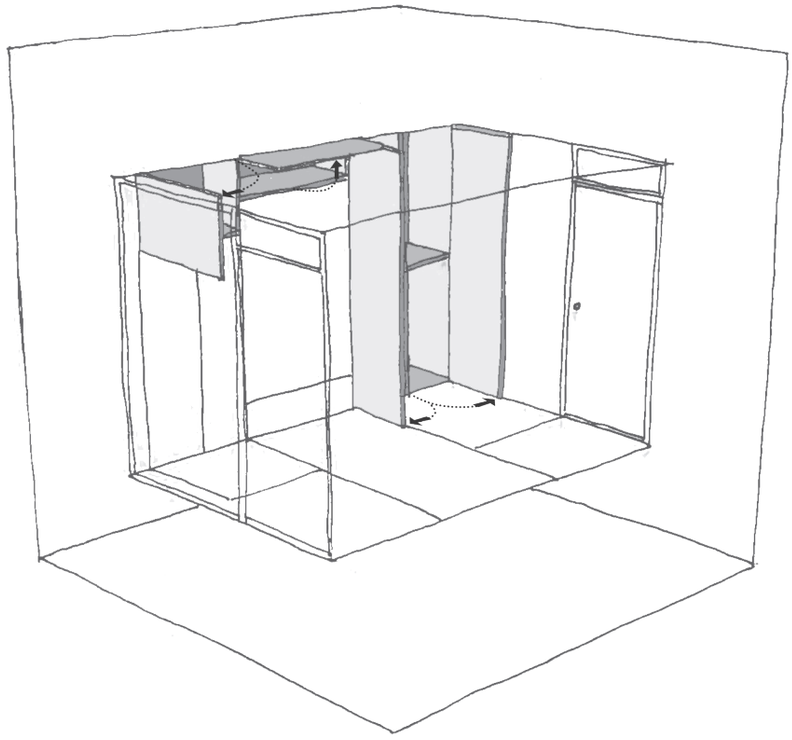


BATH

Whether you want to shower or bathe, the option is there. The dwelling has a built-in bath tub, revealed when flipping the trapdoor in the floor. From the bathtub you can enjoy the view through the window or hide behind the curtain. The bathtub also works as bathroom floor in the shower that hides in the wall. The inside of the shower is coated like a wet room, and a shower curtain can be hung between doors. Above the shower is also a powerful ventilation exhaust, connected to the dwelling's own ventilation unit.

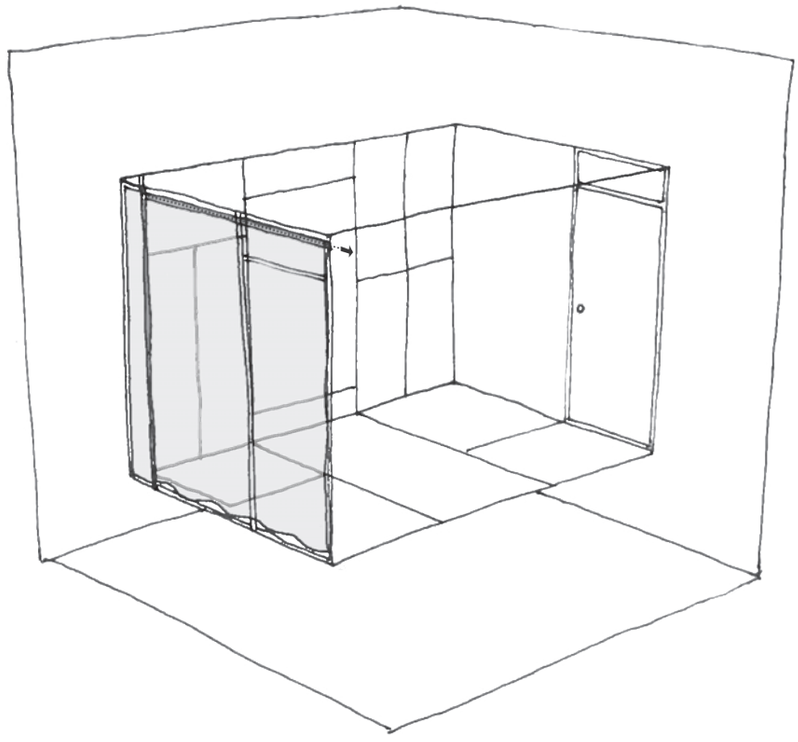
STORAGE

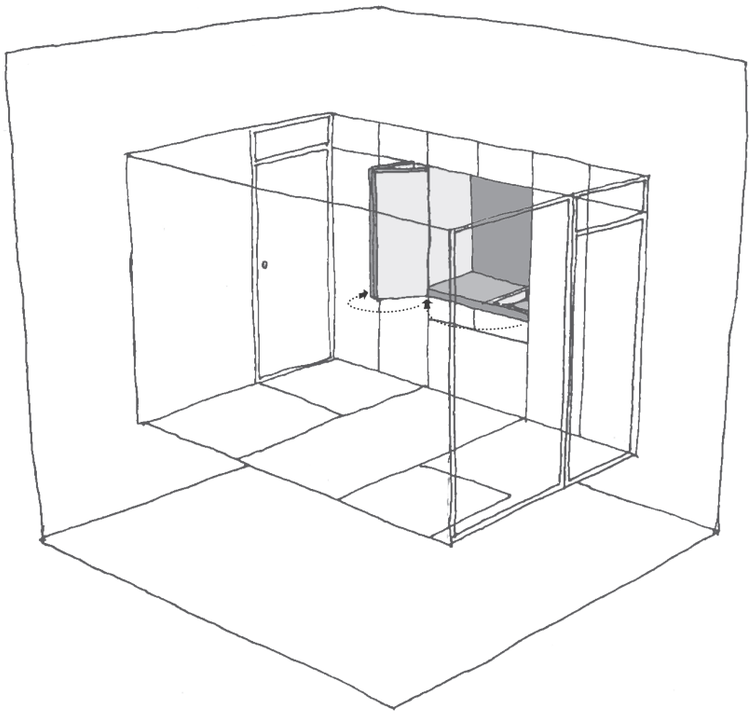
A lot of storage space is crucial for making the dwelling work. That is why there has been made plenty of room for clothes and personal belongings in the walls. All wall closets measure 600 x 600 mm, offering flexibility if a habitant feels the need for installing, for instance, a washing machine.



CURTAIN

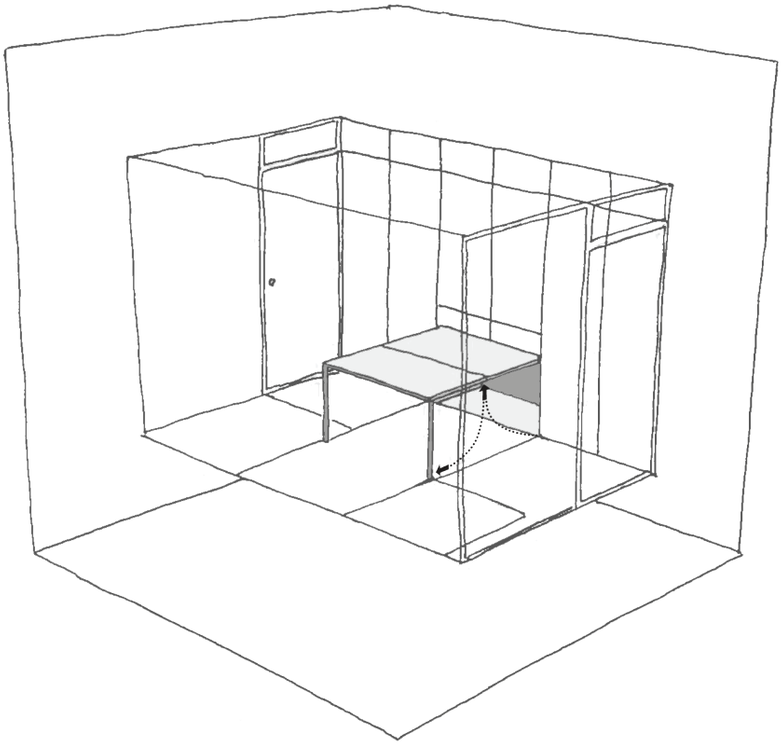
Although solar shading has been integrated in the facade, and can be closed from the inside of the dwelling, a curtain is likewise integrated. Next to the bath, a 200 mm narrow door opens up for a telescopic curtain rail that run across the room and covers the window entirely with a soft fabric. The white curtain can likewise be used for projection so that TV and movies can be watched as on a big screen. The projector could be hidden in the ceiling.





KITCHENETTE

In the dwelling is a build-in kitchenette counter in the closet opposite the bed. The counter is 1200 mm wide with a narrow sink also used as the bathroom sink. The twofold door flaps left so that it does no conflict with the toilet doors. The kitchennete does not contain any appliances as it is up to the individual to install what they feel the need for, whether that is a microwave or an electric cooking plate. There is a small refrigerator in the closet next to the front door.

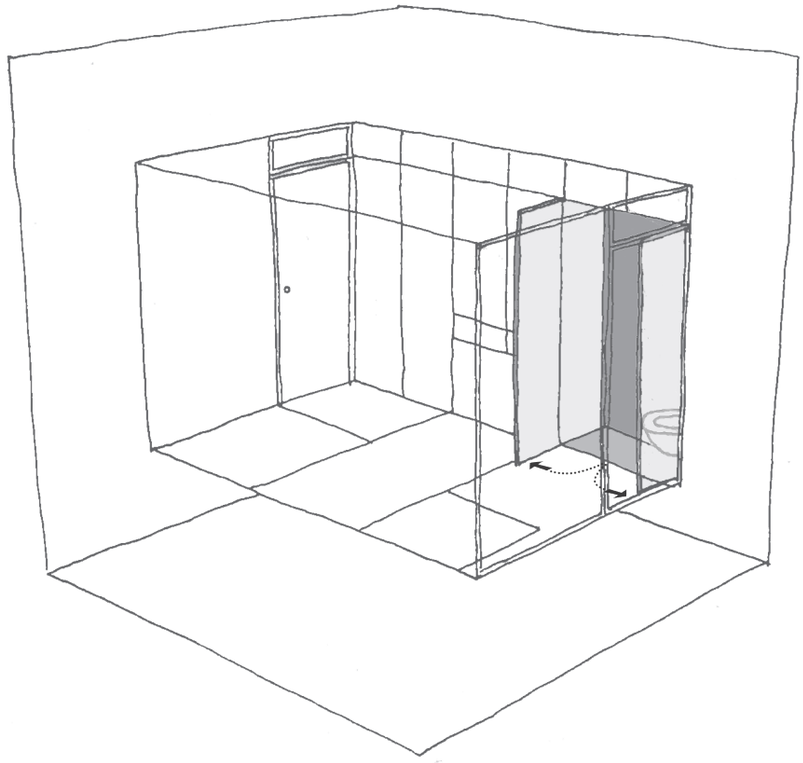


TABLE

To offer the flexibility for working, eating or relaxing, a large table measuring 1200 x 1400 mm is built in and covers for the drainage for the sink, when it is folded in. When folded out, the material from walls and floor extends into the table top and opens up for a room beneath the kitchenette counter. Here, chairs can be hidden when not in use.

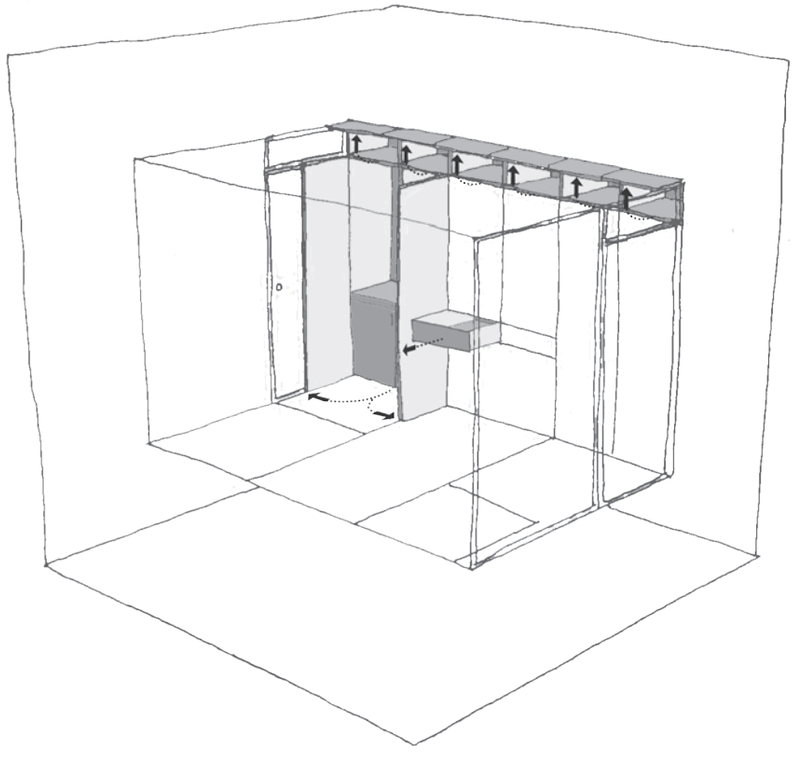
TOILET

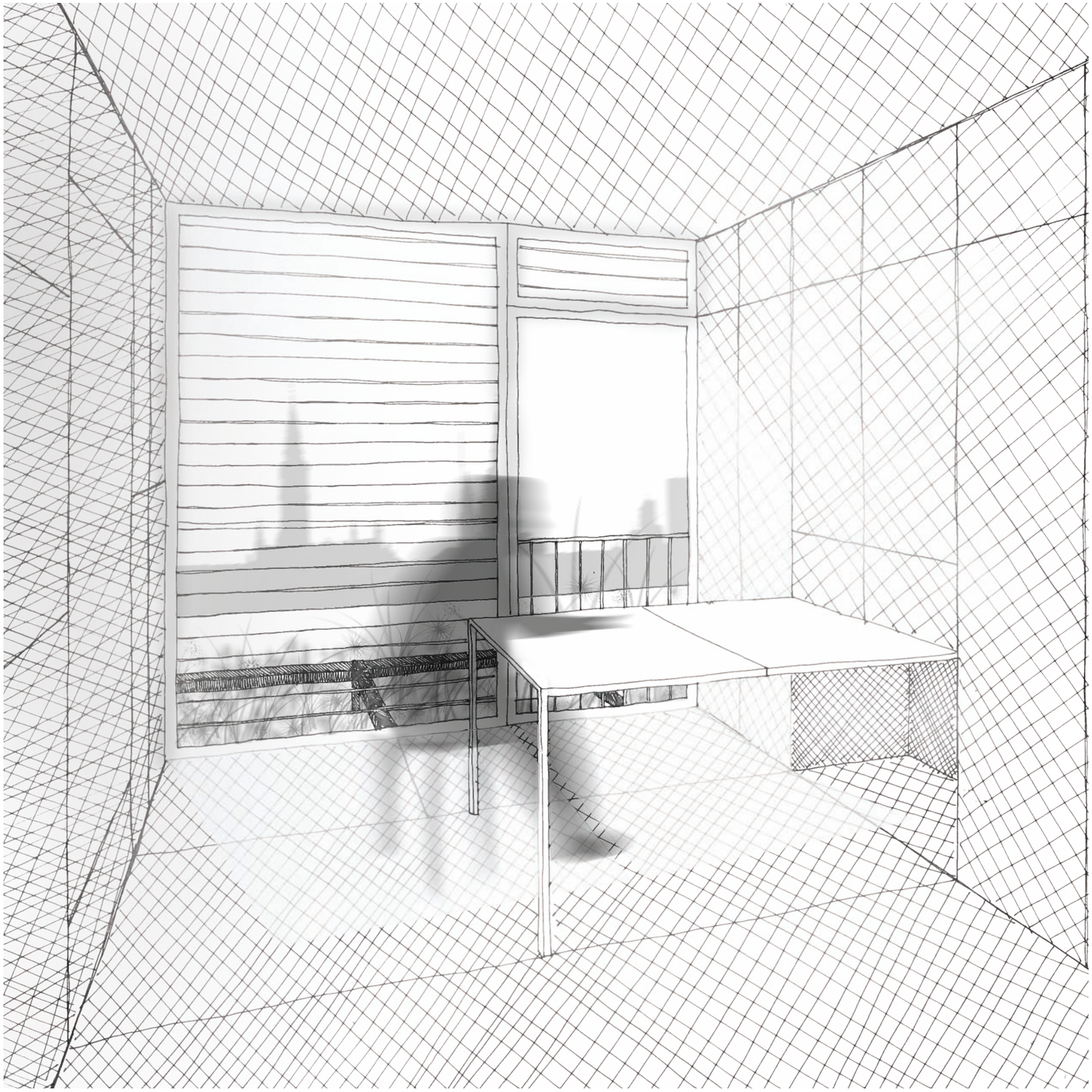
The toilet is placed in the wall opposite the bath, creating a bathroom zone, closest to the window. The window can be covered with the built-in curtain, but can also provide a quick air change through the pivot glass door. To lower expenses, there is only one sink in the dwelling - and that is placed in the kitchen.



STORAGE

Everywhere in the dwelling, gaps between functions create space for storage.The first closet when entering the front door has a compact refrigerator installed as the only built-in appliance for the kitchen. Above is a hanger rail for coats and throughout the rest of the dwelling, closets or drawers appear in the wall.

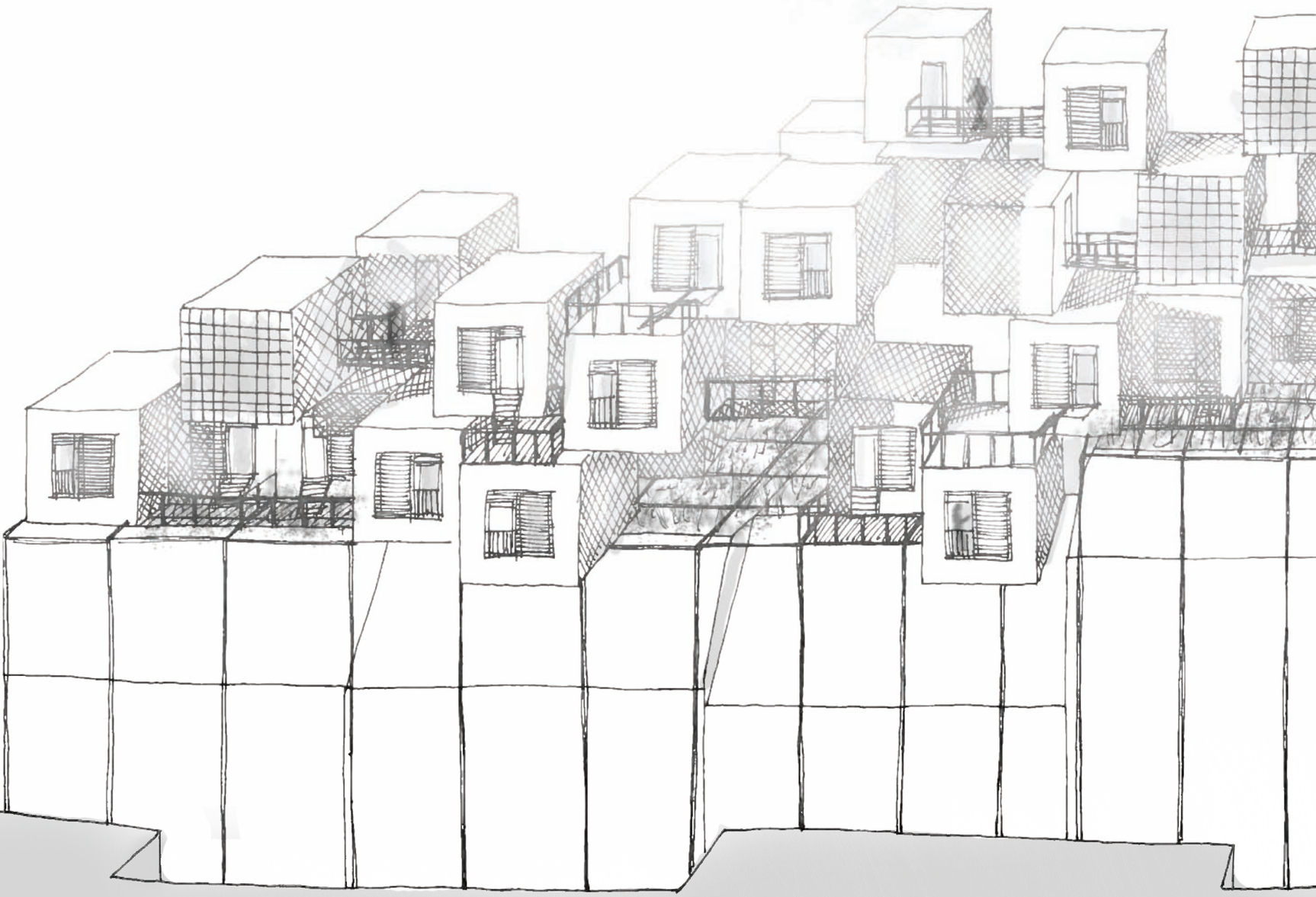


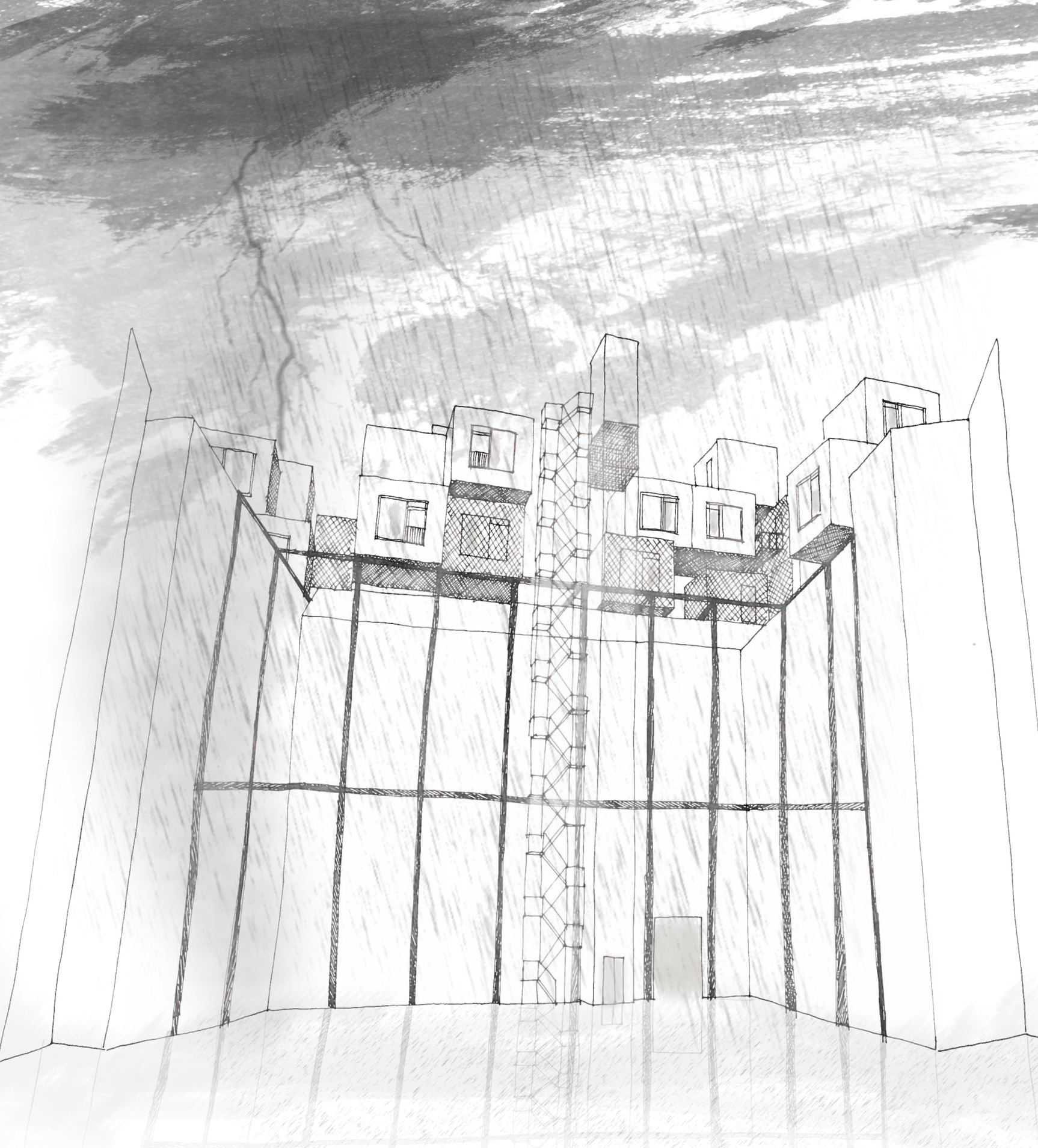


A vague city view as a lively painting filling the entire end wall of the dwelling, makes you go into a meditative state of mind together with a naked room which gives you silence, calmness and rest. The sun penetrates the windows, defines time and gives you joy by the radiation. A little glimpse of the meadow grass is seen outside the window, which softens the dark roof with a green and lively touch.

URBAN COMPOSITION

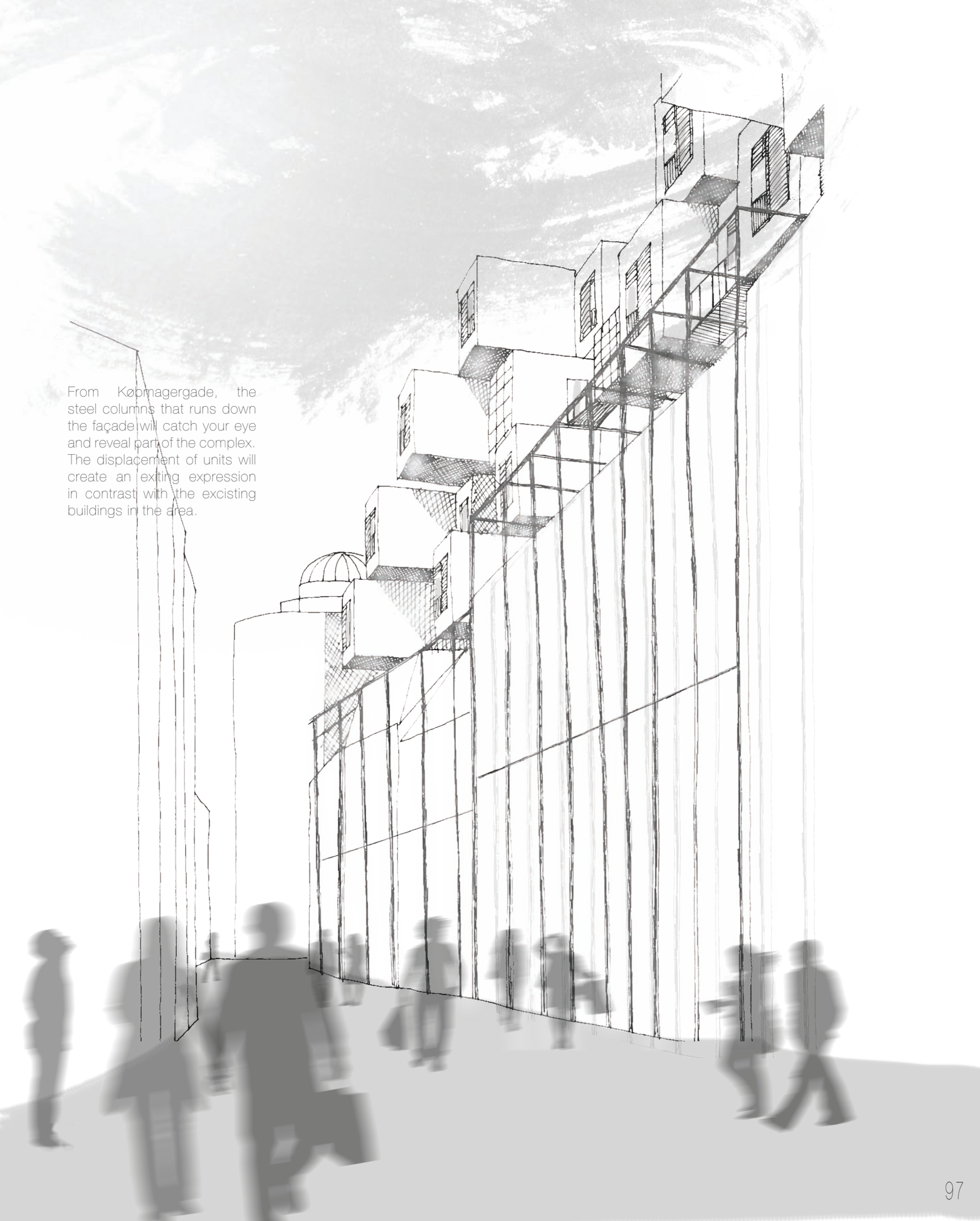
The presentation of the urban composition serves to display the vision of the project scale - an extended version of the selection which has been detailed according to exact arrangement, calculations and technical drawings.



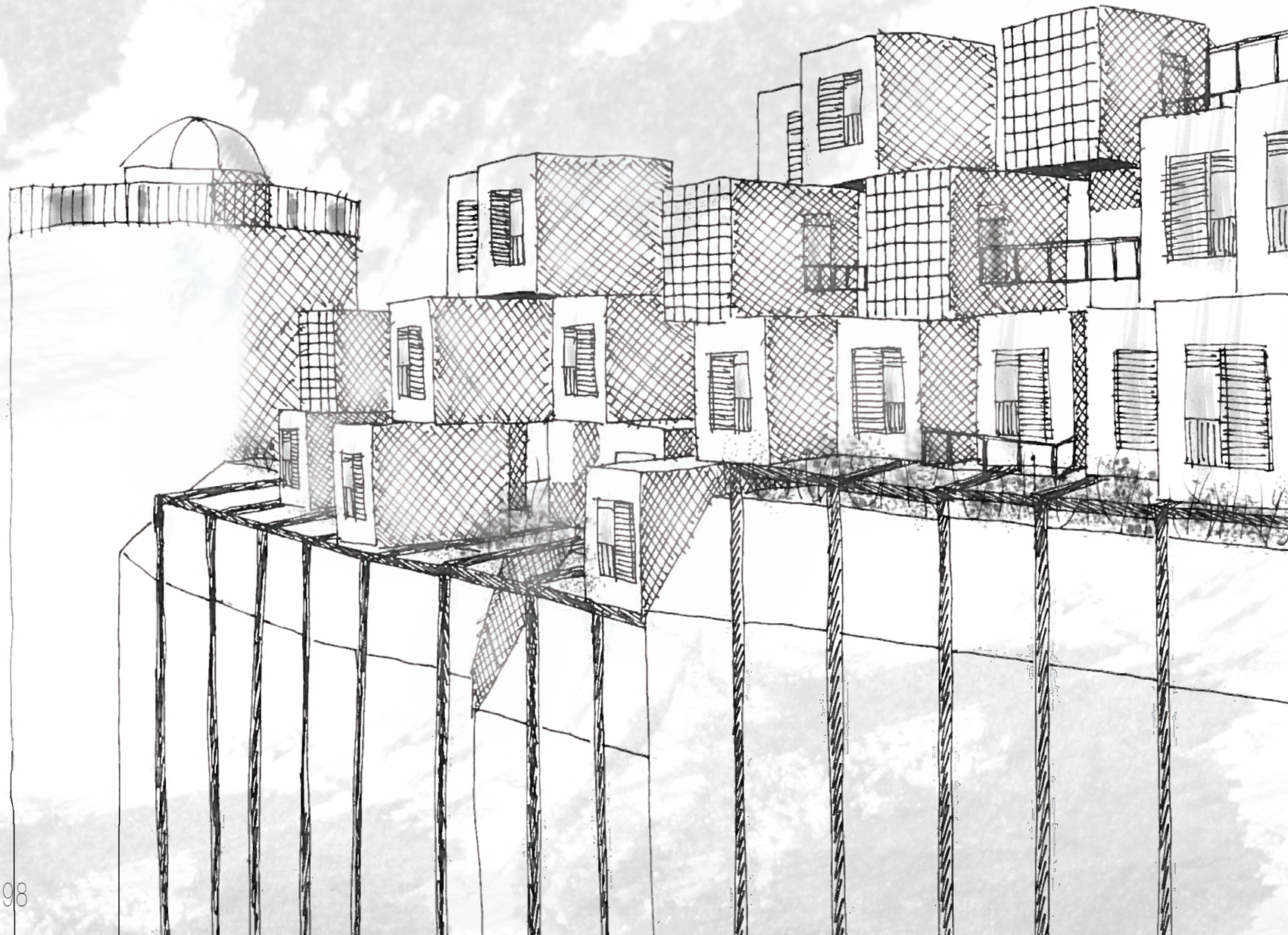


Accessing the complex happens via an elevator in the back yard. The back yard is entered through a gate passage in the subjacent building, Købmagergade 44. The elevator is made from glass and steel and fastened with the same steel columns as in the bearing structure. See appendix 8. Next to the elevator is also a fire escape stairway, that crawls up the facade as a thin steel structure.

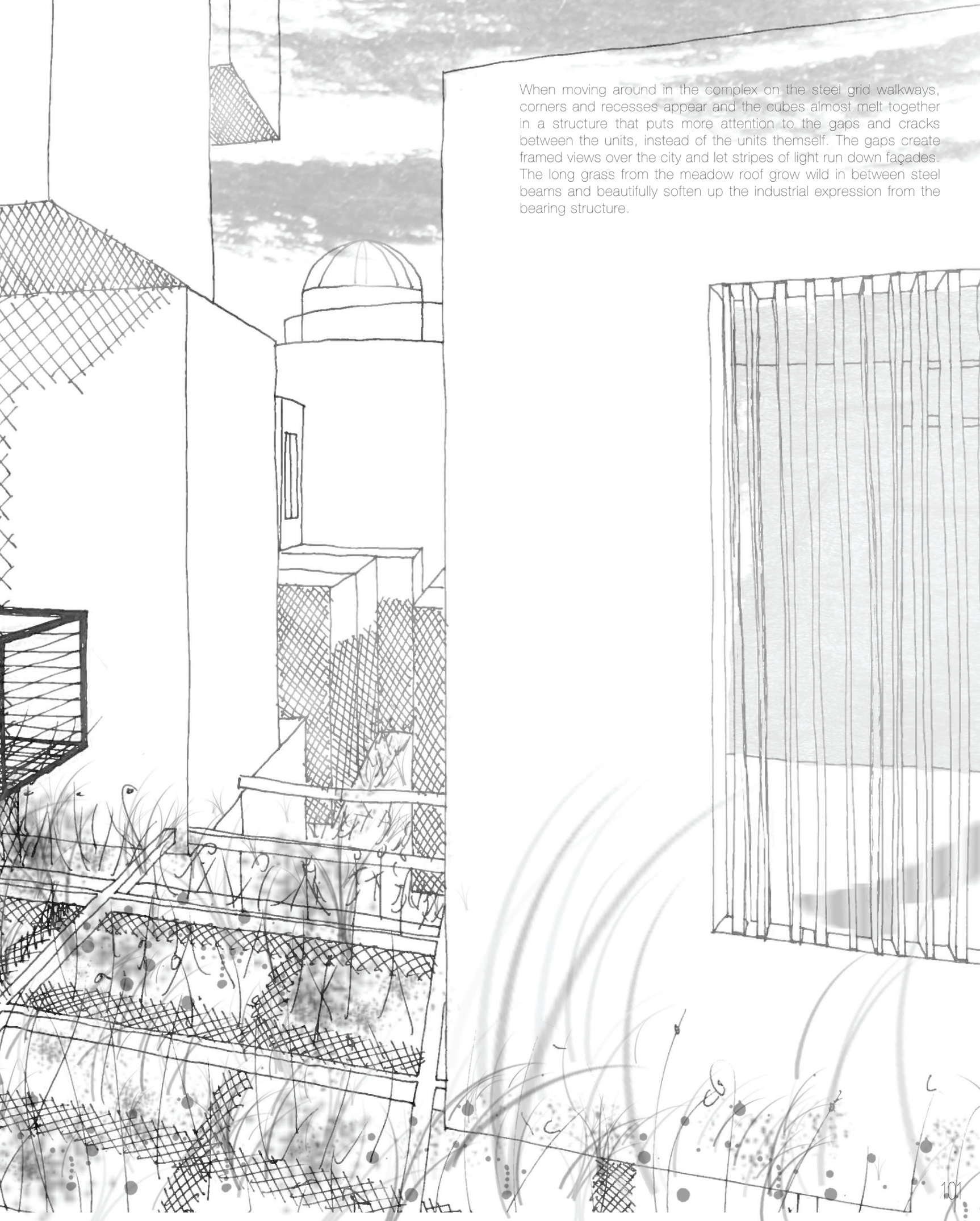
From Køpmagergade, the steel columns that runs down the façade will catch your eye and reveal part of the complex. The displacement of units will create an exiting expression in contrast with the excisting buildings in the area.



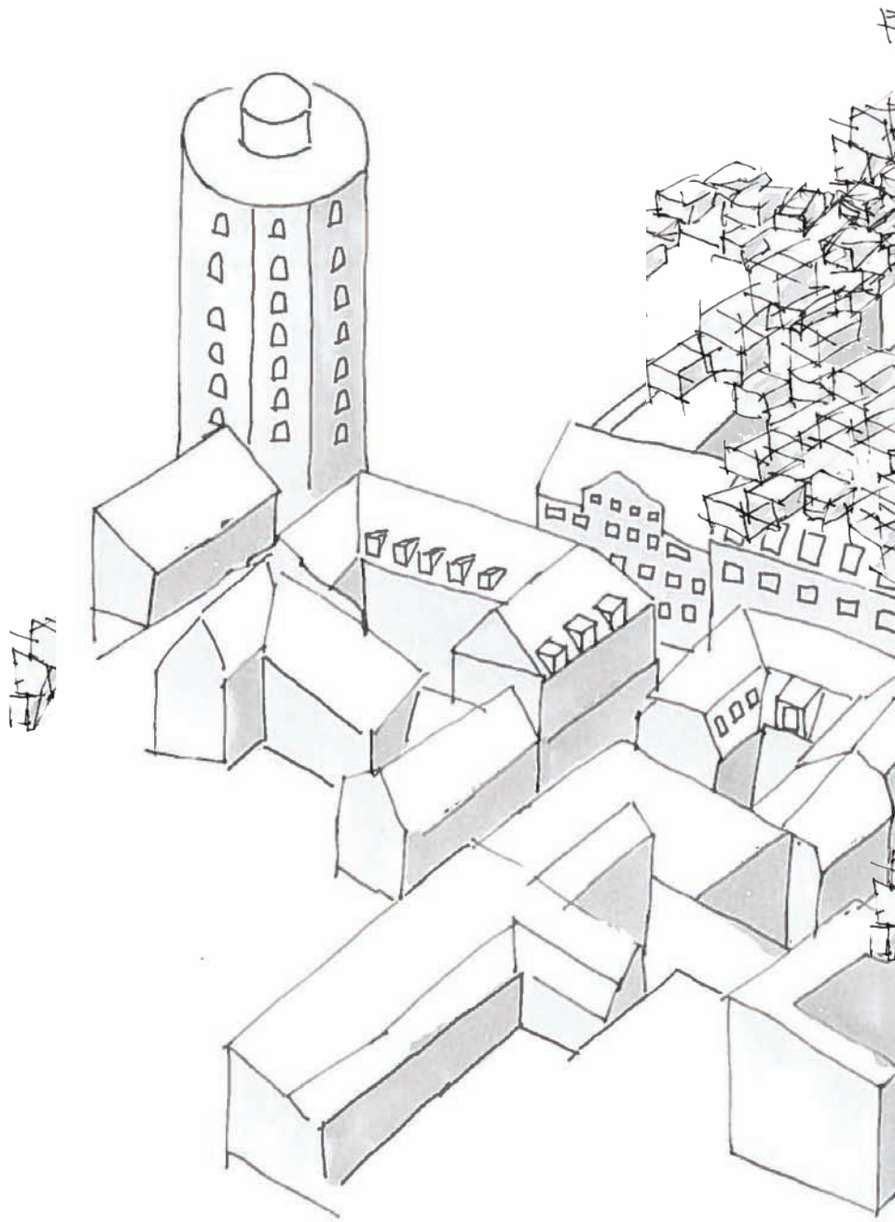
The composition hovers on top of the existing city, almost as a cloud. The geometrical shape of the units is recognisable and materials match the surrounding environment, making the complex balance between eye-catching and contextual integrated. The result is a dynamic urban sprawl that can grow both vertically and horizontal and be observed by the vsitors from Rundetårn.



When moving around in the complex on the steel grid walkways, corners and recesses appear and the cubes almost melt together in a structure that puts more attention to the gaps and cracks between the units, instead of the units themself. The gaps create framed views over the city and let stripes of light run down façades. The long grass from the meadow roof grow wild in between steel beams and beautifully soften up the industrial expression from the bearing structure.

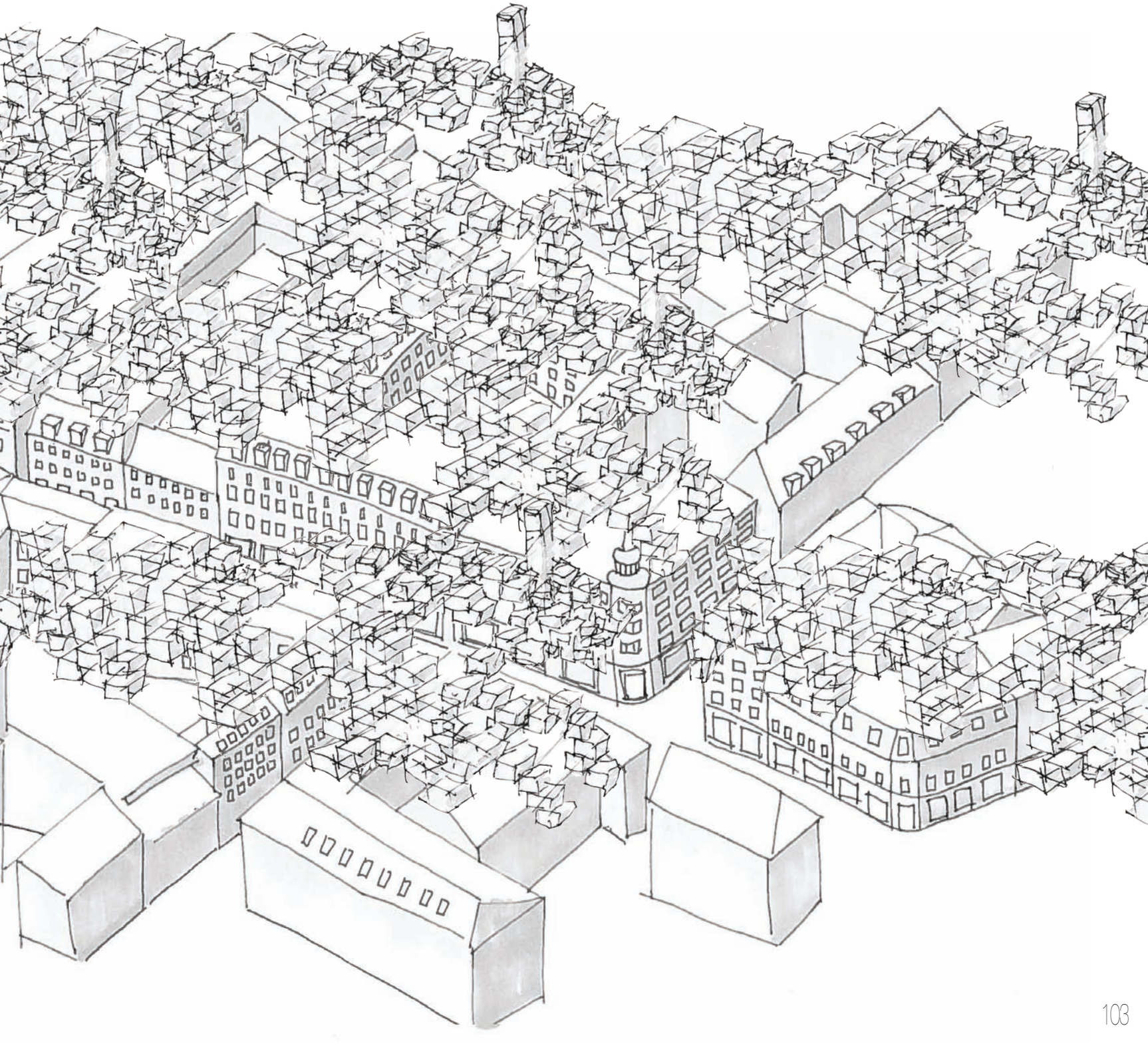


WHAT IF...



...the structure could grow endlessly?

And the structure could likewise evolve in other large European cities, or in metropolises like New York City and Tokyo. The concept could develop and we could design other variations of the dwelling. Dwellings which for example were bigger, maybe housing a couple or an entire family.



CONCLUSION

The conclusion will evaluate on the initially presented goals.

Make an experimental and visionary project with a redefinition of traditional city dwellings
Redefining a traditional dwelling can be difficult as traditions are hard to break with. People are creatures of habits, and many do not find it attractive to make radical changes to something as essential as their way of living. As architects, our responsability is to make architecture that reflects our society, and we believe that there is a great need for alternatives in dwelling types. Though the dwelling may address a certain user group, many different people in different situations can benefit from having less, in a small space. At the same time, we believe that "the more specific a design idea is, the greater its appeal is likely to be". [Frederick, 2007]

Design an inexpensive dwelling
All the way through the project, decisions have been made according to different parameters, but we have taken the economy into consideration, whenever it has been obvious to do so. Especially in the selection of materials, economy has been a very decisive factor. We haven't made compromises on our wish for architectural qualities in order to lower expenses - but instead sought alternatives. The total cost for building one cube is more than we aimed for, but considering exterior walls and installations being the most expensive part of a building, it makes sense, and we throw in the towel. Further discussion in the reflection.

Create debate about societal and architectural development
The intention of a compact dwelling is not only in matter of economy, but also to reflect a simple lifestyle. As a reaction to the last decade's consumer society, many people find more value in personal relations, travels and everyday experiences instead of the quantity of things. Few belongings and less obligations can let you focus on what you really love doing (unless that is cleaning and shopping, of course). We didn't want to dictate a certain lifestyle with this project, but rather encourage our fellow human beings to reflect. We believe that this extreme example of compact architecture will make people consider whether they could live like that. Our initial wish to uphold an utopic mentality as a base for the thesis has been accomplished. By creating a rare seen compactness in the dwelling and by combining dwellings in an inordinate urban structure, we create stir. Whenever the attention is caught, we will start the debate and make people take their stance – or at least consider their own lifestyle with the objective of general architectural development.

Combine aesthetic architectural sense with ingenious solutions, constructional comprehension and technical optimization - to underline our skills obtained through this specific education
The outcome of this project, reflects very much the purpose of the education of Architecture & Design, Aalborg University. The distribution of architectural and engineering work has been very balanced and the result has both architectural, tactile, and functional qualities while construction, indoor climate and technical solution has been integrated.

Get into the detail of the design
By creating a small space with a small scale room program, it has been possible for us to zoom in and work more the detail and execution of the scenarios, functions and details. The level of detailing, namely joints, knobs, finishes etc. may not be visible in the report, but will be presented at the exam with real touchable examples, arguing that the execution of details are more honest than a description of them.

Use experimentations and drawings as a main developing factor in the design process
All the way through, experimentations – mostly concerning spatial proportions according to the human body, has been made. This has definitely given us a completely new understanding of room size and proportions. In the same way, drawing sketches has been our way to visualize ideas and study cases. This has been extremely rewarding for both of us, and we have both improved techniques and skills along the way.

Present our project through a simple report
In order to explain our simple-lifestyle-encouraging design, we have chosen a very delicate and minimalistic report design. A report design that reflects the concept - but to a great extent also our prioritization of delivering humorous ideas and sketches rather than bulky academic reading.

Draw, draw, draw
Every illustration in the report is done by us. So, check!

Finally...
We believe that a consciousness about one's own mindset highly benefits a person's individuality. Nonetheless, it should not be underestimated how much impact it has on society too. Living in a harmonious society in close connection with your fellow human beings is crucial for our wellbeing. Utilization, engagement and enhancement of the city are jobs for the citizen. Architects play an important role too, as we create these frames – both in home- and urban scale. We need to be able to carefully handle all scales. It is a fine balance between creating comfortably enclosing homes and lively vibrant cities without de-emphasizing one of them. We are very pleased with our result, that we think proposes a innovative example of how to live and be alive in the city – not only as an individual but also in a holistic perspective.

We wanted to create a 'luftkastel' and proposed *castles in the sky*!

REFLECTION

The reflection will debate selected subjects/questions that obviously appear in relation with the project, but have not been furhter discussed in the report.

Prefabrication
Prefabricating the dwelling would be the only meaningful thing to do in this case. The building of the units would take place in an enclosed environment which could save time, materials, electricity, money etc. The dwellings could be almost completely assembled before transported to the building site and placed by a crane. The reason why we have not gone into further investigation of the possibilities of prefab is simply prioritisation. We rather wanted to go into the aesthetics, the programming and detailing of the dwelling, the urban composition and construction than being bound to suddenly designing from the dimensions of an object you are allowed to transport on the highway without having a warning truck (using fuel) driving behind you with a flag saying "watch out - wide load" (those dimensions are 4.5 x 12 meter, but with a maximum heigth of 3.2 meter).

A growing urban structure
As proposed in the final "What if…?", the structure could possibly grow and extend itself endlessly. Of course this is an utopic thought, but suggesting an independent construction for the complex will theoretically give the option of a limitless growing structure.

The dwelling and its context
The dwelling has been made specifically for the city where the city supplies the habitant with what can seem missing inside compared to traditional housing. The question is therefore whether one or several units could be placed elsewhere. Does the unit provide enough features to be sufficient housing in the sleepy suburbs? Could one unit be placed on the beach or in the woods and act as a complete dwelling? The answer must be both yes and no… The unit could work perfectly as a refuge for the open-minded light-living spirit, placed far away from the city. But without the city, the dwelling would not have the functional capacities to work optimal as a traditional suburb housing. Furthermore, the concept of a dwelling focusing on loneliness, when the environment is lively and pulsating, is very specifically conducted in the design. Opposite in nature, where you would probably seek immersion outside the dwelling. This means, that the dwelling is made specifically for its context - with the context being the dense city. This inverted versatility has, for us, been a new way of approaching design, and we can really see the potential of such a specific and programmed concept.

Ecomomy
All the way through, economy has been in focus when taking decisions and chosing materials, in the wish for a low square meter price. A way to approach economy in an even deeper level, could have been to design from an economic aspect primarily, which would have ruled the aesthetics and conceptualisation of the project. An approach we thought was too restricting when wanting . Getting an estimated material price was an eye-opener for us. We had not expected the square meter price to exceed 10.000 kr/m2 but retrospectively, it makes sense as we know that the most expensive part of a dwelling its exterior walls and its installations, which basically is all our dwelling is. It does not contain a lot of 'free' floor square meters in the middle of the house, which can lower the average square meter price. Our price is close to the average square meter price in new buildings, but if you wish to have a low-energy building, the rule of thumb is to add another 10% to the cost. That is included in our price. It could also have been of interest to make a detailed calculation of general living expenses when living in our dwelling, compared to living in a more traditional and fully equiped Copenhagen apartment. Finally, an account for rent and utilities could be very interesting to have, but was deprioritised because of the lack of knowledge to deteminate such issues.

The usage of the dwelling
The goal has been to redefine the dwelling in the city with the result being a… dwelling. This is despite the fact that it in many ways could be interpret as a very temporary unit, like a hotel room. This, does not really concern us as we certainly want to dissolve the border between settled and temporarily living, in order to find a middle course that redefines our living habbits. The dwelling can therefore also be proposed as a very temporary home, but it does not influence the design in any way which is a major triumph according to our concept.

APPE

ENDIX

WHAT IS THIS?

The report is shortened down to only present the essentials with focus on bringing the reader closer to a clear result.

A lot of research studies, investigations, models, sketches and experiments have been made prior to the writing of this report. Following appendixes will take you deeper into this process.

Some appendix chapters are supplements to the chapters in the report, going into a closer detail or argumentation, mostly according to the technical part.

APPENDIX 1

SUSTAINABLE INITIATIVES

Sustainable architecture is studied and defined in this project as three large subjects as economy, society and environmental. The subjects are defined in the report, but this is a deeper elaboration of the definitions.

ECONOMY
& ARCHITECTURE

"

...IN TIMES OF WAR OR ECONOMIC CRISIS, IT IS NATURAL FOR THE HUMAN BEING TO REACT WITH CERTAIN EMOTIONAL GROWTH...

Except from the financial sector, the building industry is one of the fields that gets very much affected by crisis. When things around us seem out of control, we as humans are often left with a reflection of our existence. And since architecture frames our existence, it is only natural that new buildings and current lifestyles reflect the mentality of the society. So what is more evident than understanding the society when working as an architect? Maybe understanding the society of tomorrow… After all, we want our homes, hospitals and public spaces to be appreciated in the future. By understanding what kind of time we live in and how it will affect the next historic period, we future-proof, at least, the settings for our wellbeing.

Through history, we have seen how an economical boom, eventually, is followed by an economical crisis. This reciprocal relation between economical upswing and depression can therefore, in a very overall picture, be interpreted as an axis of oscillation where we find ourselves on either an ascending or descending curve. Because of this, it is possible to give a reasonable prediction on reactions and consequences on a current economical situation.

If we for example look at the zeitgeist – the spirit of the time – after some of the wars or economical crisis of our history, there forms a pattern; in times of war or economic crisis, it is natural for the human being to react with certain emotional growth. When we join wars, when entire countries' economies collapse, when politicians act irrational or when we hear about the exhaustion of natural resources, the human being tend to seek a deeper meaning of life, a safety that is not to be found in a fluctuating global market. This reaction to the bad makes us worship the intense emotional life. We become more loyal and turn towards the more peaceful, comforting and meaningful nature. And this is namely visible in architecture.

"

"S-WORD" WARNING

Economic sustainability in architecture can be achieved in different ways. It can be economic sustainable if a building has long lasting materials, which is an investment, but can save money after years because the lifetime of the materials are many generations. Or if a material has no maintenance or it is a local material. There is a great balance between qualitive expensive materials and qualitive cheap materials. In the end we wish for an affordable building, which also means economic sustainable. If common people can afford to buy, there will automatically be more demands. Because of the selected target group and the society situation we are in now, this project will focus on a mix between these mentioned aspects. The economic sustainable approach will be used to evaulate the result in the designprocess. It will be a critical filter which can argue for or against a design result. The argumentation is based on logical, criticial and reasonable thinking.

SOCIETY
& ARCHITECTURE

"

...BEING LIVABLE, LINKING THE FORM OF THE CITY'S PUBLIC PLACES AND CITY DWELLERS' SOCIAL, EMOTIONAL AND PSYSICAL WELL-BEING...

"

Social sustainability is often in the shadow of environmental sustainability. It is important not to forget it, because it goes hand in hand with the environmental sustainability. Social sustainability can be pointed out as:

1.Meets basic needs for food, shelter, education, work, income and safe living and working conditions

2.Is equitable, ensuring that the benefits of development are distributed fairly across society

3.Enhance, or at least not impair, the psysical, mental and social well-being of the population

4.Promotes education, creativity and the development of human potential for the whole population

5.Preserves our cultural and biological heritage, thus strengthening our sense of connectedness to our history and environment

6.Promotes conviviality, with people living together harmoniously and in mutual support of each other

7.Is democratic, promoting citizen partizipation and involvement

8.Being livable, linking the form of the city's public places and city dwellers' social, emotional and psysical well-being [newcity.ca].

In dense cities where people live close, many settings for a good sustainable environment are given. When we live close we automatically create relations to each other and learn how to relate with neighbours. This interaction can have a positive impact on your lifestyle. We support, we share and learn by each other (point 6). In the city, people can easily get more involved because demonstrations, important political meetings and big cultural events usually take place in the city (point 7). For point 8 which more or less sums social sustainability up, it is important the inhabitants create a relation to the city's places where emotional, physical and social well-being can be explored.

ENVIRONMENT
& ARCHITECTURE

"

...LESS MATERIAL USE AND LOWER ENERGY CONSUMPTION, PLUS SHARED INSTALLATION AND CONSTRUCTION ELEMENTS...

Global warming is one of the biggest threads to Planet Earth, and humans are somewhat responsible for it. We are also the only ones who can change it. Greenhouse gases, where CO2 is worst case, are the reason why heat is trapped in the lower atmosphere, causing temperature to rise. CO2 comes from the burning of fossil fuels as oil, coal and gas, to get energy. The keyword is to create energy without the burning fossil fuels, so we need to look at renewable energy resources as the wind, the water and the sun.
[Sassi, 2006, p.200].

The demands for Building Class 2020 says that the total amount of energy used for heating, ventilation, cooling and domestic hot water should not exceed 20 kWh/m2 per year [BR10, 2011]. The goal in this project, is to fulfill buildingclass 2020 from BR10. The next step is to make the building a Zero Energy Building (ZEB) which in this project includes, that the building produces as much energy as it uses, which results in an energy frame on 0 kWh/m2 per year [Energi+arkitektur, 2011, p.13].

To fulfill these demands, solar systems are necessary, which is an important implementation in the building to reach the ZEB requirements. Besides solar systems, multiple initiatives to save energy are also crucial to reach the goal. The dense city already offers many initiatives we can use, which is described in the next section. Initiatives in general and implementation of solar energy are explained afterwards.

"

"S-WORD" WARNING

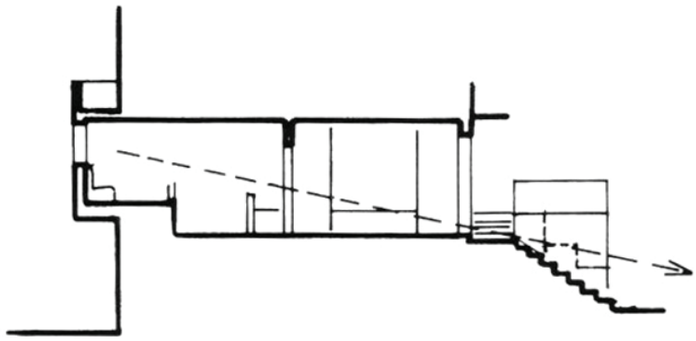
How can we use the dense city in sustainable development?
It is a fact, that European cities are growing, and the urban areas are getting bigger, expanding horizontally, while the country land gets smaller. The European Comission is searching for solutions such as a more compact and vertical urban development instead, which indeed supports the environmental sustainable development.

A more compact city gives environmental advantages, but it is important not to comprimise architectural and spatial qualities. The overall environmental aspects are area and ressource consumption, and less transport because the public functions are concentrated in the city. Environmental pros for the specific dwelling are less surface area which means less material use and lower energy consumption, plus shared installation and construction elements. The city can also be too compact if daylight, spatial qualities, green outdoor areas and wind conditions are given a low priority. Sustainable buildings are depending on these parameters, so it is important to find a good balance between compact and spatial qualitites.
[Bæk Pedersen, 2009, p.19].

APPENDIX 2

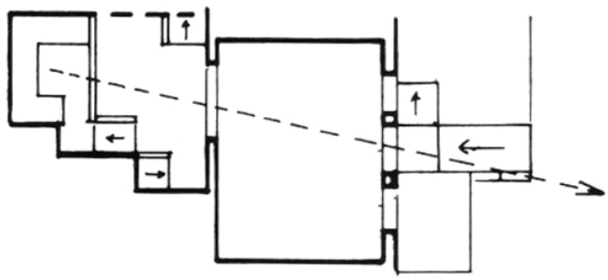
CASE STUDIES

Adolf Loos, Le Corbusier and Peter Zumthor was studied during the analytical phase. We wanted to get closer to theories about creating spaces and use materials to enhance the experience of being in a certain space. The theory is not used directly in the outcom of this project, but has more given a background of knowledge before starting the design phase.



ADOLF LOOS

The Austrian architect Adolf Loos had his prime years as an architect from 1898 until 1933, and is known for his book 'ornament and crime', which started a ground-breaking style in 1908. In this section, his raumplan is studied, which dictates his new style. We will study his spatial composition in Raumplan, to learn how to dimension quality spaces in town dwellings in a difficult timeperiod.



RAUMPLAN

Raumplan can be divided into three aspects of a plan; spaceplan, living plan and material plan. The space plan is how a three dimensional vertical volume is organized. Living plan is how the functions are placed. Material plan is how materials are used to underline characters of a space.

SPACE PLAN

Space is formed as simple, basic cubic shapes, organized in compact levels. Small spaces can often be formed in bigger spaces, which creates small recesses with a different spatial composition. Windows are often in connection with a recess and furniture as bookshelves, seats and storage units are often integrated. Staircases connect the level of spaces, and is often open, but also have other functions, mainly as a fireplace. Doors are mainly off centered, to get a better overview of the space you enter.

LIVING PLAN

Living plan is organized in compact levels with concentrated length, width and height. The levels have defined functions, and four levels are most common to have. Level one is the basement (private), level two is the living room (semi-private), level three is the sleeping area and bathroom (private), level 4 is the loft (private). Level two is semi-private because it is here you bring guests and there is also access to the outside balcony. Compact living makes the internal contact maximized, but the outside contact is minimized because of no private space outside. The entrance is there for comprimised on the outside with leading pathways, a loggia or front garden, and taken inside instead.

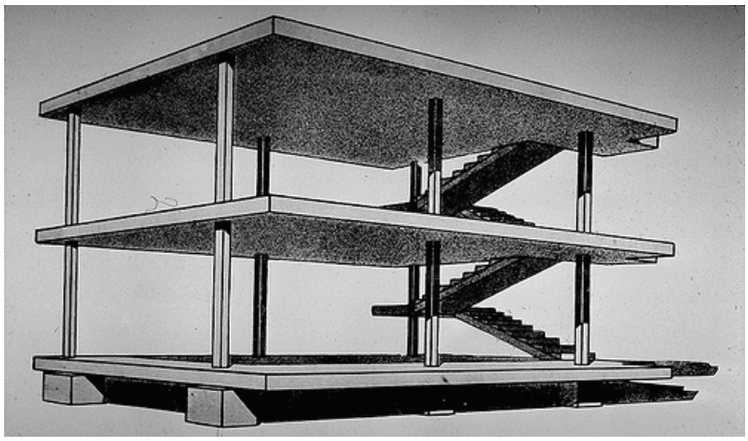
MATERIAL PLAN

Materials has an important role as well. Loos uses materials to give a space character. It can underline a specific area of a space and bring a certain mood. Space and material are in close connection on the inside, on the outside brick is often used because of its load-bearing function. Construction is not an important element to show and tell in this period of town dwellings, it is later Loos uses the column[Van de Beek, 2008, p.31-35].

The just mentioned topics describes the principles in raumplan seen in town dwellings before the World War 1. After 1916 the spatial variation became more dramatical and the column was integrated. The studied raumplan will be used in the analysis, to create parameters for a present compact dwelling in the dense city.

LE CORBUSIER

The Swiss architect Le Corbusier is well-known for his form and light in architecture. In this section his five points will be studied, to learn about his braking principles for dwellings in the city explained in the book 'Five points of a new architecture' dated back to 1926 written together with his cousin Pierre Jeanneret. The book gathers the result of many years building experience and it is clearly that Le Corbusier tried to avoid the urban life qualities as city smells, sounds and social life with these five points. The Citrohan House (1922), Maison Cook (1928) and the Villa Savoye (1930) are good examples of the principles in use, but only three examples out of many [Moffet/Fazio/Wodehouse, 2003].



PLAN LIBRE

THE COLUMN

The column is the essence of his structural principle, which goes hand in hand with the free plan and the free façade. Because of the simple structure made of columns and floor slabs the interior and external walls are non-bearing and can be placed where-ever. The column makes it possible to seperate the dwelling from the ground and get the volume up in the air, free for the city gasses, where the wind can circulate. It also creates a connection between the front side and back area. The entrance is pushed into the middle of the volume and there for not a visuel part of the building, which was ground-braking for the period. The volume is now the dominating part and not the entrance.

THE ROOF GARDEN

The roof garden explores the the fifth façade and uses the top floor where wind circulate, sun enters and there is privacy. In Maison Cook the functions of the levels are adjusted to the roof garden. The Living space is on the top floor connected to the roof garden, which forces the bedroom area to be underneath the living space and quite untraditionel.

THE FREE PLAN

The free plan has the advantage to play with interior spaces. A double-height living room is often seen linked together with the top floor overlooking the living room. The double-height room has no link to the exterior façade and is completely hidden behind the ribbon windows.

THE RIBBON WINDOW & THE FREE FACADE

The ribbon window is only possible because the exterior walls are non-bearing, hence the free façade, because of the columns. The ribbon window also hides the inside functions from the outside, it is difficult to see the interior organization when every window has the same shape and place on each floor [Risselada, 2008, p.53-57].

The five points give an easy overview of the principles which are very evident in many of Le Corbusiers buildings in the early 20th century. Avoiding contact with the ground level and the use of an private green garden proves that Le Corbusier wanted to overrule the city qualities with natural surroundings. The points are later used in the analysis to define parameters for a present compact dwelling in a dense city.

PETER ZUMTHOR

Not only should a space be a description of zones, nor only a practical organization of volumes, plans and shapes - it is also an aesthetic composition and a narrative with emotional and tactile character.

One thing is to experience the spirit of a place, another thing is to notice and point out what creates it. Peter Zumthor is a great architect of our time, accomplished in performing and describing phenomena of beatiful spaces. In his book Atmospheres, he poetically questions: What is this "Magic of the Real"? And by using some of his answers to this simple, yet complex question, we can be aware of them when analyzing and designing.

If Peter Zumthor's awareness of tactile and sensory qualities of spaces and materials is caused by the fact that he worked as a carpenter and studied industrial design before working as an architect, is unknown - but most likely. Zumthor grew up in Switzerland and was son of a cabinet maker. He learned about materials and details in an early age and has, through his years as an architect, formed many buildings with an accentuation of the sensoric aspects.

In 2003 he gave a lecture at Kunstcheune, Germany, with the title 'Atmospheres'. The lecture was afterwards published in a literal version, as a short book; a personal insight into Zumthor's way of percepting and designing architectural sensoric quality from 12 different points.

Following 6 points are chosen, in this case, to be specifically relevant for this project.
All quotes: [Zumthor, 2003]

MATERIAL COMPATIBILITY

"Materials react with one another and have their radiance, so that the material composition gives rise to something unique. Material is endless." p. 25

One material alone can be processed in unumerable ways and in combination with other materials, the compositions are infinte. Material is an essential parameter in creating and reflecting sounds, colors, temperautures, light etc. that will be described in the following. A key factor to a room's atmosphere.

THE SOUND OF A SPACE

"Listen! Interiors are like large instruments, collecting sound, amplifying it, transmitting it elsewhere." p. 29

The sound in a space also makes an impact in our intepretation of it. Think about, for example, how different a room with a wall-to-wall carpet sounds compared to a room with a concrete floor. Also the shape of surfaces and their interrelation with each other make a difference in the sound.

THE TEMPERATURE OF A SPACE

"So temperature in this sense is physical, but presumably psycological too. It's in what I see, what I feel, what I touch, even with my feet." p. 35

The sense of a building's perceivable temperature is therefore often a matter of the used materials in connection with colors and light. Steel will for example seem cold as oppose to wood that has a warmer sense to it - both in a color and tactility.

SURROUNDING OBJECTS (A SENSE OF HOME)

"And I got to wondering whether the job the architecture had set itselft here was to create these receptacles to house objects." p. 37

Zumthor argues that the personal objects that are put inside a building is of high importance considering atmosphere. As if the architecture is a shelf for displaying personality. In 'Atmospheres', Zumthor quotes a woman he meets, who tells him *"I disagree entirely. These things are nothing but a burden. I carry my world in a rucksack. I want to stay on the road. All that stuff - the sheer burden of it… not everyone wants to carry such a bourgeois weight of objects around with them, you know."* Zumthor answers: *"And that coffee table you wanted?"* She didn't answer. This could confirm that we all have a desire for objects that are either beautiful or hold personal memories. Zumthor continues: *"The idea of things that have nothing to do with me as an architect taking their place in a building, their rightful place - it's a thought that gives me an insight into the future of my buildings: a future that happens without me. […] …you could probably describe it as "a sense of home"."*

TENSION BETWEEN INTERIOR & EXTERIOR

"…an incredible sense of place, an unbelievable feeling of concentration when we suddenly become aware of being enclosed, of something enveloping us, keeping us together, holding us - whether we be many or single." p. 47

The tension between interior and exterior happens when you become aware of the difference. Maybe you are inside in a small room with one window framing the marvelous view over the city, letting the light slip in softly, as it drags you to look in the direction of it.

LEVELS OF INTIMICY

"It all has to do with proximity and distance. The classical architect would call it scale. But that sounds too academic - I mean something more bodily than scales and dimensions. It refers to the various aspects - size, dimension, scale, the building's mass by contrast with my own. The fact that it is bigger than me, far bigger than me. Or things in the building are smaller than me. […] Maybe you know a tall slim door that makes everyone who comes through it look great? […] And I always try to create buildings where the interior form, or the empty interior, is not the same as the outdoor form. In other words, where you just don't take a ground plan and draw lines and say: these are the walls, twelve centimetres thick, and that division means inside and outside, but where you have this feeling of the interior as a hidden mass you don't recognize. It's like that hollow church, and the feeling of climbing up inside the walls." p. 51

ANDREA PALLADIO

Four Books of Architecture, written by Andrea Palladio around 1570 gives an understanding of what architecture is and how it is made according to Palladio. Vitruvius was his master and guide, which the book is very much influenced by. Some quotes inspired us during the design phase, quoted from the first and second book, which we found most relevant according to proportions of spaces, organisation of functions and exploration.

"If with a flat ceiling, the height from the floor to the ceiling must be equal to their breadth; and the rooms above must be a sixth part less in height than those below"
[Palladio, 1570, p. 28]

"The small rooms may be divided of, to make closets where studies or libraries may be placed, riding accoutrements and other lumber, which may be every day wanted, and which would not be so proper to be in rooms, where one either sleeps, eats or where strangers are received"
[Palladio, 1570, p. 38]

"…and therefore, as it enjoys from every part most beautiful views, some of which are limited, some more extended, and others that terminate with the horizon…"
[Palladio about Villa Rotunda, 1570, p. 41]

APPENDIX 3

SITE REGISTRATION

This will give you a more tactical impression of Købmagergade. The life from the street is also reflected in the pictures.

KØBMAGERGADE 44 COPENHAGEN

Copenhagen City, Købmagergade 44 is situated in the middle of inner Copenhagen. See mark.

The back facade of Købmagergade 44. Here you can sense the New York style in the large windows and raw materials.

The front facade with the red brick which dominates the expression.

You can sense alll the activity and the life there in Købmagergade. Rundetårn is not far from Købmagergade 44.

There are shops at ground level and the university at 1st, 2nd, 3rd and 4th floor.

APPENDIX 4

DEVELOPMENT OF THE DWELLING

This is some of the most important experiments we went through to achieve the dimensions of the internal rectangular space of the dwelling and the urban expression.

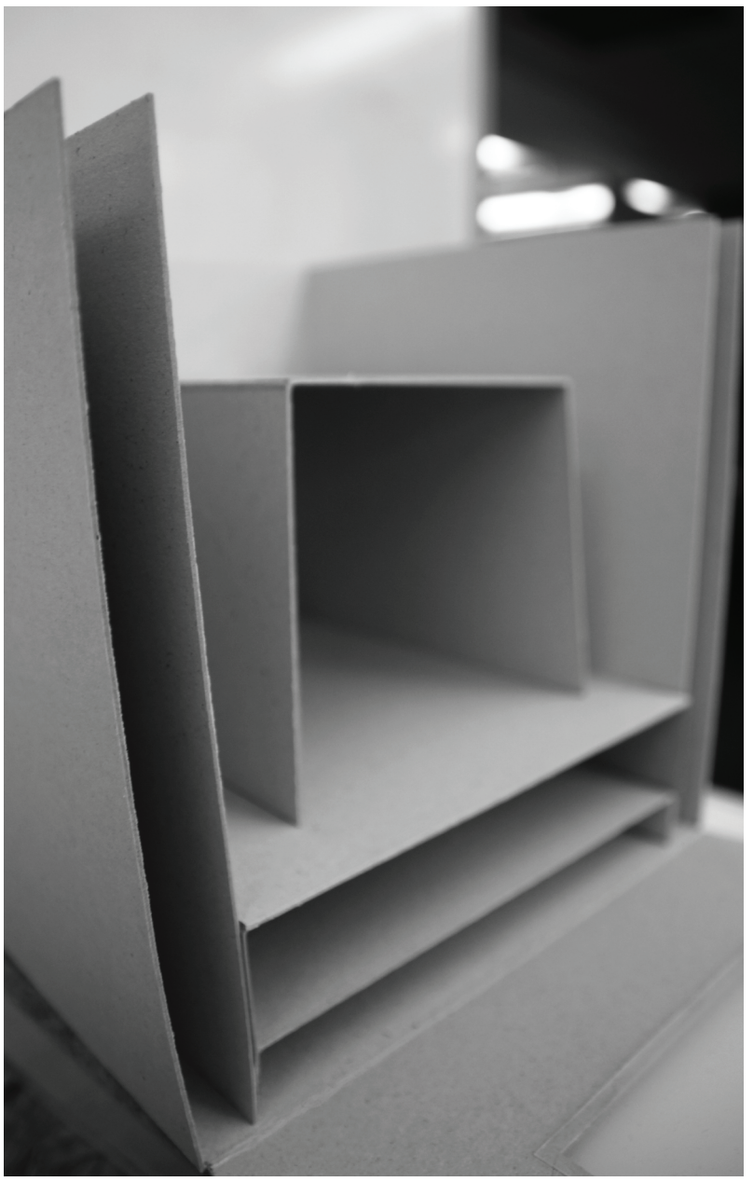
First step was to understand what effects different dimensions have in a room. What define a good space? We went out into the city and into different buildings to investigate and measure spaces.

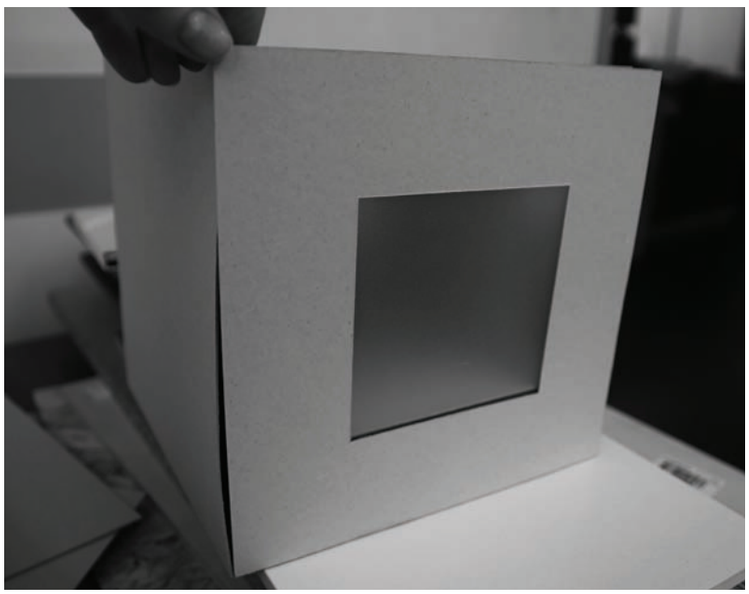
Next step was to look at different references and investigate how other architects dimensioned a perfect and beautiful space. Palladio came into the picture here, which is a chapter in the report. We studied him and the golden section which led us into a space.

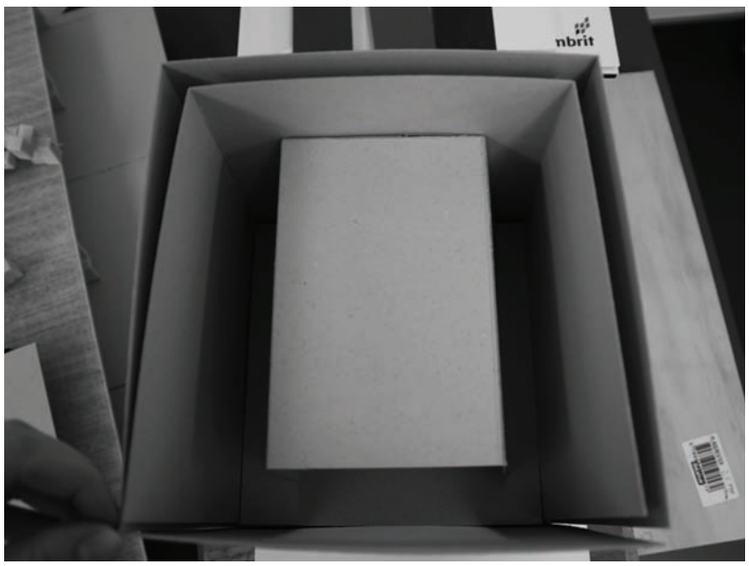
Third step was to make a mock up of the space and try to feel it in a 1:1 model. We found a matching space at school with the same dimensions and added some coverings to enclose it.

Fourth step was to adjust, not change, but adjust the space compared to save materials, optimise the space compared to functions and technical standard dimensions, which will have a large impact on the economy.

We also made a model to sense the gap in between the two shapes. We experimented with frosted glass versus regular glass and how the window should be divided into smaller windows. It is expensive to buy a special designed window with the dimensions 2,5m x 2,5m, so we divided it into smaller windows. One of them became a terrace door.



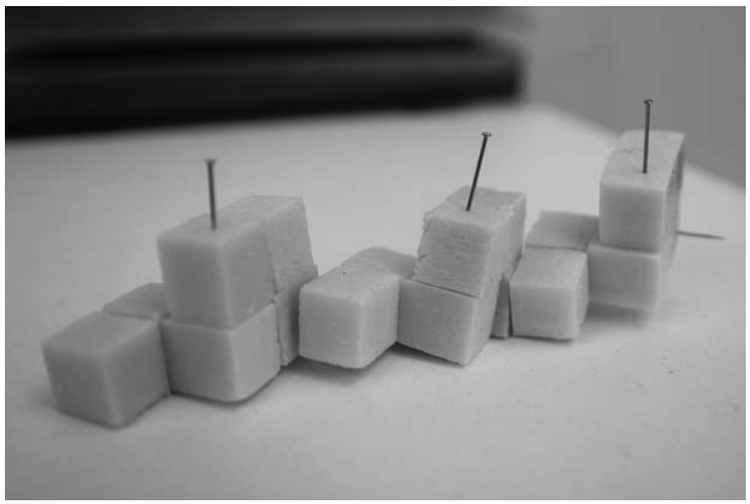




APPENDIX 5 DEVELOPMENT OF URBAN COMPOSITION

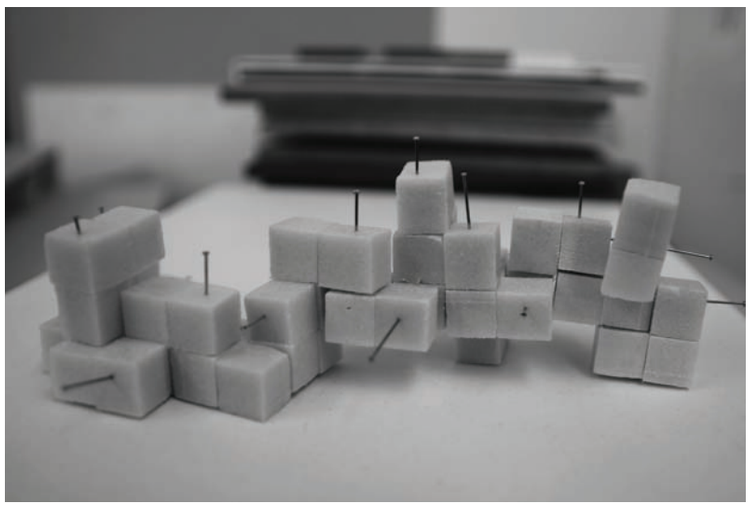
This is some of the most important experiments we went through to achieve the urban expression.

First step was to investigate references, which has given us a very early direction of expression. A 'random' look!



Third step was to detail Købmagergade 44 with dwellings put together in a 'random' expression placed in a controlled system.

The next step was to create a system where construction also was a dominating part of the design.

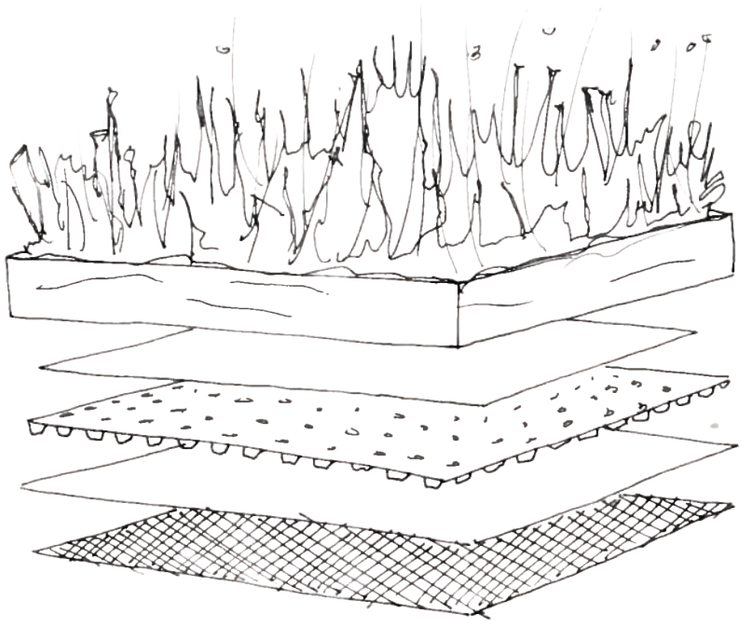


Every dwelling is placed carefully according to arrival, fire escapes, orientation, view from the dwelling and views in between.

APPENDIX 6

What are the pros and cons of a green roof?

GREEN ROOFS



Green surroundings are only an advantage, especially in the city, so why not take advantage of the desserted roofs and combine it with a green touch. In this case a meadow roof, which consists of wild grass and small wild flowers. The installation needs no maintanance plus it is drought tolerant. Listed below are some of the advantages to implement a green roof.

Studies tell us that green surroundings reduce stress.

Roofs can be very hot, up until 70 degrees, where a green roof can neutralize the temperature.

Green surroundings can absorb all the city gasses among CO2.

The earth works as an extra layer of insulation, which can have a great effect, energywise.

The earth also protects the roof from UV-radiation, which means that the roof are less damaged and can have a longer lifetime.

It reduces noise with a minimum of 40 decibel.

A green roof will approximately have a minimum cost of 500 kr m2.

Meadow roof on top of Welham studio made by Mark Merer.

High Line Park in New York. Steel meets the softness of nature.

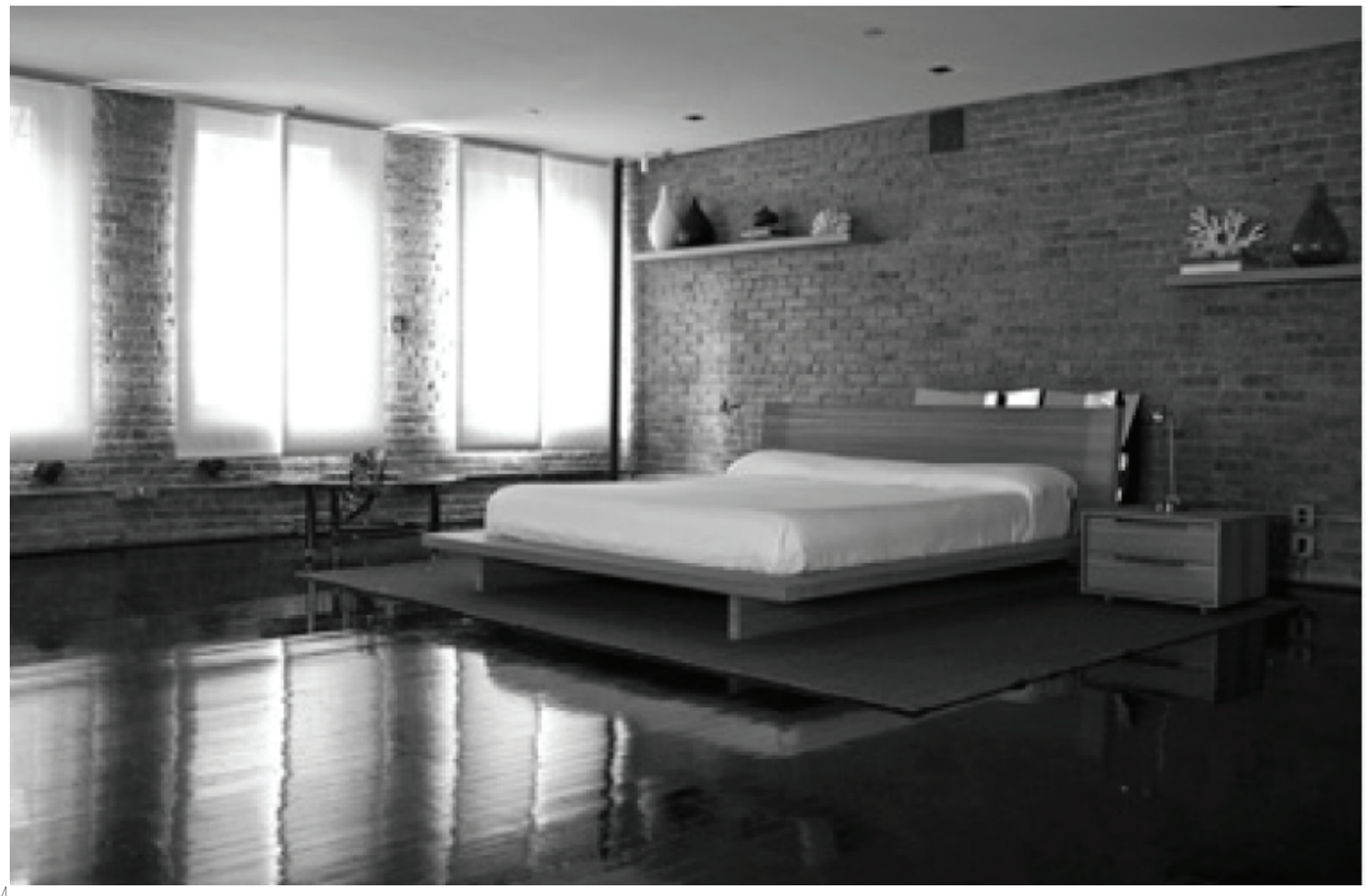
APPENDIX 7

INTERIOR DETAILS

Plywood

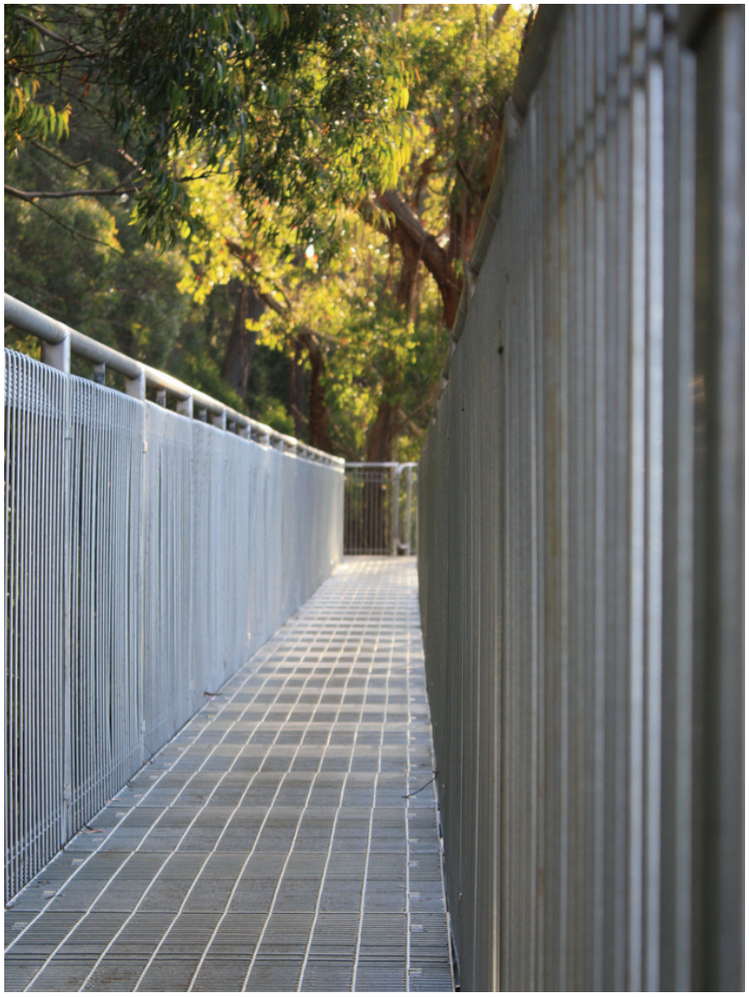
Example of a multifuntional furniture with an extractable 'harmonica' bottom. Furniture like this could be integrated and stored in the wall.

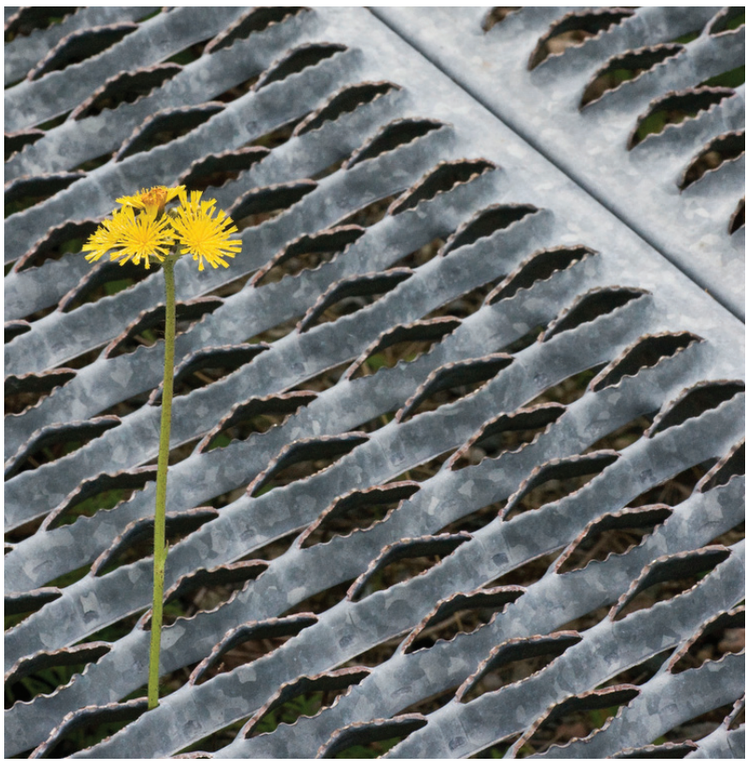
The plywood is treated with a lacquer, which reflects the light and mirrors the room as well as adding a qualitative finish.



APPENDIX 8

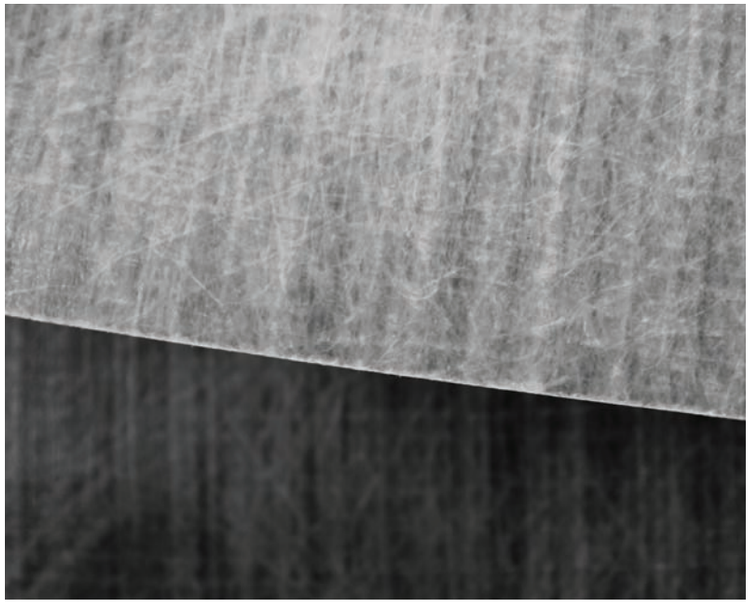
URBAN
DETAILS

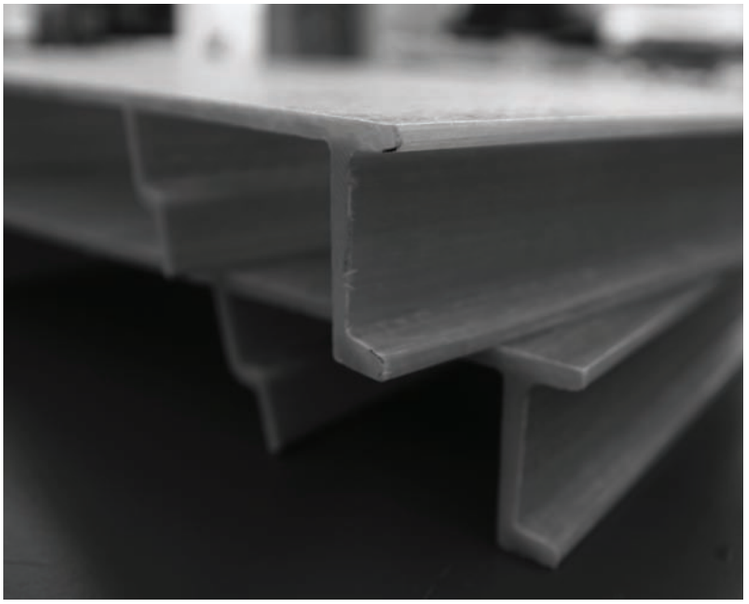




APPENDIX 9

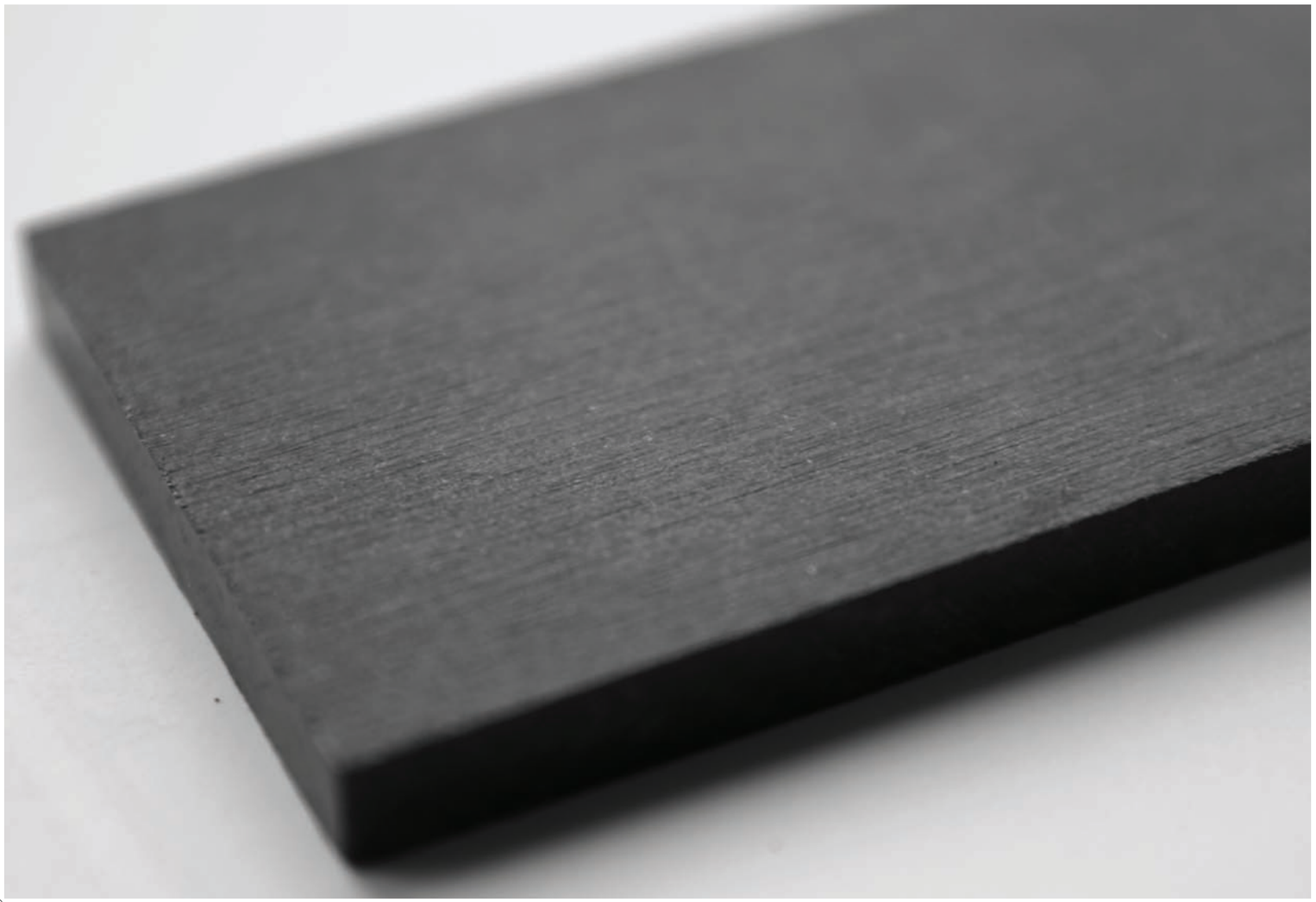
EXTERIOR MATERIALS





Fiberline's fibre glass composite facade panels

Cembrit PLAN



APPENDIX 10

TECHNICAL ELABORATION

These sections go deeper into an argumentation or elaboration of the subject. The chapters are refered to in the report.

SOLAR ENERGY

SOLAR COLLECTORS
Solar thermal collectors is a collector/system to collect heat by absorbing sunlight. It can be divided into two different systems;

Air systems, use air to transport the heat. It has lower costs, but also lower efficiency. It is not efficient to store the heat and can only be used for ventilation.

Hydraulic systems use water to transport the heat. It is better for storage and has higher efficiency. It can be used for space heating and DHW. Hydraulic systems are more efficient and are therefor investigated further. It can be divided into three technologies, which has a big influence on the architecture as well:

1.Evacuated tube collectors
2.Glazed flat plate collectors
3.Unglazed flat plate collectors [Probst&Roecker, 2011, s.15].

In general the solar collectors are forced to be implemented in the building, which takes space and very good architectural integration. Storage is also difficult, and the heat needs to be stored in the building. Solar collectors can only be used for heating, so the selection is limited. Solar collectors are therefor cheap to invest in and very efficient if it is implemented correctly.

SOLAR CELLS
The crystalline solar cells can be divided into mono crystalline and poly crystalline solar cells. Mono crystalline are the most expensive of the crystalline solar cells, but are most efficient (14-20% utilisation) and have a calm dark blue expression.

The poly crystalline solar cells are less expensive, because they are easier to produce, and the efficiency is only reduced a little (12% utilisation). The color is normally very blue, but can be produced in other colors as well.

VENTILATION

Natural ventilation is the cheapest method to ventilate with, because it is based on the wind streams. To integrate natural ventilation in the best possible way, several parameters can be adjusted;

- The natural driving force; concerning wind and buoyancy
- Ventilation principles; single-sided, cross and stack
- Ventilation elements; concerns the openings where the wind is dragged through as windows, wind towers, chimneys, atrium etc.
- Building height; low rise (1-2 storyes), medium rise (3-6 storyes), high rise (10 or more storeys)
- Supply and exhaust air paths; can be central or local, if it is central the exhaust and supply air is placed next to each other, if it is local exhaust and supply can be distributed around the building [Heiselberg, 2006].

DAYLIGHT

The DF is crucial to how you perceive a room and feel in a room. Different parameters can easily change your perception of the room. Light can enter a room in different ways, directly distributed, diffused or reflected. The orientation of the windows, how big they are, where they are placed, the form of the building and colors inside and outside have a big influence [Lechner, 2009].

MONTH AVERAGE

Three different shapes are studied to be aware of the consequences on the energy frame in the designing phase. The study case is made specific, with a volume on 125 m3, where different window sizes and orientation of the windows are studied with the different shapes. When designing a small dwelling the different shapes of the volume are limited, therefor the openings are tested with equal interest as the shape of the volume.

Case A
1 floor cube
The energy consumption equally increases with all three examples (A1, A2, A3).

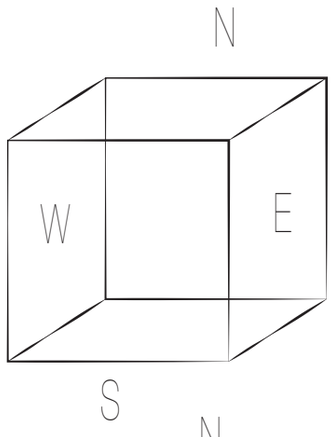
Case B
2 floor high shape
The increase between B2 and B3 is less than from B1 to B2, which in case A was equal. Though both case A and B increases from case 1 to 3 with almost the same amount.

Case C
1 floor low shape
C is different than A and B. There are big areas in top and bottom of the volume, which have a big influence. The East and West facades are very small, so the percentage constitutes a little area. This is also the reason why the step from C2 to C3 are a very small increase.

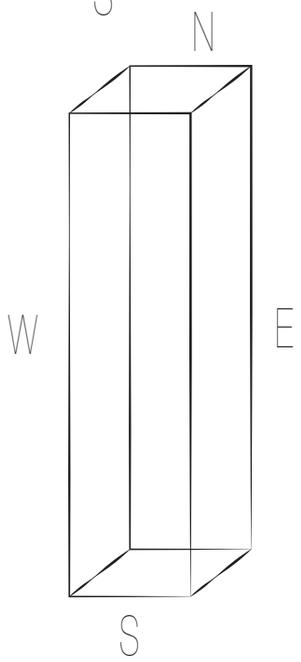
For sure case C is the example where the energy consumption is smallest. Worst case scenario here is lower than best case scenario in case A and B. The increase of window areas to the South from C1 to C2 has a big influence on the perception of the room, and in this case has little negativ effect on the energy consumption. However in case B the increase of windows to the South have big influence and would be an issue to considerate.

To sum up, a high thin shape gives a larger energy consumption than a low compact shape, which can be a design factor to considerate. But it doesn't mean that we can't design high, thin shapes, we just need to be aware of the consequences, so other parameters can be used to equalize or improve.

The less surface area, the more can we save in energy. The more surface area, the more energy is used to heat up the dwellings. From the first tests in month average, this was an issue to be aware of, though, not a factor to control the design of the building. See the CD for further detailing where the Month average spreadsheet is.

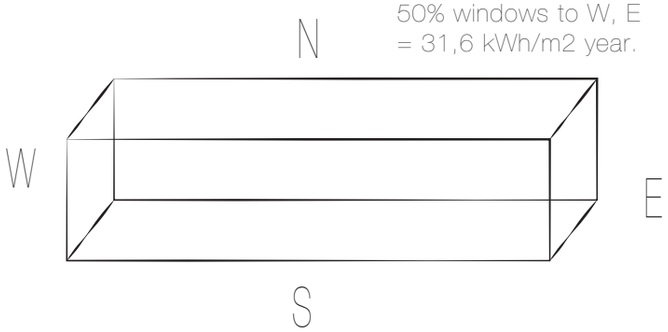


Case A
A1 - 50% windows to S
25% windows to W, E, N
= 38,5 kWh/m2 year.
A2 - 75% windows to S
25% windows to W, E, N
= 44,2 kWh/m2 year.
A3 - 50% windows to S
25% windows to North
50% windows to W, E
= 53,5 kWh/m2 year.



Case B
B1 - 50% windows to S
25% windows to W, E, N
= 64,9 kWh/m2 year.
B2 - 75% windows to S
25% windows to W, E, N
= 76,3 kWh/m2 year.
B3 - 50% windows to S
25% windows to North
50% windows to W, E
= 80 kWh/m2 year.

Case C
C1 - 50% windows to S
25% windows to W, E, N
= 27,8 kWh/m2 year
C2 - 75% windows to S
25% windows to W, E, N
= 30,4 kWh/m2 year.
C3 - 50% windows to S
25% windows to North
50% windows to W, E
= 31,6 kWh/m2 year.



24 HOUR

We did the spreadsheet for DWELLING 1 and 2 to see the difference in overheating. The results were as expected and showed a big difference between the two dwellings with a lot of overheating in DWELLING 1 and little in DWELLING 2. To see the spreadsheets, take a look at the CD.

APPENDIX 11

BSIM

The diagram shows the results for DWELLING 1 from BSim, see CD for more information.

Month	Sum	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec
Temperature	22.6	22	22.1	22.1	22.4	23.3	23	23.2	23.1	23.4	22.3	22	22
Hours > 26	42	0	0	0	0	24	2	1	5	10	0	0	0
Hours > 27	10	0	0	0	0	8	0	0	0	2	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
Air change/h	1,6	1,4	1,4	1,4	1,4	1.4	1.9	2.5	2.4	1,4	1,4	1,4	1,4
CO2/ppm	574	553	554	554	553	696	597	616	552	553	553	550	552

The diagram shows the results for DWELLING 2 from BSim, see CD for more information.

Month	Sum	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec
Temperature	22.4	22	22	22	22.1	23.1	22.8	23.1	23	22.7	22.1	22	22
Hours > 26	21	0	0	0	0	0	10	3	8	0	0	0	0
Hours > 27	2	0	0	0	0	8	2	0	0	2	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
Air change/h	1,6	1,4	1,4	1,4	1,4	1.4	2	2.4	2.2	1,4	1,4	1,4	1,4
CO2/ppm	575	553	555	554	554	553	681	598	644	552	553	550	552

BE10

Following shows the results from Be10, see CD for more information..

DWELLING 1
Building class 2015 without solar cells / 65.4 kWh/m2 year (is under 79,4 kWh/m2)
Building class 2020 without solar cells / 48,5 kWh/m2 year (should be under 20 kWh/m2)

Building class 2015 with solar cells / -8 kWh/m2 year
Building class 2020 with solar cells / -4,3 kWh/m2 year

DWELLING 2
Building class 2015 without solar cells / 76,9 kWh/m2 year (is under 79,4 kWh/m2)
Building class 2020 without solar cells / 60,8 kWh/m2 year (should be under 20 kWh/m2)

Building class 2015 with solar cells / 3,5 kWh/m2 year
Building class 2020 with solar cells / 7,9 kWh/m2 year

ALL 22 DWELLINGS
Building class 2015 without solar cells / 65,3 kWh/m2 year (is under 79,4 kWh/m2)
Building class 2020 without solar cells / 48,5 kWh/m2 year (should be under 20 kWh/m2)

Building class 2015 with solar cells / -5,8 kWh/m2 year
Building class 2020 with solar cells / -2,7 kWh/m2 year

APPENDIX 12

DIMENSIONING CONSTRUCTION

To dimension the columns which carry all 22 dwellings this formula is used:

N = (X*A*Fy)/YM1 [Teknisk Ståbi, 2011]

We experimented with different types of profiles and sizes of columns, which can be found on the CD in a spreadsheet.

The chosen dimension, 150mmx150mm in a square profile, the columns is given with:

Dimensioner/a x a	150 x 150mm
Godstykkelse/t	5mm
Areal/A	2870mm2
Søjle længden/l	1100mm
Relativ materialeparameter (Tabel 6.31)/E	1
Inertiradius, Tabel 6.18/i (red.fak.)	79,5mm
Lamda/(lambda)0	1,5
Søjlereduktionsfaktor,	0,372
se (lambda)0 i tabel 6.30, søjletilfælde a/X	
Fy (Tabel 6.31)	235
Reduktionsfaktor/YM1	1,2

N = 209080 N
N = 209,1 kN

Minimum set of columns = 14

We wanted an expression of a light steel structure, inspired by New Yorks fire escape stairs. So around 10 columns on each side of the building with a maximum of 200x200 in diameter. The calculations show that we can make the columns thinner, but with a horizontal beam to support in the middle of the structure. We use this calculation as the final result and dimension 9 beams on each side of the building.

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ILLUSTRATIONS

All illustrations and photos are made/taken by Line Hoff and Lea Klaaborg.