BETTER HOUSING OF THE FUTURE

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Content

Abstract

This report investigates and suggests a better housing of the future in collaboration with the housing company Boligselskabet Sjælland, through the context of a new city area in the east part of Roskilde that consists of both social housing, housing, stores, and offices. Based on the theory of townscape (Cullen, 1961), Image of the city (Lynch, 1970), Soft City (Sim, D. 2019.), and Vandkunstens five points for better lives of the future, this report asks the question: "Is it possible to create a city which both has the necessary density of contemporary city areas and at the same time the liveable quality of Vandkunstens dense-low buildings?".
By investigating and designing the new city area of Roskilde through three phases; The Town, The Neighbourhood, and The Home, this report both defines the importance of thinking solutions holistic and in multiply scales, to archive a design proposal that is both rational and innovative. With a sustainable, philosophic, and socialistic view, the final proposal of this project suggests a direction for the future of social housing and tries to contribute to the debate of what we as occupants of new city areas can desire and expect, and attempts to provide us with examples of design solutions that can contribute to this debate.

By this report, I hope for a better future and a more diverse city-landscape.

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Prologue

The similarity of housing complexes today is immense. No matter if you are stroking through Aarhus Ceresbyen, Carlsberg-byen in Copenhagen, or investigating the new plans for 'Spritten' in Aalborg things look the same. In a superficial attempt to create some sense of narrative, architects work with displacements of the building depth and height and the expression of the building skin. Tiles, bricks, steel, wooden boards, colours with different detailing, and small recess all hide the same concrete skeleton. Touching the façade lets you understand your build environment but gives you a misguided perception of how the building is constructed. As you let your fingers run through the rough brick façade you feel the steady pulse of brick, joint, and brick again. This understanding of the skin seems natural to you, as it relates to the story of men placing a brick on brick, building home and shelter for mankind in generations. But this continuous repetition is disturbed by the touch of a different joint. A joint which represents the actual structure of the brickwork. You understand by studying this joint that the building is not, as you in the inception assumed, constructed by brick on brick but instead a much larger tilework. A tilework which by first sight might seem hidden away, but is very much present. As you take a step back by the disclosure you find that the tilework of larger elements is the actual structure of the building, leaving the brickwork to become only a camouflage hiding the animal. Astonished by this exposure you now see that even though this large tilework is attempt concealed behind joints of windows and corners, every building surrounding you are constructed by almost the same tilework. On the surface, they seem different as they hide in different masks trying to seduce their occupants, as a sparrow uses colours to attract its mate, but in reality, they are all the same.

Entering the apartments you finally loose a complete grasp of where you are. The colourful camouflaging outer is indoor neglected to only a hollow shell of white space. Entering you find yourself in the middle of the kitchen wondering how you are ever to paint this large white canvas. Every room you enter accommodates the same needs of general daylight and atmosphere giving little indication of how you are supposed to furnish and turn this house into a home.

The hollow structures, frozen in space, leave little relation to the space between them as they neglect the vernacularism and genius loci. The urban landscape becomes a result of this painted camouflage structure, struggling to create space of meaning and history as it only relates to a superficial façade cladding. Instead of letting the building rise from a context built upon history and needs the building becomes a result of economic and design habits leaving the spaces between them a wasteland for bikes and concrete almost impossible to inhabit.

As a result of optimization, increased legislation, and new design-assisting tools a systematization and functional tradition has resulted in architecture which almost seems as it could be produced by calculations (Trebilcock, 2009. pp. 4-5). Architecture today has reached a dead-end where façade cladding and concrete structural systems have been investigated to their fullest, by an industry that allows for little or no experimenting at all. Supplying the construction with more money results in greater displacements and more exclusive materials. Rarely exclusive spatial qualities. Architecture and the space around it is almost reduced to an algorithm of economics and functionality, neglecting the atmosphere of the place and the occupants living within.

The danish author Inger Christensen describes an author's work process as a continuous search for a state of mind where writing becomes as natural as breathing. A time continuum where the author hosts an absent intimacy and words appears in structured coincidences creating lyrics that is living and self-producing. In this state, 'to write' is as easy and natural as 'to live' (Christensen, 2019. Pp. 9-65).

"... Jeg betragter det som en forfatters opgave at konstruere en kode der gør terningekastet læseligt
At finde på en sandhed der gør tilfældigheden nødvendig
og forstille sig et tegnsystem der transmittere blindheden
kort sagt jeg betragter det som forfatteres opgave
at beskæftige sig med det umulige, det ufuldkomne, det der ligger udenfor..."

"... I see it as the authors job to construct a
code which makes the throw of the dice readable
To find a truth that makes the coincidence necessary
and to imagine a symbol and systems which transmits the blindness
in short terms I see it as the authors job
to be occupied with the impossible, the imperfect, what
lies beyond ..."
(Christensen, 2019. pp. 46-47)

I too, as an architect, find myself allied with Inger Christensen and her way of looking at the process of creating. I am the author of architecture. I am too in search of that moment where things appear in coincidences, creating a holistic intuitive product. Architecture is to handle structures, functions and aesthetics through a process of coincidences and transmit this into a readable and liveable reality, which again nourishes coincidences of meetings and life. I too, like Inger Christensen, believe in the necessity of coincidences as a mean to create what lies beyond.
A utopian, nourished from ideas of the architects and urban planners, where cities and architecture, instead of being planned years in advance, is the foundation that drives peoples lives to a state where city, architecture, human and nature operates as an eco-system relation evolving ad-hoc and according to new-found knowledge and understandings (Andersson, S.L., 2012). A utopian, where people live in close relation to not only the city around them but also the humans and their families. Creating connections, relationships and interesting lives through the result of allowing people to meet by coincidences. The variation of seasons, the changing of cities and the growth of life creates new possibilities that architecture should never delay. The city should allow for coincidences to occur, not in spite of, but because of density, diversity and vicinity (Sim, D., 2020).

In an exhibition at Utzon centre in Aalborg, DK, the architectural studio Vandkunsten celebrates coincidences in architecture as the means of better lives of the future. Since 1970 Vandkunsten have revolutionized social housing and sustainable living. First with the dense-low buildings Tinggården and latest through the Exhibition Bo Bedre med Vandkunsten (Better lives with Vandkunsten). Here they define a manifesto of five points for better housing of the future which takes point in sociability, sustainability and leaving things be for coincidences to appear;

Let us live smaller and better! ***(Lad os bo minde og bedre!)***
Let us share more! ***(Lad os dele mere!)***
Let nature move in! ***(Lad naturen flytte ind!)***
Let us do it ourselves, together! ***(Lad os gøre det selv, sammen!)***
Let it be and watch the beauty! ***(Lad det være og se skønheden!)***

As the dense city might be a necessity because of globalisation and for many people a conscious choice. The five points from Vandkunsten leave one to wonder how are we to build homes in the future. This initiates the thesis for this project:

Is it possible to create a city that both has the necessary density of contemporary city areas and at the same time the liveable quality of Vandkunstens dense-low buildings?

By designing a social housing complex and its urban context, with the bullets from Vandkunstens manifesto and the knowledge of sustainable cities. This project seeks to address the uniformity and spaceless dead-end of the building industry today. Through means of CLT constructions and their life-improving qualities, together with a holistic and human-scale design process. The social housing complex and the space surrounding it should allow the occupants to inhabit their home and vicinity, creating a feeling of well-being and belonging.

Vandkunsten five principles for better housing of the future

- ***Let us live smaller and better!*** ***Lad os bo minde og bedre!***
  The large housing complex and our craving for larger homes is what destroys the climate around us and is a large part of the rash material waste in our community. Vandkusten thinks that we should live in smaller apartments but with better materials and better design strategies. By living together in a family of three to four people on just 37m2, our homes become a big part of the climate solution. Through this, you avoid wasting a lot of your time cleaning and structuring your home, as the furniture become multifunctional and material quality increases. With smaller apartments families have more time to be together while they become more reliant on their city and neighbourhood. This means that you, as an occupant, become an active part of your neighbourhood which enriches your life quality (Vandkunsten, 2020).

- ***Let us share more!*** ***Lad os dele mere!***
  Many people today experience loneliness which is only strengthened by the larger apartments filled with way too many things which have little or no purpose at all. This loneliness easily leads to dissatisfaction and bad health. By sharing more things in a house, stairwell or neighbourhood we can help each other to dis-increase loneliness. Furthermore, this is a natural result of smaller apartments which forces functions out of the apartments and into the community. E.g. Kitchen gardens, common houses, wash house in the basement, second-hand shops controlled by elder people or garage with shared cars (Vandkunsten, 2020).

- ***Let nature move in!*** ***Lad naturen flytte ind!***
  Nature is good for our health and our well-being, this is why we should live in apartments that invite nature close to our everyday life. Preferably children should have the possibility to grow their vegetables in the common gardens or collecting the Sunday morning eggs in the local henhouse. They should get dirt under their fingers and gain an understanding of how and where their food comes from. With lively nature in the backyard, children can build small treehouses and the parents greenhouses. Instead of a simple flat roof, this could be used for biodiversity and rainwater on the façade can be collected in plant trays just outside the windows. Instead of designing a city that is polished and controlled, we should design a city that is a part of nature (Vandkunsten, 2020).

- ***Let us do it ourselves, together!*** ***Lad os gøre det selv, sammen!***
  Instead of understanding architecture as static and complete, we should understand it as a living organism. People should have the possibility to take charge and change their façades, build a bike shed or moving a wall in their apartments. We should take pride in the ever-changing of things and find beauty in the diversity. Through common rooms and common workshops, every people should have the possibility to build their extension to their homes or through a tenant meeting establish a possibility to renovate parts of the housing complex (Vandkunsten, 2020).

- ***Let it be and watch the beauty!*** ***Lad det være og se skønheden!***
  Today we love new untouched and unused apartments and furniture, we like to fight off every grease spot and scars. If we were to see the beauty in the used and old furniture, accepting that things are used and not perfect we could maybe gain a more profound understanding of beauty. Instead of buying new things we should go into the local reuse store and down to the workshop area to modify or build new out of old materials. In this way, we use less money and help the environment even more. We should accept that our buildings are not perfect, just like humans. Patina and reused materials create a unique and experiential architecture where every apartment might be different. One could use old vinyl floors as façade cladding or an old pile of bricks as legs for our table. "This is not only about reducing CO2 levels and lifecycle analysis but also about personality and reality" (Vandkunsten, 2020).

1 EXHIBITION: BETTER LIFE WITH VANDKUNSTEN

A 37m2 apartment designed by Vandkunsten for a family of 3-4 people. As an example of how they think people should live in the future.

Method

When one is to approach an academic project the person will often feel obligated to address the project through a well-structured and deliberate design process. But how does such a method of research align with the idea of a design process which allows for incidences of coincidences?

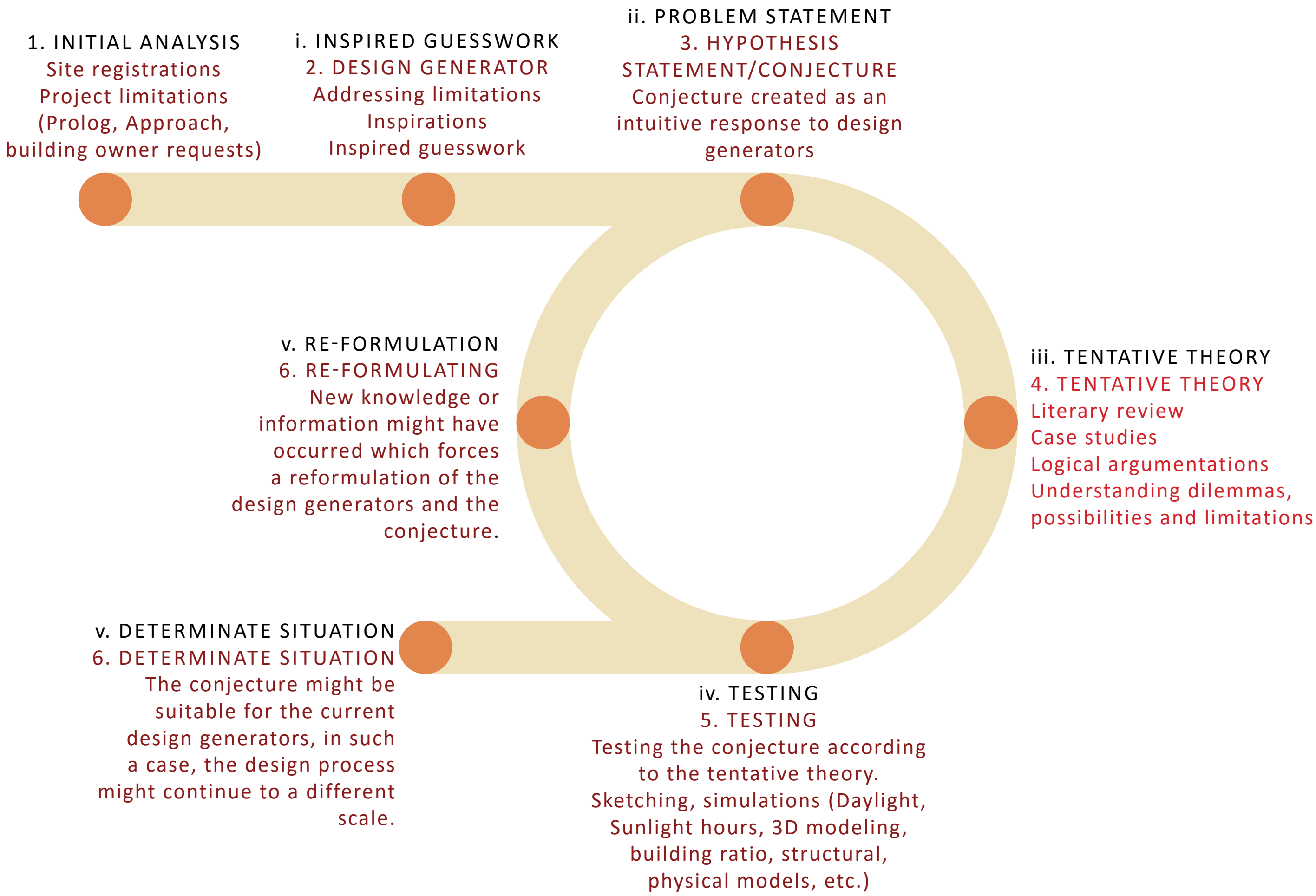
The process of architectural practice is not based on academic-logical solutions driven from a process of analysis and synthesis but rather on experiences, ideas and intuition. This allows for the designers to faster and more efficient bring design solutions to the table while keeping an open-minded trial and error process. Instead of defining and analyzing every design aspect separately and composing them through a synthetic phase, this method allows the designer to propose a holistic solution, in the beginning, adjusting this to accommodate for issues along the way.
The German mathematician and philosopher Karl Popper describes in the early 70s a new way of approaching a scientific project. Instead of approaching a project by analysis, observations and facts the project begins with a problem or analysis that nourishes a hypothesis conjecture (Bamford, G. 2002 PP. 250-251).

"There is no more rational procedure than the method of trial and error— of conjectures and refutations; of boldly proposing theories; of trying our best to show that these are erroneous; and of accepting them tentatively if our critical efforts are unsuccessful"

(Popper 1972, PP. 51)

Trebilcock compares in 2009 the classical Analysis/Synthesis method with a 'Popperian' nourished Conjecture/Analysis method in his academic paper Integrated Design Process: From analysis/synthesis to conjecture/analysis. The Conjecture/Analysis method is in many ways similar to the method of architectural practice, as it proposes in the early stages of the project a solution that is validated and further improved and augmented through an analysis phase. The method is further developed by Jane Darke where she suggests that a design conjecture is often driven by design generators defined by the designer and clients (Darke, J. 1979).

By addressing this project through the Generator/Conjecture/Analysis method, coincidences and guesswork is acknowledged not only as unforeseen quality in the result but as a driving aspect through the process. Allowing for flaws to become concepts and accepting that one design solution might be just as right as another.



GENERATOR/CONJECTURE/ANALYSIS METHOD

The design process of generator/conjecture/analysis, based on Isak Fogeds illustration of “Diagram based on Dewey and Popper’s cycles of research progression, from axiom indeterminate situations to theory, testing, re-formulation and determinate situations, 2015.” - Beneath the different phases defined by Foged, is a short description of the tools and sub-methods which can be used to gain a deeper understanding of one’s design defined by how I have been using the method throughout the process (Marked in red) (Mikkelsen, J. B., 2016. PP. 96-115).

Tectonic approach

The classical introduction of tectonic is thought the Greek meaning of Tekton being the carpenter or master builder. This gives the idea that tectonic is very much associated with a time where you implied that the act of putting elements together was a poetic and noble act (Frampton, 1995 pp. 4).
In this historical sense of construction, it is natural to compare and understand tectonic in relation to the Vitruvian triad where architecture can be understood as an equal matter of Utilitas (functionality), Fermitas (structure) and Venustas (beauty).

Tectonic, for this reason, differs from the words of construction and structure, where construction is the simple act of joining elements and structure an abstract concept of a principal or a system that handle e.g. structural forces in a building.
Instead tectonic has a more profound meaning for the reading and understanding of the whole. When a structural concept has found its implementation through construction the result affects us with certain expressive qualities which somehow relates to the play of internal forces as the result of the construction of structures. The interplay between these structural forces and their expressive qualities is what comes closest to understanding tectonic in a comprehensive view (Sekler, 1946 pp 1).

In a design matter, this understanding can be used to create a common understanding between the work of an architect and engineer. As the building is constructed of elements, materials, and structures we gain an understanding of these elements, their internal forces and their expressive qualities. We have, through this, the possibility to understand and read the building form (Sekler, 1946 pp2) which allows us to work with and adjust these elements in the act of creating better and holistic architecture. Whether you work with the elements of construction or elements of sustainability, tectonic provides a way of understanding architecture as a relation between different adoptions. It is important to notice that tectonic not only lets you understand an insulated incidence of architecture. Tectonic also lets you understand the interplay between building and landscape, or, in that case, building and city. In some ways, the gardener like the carpenter is also a Tekton, as he, in the landscape, works with the interplay between plants and terrain (Dam, 2007). This understanding of tectonic allows us to accept that every aspect relates to one another, implementing that by being aware of elements and their expressive qualities in all scale, you are given a profound way of understanding and create architecture which is beyond just one building.

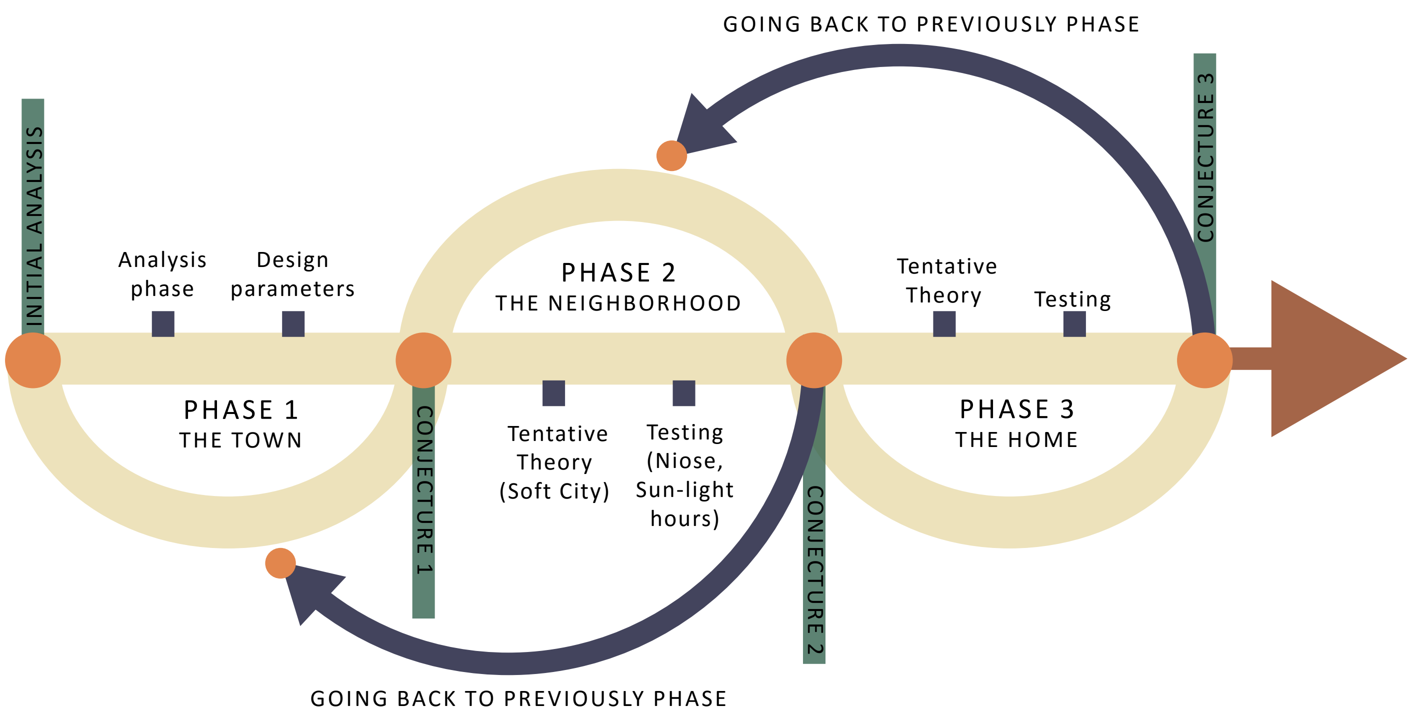
With our understanding of tectonic as a way of structuring elements of architecture as a holistic approach, where changing one property in an element changes the expressive quality of the whole and their relation to our working method of conjectures and analysis. We are allowed to create a free and intuitive design phase where the project will be an attempt to utilize a holistic design proposal as it is evident to create a comprehensive design of the future.

The design process is structured into three main phases, a Town phase, a Neighborhood phase and a Home phase. Each phase is represented with its theory, conjecturing and analysis allowing the reader to follow the process more fluently and without back-trace. In reality, the process of design is counterintuitive and reflects back and forth as changes occur.

- **Phase 1 – The Town phase**
  In this phase, we investigate the large scale of architecture and how we are to create a conjecture of a part of the city within the existing city. This is done through site analysis and theoretical studies (Based on Kevin Lynch and Gordon Cullen) elaborated through pictures and mappings which should nourish initial design parameters and then a conjecture.

- **Phase 2 – The Neighborhood phase**
  Based on the conjecture from the town phase, this phase should understand the basics of a good neighbourhood and street level. This is done through the literary review of David Sim, Soft City, and case studies where this tentative theory is understood and elaborated. Next follows a testing phase of sketching, 3d modelling and based on the design parameters and the tentative theory. Furthermore an analysis of important factors for gaining an understanding of the problems and solutions that drives for a new and more detailed conjecture of the neighbourhood landscape.

- **Phase 3 – The Home phase**
  The second conjecture gives the basic understanding, limitations and conditions for the social housing situation. In this phase tentative theory of Vandkunsten and CLT-construction elements is relieved and analyzed through concrete design strategies. Based on this, a testing phase of sketching, 3d modelling drives the design proposals of different apartment layouts. This should create a conjecture of how families are to live in a small apartment in a dense city.



PROJECT PHASES
The process of the project is divided into three phases, the town, the neighbourhood, and the home, which overlaps each other in scale and theory.

Boligselskabet Sjælland

Social housing or "Almen" housing is a danish concept of public founded housing to ensure a variated supply of affordable housing build on a foundation of a tenants' participation.
The social housing as we know it in today was founded in 1933 with the establishment of "Kanslergadeforliget", which by law defined how the non-profit social housing organizations should operate. Before this social housing was organized by private workers and trade unions. One of the earliest examples of a social housing is "Brumleby" at Øster Fælled in Copenhagen, 1853, this where built by the Medical organization as a response to the cholera epidemic.
Now days only state-approved social housing organizations are allowed to get public founding and build social housing (Vestergaard, H. 2016).
The differences to social housing and rental housing is that the social housing is organized by a non-profit organization, in reality the occupants whom lives in the housing complex handles the economy by democracy and together saves for future improvements of the housing complex. This means that the social housing concept is a very communitive and cheap way of living.

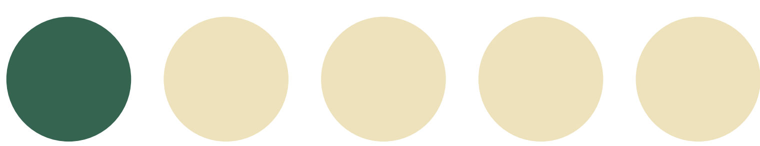
Today there are around 550 social housing organizations and 7000 social housing complexes in Denmark. Around 20% of the danish population lives in social housing. In general it is often the lowest income families that lives in social housing, as 31% of the occupants are welfare dependency and their average income is 45% less than the average income in the country (Danmarks statestik, 2018). Social housing is for both student, singles, families and elderly and is found all over Denmark both in large cities and in the countryside.
Mainly there are three reasons for choosing to live in a social house: one is because of the affordable housing, seconded is because of your political beliefs and the last reason is because of necessity (Boligselskabet Sjælland, 2021) – up to 18% of people living in the social housing is because of municipal instructions (Landsbyggefonden, 2010)

"An average household is at 2,7 rooms with 1,8 persons – most often it is single women and men with an average age of 42,2 – who will live in the household for approx. 10 years."

(Landsbyggefonden, 2020).

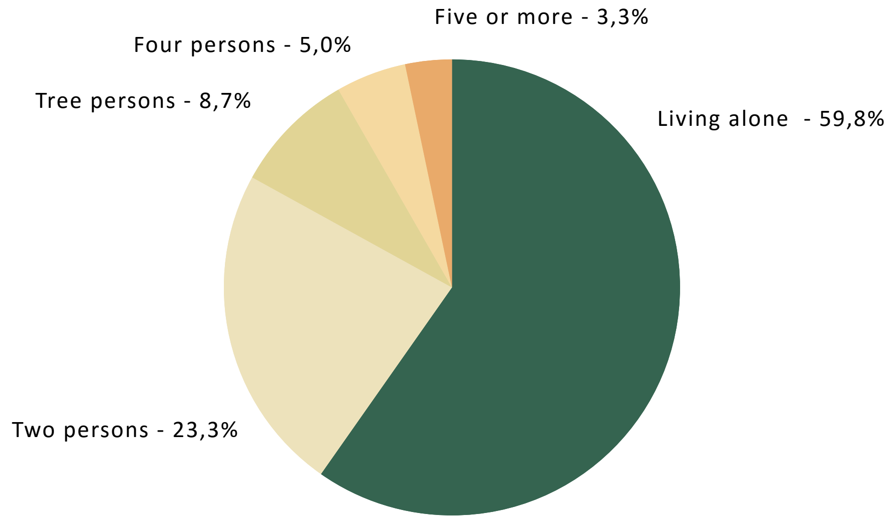
Boligsekslabet Sjælland (BOSJ) was founded in 2007 through a merge of a number of smaller housing organizations. With 12.500 housing units across most of Zealand, it is the fourth-largest housing organization in Denmark. With roots back to 1899 the company is still in growth and invests in both renovation and new housing for an increasing number of applicants. As a green initiative the housing organization invested in 2017 in an initiative called "Boligtræ" or "Housingtree" which makes the organization one of the first to build social housing in CLT-construction (Boligselskabet sjælland, 2021).

1 OUT OF 5 PEOPLE LIVE IN SOCIAL HOUSING IN DENMARK

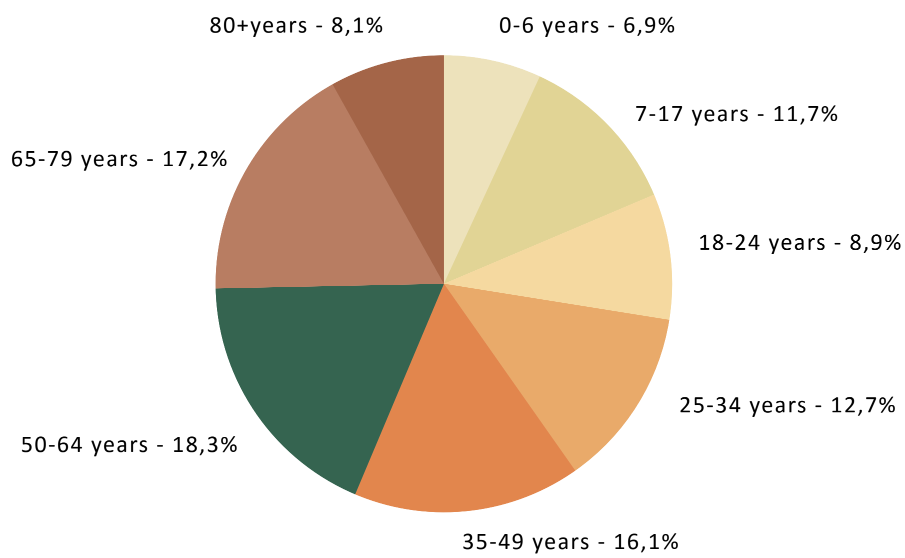


THE DISTRIBUTION OF MEN AND WOMEN LIVING IN SOCIAL HOUSING IN DEMARK

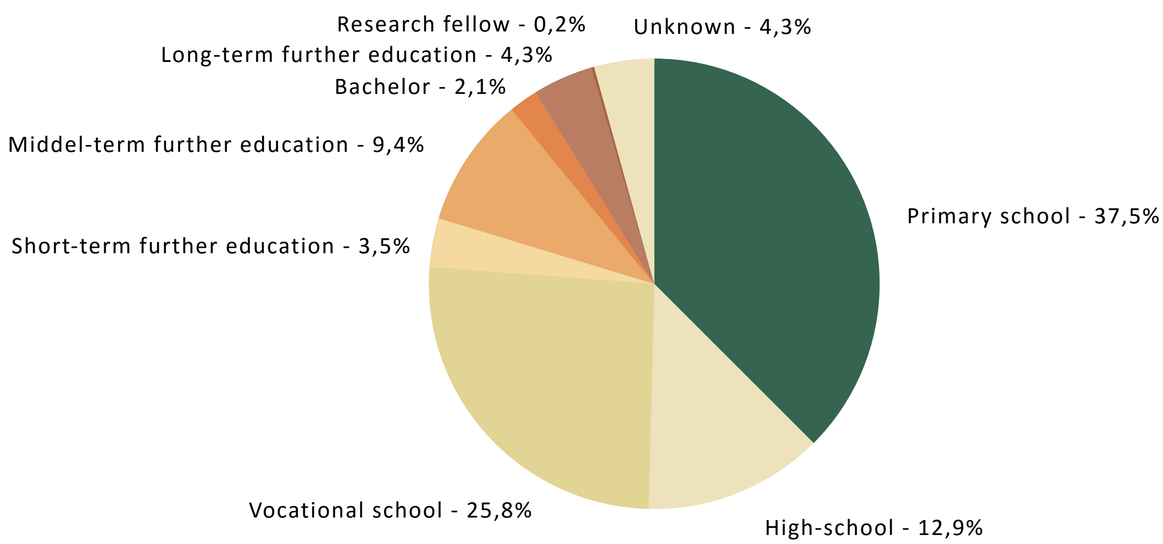
NUMBER OF PEOPLE LIVING TOGETHER IN SOCIAL HOUSING



AGE OF PEOPLE LIVING IN SOCIAL HOUSING IN SJÆLLAND



HIGHEST FINISH EDUCATION IN SOCIAL HOUSING IN SJÆLLAND



Town program

In a collaboration with Boligselskabet Sjælland, an initial design program for the site is established. The program is based on correspondence between me and BOSJ. By the idea of creating a diverse area that is both dense and multifunctional. The area should mostly be residential apartments but should have both shops, offices, and public buildings in order to create a neighbourhood that is used at every time of the day (BOSJ, Email. 2020).

Site area 36000 m^2

Program in coporation with Boligselskabet Sjælland:

Building ratio 120- 140 %
Gross floor area 43200 - 50400m2

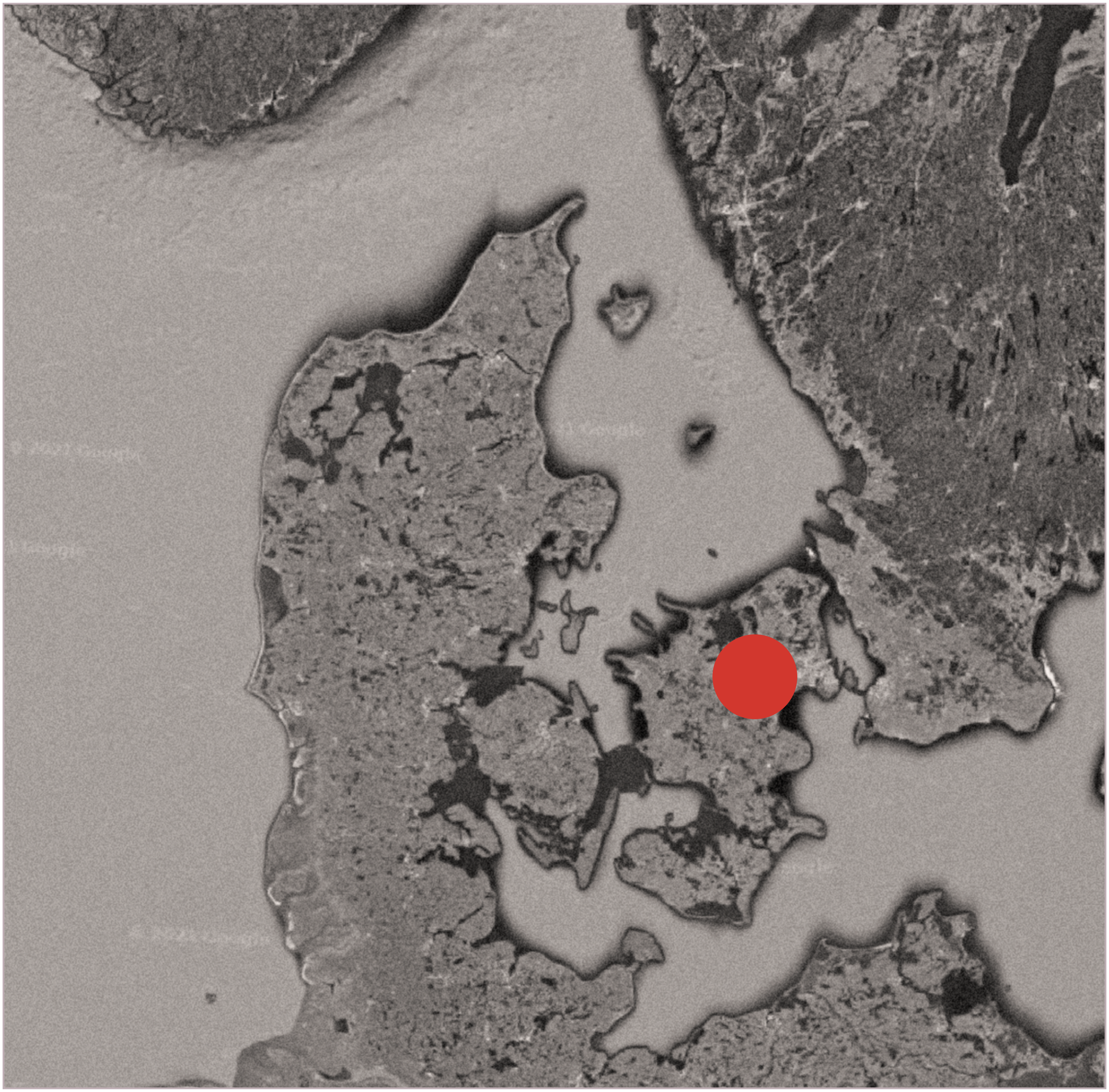
Parking spots 530 parking spots ◦ 30m^2 = 15900m^2 (Roskilde Kommune, 2010)

Offices		25%	**10800-2600 m^2**				
	Large sized offices	30%	3240-3780m^2				
	Medium sized offices	40%	4320-5040m^2				
	Small sized offices	30%	3240-3780m^2				
Shops		10%	**4320-5040 m^2**				
	Silvan	30%	1296-1512m^2				
	Groceries	30%	1296-1512m^2				
	Retail trade	30%	1296-1512m^2				
	Marked	10%	432-504m^2				
Resturants		10%	**4320-5040 m^2**				
	McDonalds	30%	1296-1512m^2				
	Cafe/Bar	50%	2160-2520m^2				
	Roof top resturante	20%	864-1008m^2				
Public Buildings		5%	**2160-2520m^2**				
	Sports	40%	864-1008m^2				
	Daycare	30%	648-756m^2				
	Libary	30%	648-756m^2				
Private Housing		30%	**12960- 15120 m^2**				
Social Housing		20%	**8640-10080 m^2**		**Apartment size**	**Number of apartments**	
	Co- Housing			3675 m^2	60-95 m^2	45	Apartments
	Small	10%		496,5-640,5 m^2	35 m^2	14-18	Apartments
	Medium-Smal	10%		496,5-640,5 m^2	45 m^2	11-14	Apartments
	Medium	20%		993-1281 m^2	65 m^2	15-20	Apartments
	Large	30%		1489,5-1921,5 m^2	75 m^2	20-26	Apartments
	Family	30%		1489,5-1921,5 m^2	100 m^2	15-19	Apartments
					Total of	120-142	Apartments


Plads til dig
BOLIG

Roskilde

Roskilde has a great history, as it has been around for over a thousand years. In the beginning, the area was inhabited by small viking settlements but as Denmark turned Christian, the city started to develop. Around the year 1000, the king of Denmark, Knud 'the great', build the large cathedral and made Roskilde a central city in Denmark for the top upper class. The city was different from other large cities of its time because it was built with fewer fortifications than one would normally do – On the contrary, some of the largest ships from this period have been found in archaeological excavations in areas around Roskilde.
In 1500 the city lost its greatness as the royal family turn out to be more interested in Copenhagen and the Roskilde became a marked town and transit city for Copenhagen (Juelsgård Horte and Jensen, 2021). Today the cathedral still has a large impact on the city centre, as you walk through the main street of the "old" city on cobblestone and besides small old shopping streets. A large university brings many young people to the city and in the circumference of the city a strong industrial character benefits from its close location to Copenhagen.
The area which in this assignment is to be developed is a close part of this industrial area bought by a developer. The ideas for the area is to build a new housing area which is close to the city with both livable areas, shops, restaurants and offices.



PICTURE OF ROSKILDE CITYCENTRE, CLOSE TO THE VERY DEFINING CATHEDRAL OF ROSKILDE


Byens hus

PHASE 1

The Town

The town

The city has evolved together with society and has changed accordingly to the challenges and beliefs of the people living in them and the people planning them. In ancient Greece, Hippodamus laid the name for a town planning of an orthogonal grid structure like the once in the cities Miletus and Piraeus. These cities were situated close to water allowing them to easily transfer goods to other cities and making them easy to protect against enemies. Throughout history, city planning has seen many different faces, which all have their possibilities and limitations e.g. the English garden city movement in 1898, led by Ebenezer Howard or the planning of a new city in Brazil, Brasília in 1957 by Lúcio Costa.
To design and manoeuvre in this field, we have to understand cities and urban landscape in a theoretical context and to know-how about creating coherent cities.

THE IMAGE OF THE CITY

Kevin Lynch proposes that one way of understanding a city is to create a common 'image of the city'. Through analysing and observing physical things, people create environmental images as a result of the spatial relation between the observer and the object. This imageability can be understood through analysing the identity, structure and meaning of the object and through this define the quality of a physical object. When many people in a city or area have the same understanding of an object; it becomes a part of the image of the city and is hence essential to understand, connect to, and navigating in the city (Lynch, 1960. Pp 1-14).
Kevin Lynch classifies these images into five categories, divided into major and minor influence (Lynch, 1960. Pp 47):

Paths: These are streets, walkways, train lines, canals and railroads. In general, elements which people customarily, occasionally, or potentially moves along.

Edge: These are elements that are not considered as a path but are more like a boundary, barrier or transition from one area or element to another. This could be shores, railroads, development edge or walls.

Districts: These are areas of the city whom people can be "inside" and which have a common and identifying character both from outside and inside the district.

Nodes: These are points or spots which people can enter, this can be junctions, breaks in transportations, crossing and connections of paths. – Often these come in the convergence of paths.

Landmarks: These are points that people do not enter, but elements people use to measure distance and direction. These could be towers, domes, signs or doorknobs. This could also be a moving element such as the sun.

These observations exist on many scales, both on a large city scale but also urban landscape or district scale. Houses and small paths might as well be a part of the image of the city as railroads and large domes. To gain a concise understanding of the image of the city, Kevin Lynch both interviewed and walked together with citizens making the images a result of various citizens perception (Lynch, 1960. Pp.138-179).
By understanding and mapping, the image of the city one gains the knowledge of how the city is put together and how citizens navigate and observe their city. This allows for a design that relates to the existing surroundings without risking the "terror of being lost". Through understanding the parts you gain a way of understanding the whole (Lynch, 1960).

TOWNSCAPE

Like Kevin Lynch, Gordon Cullen believes that through examining a world of examples you gain the possibility to manipulate the whole. Cullen gives, through his 'cookery book' a 'list of ingrediencies' which can be mingled and modified in different ways to create an interesting and eventful city. Through this, designers and city planners can avoid designing "disastrous" cities where "everybody is bored stiff" (Cullen, 1961. Pp. 193-196).
The purpose of the book is to expose the elements which are used in the art of environment, which Cullen names Townscape.

Through the means of Serial Vision, Cullen describes how people perceive the city as a sequence of images contrasting and wakening feelings in the perceiver. Elements as enclosure, changing of levels, netting, division of space, gestures, deflection, exposure, intimacy, railings, lettering etc. are all ingredients that can be used in the understanding and designing of the urban landscape (Cullen, 1961).
Cullen describes that through a process of three phases one can begin to practice the art of environment (Cullen, 1961. Pp. 193-196).

A. By being aware of the ingredients of Townscape.

B. By being aware of our awareness of the environment.

C. By creating a system of ingredients and how they should be put together.

Through the elements of Townscape, it is made possible to not only understand the image of the city but to understand the ingredients in the movement through the city. By this understanding, being able to manipulate and design new sequences of perception.

4 ROSKILDE

North east part of Roskilde, the site is indicated with the red area.

In Denmark, cities are handled by the Danish Planning Act, which is divided into smaller local or district plans defined through a discussion with the citizens, the municipality and potential developers.
One of the main concerns with the urban landscape in the present is the liveability of an area. In general, it is difficult to measure how liveable a place is and there are various ways, in various institutions and countries, to measure this. Matthew Taecker defines liveability, by validating multiply descriptions of liveability, as:

"Livability is the accessibility people have to opportunities in and around the public realm (for commuting, work, education, rest, rejuvenation, etc.) to improve and/or maintain their desired quality of life."

(Matthew, 2014. PP12)

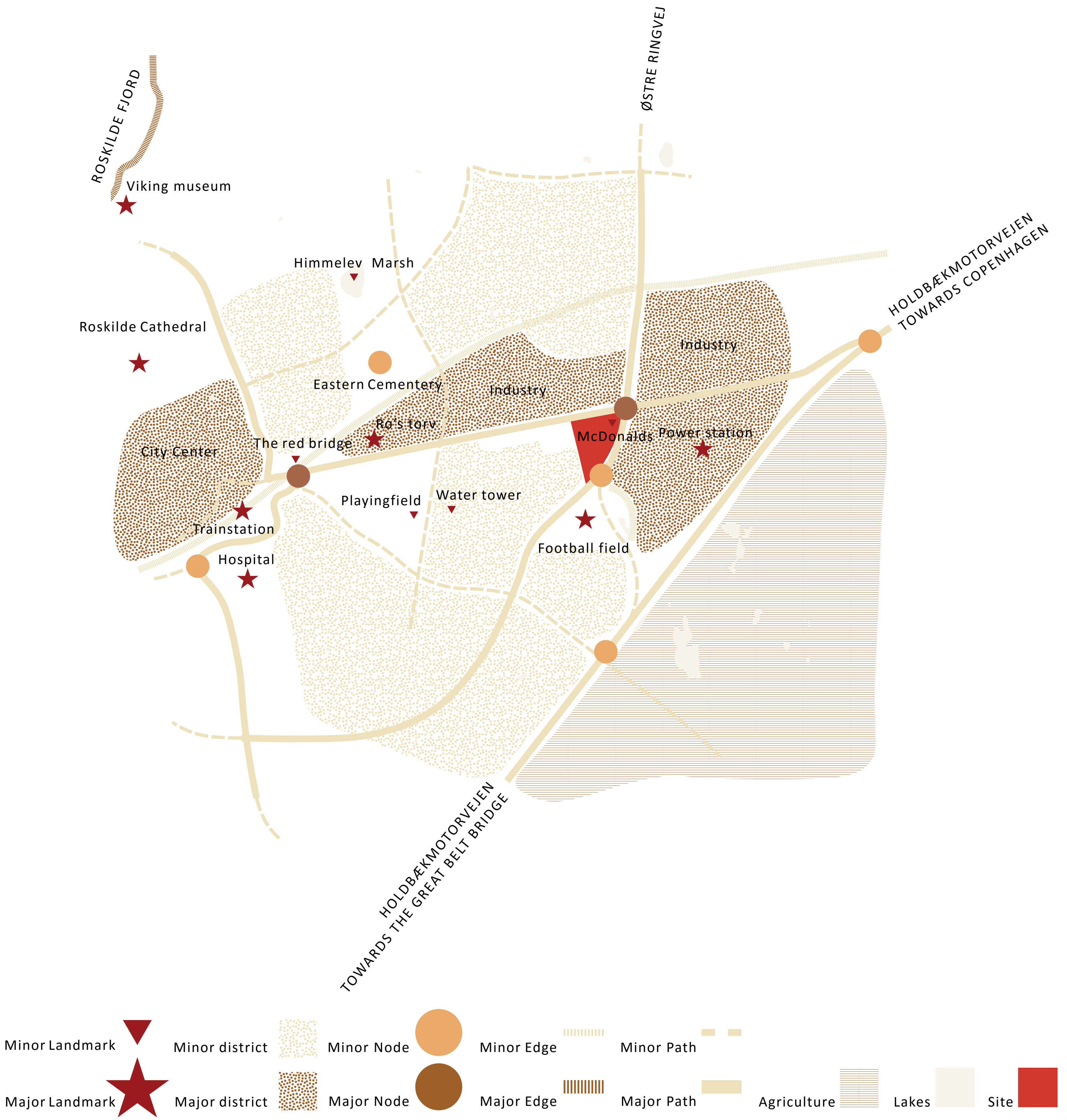
And declares that to this, it is important to be aware of the following two things:
A. One's pursuit of quality of life satisfaction should not unduly detract from the livability of others.
B. Care should be taken to meet the needs of society's most vulnerable, including the poor, the disenfranchised, and those engaging in human, non-mechanized forms of transport.

Furthermore, environmental conditions and climate changes begin to have a large influence on how we plan our cities and Stig L. Andersson defines, in response to this, a new way of looking upon our city planning. He calls the approach 'Process-urbanism' (Procesurbanisme) (Andersson, 2012 pp 1). Instead of the traditional way of very strictly structuring and controlling the urban design, process-urbanism focus on what we know of nature- and eco-systems and how it functions. The aesthetics become less important and nature is set free to sprout helped by intelligent design strategies. Replacing the master plan with a process plan allows, the plan to adjust ad-hoc whenever changes are needed or new knowledge is gained (Andersson, 2012 pp 2-3).

Even though Lynch and Cullen's theories are long-standing their observations are still what gives designers a foundation of theoretics to understand and manipulate the cities today. The classic 'cookery book' is still suitable today, as the ingredients never change. Together with the understanding of liveable cities and newfound environmental necessity, we should be able to create a conjecture of a coherent urban landscape.

THE IMAGE OF THE CITY

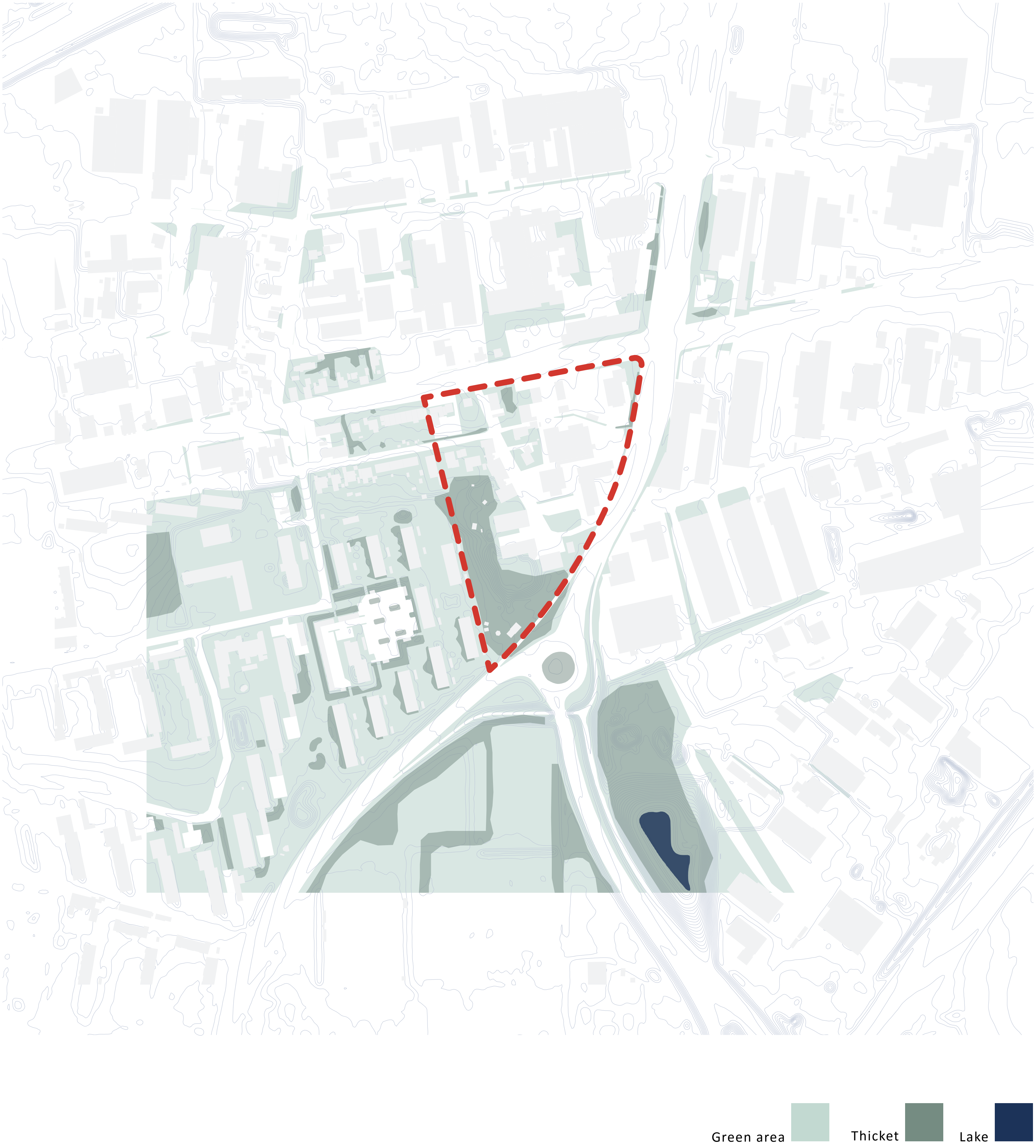
1:10.000 - An analysis made on the basis of Kevin Lynch idea of Image of the City. The area is defined by the two main roads, Østre Ringvej and Københavnsvej and becomes an area that is very exposed when entering the city from the east.



PICTURE TAKING WHEN WALKING TOWARDS THE SITE FROM THE TRAIN STATION. THE LARGE POWERSTATION AND THE WATER TOWER SHOWS THE WAY TO THE AREA.

LANDSCAPE CONDITIONS

1:4.000 - The area is mostly flat with a slight incline towards the north and a large pit on the south side. The vegetation comes from the south and culminates at the site.



CULTURAL CONDITIONS

1:4.000 - The area is mostly industrial use close to a large area of residential use. Punctual public buildings for sports and communities is to find around the area which has bus stops close by.

PICTURES ENTERING THE SITE.
1:4000 - Paths when entering the city.

1. Entering Roskilde, the site appears in the green.

2. When at the roundabout the site is almost fully visible.

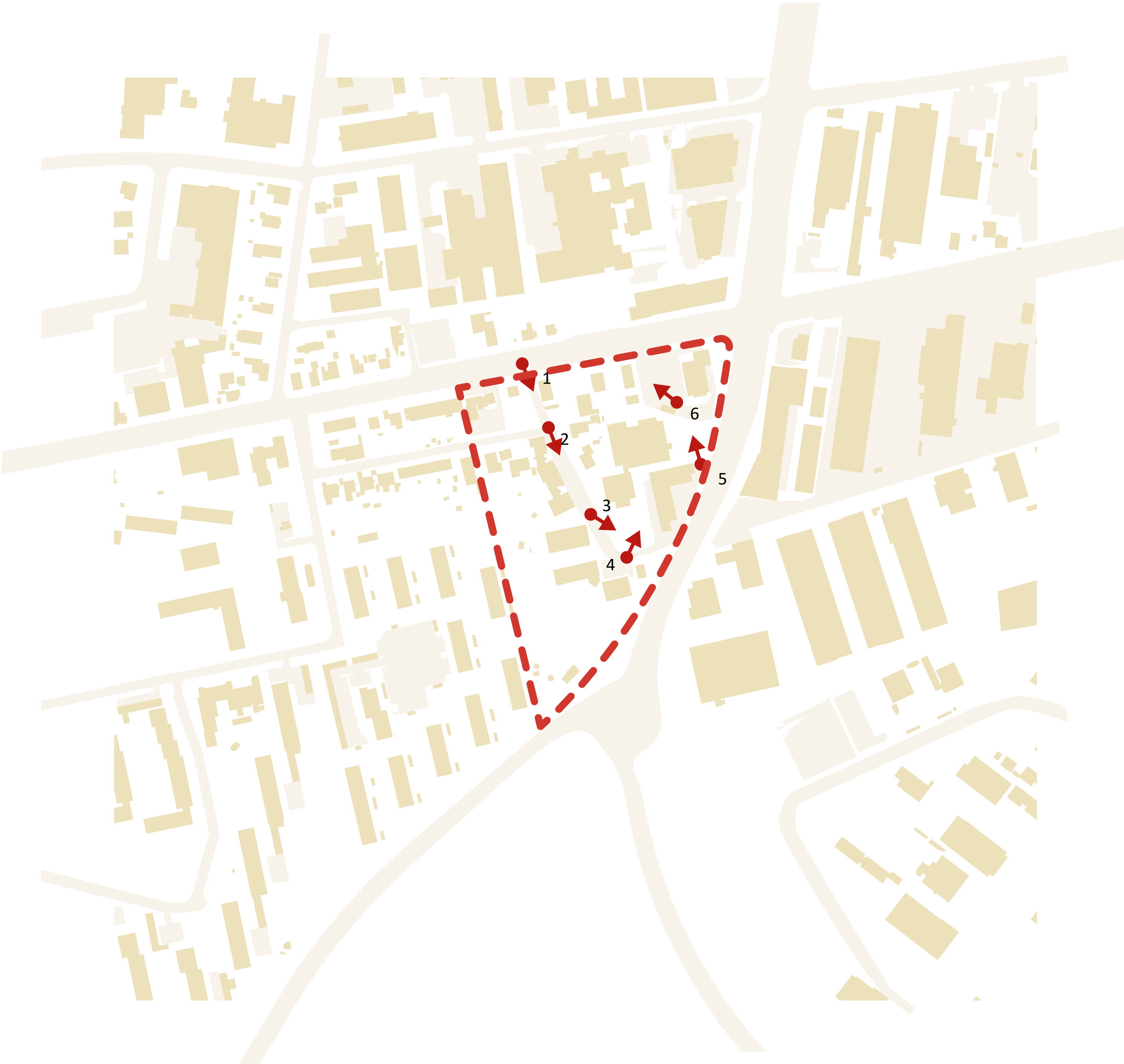
3. The site is open when driving along Østre Ringvej.

4. Entering Roskilde the Mc.Donalds appears as a landmark.

5. The site is fully visible with the Mc. Donalds in front.

6. An entrance just after the traffic lights confuses.

PICTURES AT THE SITE
1:10.000 - Paths within the site.



1. The entrance by first hand seem like residential.

2. Hedges creates a private atmosphere.

3. At the end the landscape opens op.

4. Turning around the buildings performs a backyard.

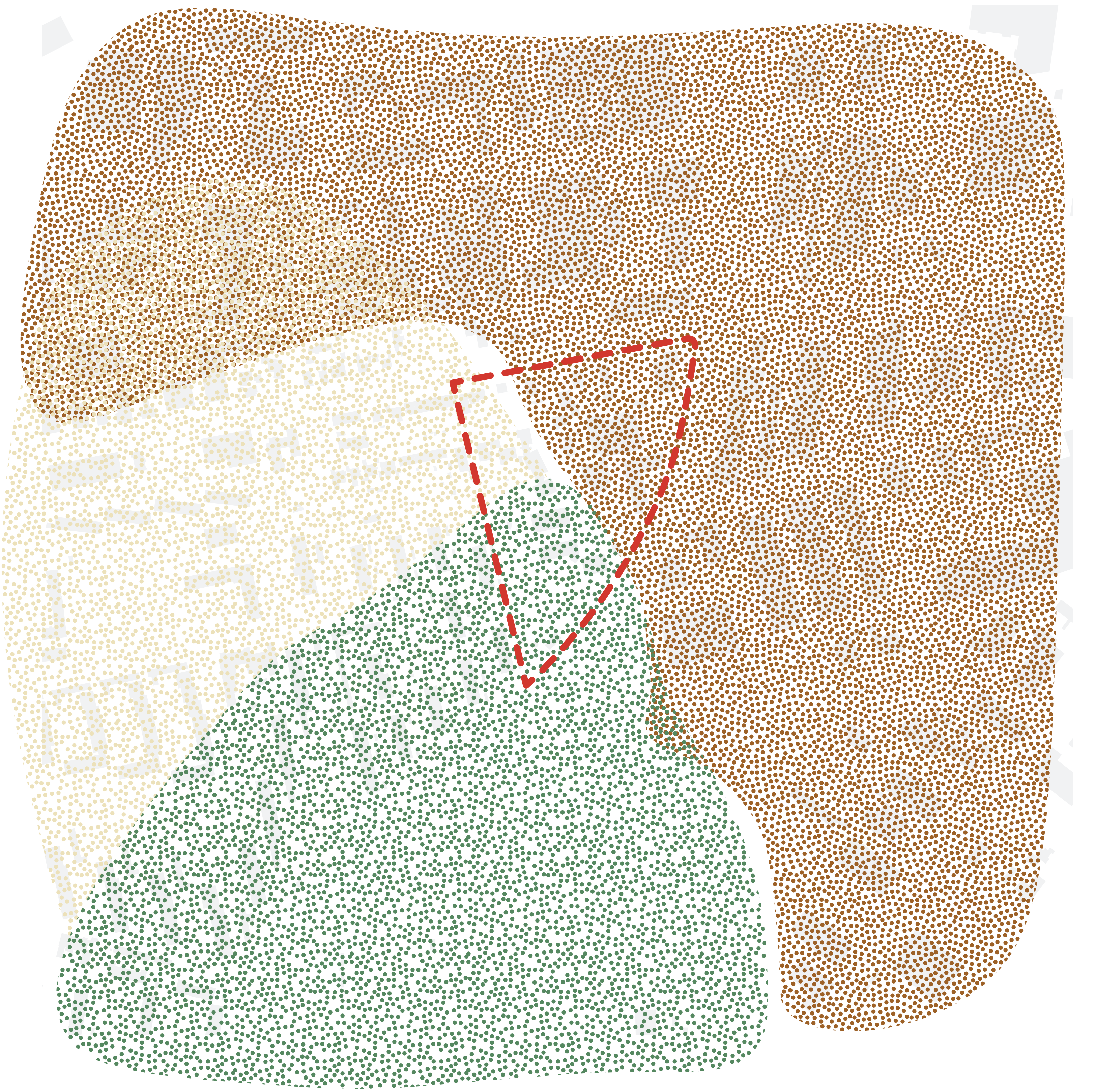
5. Most of the area is used op for parking for the industry.

6. The area is mostly a playground for cars.

PICTURE OF THE POWER STATION, TAKEN FROM ALONG THE BYSCYCLE PATH FOLLOWING THE SLIP-ROAD FROM THE FREEWAY.

CONTEXT

1:4.000 The site is situated where areas of residential, nature and industry reach each other.



TRAFFIC NOICE IN 1.5M HEIGHT
1:4.000 The large roads leaves a lot of traffic noise, making the area almost uninhabitable.

Points of measuring at the side | 55 - 60 dB | 60 - 65 dB | 65 - 70 dB | 70 - 75 dB | Above 75 dB


Looking into the site when entering from the city through Københavnsvej.


Standing at the site looking towards south/west and the residential area.


Looking out from the site along Østre Ringgade and the industrial area.


Standing at the south side of the site, looking towards the north.

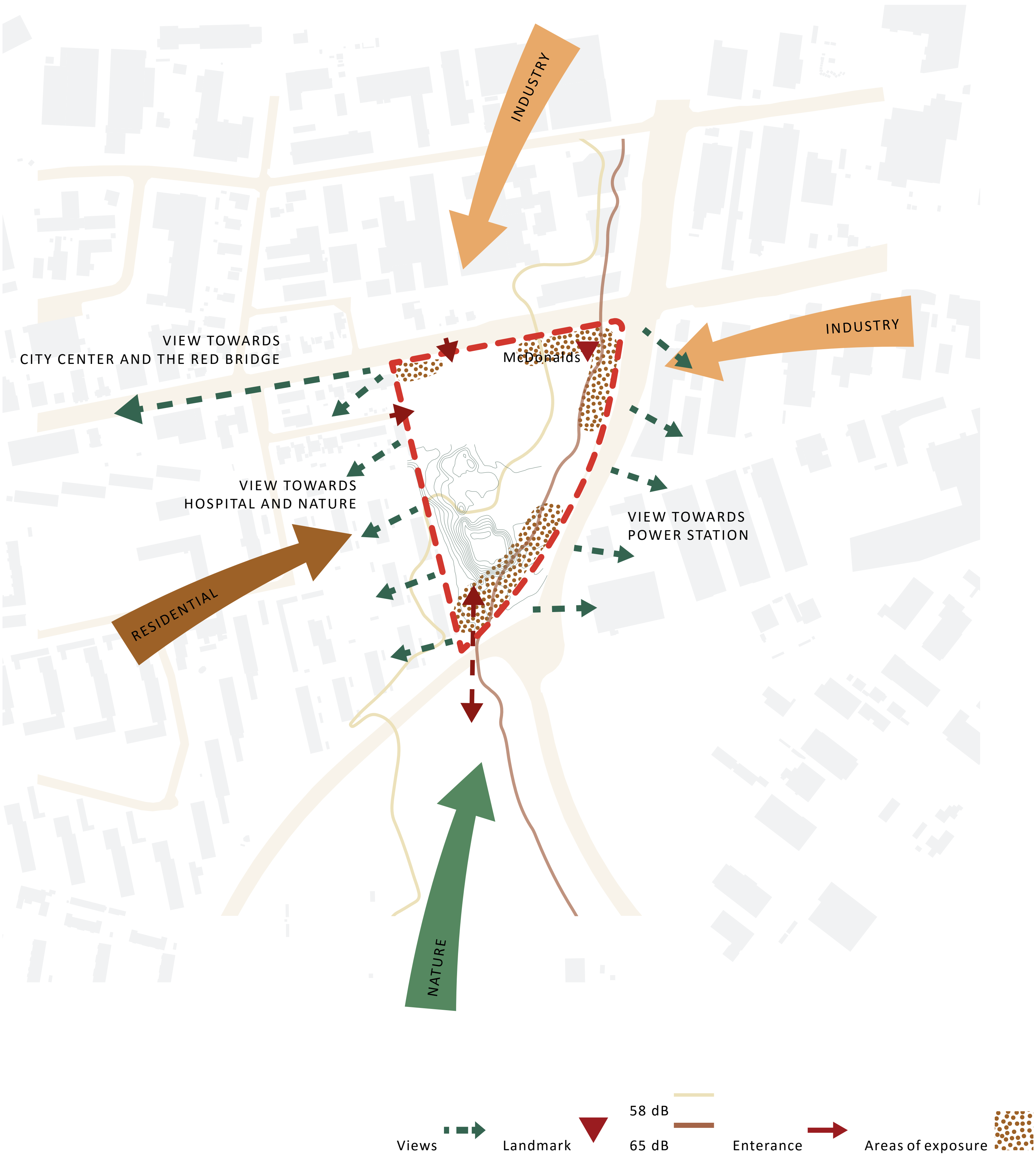

Standing inside the pit, looking at the residential area.

Design Parameters

By the combining knowledge of each map it is possible to gain a deeper understanding of the site, its possibilities and limitations. The site is an important location when entering the city from Copenhagen, one could say; the face of the city. This also results in some issues of exposure and noise. The industrial history of the site leaves a flat terrain with a large pit in the southern side. The residential and green areas which comes from west and north should natural be drag into the site to create more coherence with its surroundings, while the industry have little or no residential qualities. As the site is a part of the entrance to Roskilde one should also understand it in the sequence of driving and the sites important part navigating in the city. Furthermore the site has multiply points of interest for viewing, along Københavnsvej, the liveable-green residential areas and the power station.
Because of its location along the large main roads, the site also have an issue of entering, while one world preferably keep the landmark of McDonalds, more access/entry points will slow down traffic resulting in annoyance for the rest of the city.

The map to the right, the Design Map, shows the issues and limitations which one have to accommodate for when designing a new residential area for the site. By using this map as a design generator or design parameters, one can begin to propose conjectures.

DESIGN MAP
1:4.000



Selected design criterias for the town phase

The new town landscape should be a part of the city entrance from Copenhagen (Kevin Lynch)

Because the area is unavoidable when entering Roskilde from Copenhagen it is important to think of the area as the entrance for the city of Roskilde.

Activate exposed areas (Kevin Lynch & Gordon Cullen)

The exposed areas, as shown in the design map, shows areas that are avidly exposed when driving or biking around the site. These areas should have extra care as they are the ones one will comprehend mostly.

Shield for traffic and industry noise (Gordon Cullen & Noise Map)

The industry at the east of the site and the large roads of Østre Ringgade and Københavnsvej creates a lot of noise. In some way, this noise should be abrupt so that most of the area is without noise problems.

Create a connection between the town landscape and surroundings (Kevin Lynch)

The site is at this point disconnected both to its industrial and green areas by Østre Ringgade, and the residential area because of fences and changes of function. The connection between the site and residential and green areas should be made stronger.

Make use of views towards the city (Kevin Lynch & Gordon Cullen)

The analysis inspired by Kevin Lynch shows how there are great landmarks in the area. By creating views towards these you gain a connection to the surrounding city.

Making use of terrain conditions (Landscape Conditions)

To avoid expensive terrain transformations and to allow for the atmosphere of the place to be a part of the new town landscape the old terrain conditions should be kept and enhanced.

Invite nature into the area (Kevin Lynch & Vandkunsten)

Nature is in general neglect at the site. Accordingly to Vandkunsten; vivid nature should be a large part of the new town landscape.

Having only a few entrances to the area (Boligselskabet Sjælland & Kevin Lynch)

The large roads have a lot of traffic which should slide as easily and quickly as possible. To avoid annoyance for the public there should be as few entrances as possible. These should only be situated towards the west and Københavnsvej as the traffic is too dense at Ringgaden.

Building ratio of 120-140% (Boligselskabet Sjælland)

In a collaboration between me and Boligselskabet Sjælland, it has been decided that the building ratio should be around 120-140% This creates a dense city and a need for a large variety of different functions creating a lively town landscape.

Mixed-use buildings (Restaurants, Offices, Public and Residential) (Vandkunsten, Livability)

The buildings should be mixed-use and should have different functions to create a lively and livable city with easy access to most of the needed things in everyday life.

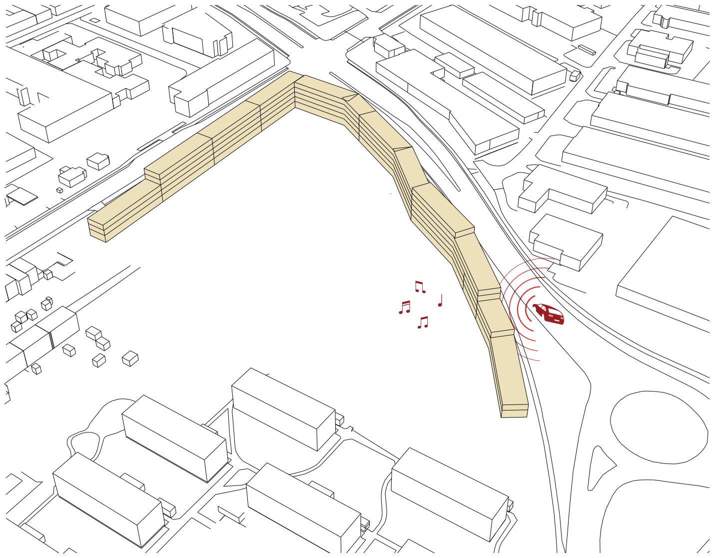
Internal spaces should have different characters and spatial experiences (Gordon Cullen)

The town landscape should consist of a variety of multiply special compositions such as enclosure, gestures, deflection, exposure, intimacy, levels. This creates a city of experience and excitement where one can both discover new things and find one way when necessary.

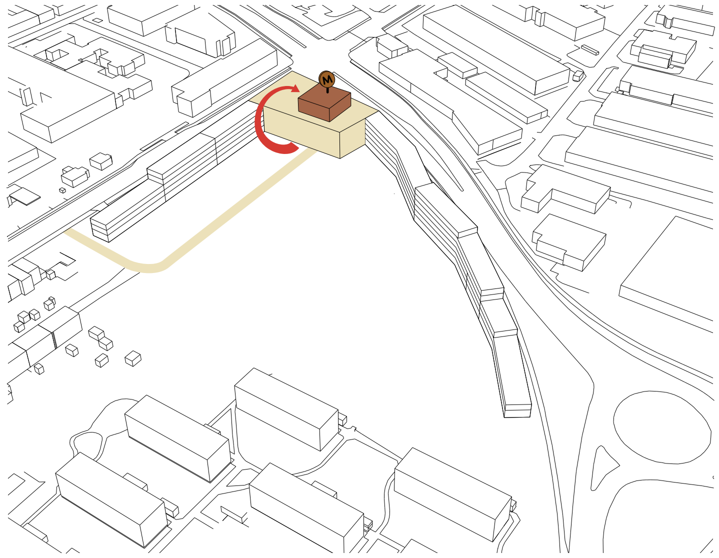
The new town landscape should allow for changes according to new knowledge (Process urbanism)

To accommodate for new knowledge and needs the area should be provided with flexible and changeable solutions which can be multifunctional or changed through time.

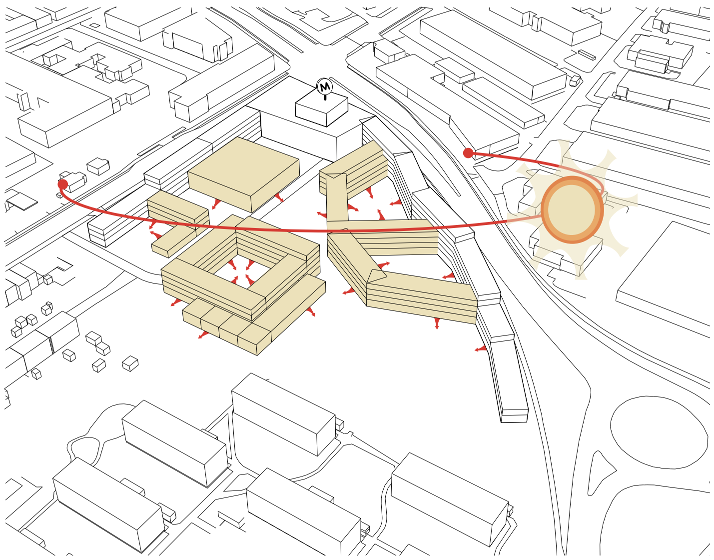
DESIGN STRATEGIES
Different strategies accommodate different problems stated in the Design map.



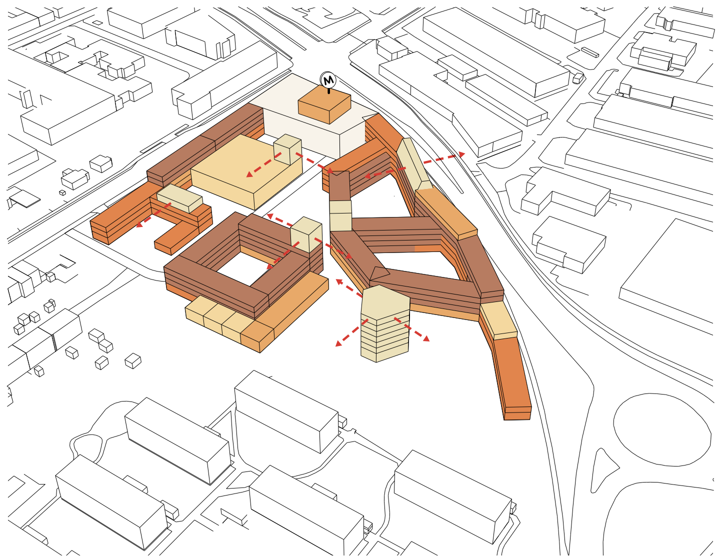
BUILDINGS SHIELD FOR NOISE CREATING A LARGE LIVING AREA



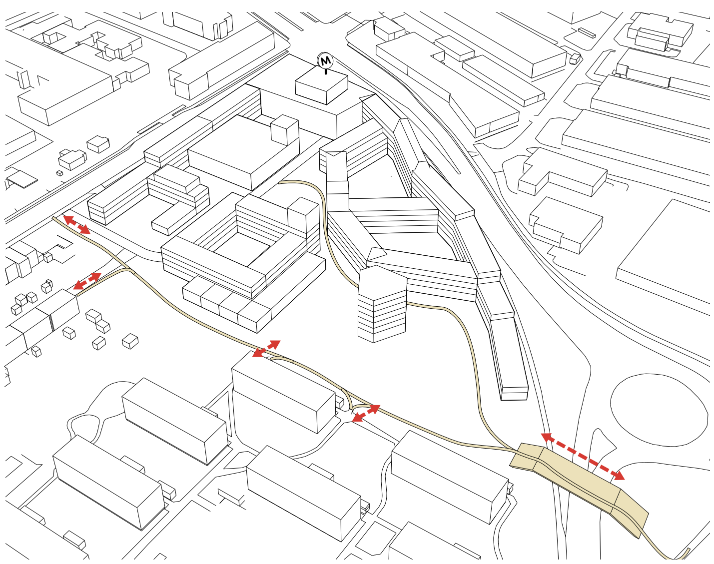
ONE MAIN ROAD LEADS TO A PARKING AREA WHICH HANDLES THE MCDONALDS



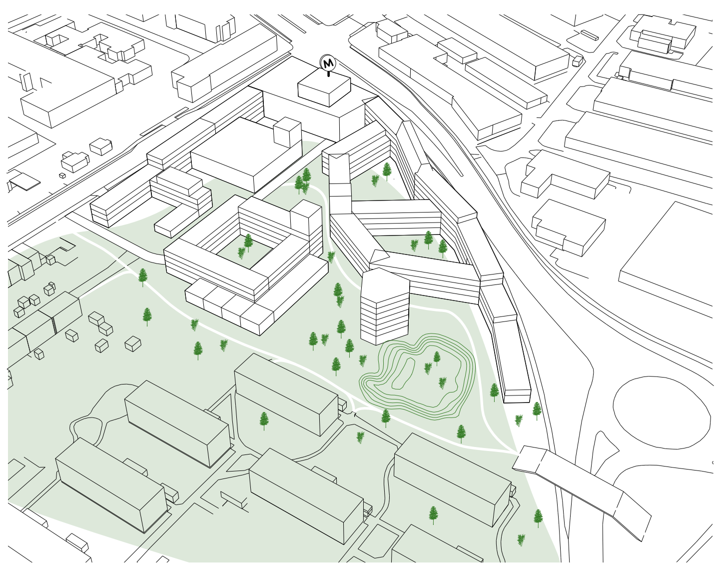
COURTYARDS WITH VARIATION I BUILDING SIZES AND HEIGHTS ALLOWS THE SUN TO ENTER



TOWERS CREATE VIEWS, VARIATION AND ORIENTATION VARIATION IN A FUNCTION CREATES DIVERSITY

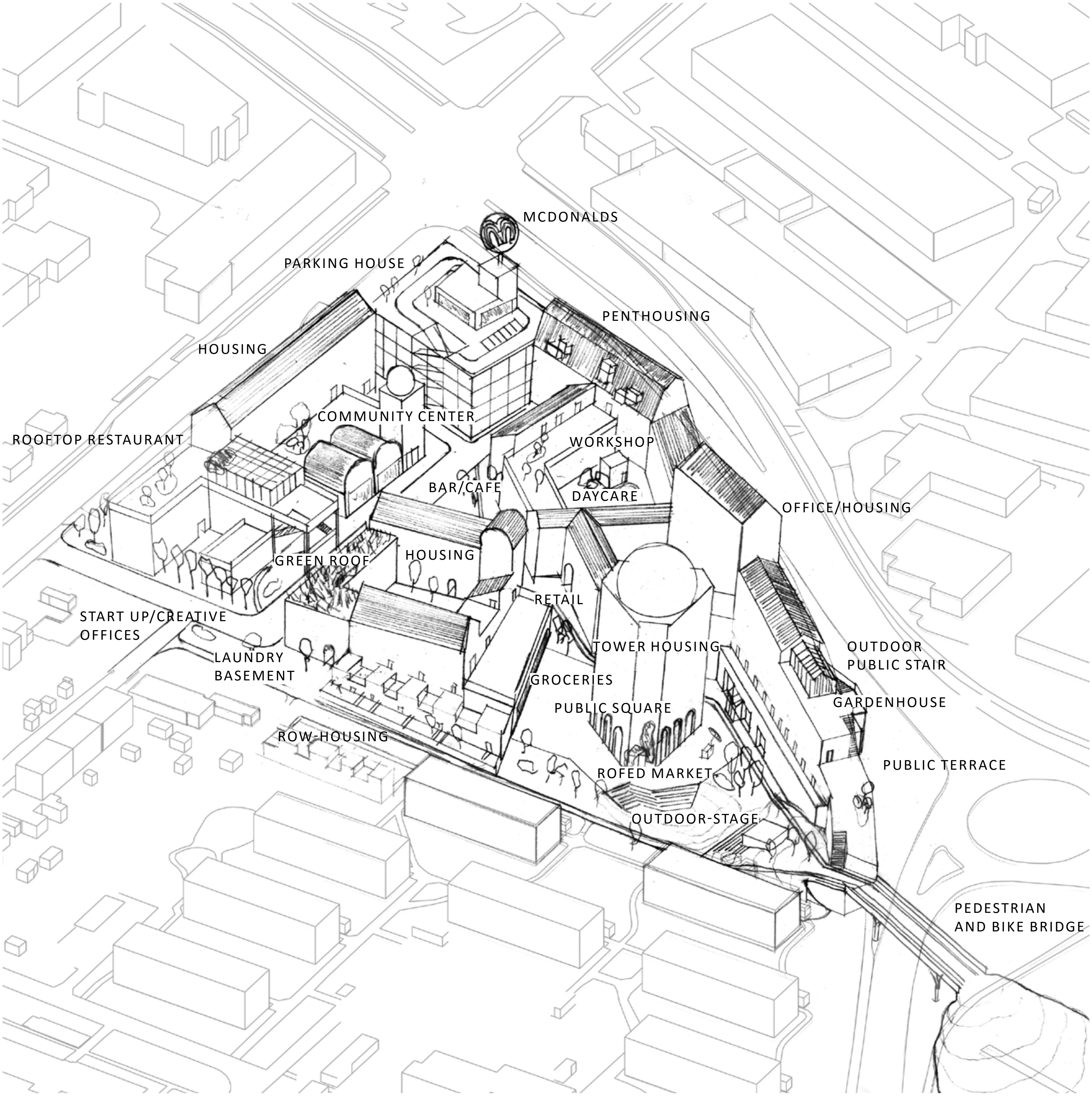


BRIDGE AND PATHS CONNECTS THE AREA TO THE REST OF THE CITY



GREEN AREA AND EXISTING TERRAIN IS INVITED INTO THE AREA

CONJECTURE 1
An urban landscape of multiply use and variation in spatial qualities expression and hights.



Phase 2

The Neighborhood

The neighborhood

As we analyze our design parameters through the conjecture of the town phase we begin to understand what the neighbourhood might seem like in our studies. Even though there is still a very long way towards something meaningful. The conjecture gives us answers to some of our found problems and provides us with an image that we can use for further investigations. A stepping stone for our header into the design phases.

Our conjecture of a town provides us with new questions and new problems which should be addressed on a scale of the neighbourhood. How are the buildings orientated towards one another, what are the scales of outdoor spaces and what are the uses of these? Do we provide the buildings with necessary lighting conditions, what are the result of buildings as the means of shielding for the noise? These and many other questions occur while still new ideas and yearns emerges from our first sketches.

To understand our neighbourhood we begin by understanding a neighbourhood, its theoretical elements, internal forces and their expressive qualities.

Just like cities, neighbourhoods have evolved and is a result of changes according to newfound knowledge, challenges, and beliefs of the people planning for them, building them, and living within them. Investigating the history of Copenhagen The danish author Tove Ditlevsen describes in "Barndommens Gade" her childhood home in the slum of Copenhagen in the 1920'ies as almost happy melancholy. But looking at the neighbourhood from outside only the gloominess is described:

"... Bag facaderne (Vesterbrogades pæne facader (red.)) tårnede parallelle rækker af høje ejendomme sig op om første, anden og undertiden også tredje baggård. Den inderste af disse smalle skakter mellem himmel og jord blev ofte kaldt "den grønne gård", fordi solens stråler aldrig nåede derned og plankeværkerne derfor var evigt algegrønne"

"Behind the facades (Vesterbrogades nice facades (red.)) grew parallel rows of high housing up around the first, the second, and now and then also the third courtyard. The central of these narrow shafts between the sky and the earth was often called "the green yard" because the rays of the sun never entered and billboards were because of this forever alga-green" (Pia Fris Laneth, 2018. About Tove Ditlevsens childhood neighbourhood).

In 1853 the Cholera epidemic reached Copenhagen and because of the slum and poorness, people lived in, the city where afflicted hard. The open sewers, the lack of healthcare knowledge and the enormously density people lived in were good conditions for the epidemic. As a response to this, the first common housing was built by the Danish medical association. These housings were constructed to provide the poor a livable home with fresh air, daylight, and large green areas. The houses were constructed outside Copenhagen next to cow fields and were named according to that "Brumleby". Since then the common mantra of new housing has always been to provide fresh air, daylight and nature whatever you live in the city or at the countryside (Dansk Arkitektur Center - DAC, 2021).

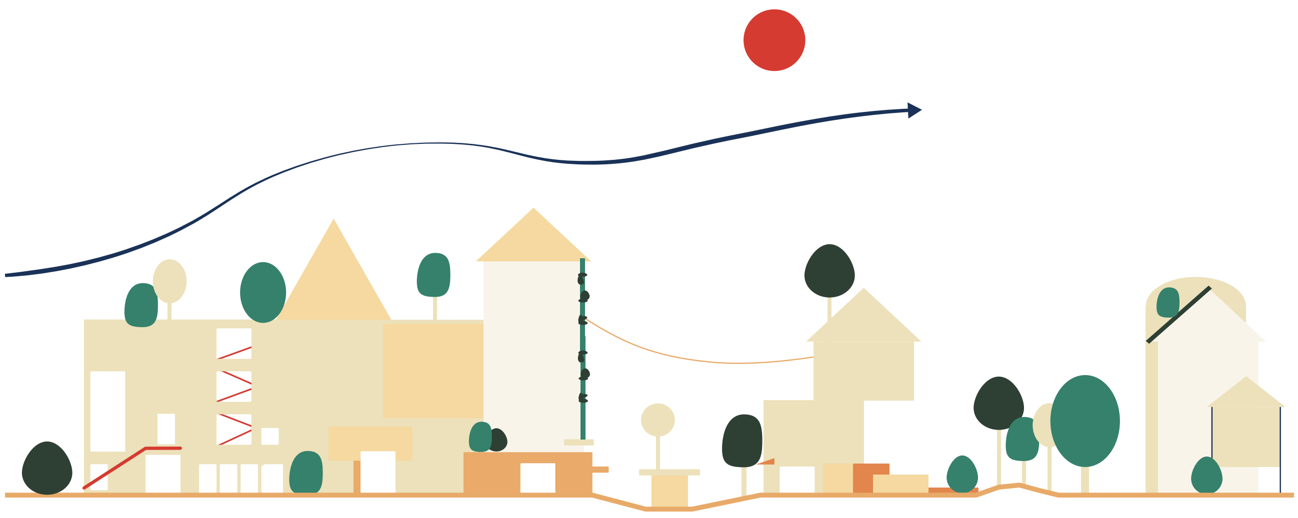
In 1970 Copenhagen initiated their "urban renewal" initiative which removed the rest of the slum and established green and open areas inside the courtyards. After the second world war, it culminated with large building blocks as Gellerupparken which were built upon the ideas from the modernism architecture period, providing both space, light, fresh air, and cheap apartments for everyone. Today these areas are often known as ghetto areas where crime and immigration are the most common associations one gets to these buildings. The response to these issues came from Vandkunsten in 1983, where they build Tinggården and defined a new way of living in common-housing; the "dense-low" movement.

Today in Denmark more and more people are moving to the larger cities. The government have used several initiatives to keep or move some of the jobs to smaller cities but despite this attempt, the cities are under large developments. This urbanization combined with increasing climate awareness makes it important to ask the question of what kind of neighbourhood we are actually designing. Maybe it is time to reconsider the idea of living in the city referring to our initial thesis:

Is it possible to create a city that both has the necessary density of contemporary city areas and at the same time the liveable quality of Vandkunstens dense-low buildings?

One of the leading studios working with a practical implementation of livability today is Gehl Architect. Jan Gehl, with his book "Life between buildings", has defined a new way of looking upon urban design which is practical, functional and sensible. Latest from the same studio, the partner, David Sim defined "Soft City" which should be understood in the context of "Life between buildings" and as a modern and updated version of this.
Soft City is a response to the challenges which the modern city is faced with today; Climate changes, fast-growing urbanization and congestion and segmentation (Sim, D. 2019. PP.3) A soft city is not about the viscosity of a city but should be understood as a feeling or state of mind. Soft City is related to words as easiness, comfort, diversity, simplicity, senses, trust, inviting, ecologic and solitude. David Sim defines nine criteria for a dense city that is "nice to live in". These criteria can be almost 1-1 implemented in a project as they work as guidelines and examples of ways of addressing different issues of the city.

To gain a larger understanding of these criteria we afterwards attempt to discuss and implement the terms in an analysis of two different neighbourhoods. Øgaderne and Ceresbyen in Aarhus. In this way, we might be able to understand how neighbourhoods from two different periods and with two different backgrounds address the livability of a dense city.

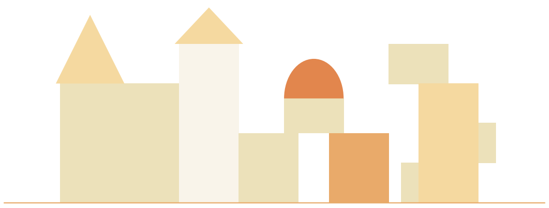


A dense city that is "nice to live in"

Soft City

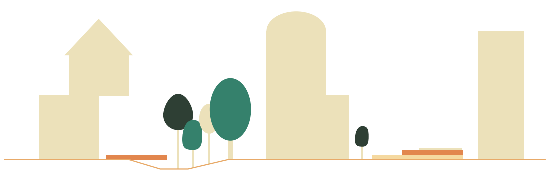
The nine quality criteria defined by David Sim are a way to understand and talk about livability in dense cities. In general, the criteria expresses the quality in diversity, flexibility, nature and human scale. The building ratio and quantitative data are less important where qualitative feelings and experiences is a significant factor. Cities should bring people closer together. Besides these criteria, David Sim stresses the importance of relating to surroundings and existing physical constraints (Sim, D. 2019 pp. 212-231).

Different building forms:



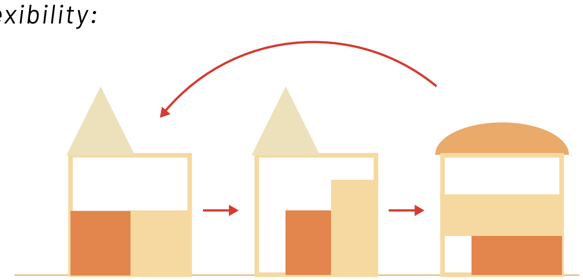
- Different buildings
- Different dimensions
- Different typologies
- Smaller building sites
- Different forms of ownership
- A balance between building components: Ground floor, middle floors and roof floor
- Visual variation

Diverse urban spaces:



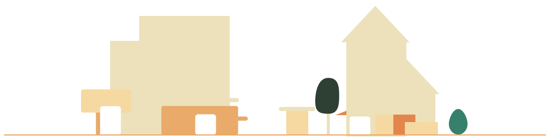
- Different public spaces
- Different private spaces
- Different shared spaces
- Different typologies of spaces that meet different users and needs both general and specific
- Hybrid spaces that connect outdoor and indoor
- Different dimensions of spaces
- Variation between surfaces in different spaces
- Streets as public spaces
- Public spaces as places for mobility

Flexibility:



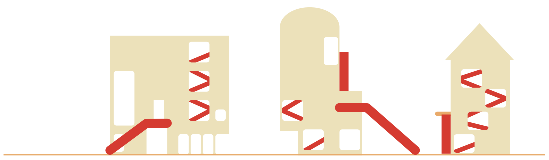
- Multifunctional spaces, indoor and outdoor
- More building volume on the ground floor
- Direct access to different parts of the building
- Secondary spaces as basements, roofs and sheds
- Backsides with space for expanding
- Encircled spaces that allow for different activities
- Used edge zones along the building façade
- Property and buildings as independent parts

The human scale:



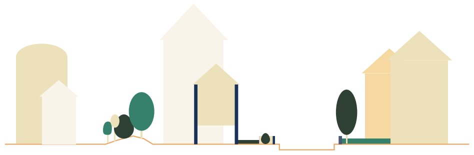
- Smaller dimensions
- Smaller spaces
- Preferably 4-5 stories max.
- Variation of sensual experiences
- Designing for eye-high experience
- Quality in eye-high

Walkability:



- Buildings that are easy to walk into
- Buildings that have direct access to the front and backyard
- Buildings with a height which invite to take the stairs
- A larger area of ground floor
- A visual and physical connection between outdoor and indoor
- Buildings with direct access to usable outdoor spaces
- Walkability in the neighbourhood

A feeling of control and identity:



- A clear distinction between public and private
- A hieratic of clear known places
- Spaces that invite the community
- Front and backsides
- Encircling spaces and special clarity
- Smaller units and building sites
- Usable edge zones
- Important building edges

A comfortable microclimate:

- Stabile climate conditions in spaces
- Protect against strong wind and turbulence
- Smart use of shadow and sun
- Aerodynamic roof forms
- Protecting and encircling outdoor spaces
- Usable openings as windows and doors
- Protection against rain

Smaller carbon footprint:

- Fewer exposed facades
- Less dimensioning in consideration of ventilation and natural light
- Simple building methods and foundation methods
- Less complex technology
- Organization that allows for walkability

More biodiversity:

- Many smaller individual green areas
- Many protective spaces and edge zones
- Smaller building dimensions with green walls and roofs
- Green elements where it is possible
- Smaller scales of water filtration
- Street trees
- Flood managing in green areas

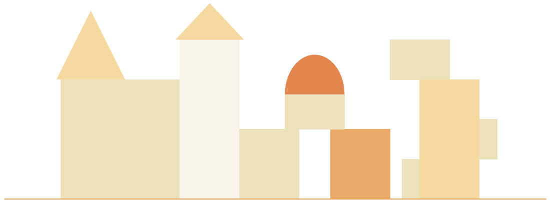
Case studie: Øgaderne in Aarhus

Øgaderne is the first working-class neighbourhood in the city of Aarhus. The oldest buildings date back to the year 1850. It has been the home for unskilled workers, craftsmen, sewer, artists and students for many years with a history as one of Aarhus most multifarious areas. Tenants' group meetings and resident co-working has defined the streets for years which today results in strong solidarity and unique living situations. The neighbourhood is one of the most popular and expensive places to live as it is close to the city and offers a romantic and historical atmosphere (Aarhus.dk, 2021).

5 ØGADERNE IN AARHUS

Site area:	300.000 m2
Building ratio:	100%
Building hight:	1-5 floors
Site use:	Housing, kindergarden, School, Offices, Fire station, shops, Cafe, Common buildings
Build in:	1850-1970

Different building forms:

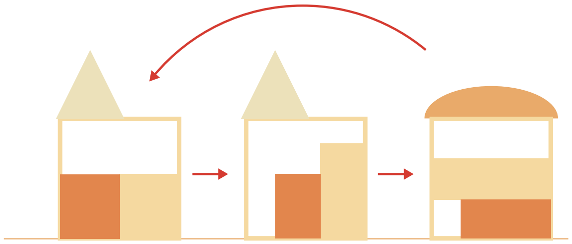


The area is defined by large building blocks, divided into smaller building sites, owned by various people. This gives a variation in building forms, typologies and roofing. Especially the visual variation differs a lot as building owners have chosen different materials and building techniques for their building. The building sites are often divided into smaller sizes which creates a rhythm, even though the street facades have little or no displacements. Mostly these variations and displacements are found inside the backyards. The height of the building blocks provides a good balance between the ground floor, middle floor and roof floor which also gives visual and livable variation for occupants and pedestrians.

Diverse urban spaces:

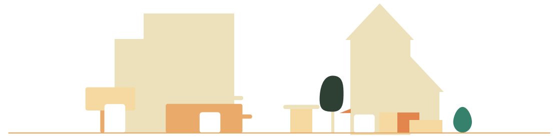
The variation in public spaces is often defined by the variation in the streets. There are almost no larger public areas in the area. On the contrary, there is a large variation in the private spaces, as gardens and roof tops create multiply ways of using spaces. Often the gardens work as shared spaces where everyone from one building site can meet together for a beer on a sunny day. The shared spaces are often situated together with the public buildings and community buildings, where residents meet with other people from outside areas. Between some of the building blocks, there are some breaks in the street urbanity where larger gardens or daycare playgrounds occur.

Flexibility:



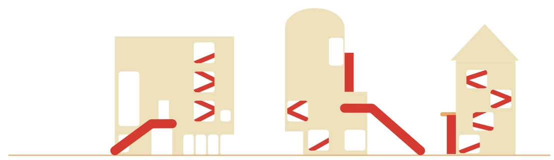
The neighbourhood is very much characterized by the changing of function over time. People have had their possibility to add and subtract to their homes, changing some of them into offices or and some from workshops into homes. Many additions have been built on the ground floor because of need or want from the residents. Housing inside the courtyard may be used for offices as they don't require the same indoor conditions as homes. This creates diversity in how and when areas are used. Many of the houses have basements and rooftops which allows for many variations in use as well as variation in flow and expression.

The human scale:



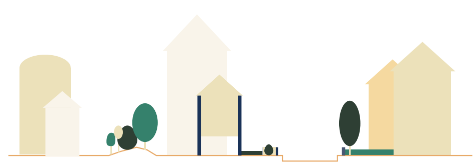
The area is mainly kept in a human scale with building blocks of maximum 5 stories and large variations inside the blocks. Smaller spaces both private and shared create the possibility to feel enclosed and safe. The level of detailing in eye height is high as doors are painted in various colours or special woodwork details attracts the eye. This sensual experience is both a result of the old buildings from a time where workers labour were less expensive, but also a result of user interaction and personalization throughout the years.

Walkability:



Because of the low building heights - and that many of the buildings were build before the requirements of elevators - the walkability is very defining for the area. Scales of streets and outdoor areas are built for pedestrians and it is easy to access from apartments to both the street and green areas. The use of rooftops and sheds creates a possibility for an experiential walk where one can go on an adventure while the streets allow for fast access to different parts of the city.

A feeling of control and identity:



The building blocks create a clear distinction between public and private spaces. The levels of details create a feeling of identity and can be used to navigate for occupants. The lack of landmarks makes it hard for people from the outside to find their way, but for this area, getting lost is a part of the romantic experience. There could be a more integrated use of the edge zones and public spaces to make room for more community and to construct a city that is more "alive" throughout the day.

A comfortable microclimate:

The clear distinction and variation in publicity and green spaces gives room for many different microclimates. One can see how different spaces are used to both gain sun, shadow and shelter. The buildings have openings which allows the apartments to interact with nature and invite nature inside. Some places the lawn becomes a community space other places the shed a roof terrace.

Smaller carbon footprint:

The clear distinction and variation in publicity and green spaces give room for many different microclimates. One can see how different spaces are used to both gain sun, shadow and shelter. The buildings have openings that allow the apartments to interact with nature and invite nature inside. In some places, the lawn becomes a community space other places the shed a roof terrace.

More biodiversity:

The area is by first hand not very biodiverse. The green areas are often hidden inside the building block. The area could benefit from having more public greenery in streets and public areas. On the other hand, nature is vivid and free inside the courtyards, where it seems as if the occupants have a competition with their neighbour about who can have the most plants. This allows for great biodiversity inside the building blocks. Plants are allowed to grow on facades and are allowed to grow without much interaction from occupants, this gives the feeling that the houses are an integrated part of nature.

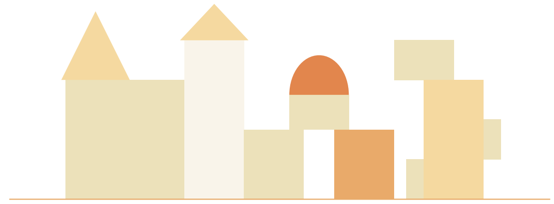
Case studie: Ceresbyen in Aarhus

Ceresbyen is a transformation of an area that was once the location for the old Ceres brewery factory. Today it is a modern city area, close to the centre of Aarhus and the nature areas of the Brabrand-lake and Ceres park. The area houses around 2000 people both large family apartment, elder apartments and student housing. Furthermore a large VIA collage of 5000 students, a small café, offices and groceries. This means that this new area is in use most of the day and is a central part for many of the occupants of Aarhus.

6 CERESBYEN IN AARHUS

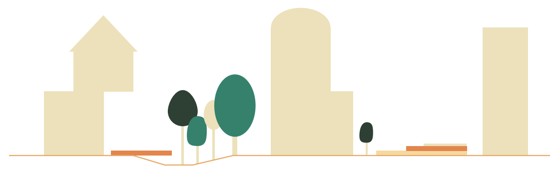
Site area:	80.000 m2
Building ratio:	175%
Building hight:	3-18 floors
Site use:	Housing, VIA-School, Nursing home, Offices, Park, shops, Cafe
Build in:	2018

Different building forms:



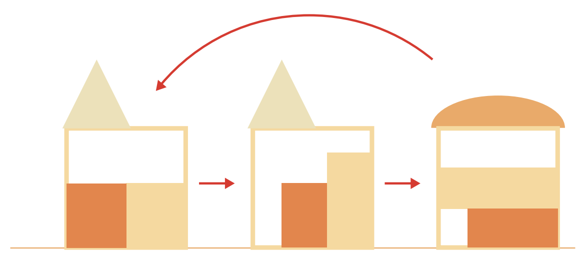
In Ceresbyen every building block seems the same as material expression and building form is similar across every building block. There can be small variations where one or some of the facades are changed. Almost only the buildings have a different function, as the VIA college have a different form. It is difficult to distinguish between the different building layers as there is almost no difference from the ground floor to the roof floor. This lack of differentiation makes it easy to get lost and boring to walk around. Furthermore, the similarity in building form makes the apartments seems the same. This means that you as a pedestrian wouldn't walk around and point to different places you wish to live in, as you don't see much difference in any of them.

Diverse urban spaces:



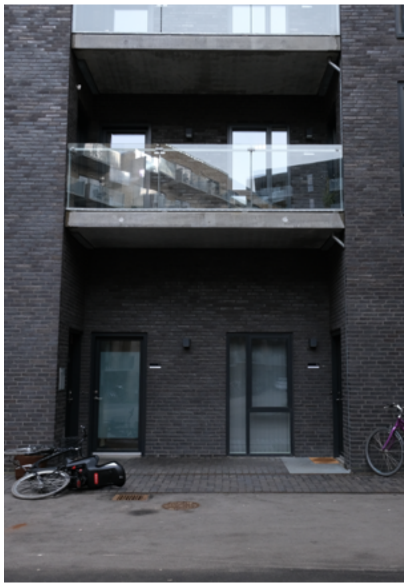
A main road goes through Ceresbyen which, when you follow it, takes you through a variety of urban spaces and small squares. This road is intersected with some smaller paths providing connections from the neighbourhood to the park. The variation of these roads works well and creates excitement when walking along, as you often see something new. When you look inside the building blocks, most of the shared spaces seems similar with a clear lack of private spaces in general. Most of the build area is full of asphalt and sharp edges which provides a certain feeling of contrast when you walk into the parking area.

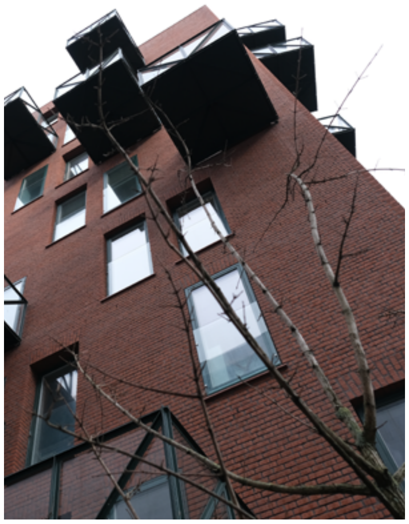
Flexibility:

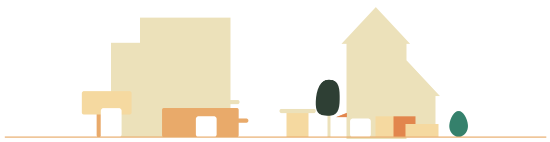


In general, the building blocks feels very rigid and fixed, with little or no possibility to change, add or subtract building volumes. Especial the materials of concrete, steel and glass make it hard to imagine small changes, as the material in themselves are hard to process. The back yards are filled with pre-defined and insito-cast programming which makes almost no room for activities of the occupants. On the contrary, the apartments are made easy for changes, as a 4 room apartment can be made into a 3 room by simply removing a wall. The combination of materials and similar ownership and occupancy in the apartments results in limited variation in apartment expression.

The human scale:

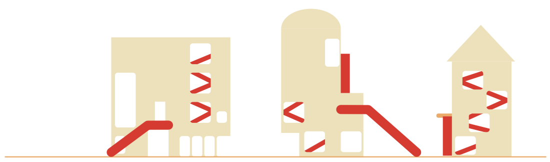






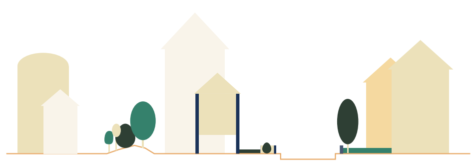
The areas are in general designed with large dimensions, and large spaces which seems unused. This result in an area where the bikes and the bulky waste is the most exciting thing to investigate. The lack of finishing on the ground floor makes the facades uninteresting and sometimes unpleasant to walk beside. The nicest places to walk is beside the café, sports area or workshops by the VIA Collage, but right next to this -exciting glimpse of what happens on the inside- the wall turns massive concrete and 8 meters tall.

Walkability:



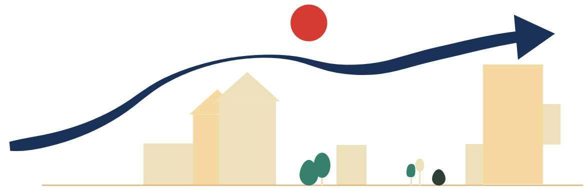
The area is in general easy to walk around in as it is almost car-free. This is a result of a major car park below ground level. This means that in many places, one has to climb stairs to access the area. One could this as both annoying and as an interesting part of experiencing the neighbourhood. The large building volumes and the lack of ground floor doors make it hard to understand the flow in and out of the buildings. Often there is only access to the apartments from either the front or the backyards, and the outdoor gateways are often in a dimension where one is in doubt whatever the backyards are a public or semi-private space.

A feeling of control and identity:



The similar building materials and volumes and the unclear distinction between private and public areas make it difficult for people to inhabit both their common and private spaces. The edge zones become unusable for anything else than trash and bikes. Only a few places people have managed to fight the uniformity, but it is as if the buildings almost fight against it. As an example; the florist has inhabited the sidewalk, but the overhanging balcony, which is identical with almost 100 balconies above and besides, somehow makes no room for other things than itself.

A comfortable microclimate:



The area has made use of modern technologies of daylight and sunlight analysis. But the microclimates are somehow lost in the equation. There is little or no public protection against sun, wind and rain in the area. The large buildings push the wind into the main street and thereby enhancing it. Many of the balconies are placed in all-year shadow or extremely radiation during summertime. The nicest place to be is between two large building blocks covered with weirdly sized indoor walk-bridges. This space provides both the perfect amount of sun and shelter.

Smaller carbon footprint:

The optimized and dense building blocks are nevertheless built to optimize energy consumption. But this is done with the price of a CO2 costly material, concrete. Many of the buildings seem to rely very much on complex technology as large mechanical ventilation systems and solar power. The openings in the façade are optimized for extreme passive sun radiation and then ventilate to the fullest when overheating occurs. Some places as the VIA College uses low technology strategies as the overhang in front of windows, which gives some sort of identity to an otherwise dull building.

More biodiversity:

Each building block has its green area, often this is just grass or a few trees. A few places the park enters between the building sites, this allows for a more green but still very controlled area. A few street trees surrounded by concrete are to live up the grey surroundings in the main road and almost no buildings are with green roofs, even though every roof is flat. It seems that the only reason for using and establish green areas is because of flood risks.

Design Parameters

Through the first conjecture, we have gained an understanding of how we can solve some of our initial and site-specific problems by using them as generators for a design proposal. To gain a more profound understanding of this design proposal we have investigated what is meant by neighbourhood and what it should provide us so that we have the possibility to plan for it. This is done through investigations of the "Soft City" which presents us with terminology and dilemmas for neighbourhood planning. Important issues as the necessary noise reduction and passive solar radiation have been investigated through quantitative analysis and oriented solutions (Appendix pp.126-132).

The plan to the right shows the result of how the first conjecture have been manipulated through the gained knowledge of the analysis and a new conjecture occurs. This plan addresses the issues of a neighbourhood but forces us to ask new questions as to how are the building expression, how are the different areas used and what defines these uses. The conjecture divides our city landscape into several different smaller urban spaces which all are defined through their limitations and possibilities. In general, there are four main characters of urban spaces; the courtyards, the rooftops, the streets and the squares. These are again divided into sub-areas which have to interrelate with the programming of the building and their site-specific necessity.

Courtyards
- Entreperneur Courtyard
- Urban Courtyard
- Public Courtyard
- Childrens Courtyard
- Garden Courtyard

Rooftops
- Active Roof
- McDonald's Roof
- Public Roof

Streets & squares
- The main street
- Predestrian street
- The alley
- Markeds Park
- The Pit

PLAN OF CONJECTURE 2
1:2.000 with a building ratio of 140%

Selected design criterias for the town phase

Buildings should have different uses according to their placement (Soft City, Noise & Sun analysis)

The different areas on the site have different limitations and possibilities. Some of them have issues with noise while others have minor sunlight or outdoor spaces. This means that buildings and functions should be placed so that their uses fits the environment. Furthermore, this creates a variation in city areas.

Floors should have different expressions and uses according to their conditions (Soft City, Noise & Sun analysis)

There are different conditions for the different floor plans; the ground plan have access to outdoor spaces but little light and the roof plan have much light but is more disconnected to the urban environment. This means that buildings should have different expression and functions according to floor plans.

Social and common activities should be integrated into the area (Soft City & Vandkunsten)

To create an area that is used and occupied by the occupants it is important to have a large variety of different common activities and functions. This creates a flow and meeting spaces for both residents in each stairwell, building, building block and neighbourhood.

Nature should have large freedom and influence on the area (Soft City & Vandkunsten)

Nature is a part of our health and well-being, this is why it should be an integrated part of the neighbourhood. The vivid and free nature creates also experiments and areas for adventure for kids while it is one of the most important factors for biodiversity and the planet environment.

Rooftops and easy access to outdoor areas are important (Soft City & Sun analysis)

Light and air is an important factor for our well-being, this is why we should have easy access to areas with fresh air and sunlight especially when living in a dense city. Through rooftops and outdoor spaces with a large variety, you not only gain a city of sunlight and fresh air but also a city with views of green areas and green roofs.

Outdoor areas should have different use and characteristic (Soft City & Sun analysis)

Each outdoor space has different conditions which allow for different functions, furthermore, there should be a large variety of spaces to create excitement and a feeling of belonging for each of the urban areas.

Roads should be for pedestrian mainly (Soft City)

Cars should be allowed to enter the different areas, especially because of people moving in and out, but also because of an occasional fire. Mainly the roads should be for pedestrians and there should be space for playing and meeting together with neighbours and visitors.

Buildings should not cast shadow on themselves or other (Sun analysis)

As the areas are planned as a completely new area, it is important to avoid building casting a constant shadow on themselves or other. This ensures that buildings have the necessity to gain the passive standards which are needed in the future.

Noise solutions should be a compromise of optimal special use and economics (Noise analysis)

There are many ways of containing and withholding the noise, but in general, it is a large part of the areas. This means that one should work with and accept this condition. The solutions should not only be to avoid noise completely but to optimize the area in a way that most of the area is livable and is occupied.

The different urban areas

One of the important factors of the design proposal is to foster and design for different spaces with different uses. The main typologies of urban spaces, Courtyards, Rooftops, Streets and Squares have different characteristic and functions which should relate to the buildings and the function of the buildings. Below are listed which functions should be placed in which urban spaces in general and some specific functions for the specific areas.

Courtyards

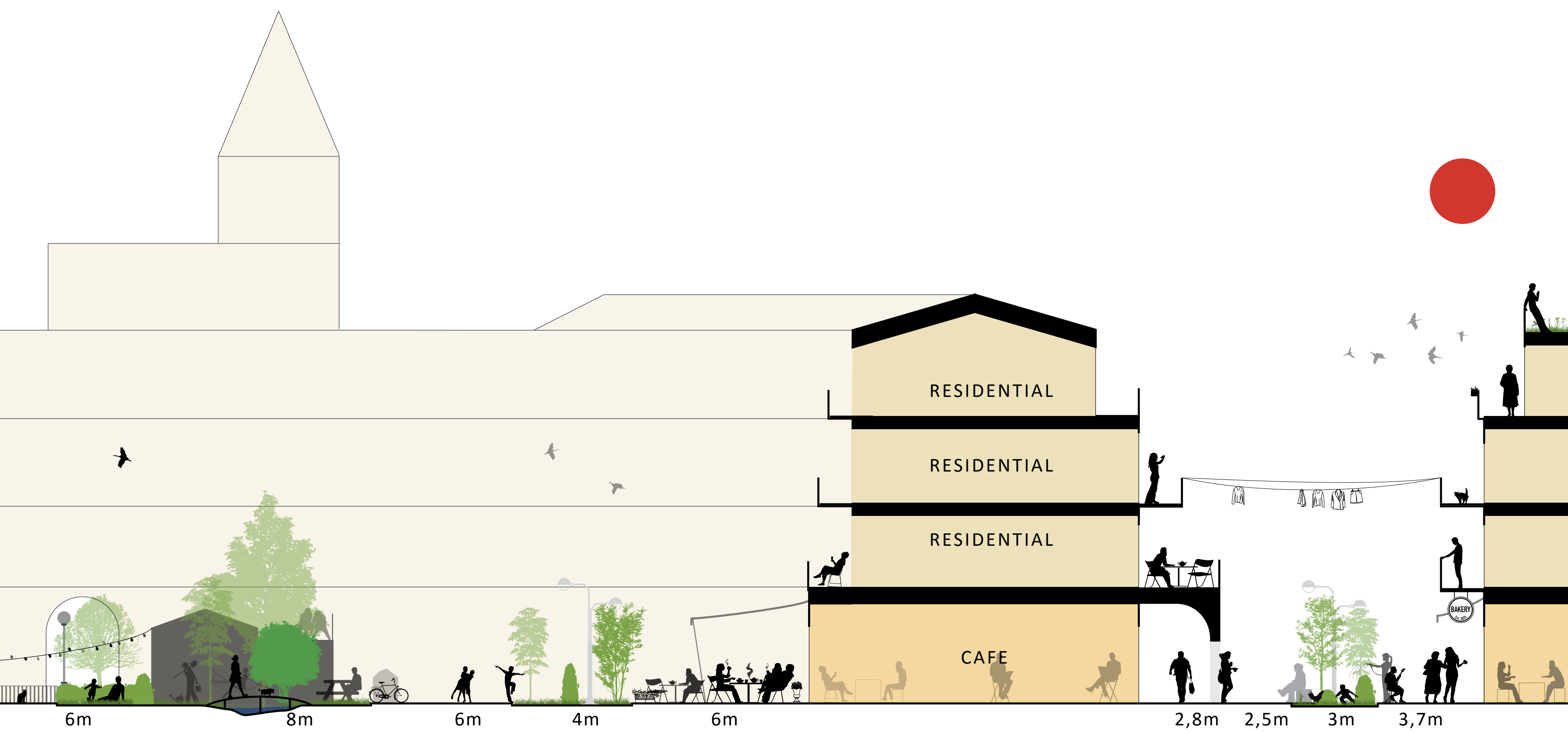
Common areas with shared functions
(Kitchen gardens, Animal stock, Greenhouse, Workshop area, Storage)
Waste sorting
Biowaste
Bike parking
Access for cars when moving in
Acess for firetrucks
Different character in each courtyard
Large areas of free and diverse nature
Directly access from the apartments

Rooftops

Private areas for each stairwell
Common areas with common
Views towards different landmarks
The green roof where it is possible
Home for birds and insects
Aerodynamic roofing
Different character at each rooftop
Optimized for sunlight
Should integrate green energy sources

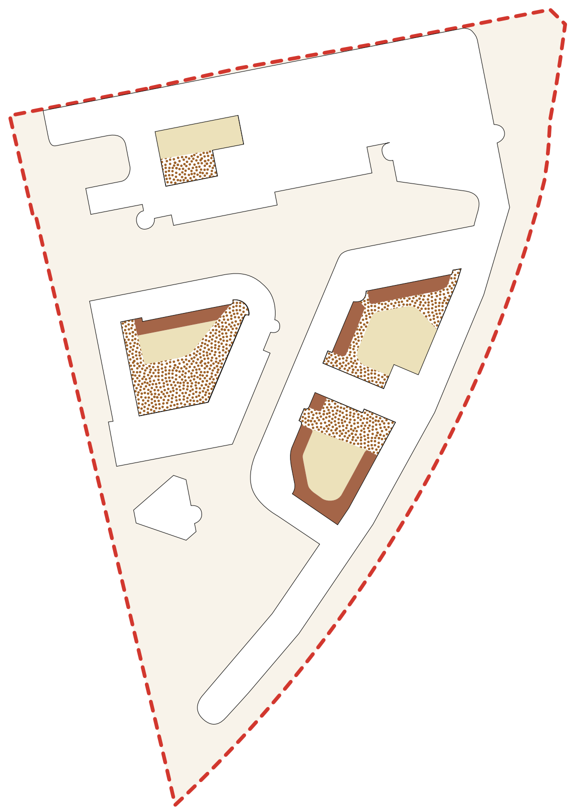
Streets and squares

Directly access from the apartments
Bike parking
Access for cars when moving in
Access for firetrucks
Different character in each street
Large areas of free and diverse nature
Handling of rainwater
Places to sit and rest
Pedestrians first
Bikes protected by cars and trees
Sheltering from rain and wind



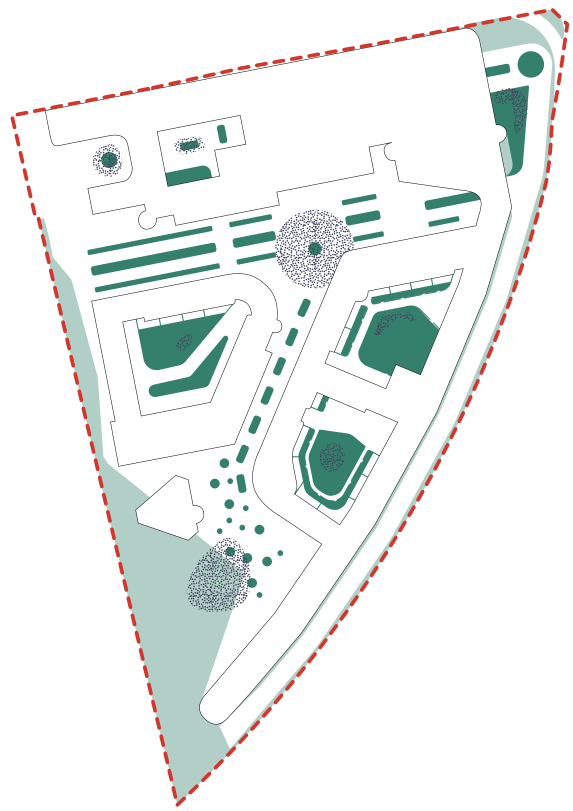
PRINCIP SECTION OF THE MAIN STREET, PEDESTERIAN STREET AND PUBLIC COURTYARD

Section 1-200. Showing how the pedestrian street has lots of variation both at the different floors, outdoor and indoor space. The space is a public space but can be inhabited by neighbours as an extension of their private gardens.



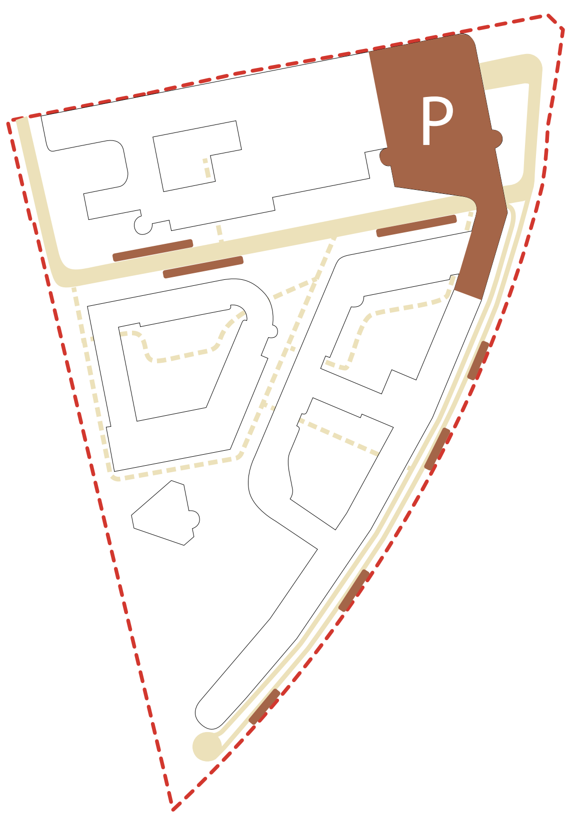
PRIVAT/PUBLIC

Public Semi public Semi Privat Privat



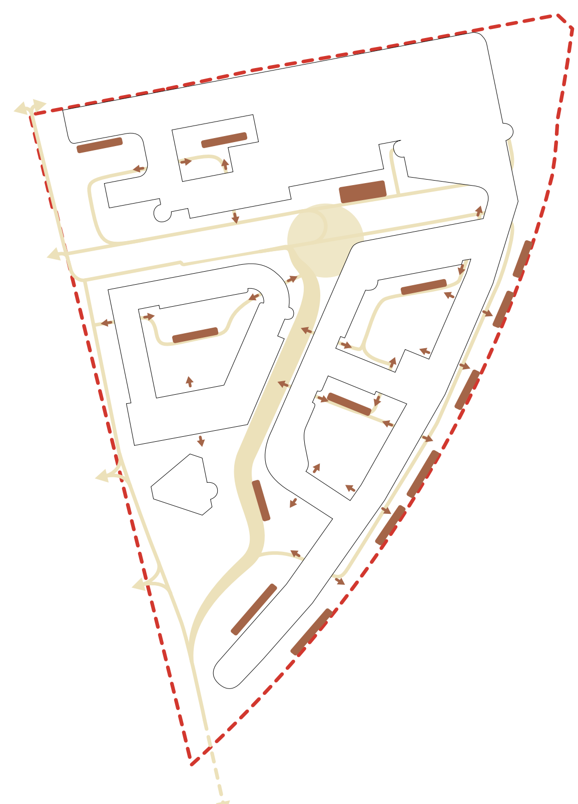
GREEN PRINCIPLE

Wet areas Green areas



FLOW FOR CARS

Roads Carparking



FLOW FOR PEDESTRIAN

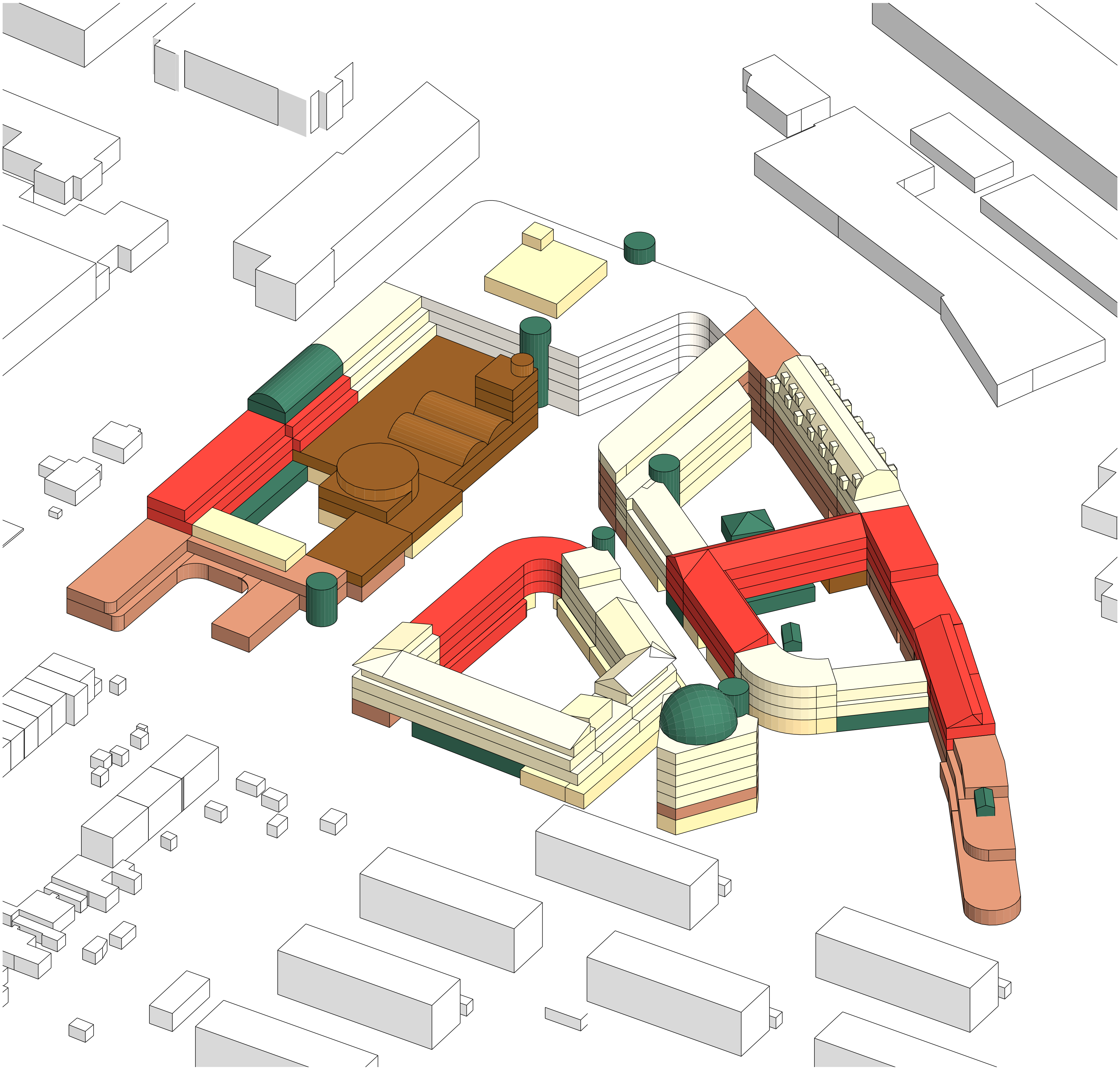
Paths Bikeparking

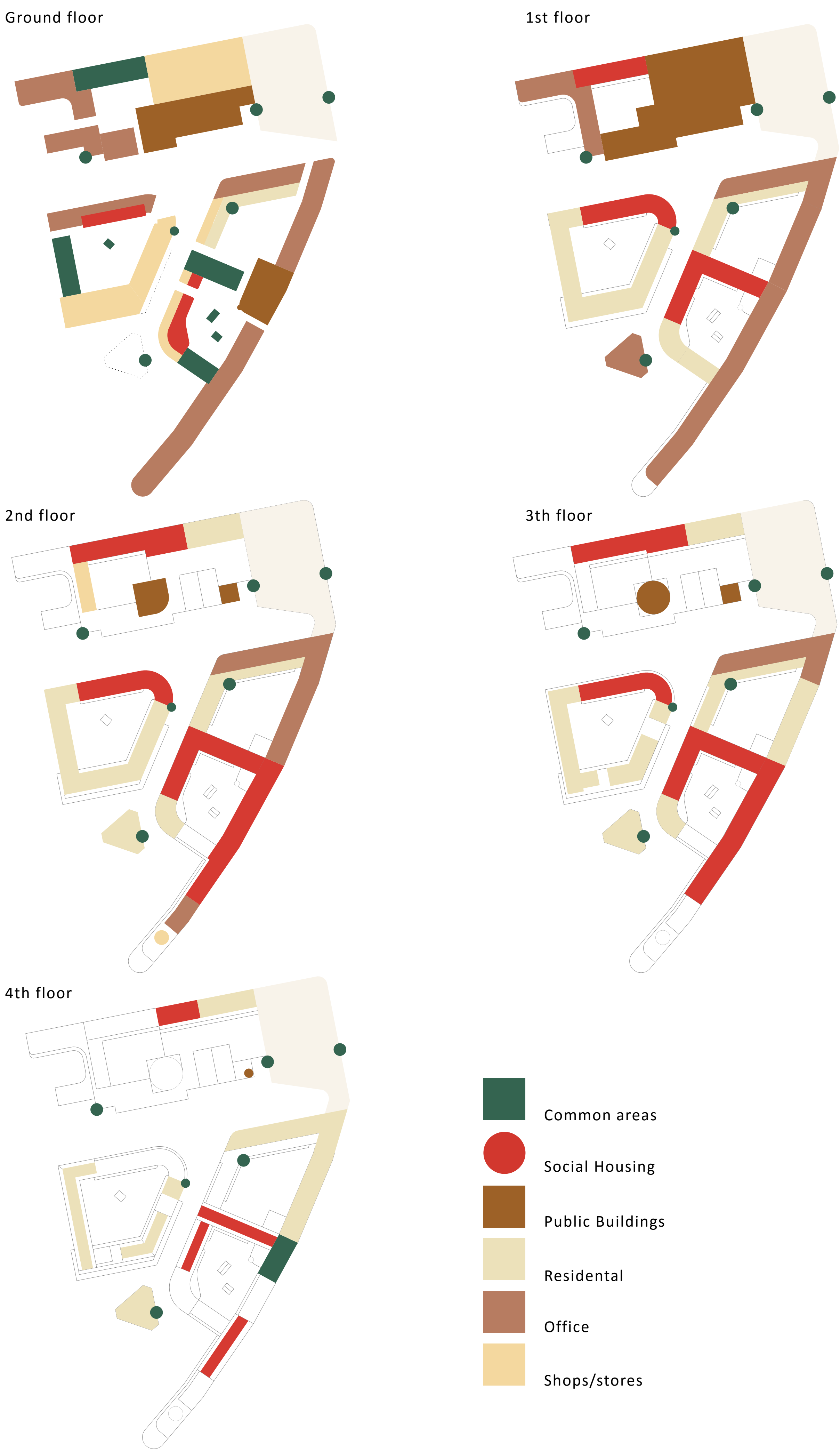
SKECTH OF THE PEDESTERIAN STREET

Showing the diversity in facade expression both in building blocks and at the different levels, furthermore, it shows how the area is to be occupied by the residents and streets are made for nature, animals and pedestrian.

3D SKETCH OF THE DIFFERENT FUNCTIONS IN THE AREA

The different colours represent different functions and express how the ground floor has a large variety of functions while the top floors mainly become residential.




Ground floor
1st floor
2nd floor
3th floor
4th floor
Common areas
Social Housing
Public Buildings
Residental
Office
Shops/stores

Phase 3

The Home

The Home

As our neighbourhood areas start to emerge from our conjectures and establish themselves by relating to different functions, uses, user groups and conditions. We begin to understand that a neighbourhood is only what it is because of the areas surrounding, them and the people inhabiting them. As spaces between the buildings manifest and appears form, the understanding of a city takes shape. Morphologies of buildings create analogies of urban areas which is not fully understood before the buildings themselves has been taking into detail. This relationship between urban space, building and occupants is back and forth as a pendulum where the buildings are directed by urban conditions, the use directed by the user, and the user is directed by the urban conditions. In this complex clockwork of a neighbourhood design, one must balance interior and exterior allowing the buildings to not only be a shelter in a no man's land but to benefit from each other.
But at what point will this shelter become nested into its surroundings in a way where it seems as natural as the surrounding itself? At what point will the building become a part of the area and when will the house become a home.

14.000 years ago the hunter-gatherer people wandered around the open and uninhabited "no man's land" as they travelled to collect food and hunt animals. The first settlements are recorded back to the ancient times where people started agriculture (Holm, 2021), here cities emerged and housing where defined. These times were very much defined by how we as humans found it suitable to survive. Today this idea of survival might still be the reason for our way of inhabitation and sustain basic needs but our understanding of house has changed from shelter to a much more complex understanding which we today call home. Our home is not only the four walls and a roof surrounding us but becomes a materialistic reflection of ourselves. It is both a canvas to display our positions, aesthetics and interests and a mirror where we see ourselves. At the same time, our home is our safe space and the place we go to when we need to be alone.

Somehow this idea of home, as a very complex parameter in our lives, is neglected in the way we build our houses in the city today. The white canvas of our interior, which covers the complex solutions and uncomprehensive technology that supports our building of the present time is almost impossible to inhabit. This technology of concrete, plasterboards, plastic and mechanics is enough to make occupants give up, as we are left alone to understand it with no help from the people who designed the buildings. As architects, we leave the space white and rectangular because this is what the building regulation dictate us. Occupants are left with an immediately blank canvas but find that it fights back as they attempt to pierce through the concrete wall in the hopes of a characteristic and unique placement of their TV. This resistance often results in relinquishment of the idea, leaving the furnishing similar to the otherwise identical white-canvas apartment next door.

One is left to wonder if this is the future of homes? The white canvas that performs the bare minimum of special conditions whiteout excitement and personality in the spatiality. Where is the identity as in the houses of Øgaden in Aarhus, the poetics as in Blangstedgård by Poul Ingemann or the "hygge" as in the houses of Vandkunsten? There should be as many different homes as there are occupants. Why are we as occupants of the new dense cities, not allowed to choose between different expressions, why do we have to settle for the white canvas when it is often easier and more inspiring to colour in-between the lines?

The five points from Vandkunsten are one way of addressing this issue of how cities and homes can develop in the future. One way for occupants to choose to inhabit. But how are these manifesting points expressed in the reality of homes and how are people to live in a building which accommodates these points?

The neighbourhood, as we have now conjectured it, is left with four buildings which are defined as social housing. The four different blocks have different possibilities and limitations defined by the condition of their neighbour buildings, the condition of the climate and the conditions of the urban areas. This means that all of these in reality should have different expressions. Some have to accommodate for noise, some for shadings, some have to be active in both facades and some can be introvert. These different expressions logically attract different users and create diversity within and between the individual building blocks.

For the next phase, the phase of the home, we investigate how the five points of Vandkunsten will influence **Building I**. This building block is located towards the active road Østre Ringvej on the south side and towards the garden courtyard on the north side. These conditions together with a building system of CLT elements will be our preliminary design parameters.

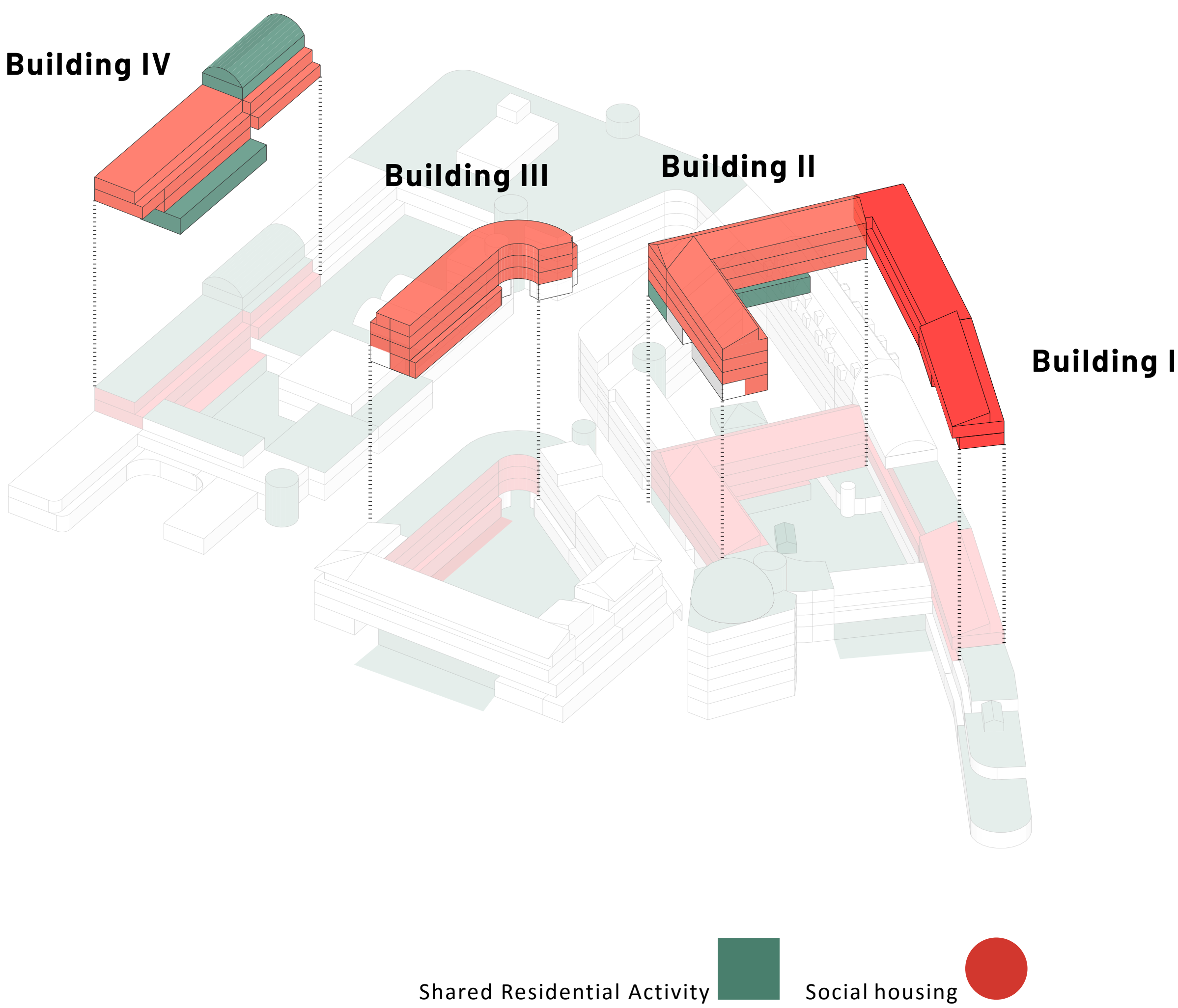


DIAGRAM SHOWING THE AREAS OF SOCIAL HOUSING AND THE SHARED AREAS WITH ITS COMPLEX SYSTEM OF INTERACTION AND ACESS

Social housing of the Future

The five points from Vandkunsten can be hard to turn into form just by reading it, because what does it mean to live smaller and better? What does it mean to do it ourselves? Undoubtedly, the apartments will be smaller than contemporary apartments, and a larger part of the program will be redefined so areas and function of the community will be enhanced, i.e. storage, greenhouses, community houses, workshops, drying room for clothes etc. Likewise, small animal farms will all be subjects, which should be considered in the making of a program, which addresses the future of social housing. Below are listed some references which could be 1-1 incorporated in a design proposal. It is also important to state that the five points can be mixed or reach into each other, for example, is it obvious in the process of living smaller to do it yourself, i.e. builds a small kitchen unit, or a bed into a small structure for storage.

Let us live smaller and better! ***Lad os bo minde og bedre!***

7 Bedrooms as alcove in smaller apartments.

8 Smart integrated storage.

9 Small accessible kitchens.

Let us share more! ***Lad os dele mere!***

10 Common gardening, could be taken care of by social disabled

11 Common rooms with large kitchen and seating space.

12 Common greenhouse.

Let nature move in!

Lad naturen flytte ind!

13 Small playgrounds in nature surroundings.

14 Plants in the windows.

15 Large green walls

Let us do it ourselves, together!

Lad os gøre det selv, sammen!

16 Common workshop area.

17 Selfmade detail at a greenhouse.

18 Community meeting.

Let it be and watch the beauty!

Lad det være og se skønheden!

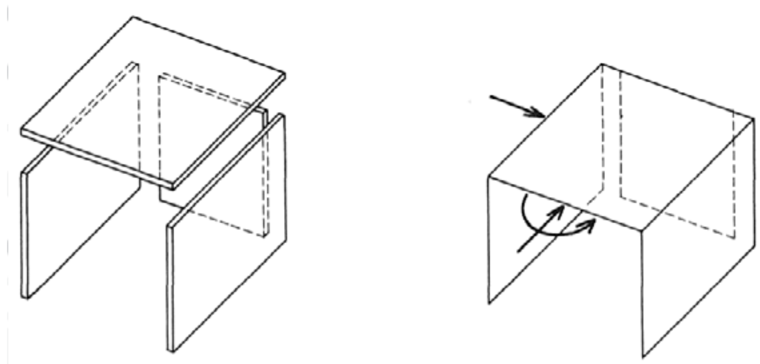
19 Reuse of old roofing tiles.

20 Reuse of old industrial matal cladding.

21 People enjoring the wild nature just outside their homes.

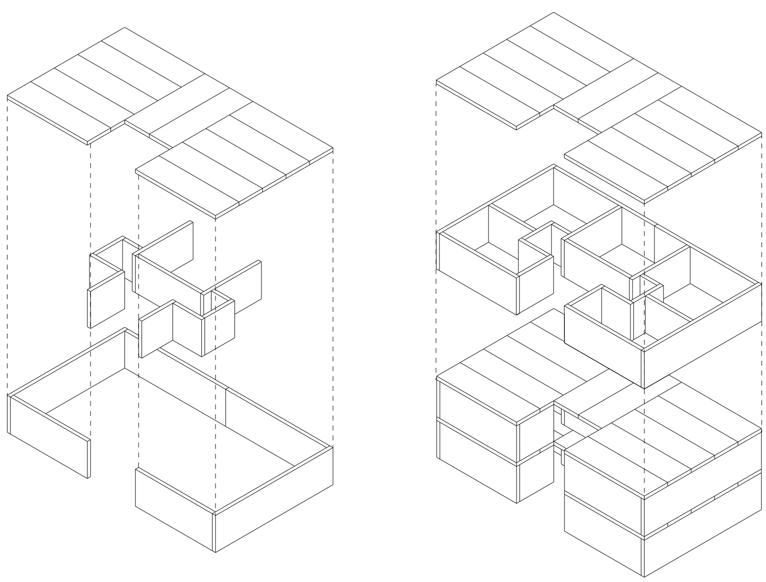
Cross-Laminated Timber Construction, CLT

Cross-laminated timber has been around for almost 50 years, as it was developed in Europe in the 1970s, mainly in countries as Austria and Germany. But it is not until recently this type of construction, which generally has many similarities with the well-known concrete elements, begins to win its place in the housing complex structures around the world (Structural Timer Association, 2015). Today large buildings constructed of CLT starts to raise, as you would find that CLT not only obtains strengths similar to concrete but also have large fire resistance, better environmental conditions (low embodied carbon footprint), better construction environment and provides better indoor informant for the residents.
Boligselskabet Sjælland has developed a system of CLT together with the architecture studio Vilhelm Lauritzen. The basic idea is to only construct the elements which are required for load-bearing and stabilizing of the building, this provides a cheap and fast construction with multifunctional spaces.

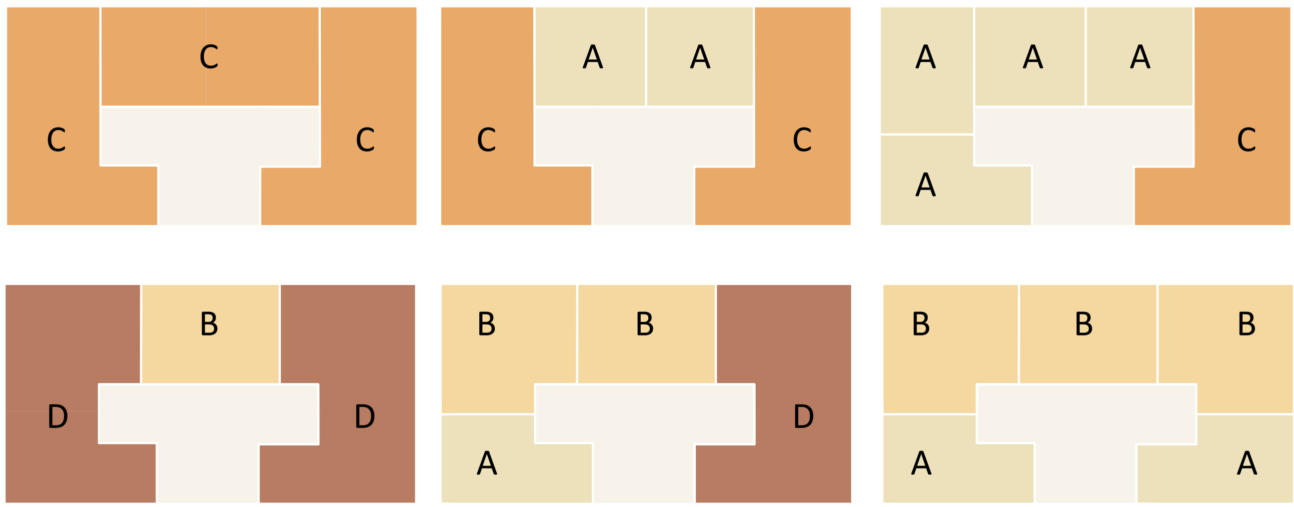


PRINCIPLE OF STABILITY WITH PLATES

To obtain structural stability through the use of plates, one has to make sure that the structure has no possibility to move. This can be accomplished by having three plates with different points of rotation. Through this, the structure has the possibility to absorb loads in every direction (Buhelt M. 1976).



THE CONCEPT STABILITY AND DEFINING APARTMENTS



The concept of stabilizing with three plates in different directions is here shown in relation to the different sizes of apartments. By using this system one is to obtain the same stairwell while making changes in the apartment layout depending on the needs and wishes of the building owner. Further dividing of space can be done by non-loadbearing walls like plywood elements or gypsum.

APARTMENT A - SMALL
35 m²
1-2 persons

APARTMENT B - SMALL FAMILY
45 m²
2-3 persons

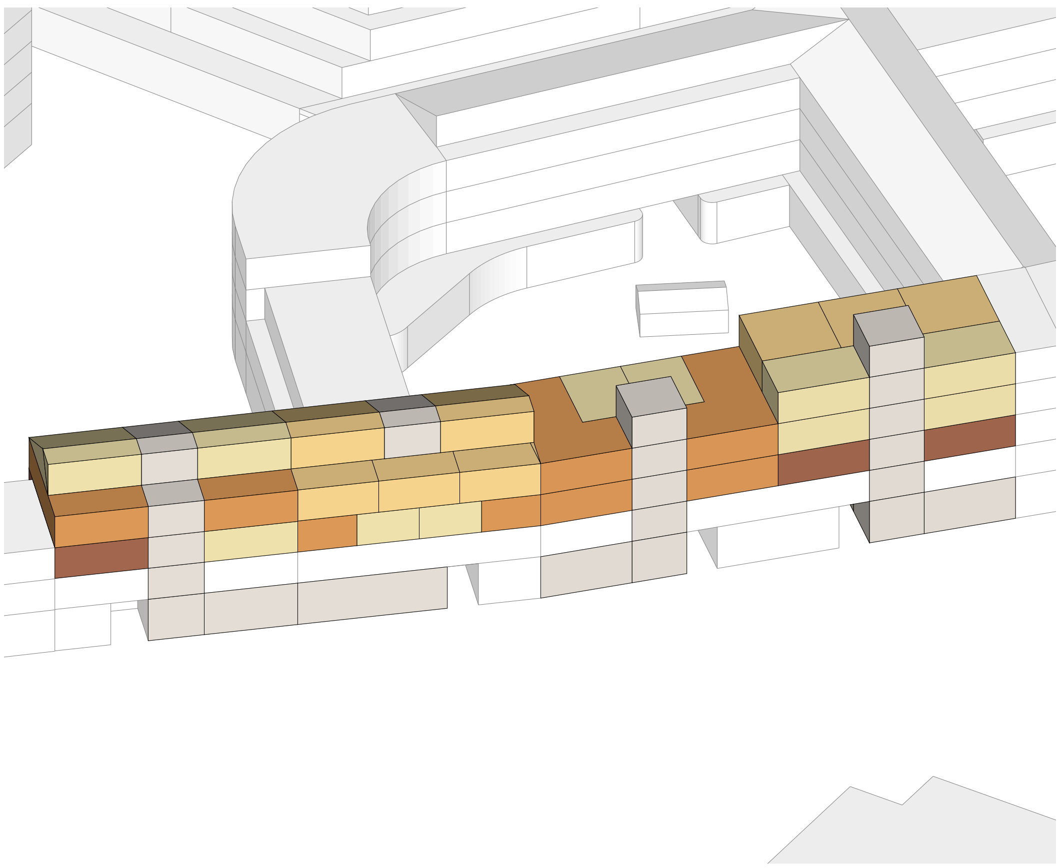
APARTMENT C - MEDIUM
65 m²
3-4 persons

APARTMENT C - LARGE
75 m²
4+ persons

Room program

With the principles of Vandkunsen occupants should live in smaller apartments with larger shared areas, this provides the occupants with a large variety of shared possibilities, at the expense of smaller private living areas. A result of this is also the fact that large families should live in smaller apartments, here the largest apartments, family apartments are 75m2. The different users are defined by BOSJ (Bro, P. 2017)

Social Housing	%	2030 m² total area	Apartment size	Number of apartments	
Small	20%	405 m²	35 m²	12	Apartments
Medium-Small	30%	610 m²	45 m²	15	Apartments
Medium	25%	505 m²	65 m²	8	Apartments
Large	10%	200 m²	75 m²	3	Apartments
Common areas	15%	300 m²			
			Total of	38	Apartments



PRINCIPALS APARTMENT LAYOUT FOR **BUILDING I**

Small apartments	
Total m^2	35 m^2
1-2 persons	
Entrance	1 m^2
Kitchen	6 m^2
Bathroom	3 m^2
Livingroom	6m^2
Bedroom Master	6 m^2
Hallway/Shared	10 m^2

Amar
28 years old, shop assistant.
Likes to fitness and dreams of starting a family.

Emilie
18-29 years old, student.
Dreams of natural areas and a garden.

Micheal
47 years old, early retirement.
Dreams of a workshop area and likes an open floor plan.

Small apartments	
Total m^2	45 m^2
2-3 persons	
Entrance	2 m^2
Kitchen	6m^2
Bathroom	4m^2
Livingroom	10 m^2
Bedroom Master	10 m^2
Hallway/Shared	13 m^2

Susanne
59 years old, a teacher with a part-time kid.
Would like a small garden.

Dagmar
80 years old, retired.
Would like a small home and to meet people in real life instead of through social media.

Olivia & Oskar
31 & 33 years old, biologists.
Wants large green areas and lots of storage.

Small apartments	
Total m^2	65 m^2
3-4 persons	
Entrance	2 m^2
Kitchen	9 m^2
Bathroom	6 m^2
Livingroom	12 m^2
Bedroom Master	10 m^2
Bedroom Small 1	8 m^2
Hallway/Shared	17 m^2

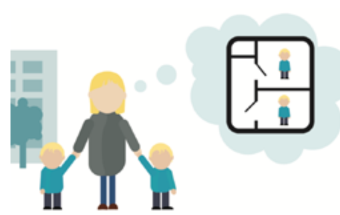
Hans & Ulla
69 & 57 years old, retired and active.
Dreams of a green garden and to be close to the city.

Aisha & Hassan
25 & 28 years old, pregnant.
Wants to live in a social community and live ecologically.

Amar & Clara
33 & 26 years old young parents
Likes to be a part of the community.

Small apartments	
Total m^2	75 m^2
4+ persons	
Entrance	2 m^2
Kitchen	12 m^2
Bathroom	8 m^2
Livingroom	15 m^2
Bedroom Master	10 m^2
Bedroom Small 1	8 m^2
Hallway/Other	20 m^2

Anna, Emil & Fie
19-29 years old, students.
Likes to be part of a community and to be active.



Camilla
38 years old, two kids.
Would like a residential community and a separate room for each kid.

Martin & Anna
37 & 35 years old, with two kids.
Likes to be in the kitchen and in their garden.

Selected design criterias for the home phase

Let us live smaller and better

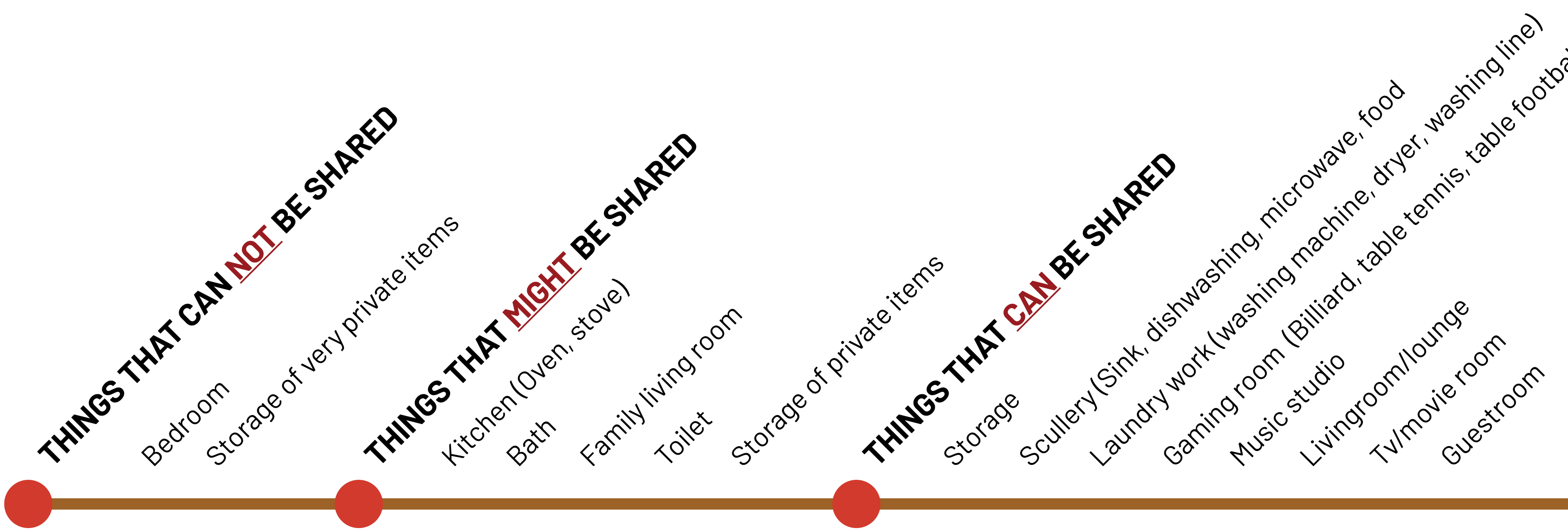
- More and smaller apartments
- Multifunctionality – integrated storage, alcoves, hallways as working areas, changeable walls
- Few private rooms, more space for everyone
- Large interaction between occupants
- A large variety of shared activities

Let us share more

- Every aspect of the housing unit is an extinction of the home
- Common areas give the possibility for more activities
- A soft gradient in public and private
- Apartment and companies/offices share common areas

Let nature move in

- Green terraces for growing vegetable, flowers and biodiversity.
- The stairwell as a greenhouse
- The façade as a living organism
- Common gardens for the use of everyone
- Integrated plant pots in windows for beauty and shading
- Space for animals and untrimmed nature
- Outdoor activities
- Outdoor areas as an extension of the home



Let us do it ourselves

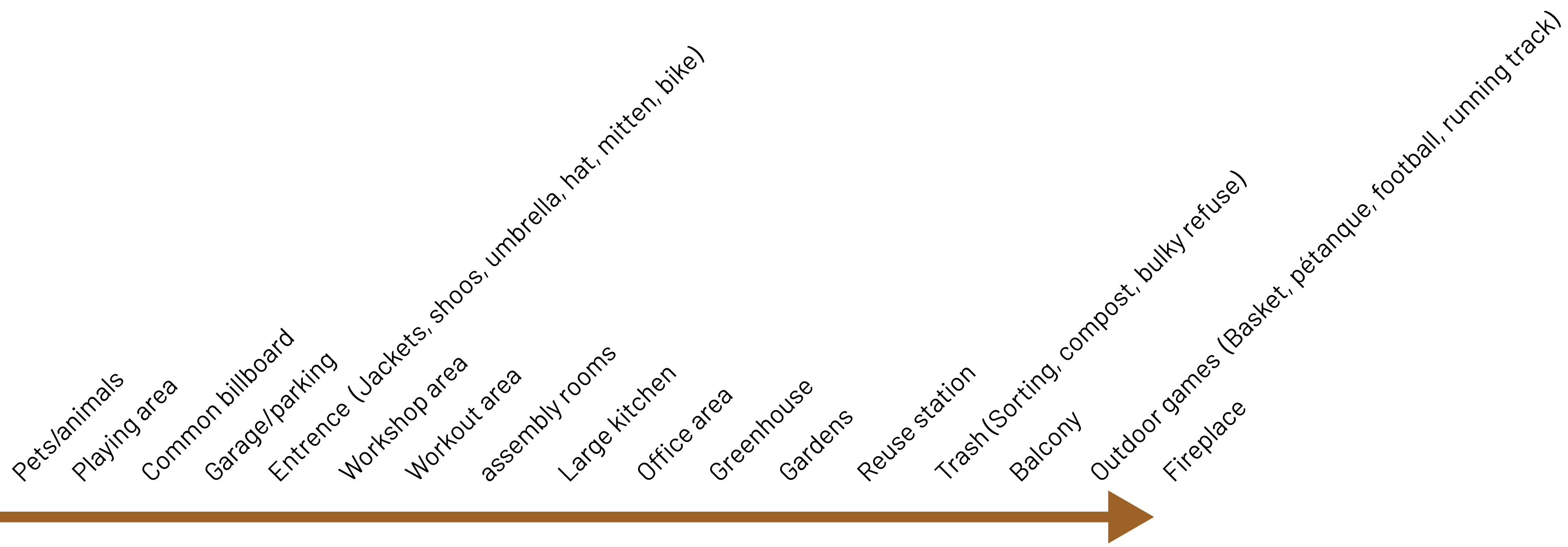
- Reuse of materials for buildings and workshops
- Large workshop areas
- Residential community meetings, co-meal systems
- Living apartments can change according to residents changing needs and wants
- Allowance for residents to upcycle buildings by building extinctions and add-ons

Let it be and watch the beauty

- Use materials with a focus on patina
- Nature should be integrated and uncontrolled
- Apartments shouldn’t be neutralized when moving
- Reuse of old materials and furniture through the workshop areas and recycling centre

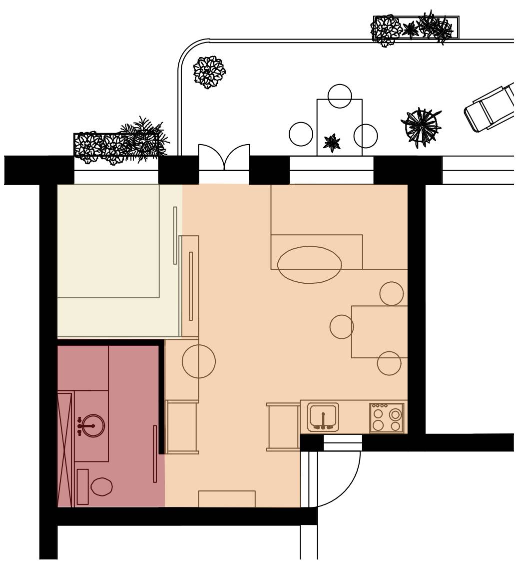
Wooden housing

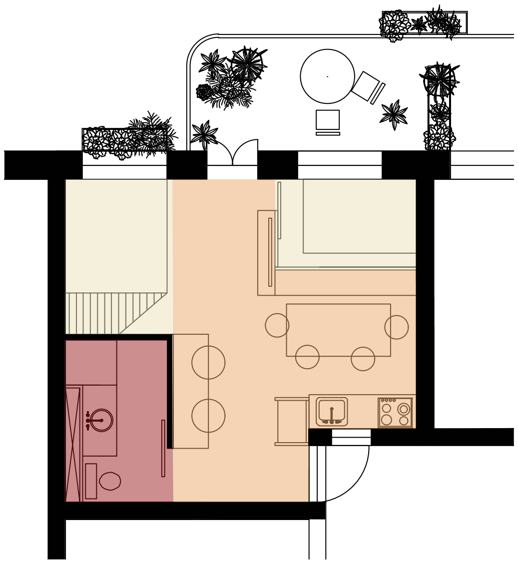
- Construction of CLT elements
- CLT and wooden elements should be present inside buildings
- As few elements as possible to minimize cost
- Interior walls should be stabilizing
- The façade should reflect the wooden interior
- Details and assemblies should be logical and as exposed as possible
- Material used for construction should be designed according to structural stresses

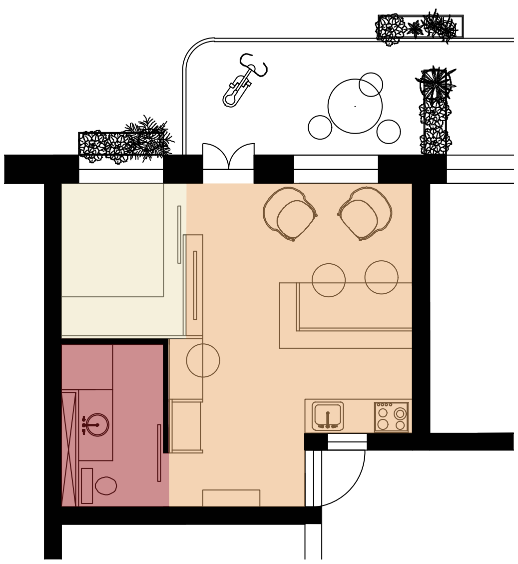


Different interior for different users

As each apartment type have different user groups, it is important to create a starting point that allows the user to organize in different ways according to their needs and wants. The three plans below show how apartment B, 45m2 can be interior accordingly to our occupants' needs. Some people might want to live more traditional, while others are interested in living alternative. The basic apartments allow for this and can be changed in case of new occupants or, you can live the built environment for the next occupants to inhabit. By choosing the last of these two options, the apartments can grow separately becoming unique and personal.







Dagmar
80 years old, retired.
Would like a small home and to meet people in real life instead of through social media.

Susanne
59 years old, a teacher with a part-time kid.
Would like a small garden.

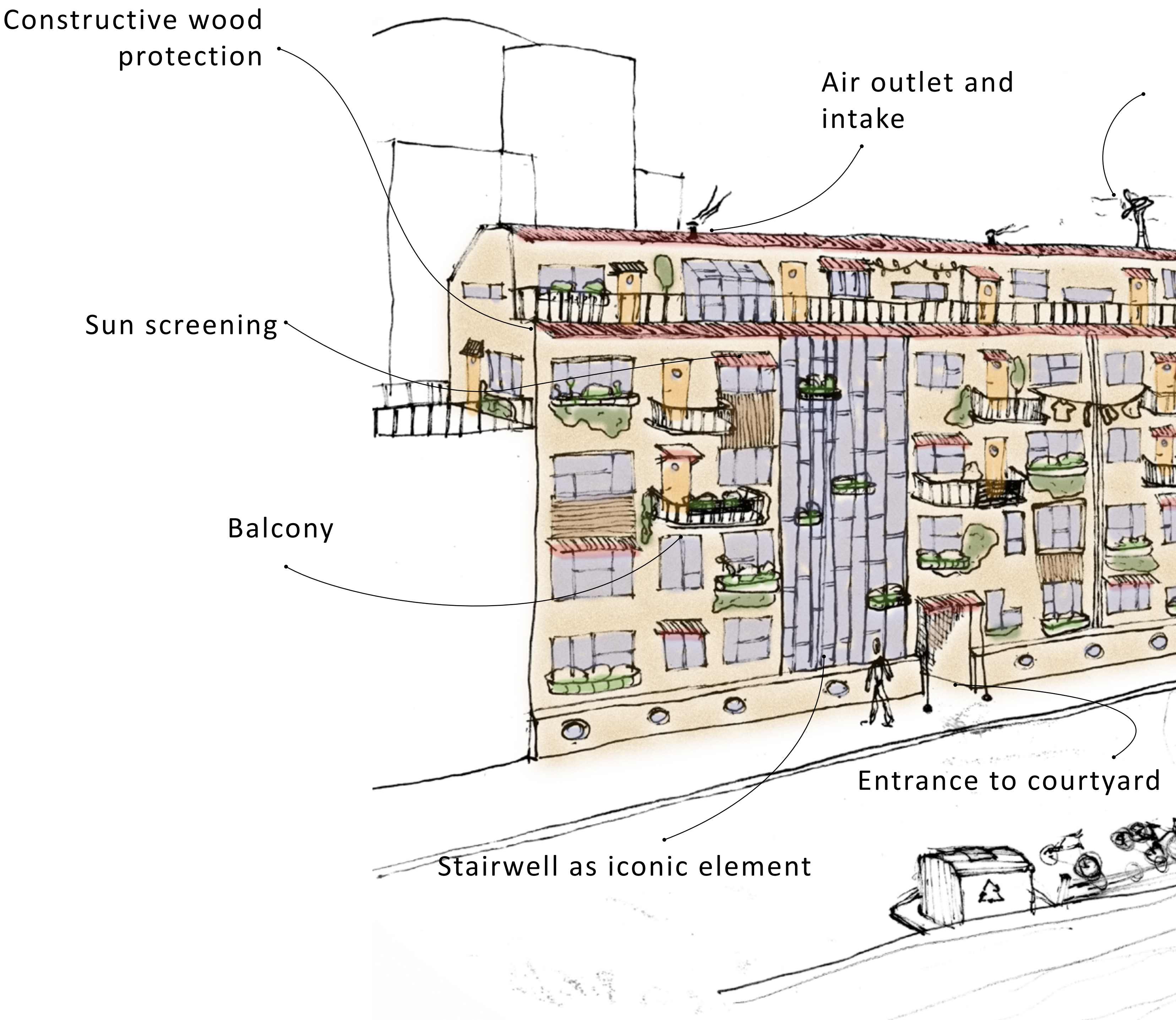
Olivia & Oskar
31 & 33 years old, biologists.
Wants large green areas and lots of storage.

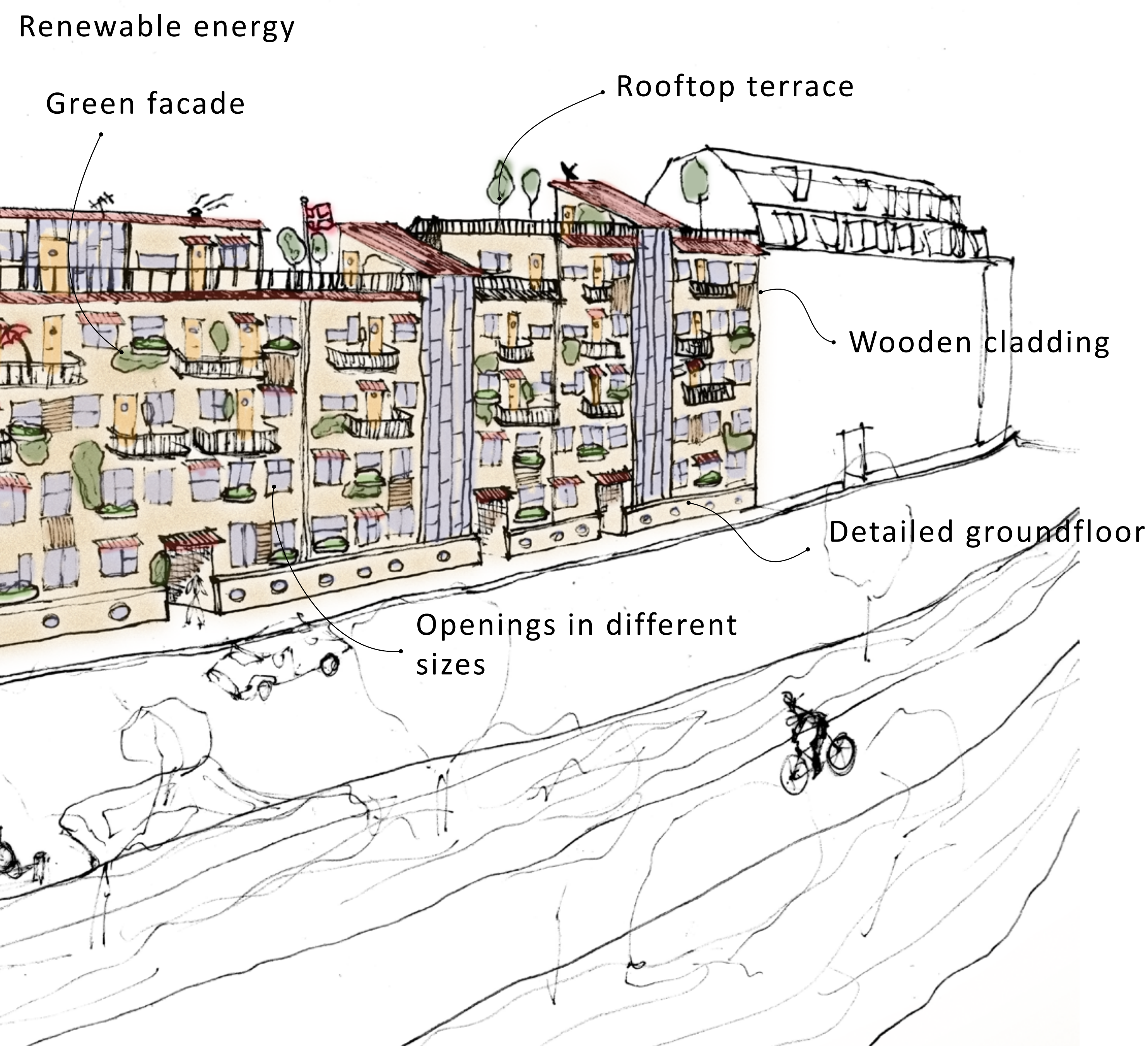
22 SMALL BEDROOM FOR TWO PERSONS WITH INTEGRATED STORAGE AND BENCH

23 A PART OF THE EXHIBITION BY VANDKUNSTEN. A SMALL SLEEPING AREA IN CLOSE RELATION TO A SMALL OFFICE AREA, IN AN OPEN FLOORPLAN.

Facade layout

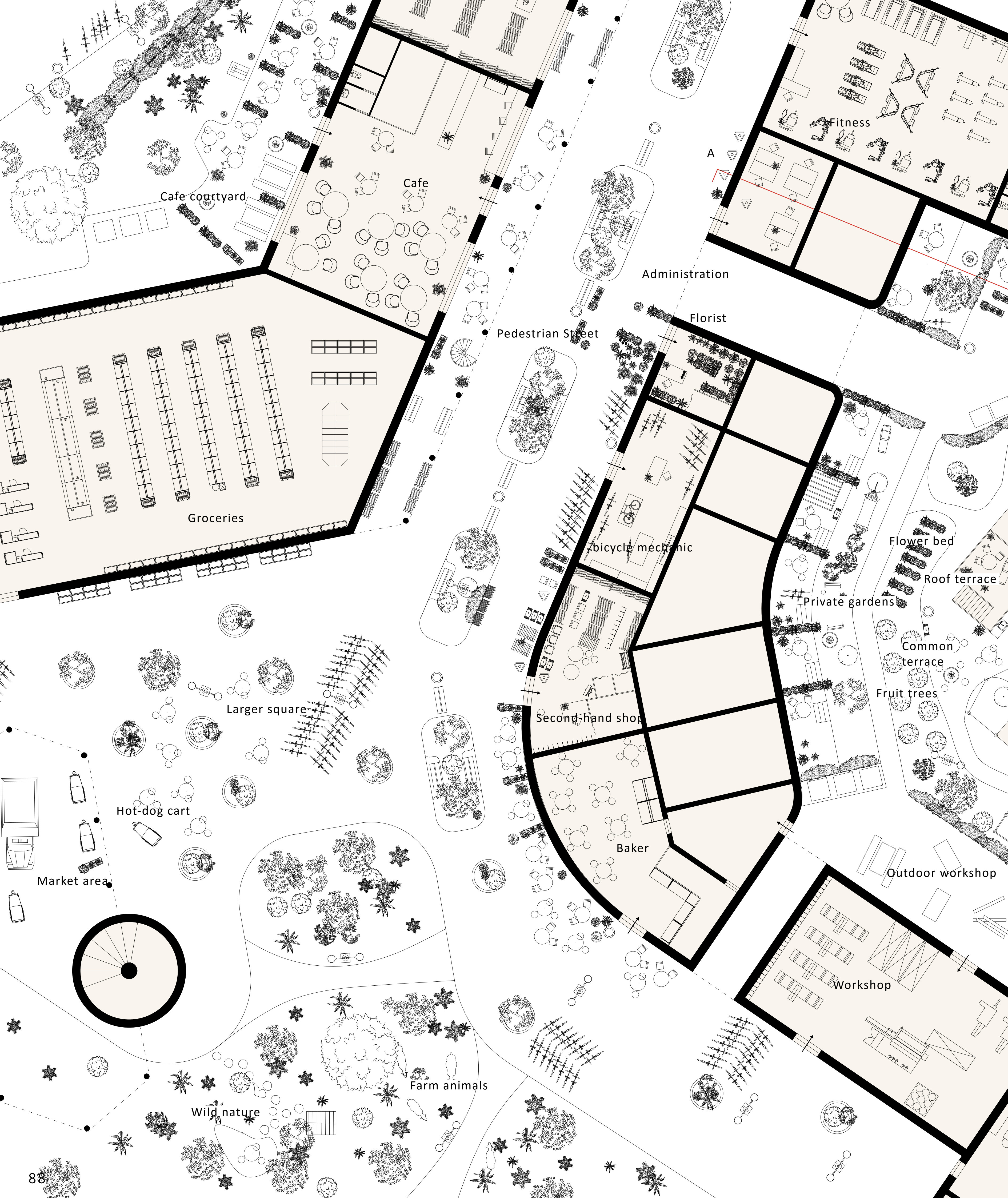
The facade towards the Østre Ringvej becomes the face of both the city and the neighbourhood. This is why it is important that it shows and represents the lively and liability that is also represented in the interior of the neighbourhood. Furthermore, the facade should be usable for the occupants and should be designed with close relation to the ground floor as this is where people will often engage with it. The illustration below shows some of the elements which have been taken into consideration in the design of the facade.




Renewable energy
Green facade
Rooftop terrace
Wooden cladding
Detailed groundfloor
Openings in different sizes

FACADE TOWARDS ØSTRE RINGVEJ


Part of the facade has green walls which ensure that the building seems alive and work a living noise reduction system.
Small roofs made of cheap materials like polycarbonate or metal works as sun shading activating the facade.
The building lands on a base as a part of constructive wood protection, while providing a rich level of detailing in eye height.


Cafe courtyard
Cafe
Fitness
A
Administration
Florist
Pedestrian Street
Groceries
bicycle mechanic
Flower bed
Roof terrace
Private gardens
Common terrace
Fruit trees
Larger square
Second-hand shop
Hot-dog cart
Baker
Market area
Outdoor workshop
Workshop
Farm animals
Wild nature

THE GARDEN COURTYARD 1:250

To live in the city is not only about the apartments, but about your possibilities and what you live next to. The city around you should be an extension of your home and you should be able to occupy it and make it your own. This illustration shows how there are an insanely amount of possibilities and varieties of experiences just a few meters from your apartment. The soft transition between your private space and the public space gives a natural flow and lets you easily move both physically and mentally from being by yourself to be a part of the community. Nature, variation, experiences are keywords when designing outdoor spaces which feed adventure.


COURTYARD
The outdoor kitchen makes it easy for occupants to meet in the outdoor space.
The vegetation should be wild and uncontrolled to enhance biodiversity.


Farm animals contribute to the biodiversity of the city while letting people understand where their food comes from.
Green energy solutions should be a part of the outdoor space.
Shared greenhouse and sheds give occupants the possibility to work with different hobbies.

SECTION AA

The section shows how the interior can vary on different floors, but mostly how the level of the built area is larger on the ground floor than the top floor. This creates excitement and adventure when walking around the city while it gives the occupants air and overview from their apartments.

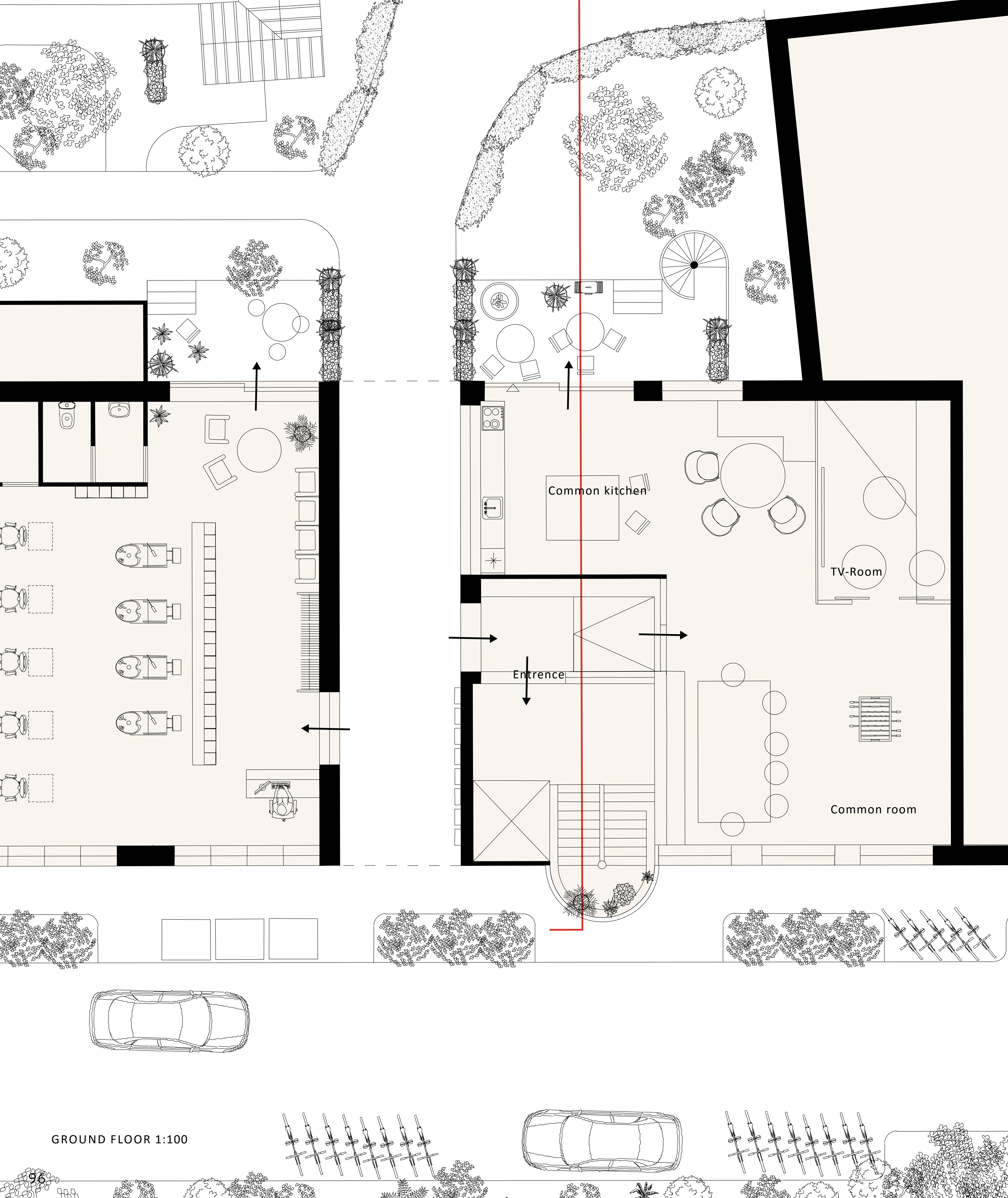

SHARE YOUR CITY

FACADE TOWARDS THE COURTYARD

The fire-escape stair gives occupants the possibility to socialise across floors while giving easy access to the courtyard.

Barcelona windows as patio door provide the occupants with many possibilities to open the apartment.


Shared balconies allow residents to meet across the apartments while providing shading for the windows.
The raised level gives a feeling of comfort and privacy to the common terrace.

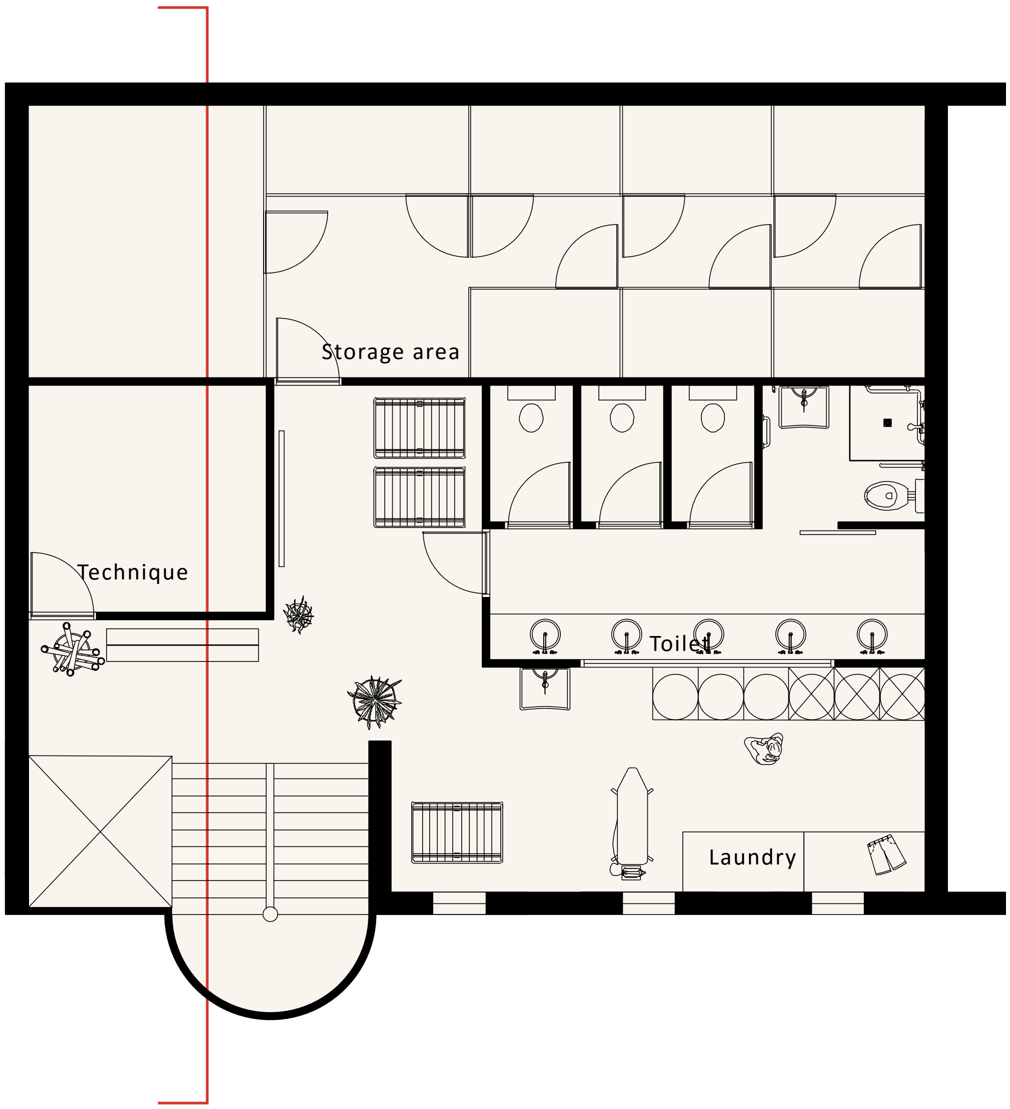


GROUND FLOOR 1:100

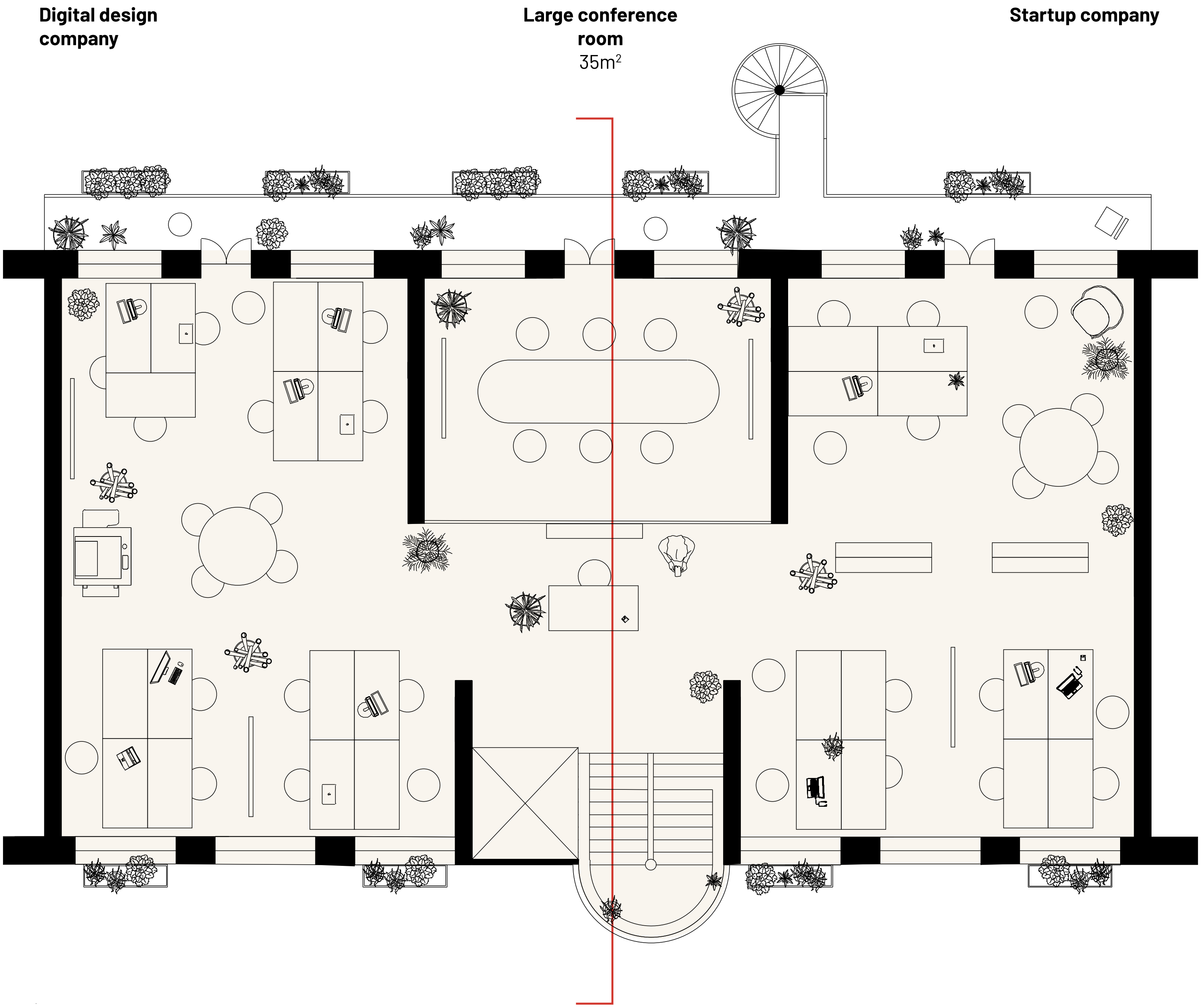
Plan layout

The seminal principles for the floorplans can be found in the five points from Vandkunsten. The plans consist of a large area of shared spaces, not only the residents are taking part in this community also the offices represents a big role in activating the building every hour of the day. When residents are at work, the office takes over the building and activates the common spaces, when afternoon occurs, the residents arrives and takes over creating life, comfort and variation.

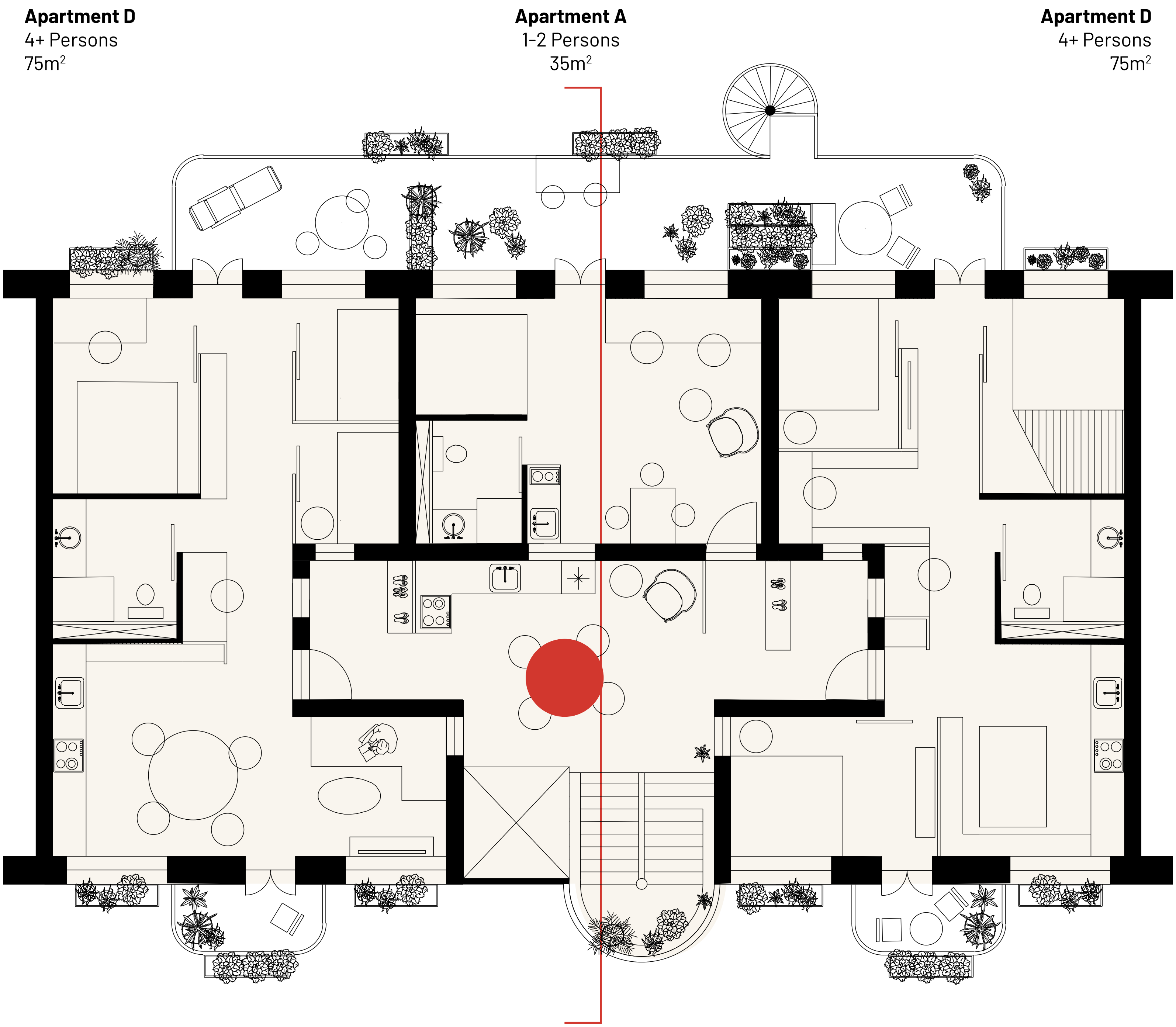
Basement floor 1:100



First floor 1:100



Second floor 1:100



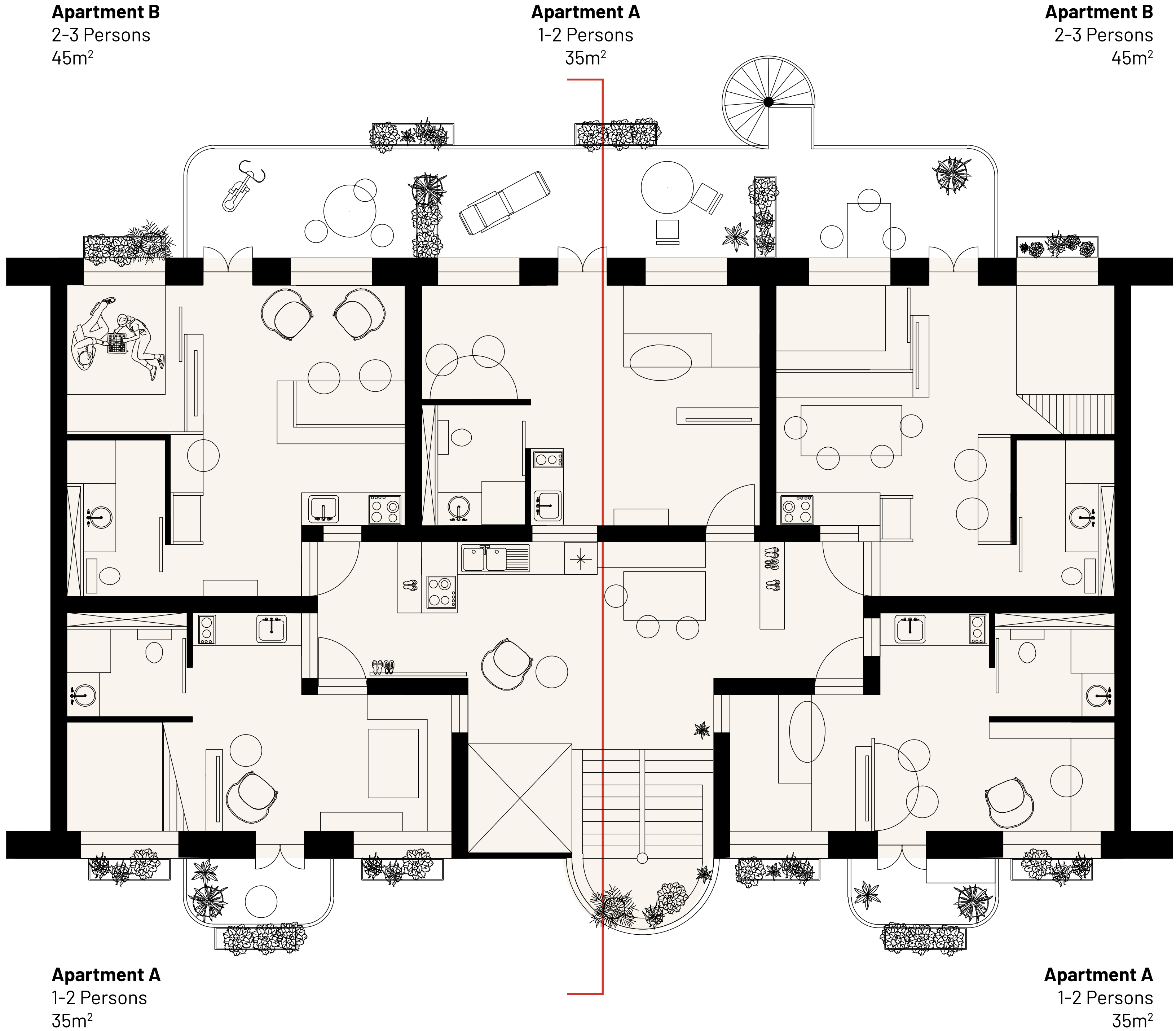
The stairwell

The stairwell is a space that is necessary for every housing block, instead of leaving it to be only a functional space it should be utilized by designing it as a central space for the occupants, the heart and backbone of the building. By giving this area more space it is possible to inhabit for the occupants which means that, because every resident is different, the different areas will be expressed differently and residents have the possibility to meet each other forcing a strong community.
To let light into the shared space, the stairwell is covered with mirrors. Only the imagination can give you an idea of what kind of experience it will be when walking up through this jungle of plants, herbs and items which is mirrored to eternity.

SHARED SPACE

STAIRWELL

Third floor 1:100

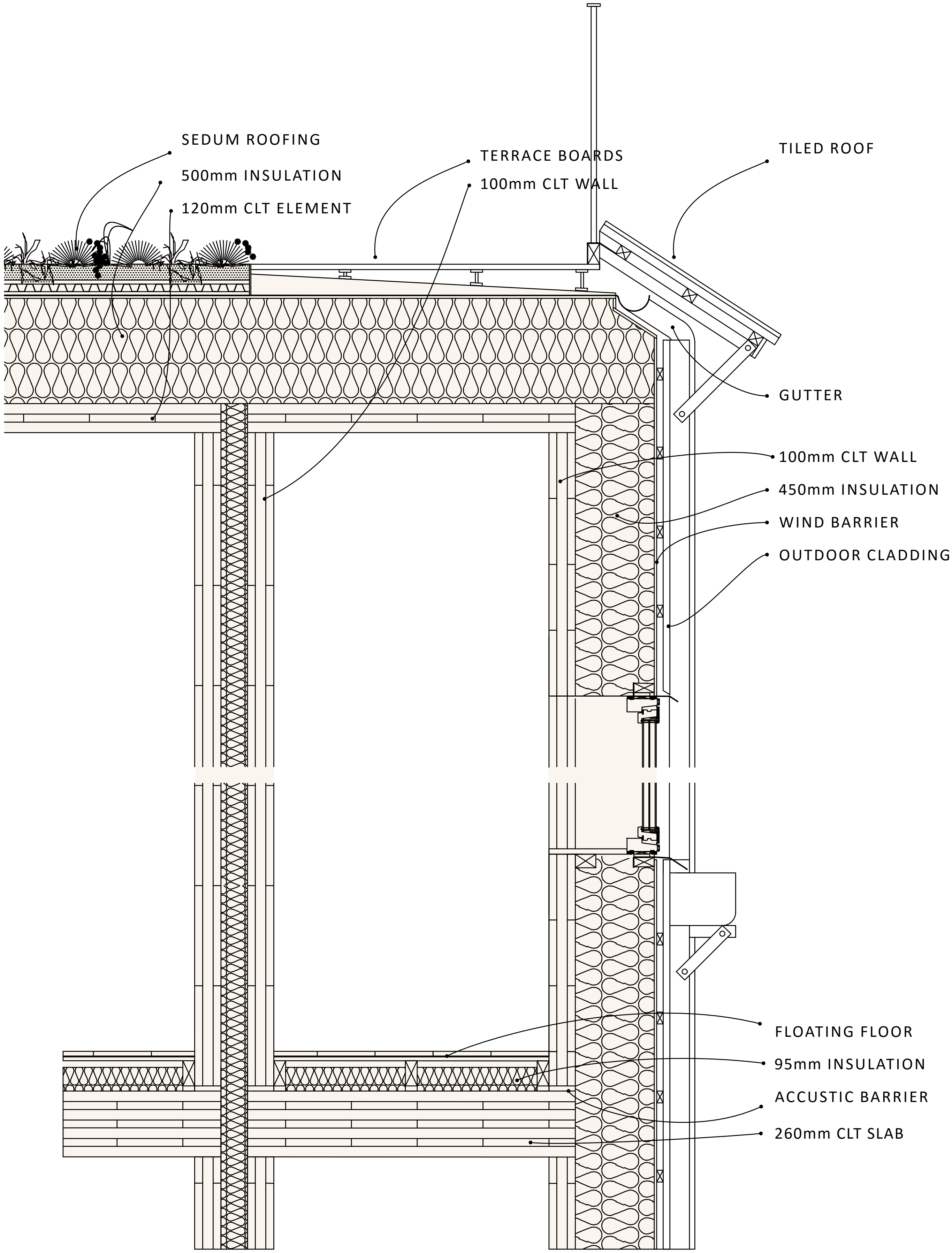


APARTMENT A

BALCONY AT THE SOUT FACADE

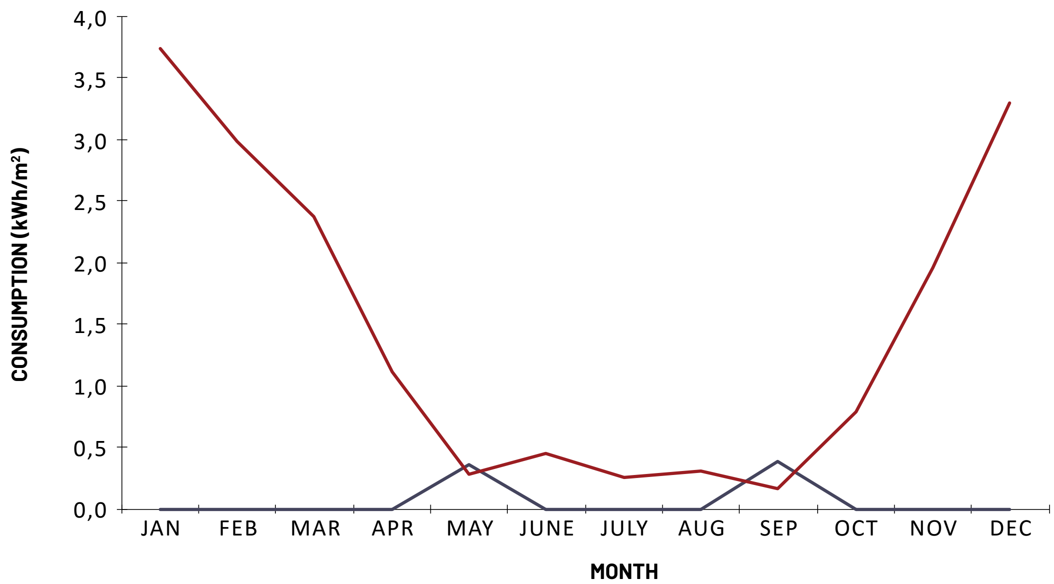
DETAIL DRAWING 1:20

The detail shows different solutions for detailing and combining different elements.



Energy Consumption

From an environmental view, a CLT building has a lot of advantages concerning the embedded energy of the materials as the building is constructed by almost organic materials. Furthermore, CLT buildings are faster and easier to manipulate at the construction site and provide advantages to the indoor environment as the material is alive and moving - responding to humidity and interior pollution.
Because of the low thermal mass, resulting in low heat accumulation, in CLT buildings the buildings must have a large level of possible variation. The building has to be able to respond to different environmental conditions to gain a low energy consumption. This can be done by having the possibility to open smaller and larger areas of the windows or by movable sun screening.



Energy consumption for heating	**18,2 kWh/m² year**
Energy consumption for cooling	**0,9 kWh/m² year**
Total energy consumption	**19,1 kWh/m² year**

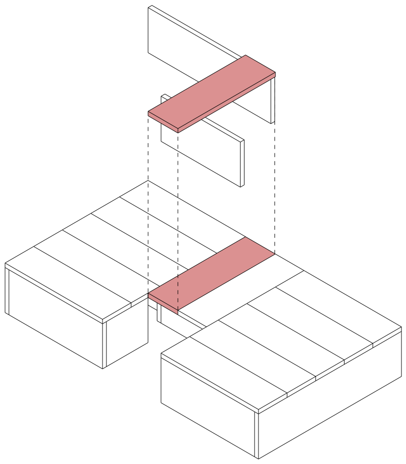
These variations in the facade also have a big influence on the thermal comfort in the apartments. In a day where the outdoor temperature is high, it is important to be able to provide a lot of shadow and ventilation to the building. On the contrary, on a day with low temperatures, it is important to be able to gain a large amount of passive solar heat.
Some of the strategies used for obtaining low energy consumption and a pleasant indoor environment are:

- Overhang above windows
- Sunscreen in front of windows
- Large window area
- Possibility to open smaller parts of the window
- Plants and vegetables as sunscreens
- Less relative rightness - letting the building breath (Compared to concrete buildings)

24-hour average	**24,9 °C**
Tempature variation	**5,4 °C**
Max. Temperature	**27,6 °C**

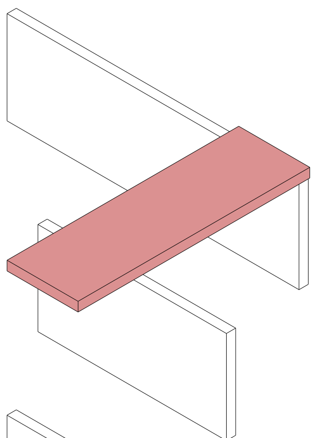
APARTMENT A

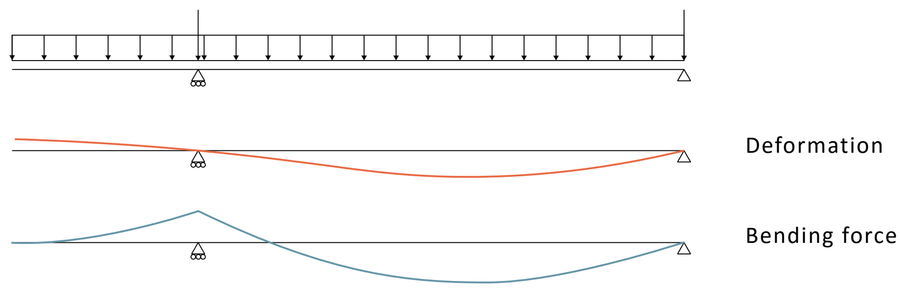
Engineering CLT elements



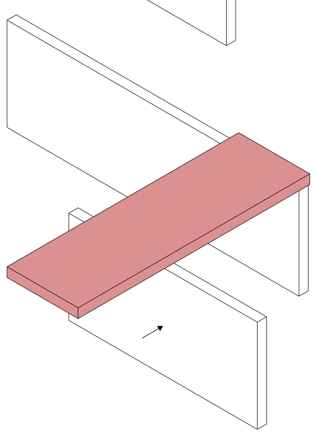
To gain a large understanding of how CLT elements work in reality, we take point of departure in one of the most complex CLT slabs in our structure.
First, it is important to understand the structure and its internal forces. With this cantilevered slab it is possible to change the placement of the support to optimize the internal bending forces - the placement of cause have an effect on the size of the shared area. Often it is logical to want an even distribution of internal forces in the structure to make the cross-section of the element as simple as possible. In reality, CLT elements have a large possibility for variation as you can use different strength of wood in different cases.
Below are listed three different cases of support and their result to the deformation of the slab and the internal bending force.

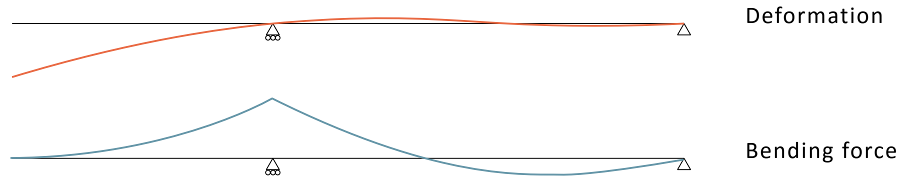
Case 0



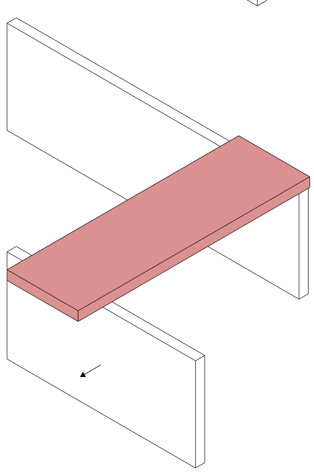


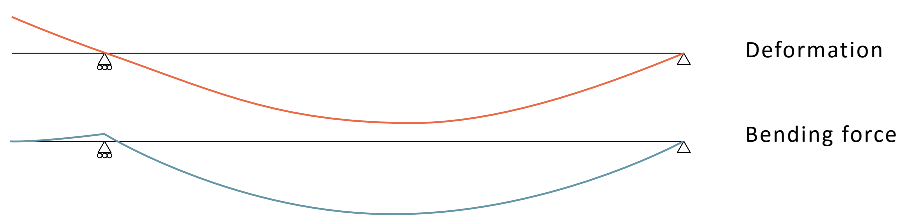
Case 1
Front wall moved backwards

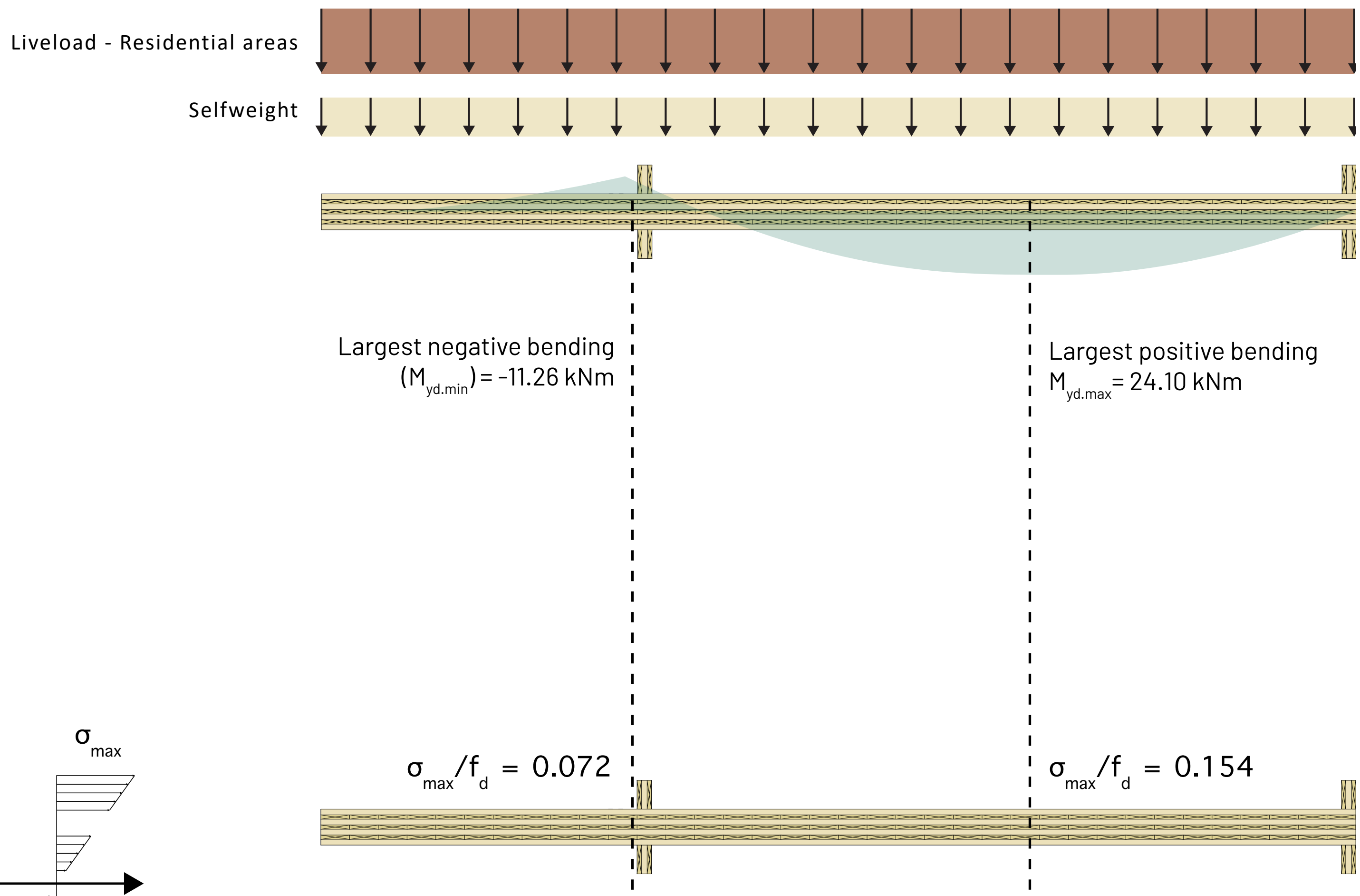




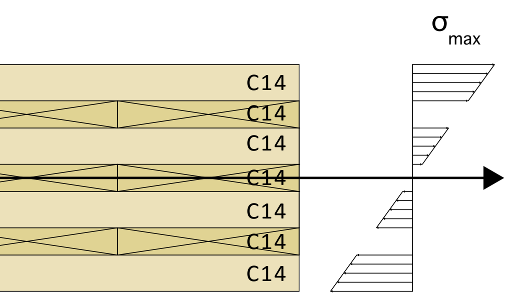
Case 2
Frontwall moved forwards



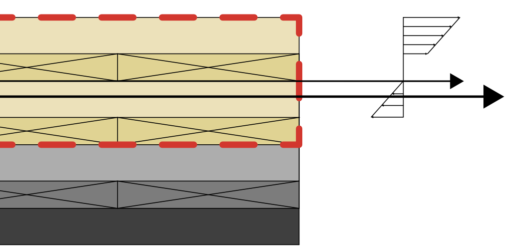


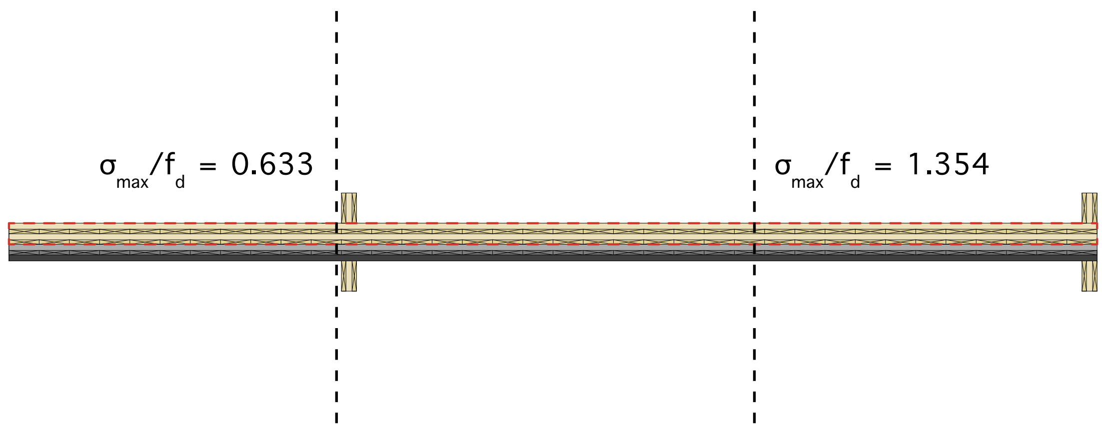


Cross section 0



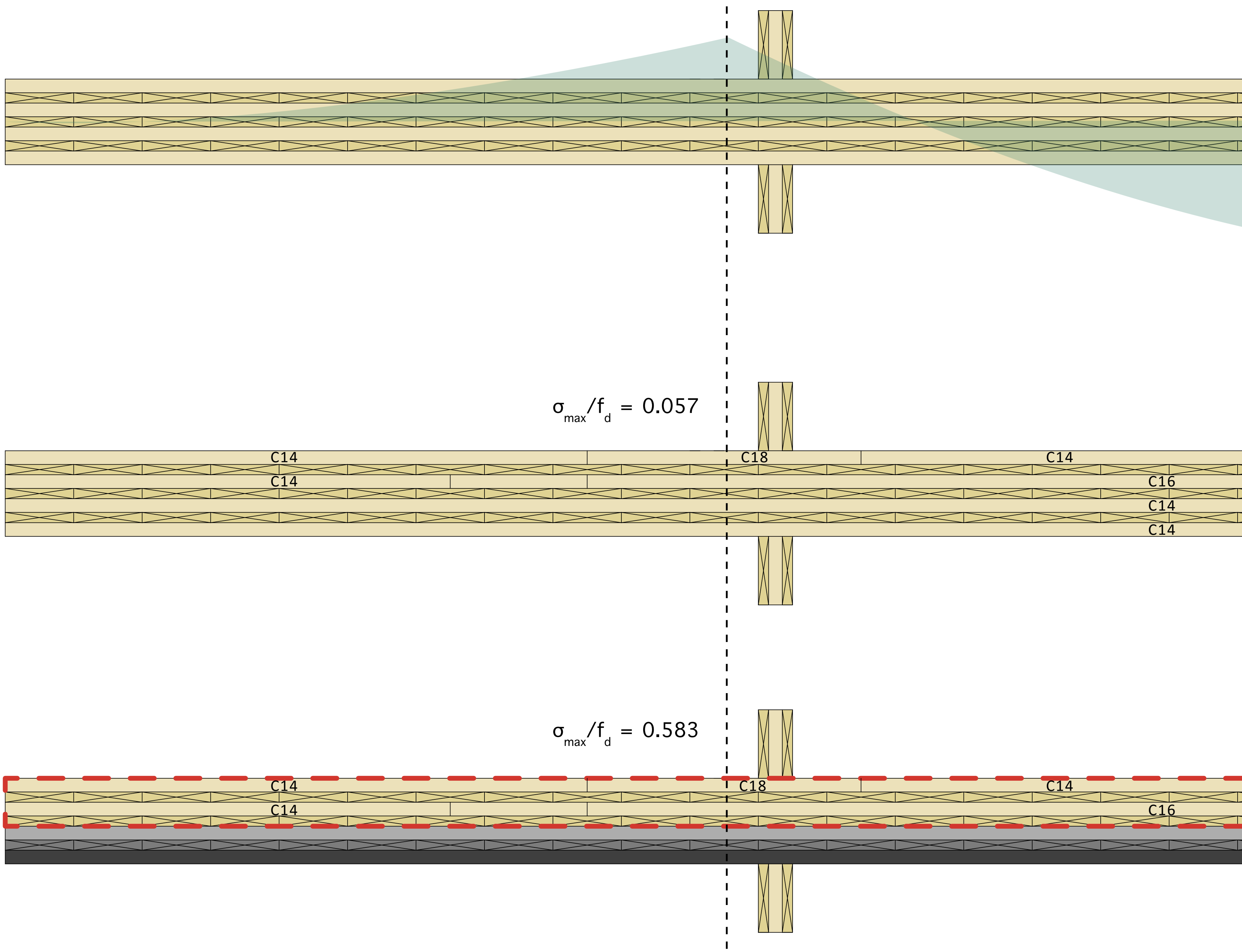
The validation of a timber element depends on the internal stress and the strength of the material. CLT elements gain extra strength compared with construction wood, because of the glue between the boards. But as a result of the anisotropy of the wood, the internal stresses will act differently in the different layers of the CLT element. At the illustration to the right, it is shown how the internal bending stress is high where the fibres are along the bending axis but almost none in the layers perpendicular.
You see in the illustration above that the CLT element with C14 wood can support almost 10 times the weight from the live load.
In case of fire, one would work with a reduced cross-section, below are listed the case of a reduced cross-section after 90 minutes of fire. This case shows failure in the largest positive bending stress point.

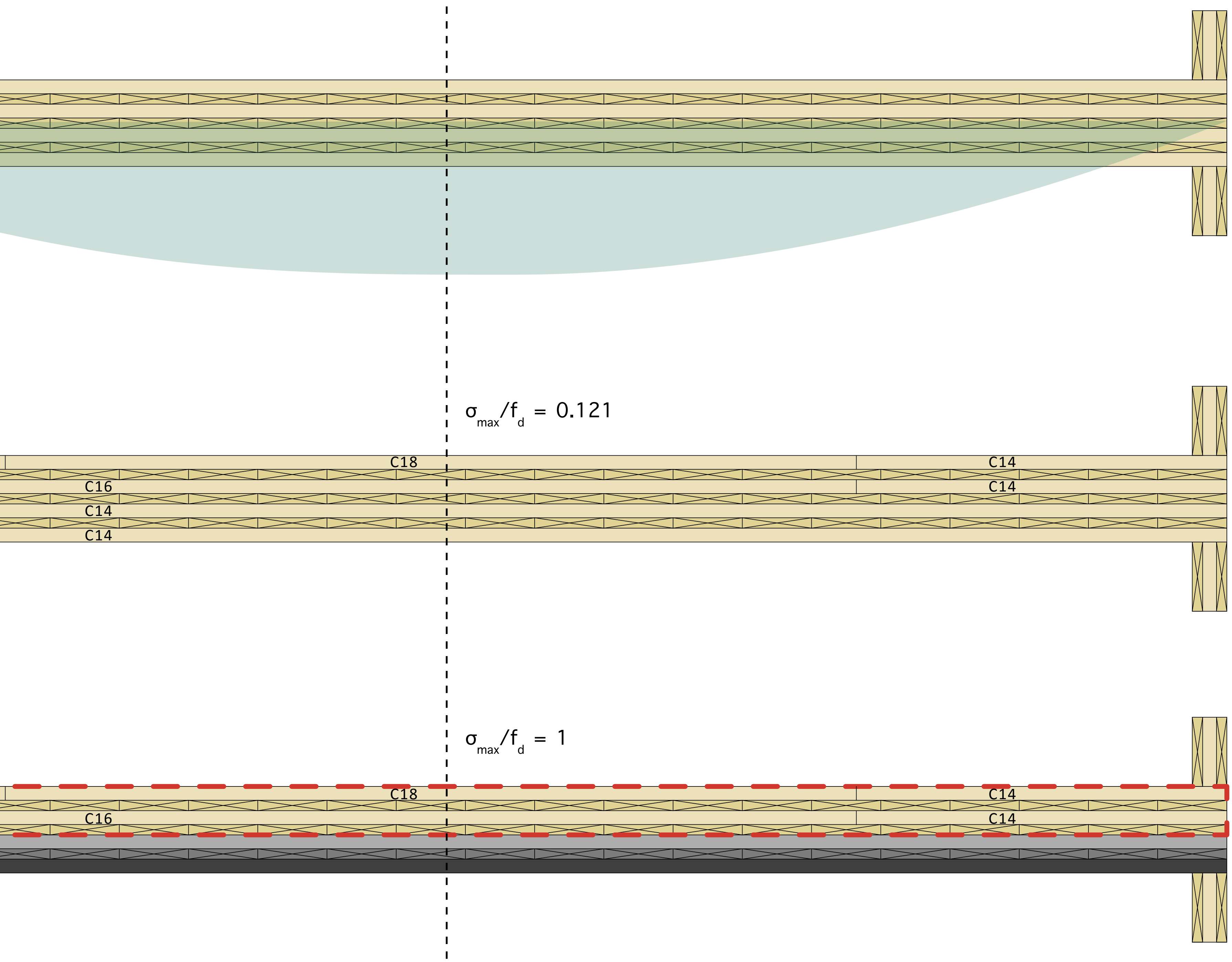




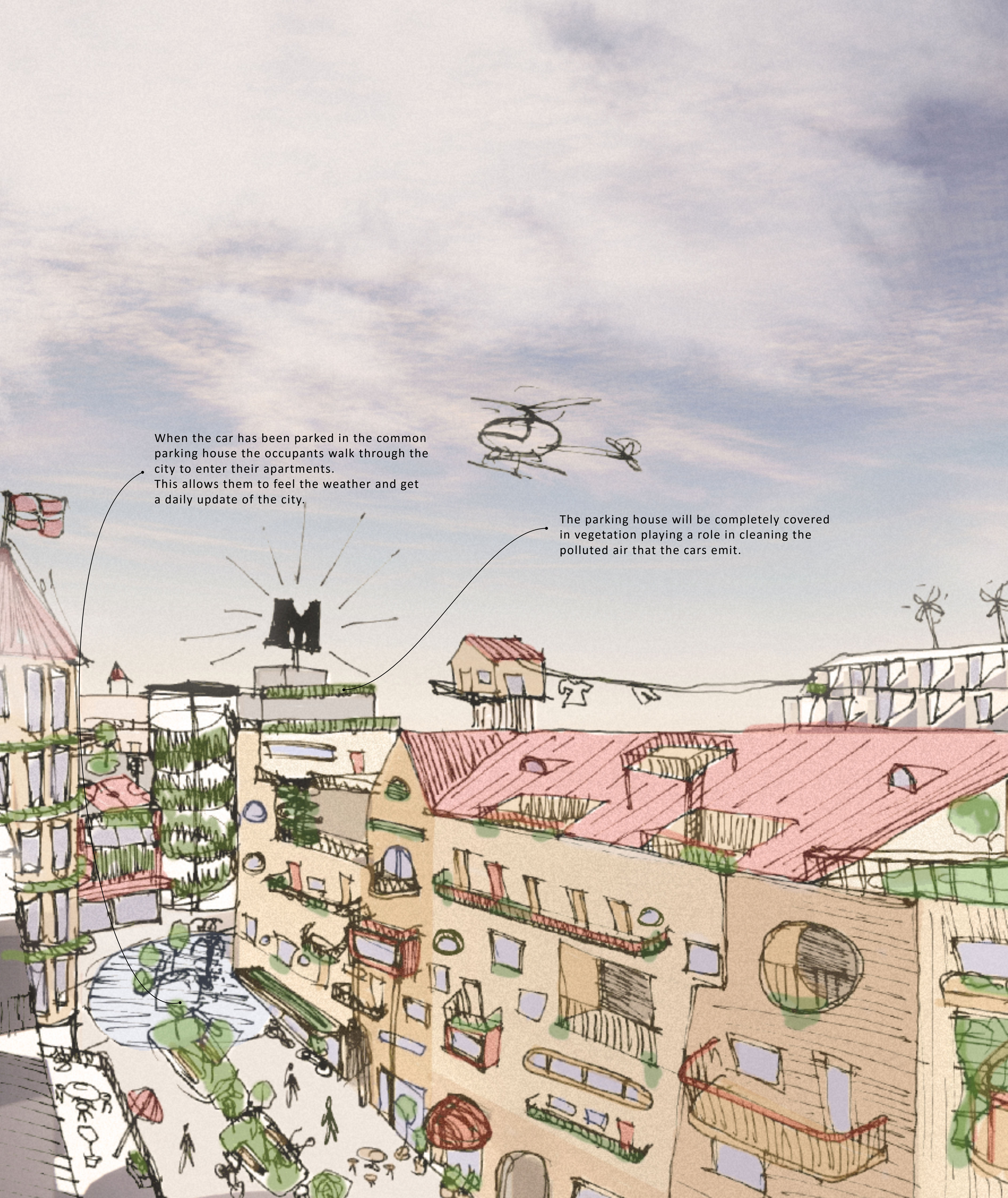
Optimized cross section

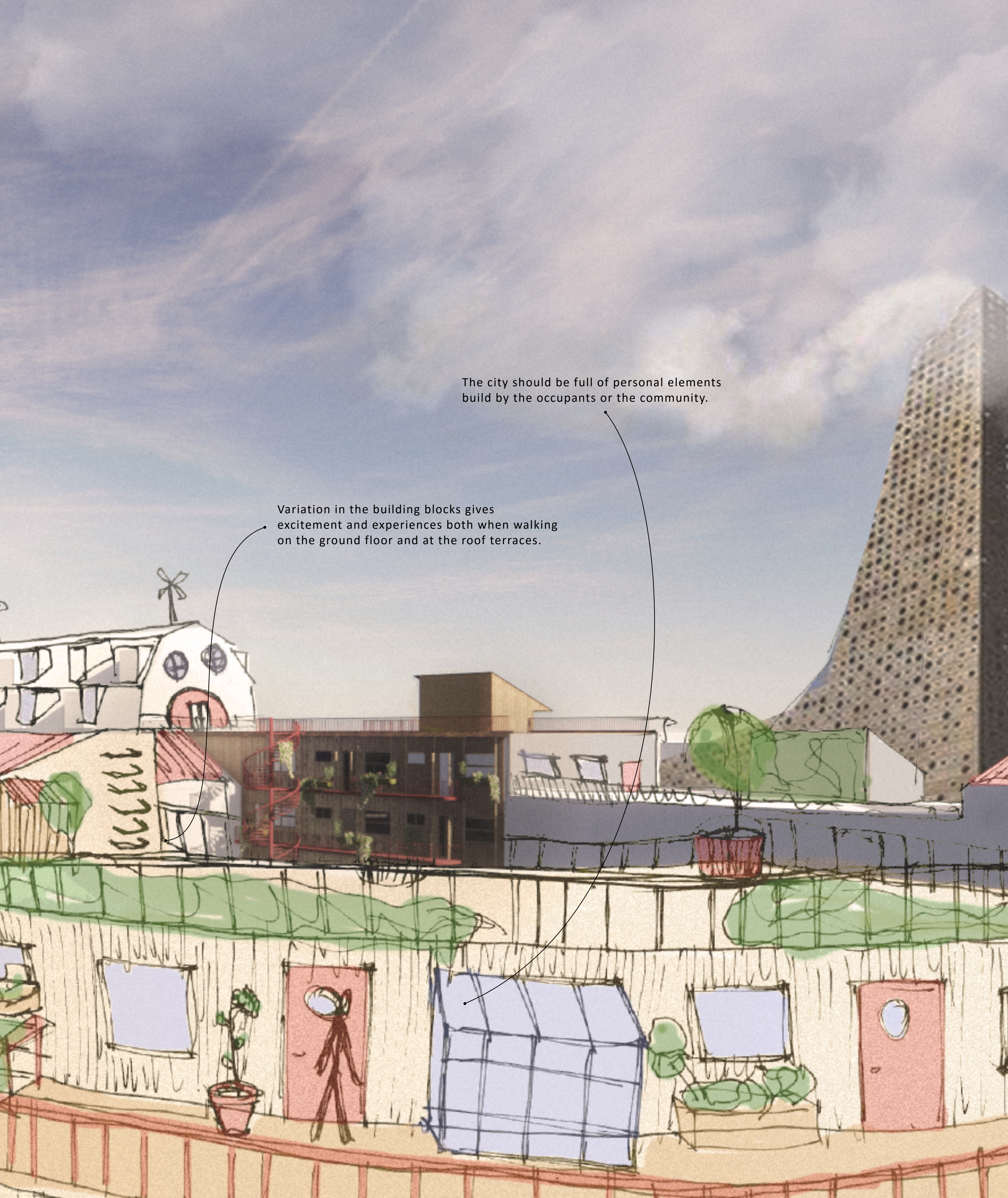
With this knowledge of how CLT acts under stress and fire it is possible to make a conjecture of how one can construct a CLT element with different strengths and wood types where it is needed.





σmax/fd = 0.121
C18
C14
C16
C14
C14
C14
σmax/fd = 1
C18
C14
C16
C14


When the car has been parked in the common parking house the occupants walk through the city to enter their apartments.
This allows them to feel the weather and get a daily update of the city.
The parking house will be completely covered in vegetation playing a role in cleaning the polluted air that the cars emit.


The city should be full of personal elements build by the occupants or the community.
Variation in the building blocks gives excitement and experiences both when walking on the ground floor and at the roof terraces.

Conclusion

Our journey began by sensing a city area build of concrete and asphalt, one could ask; What are the future of these places? Numb spaces of forsaken personality. Is it possible to create a city that both has the necessary density of contemporary city areas and at the same time the liveable qualities of Vandkunstens dense-low buildings?

Together with Boligselskabet Sjælland the framework for the context where set as they define the conditions for the area and contributed with an understanding of the occupants of the future; their desires and visions of future housing. With the context of the city area of Roskilde as the source for design conjectures, the design process was driven through a holistic approach of investigating in multiply scales. The different phases, The Town, The Neighbourhood, and The Home, has let on to investigate through an interdisciplinary design phase which naturally acts across the different scales as a change in one of the scales often influence the other scales. The tectonic approach, which has worked as a way of approaching a problem throughout the work, helps to understand the elements within every decision. Through this understanding, one sees that a change in one element results in a change of the whole.

To structure and handle this process of holism, the theoretical foundation has to likewise be both interdisciplinary and across scales. With the five points of Vandkunsten as the general guidelines and posture of investigations, it has been possible to wield the theory of both Cullen, Lynch and Sim in a direction that corresponded. These theories of different scales help to define the vocabulary for a discussion that can be used to make a conjecture of a future of social housing, that is both rational and innovative.

The result is a conjecture of a different approach to understanding our city, based on ideas of a sustainable, philosophic, and social rationale. An alternative solution to living together makes an allowance for our differences by creating a framework where we as occupants can be together, contribute to the city and, in solidarity, share the resources that are accessible. This social-oriented city is reflected in the social housing where they gain increased value by being codependent, this is what could very well be; better housing of the future.

Reflection

I believe that it is important to have hopes and visions for the future, to aim towards something out of the ordinary, and to allow ourselves to see above legislation and regulations. This rapport is an attempt to go a little further towards an architectural vision. An attempt to show opposition to the common idea of a city with some sense of utopia but mainly rooted in practical experience adding theoretical knowledge and sanity. I believe that the result is something that people might understand and gain an opinion about. The project only scratches the surface of what architecture is but reflects the many layers, scales and holism the whole industry needs to engage in, to create even small changes. Mostly I hope that this work can act as a foundation for me to discuss and show citizens, occupants and families that the cities don't need to be exactly the way they are today, but that we have an alternative. If we can think of it and if we can describe it, we can create it.

The result of this work suggests one way of addressing this future city where social awareness according to Vandkunstens principles is very much defining, but this direction is not the only direction to choose. Vandkunstens principles define ecologic, reuse, solidarity and diversity, but there are as many different suggestions to a better life as there are different people in the world. For some this suggestion might seem too limiting in response to our private lives and some people will find it very disturbing to live four people in an apartment of 75m2, while others might ask for even more sustainability and wishes for a city which is 100% self-producing in both materials and provisions. Because of the coronavirus, we might see the necessity for private space now that, as an example, our home office has advanced, but the crisis has also shown us what we are very much dependent on other humans. A social city might have the possibility to give us the necessary push to befriend our neighbour. Corona has also shown us that in crisis we stripe to be close to our wild nature, I think this will help us understand that the city does not have to be dominated by paving and asphalt but that city and nature do not need to be two separate.

Because of the small timespan relatively to the project scale span and the fact that only I could contribute to developing this project, it was important to choose a method that allowed me to design at a swift pace. The Generator/Conjecture/Analysis method provided me with the theoretical and semantic foundation for making decisions upon a short time of analysis, and different conjectures based on these and based on coincidental thoughts. This means that solutions in this process might not be the best solutions, but rather are a result of experience and intuition. By conjecturing, analysing and improving, one is to fast bring solutions to the design process and acknowledging to follow an intuitive thought. The fact that I rapidly suggested conjectures on one scale allowed me to early make conjectures into the next scale. This means that the process of phases and scale was back and forth as analysis showed problems or conjectures showed more convenient solutions. Conjectures in the neighbourhood scale made changes in the town scale while they defined directions for the home scale. Together with this underlying understanding of tectonics as the means of investigating elements in perspective to other elements, I managed a process of awareness where things correspond to each other and the hierarchy of ideas. The integrated design process, which is normally though at Architecture & Design at Aalborg University, could very well have nourished the same result, as it allows to freely jump back to different design phases. But I found strong inspiration in the freedom of conjecturing. In reality, the design process has been a combination of the methods as I have used my understandings of the faces from the IDP method and implement them into the G/C/A method.
By the clenched fist, I find that this work might contribute to a debate of cities and the future of social housing. I believe that housing architecture is just as important, if not even more, than architecture unique as a philharmonic concert halls or a dramatic theatre.
In the end, I will leave you with this quote, hoping that it will inspire you to make small changes in the world as a part of our common amendment towards a more interesting housing of the future.

In the end, I will leave you with this quote, hoping that it will inspire you to make small changes in the world as a part of our common amendment towards the dense city.

"Husk menneske! Universet er ikke til for dig. Husk det, eller det skal blive din undergang. Jeg sluger din sol og dræber din gud... "

"Remember human! The universe is not for you. Remember this or it will be your doom. I will swallow your sun and kill your god..."
- The Fenrir wolf (Ørntoft T. 2018)

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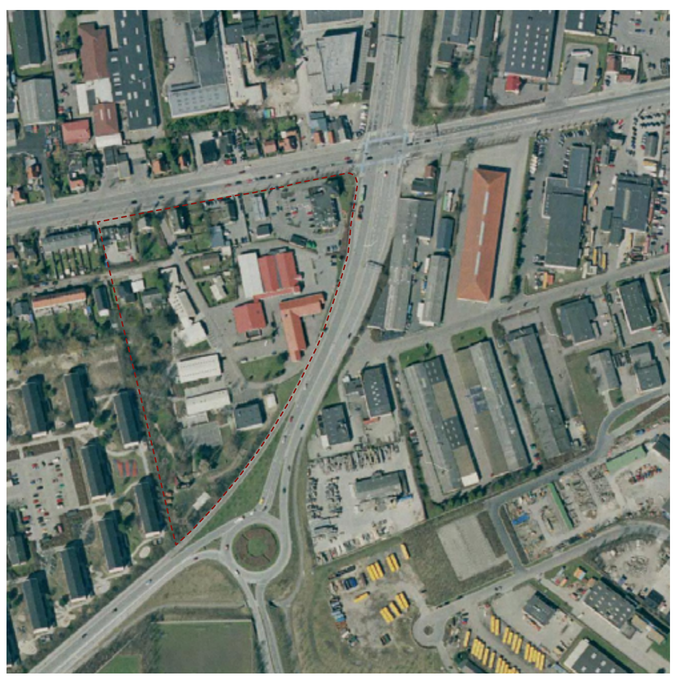
APPENDIX

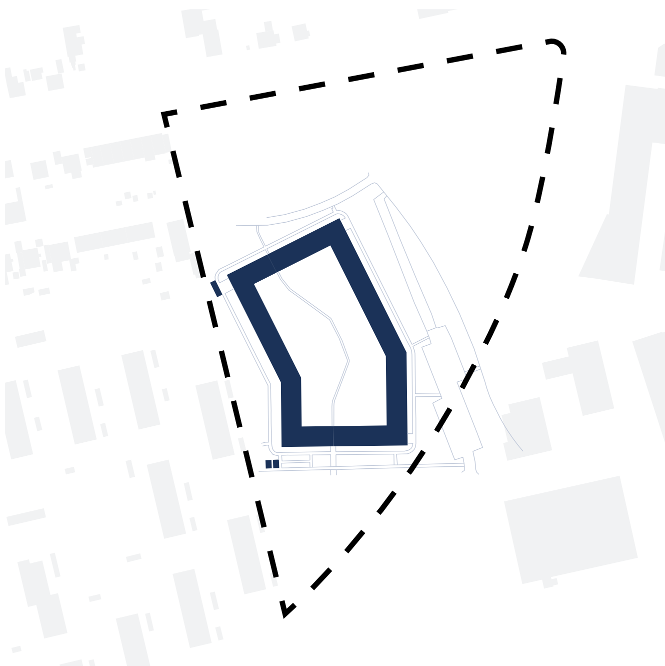




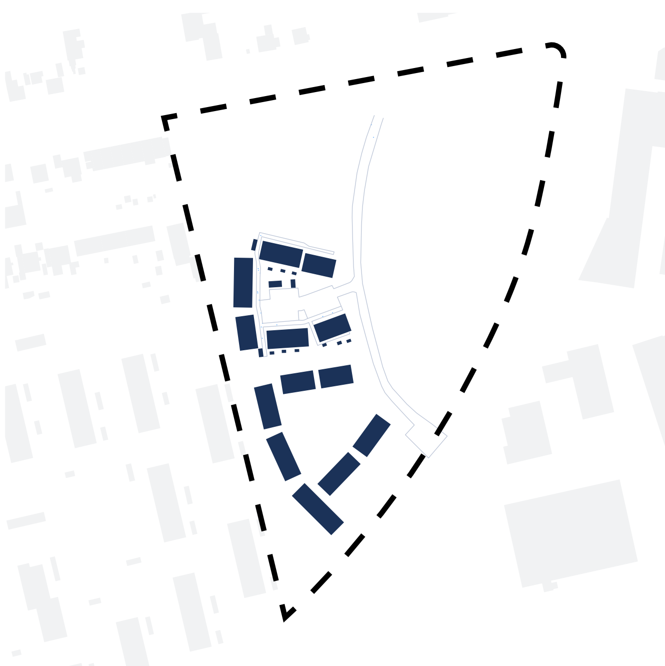



SITE COMPARISON

TINGGARDEN	
Architect:	Vandkunsten
Year:	1971-1978
Location:	Herfølge, DK
Use:	Social housing
	78 apartments
	6 Common houses
Ground area:	4.800m^2
Storey heigh:	1-3



LANGE ENG	
Architect:	Dorte Mandrup
Year:	2009
Location:	Albertslund, DK
Use:	Shared living
	54 apartments
	1 Common houses
Ground area:	3.400m^2
Storey heigh:	2-3



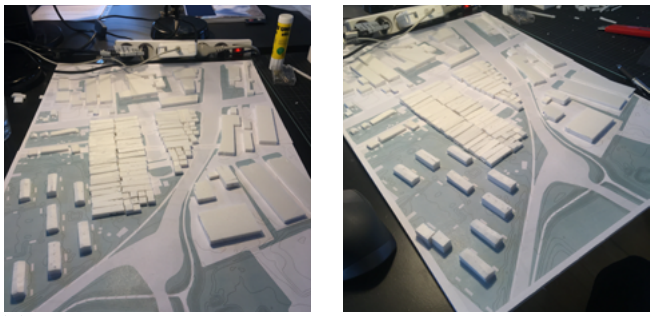
SKADEMOSEN	
Architect:	Vilhelm Lauritzen
Year:	2019
Location:	Roskilde, DK
Use:	Social Housing
	44 apartments
Ground area:	2.700m^2
Storey heigh:	2.5-3.5

VOLUME STUDIES

1-2 storeys

One dense building volume.

2 storeys

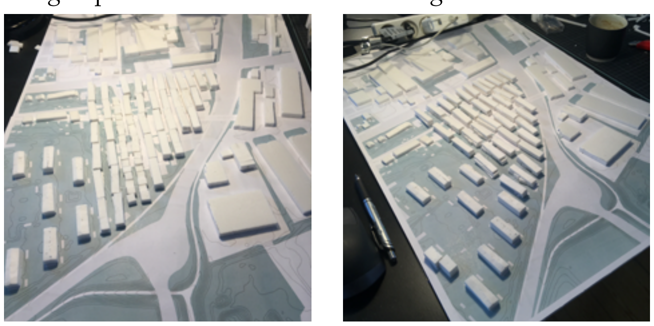


Two dence building volumes creating a space between.

2-3 storeys

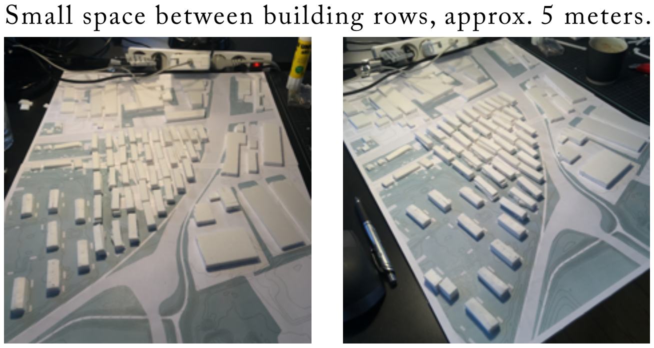
Large space between dence building volumes.

2-3 storeys



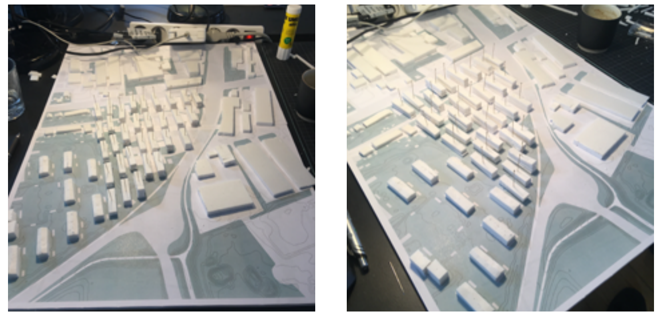
Small space between building rows, approx. 5 meters.

3 storeys



larger space between building rows to both sides.

3-4 storeys

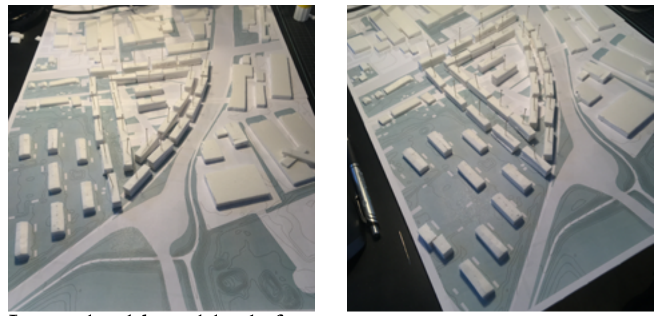


Space between buildings , approx 10 meters.

4 storeys

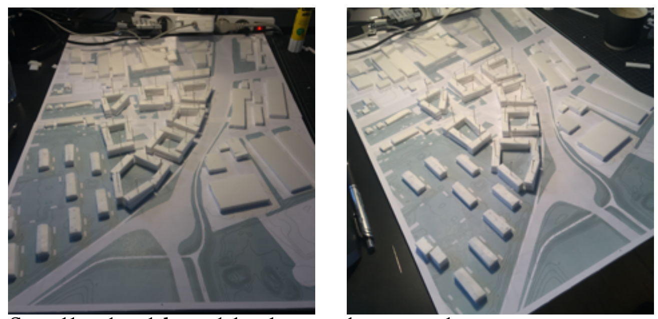
Larger space between building volume.

4 storeys



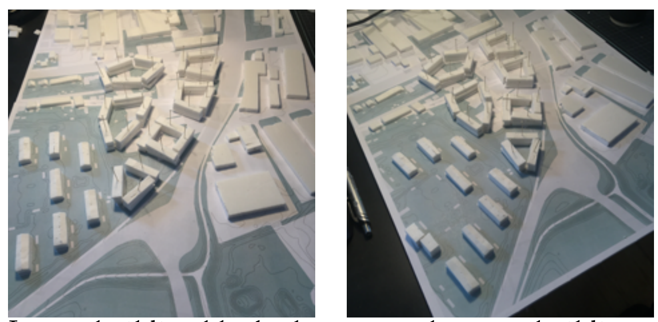
Large building block formation

4 storeys



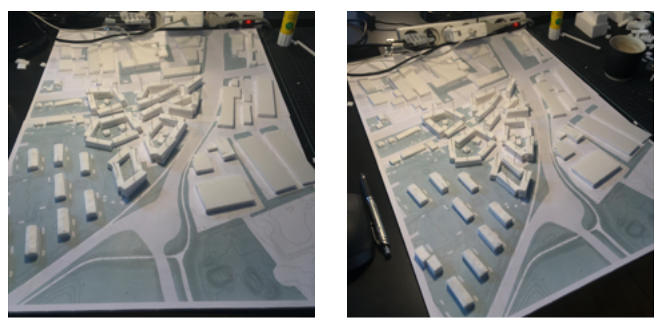
Smaller building blocks, with central common square.

4-5 storeys

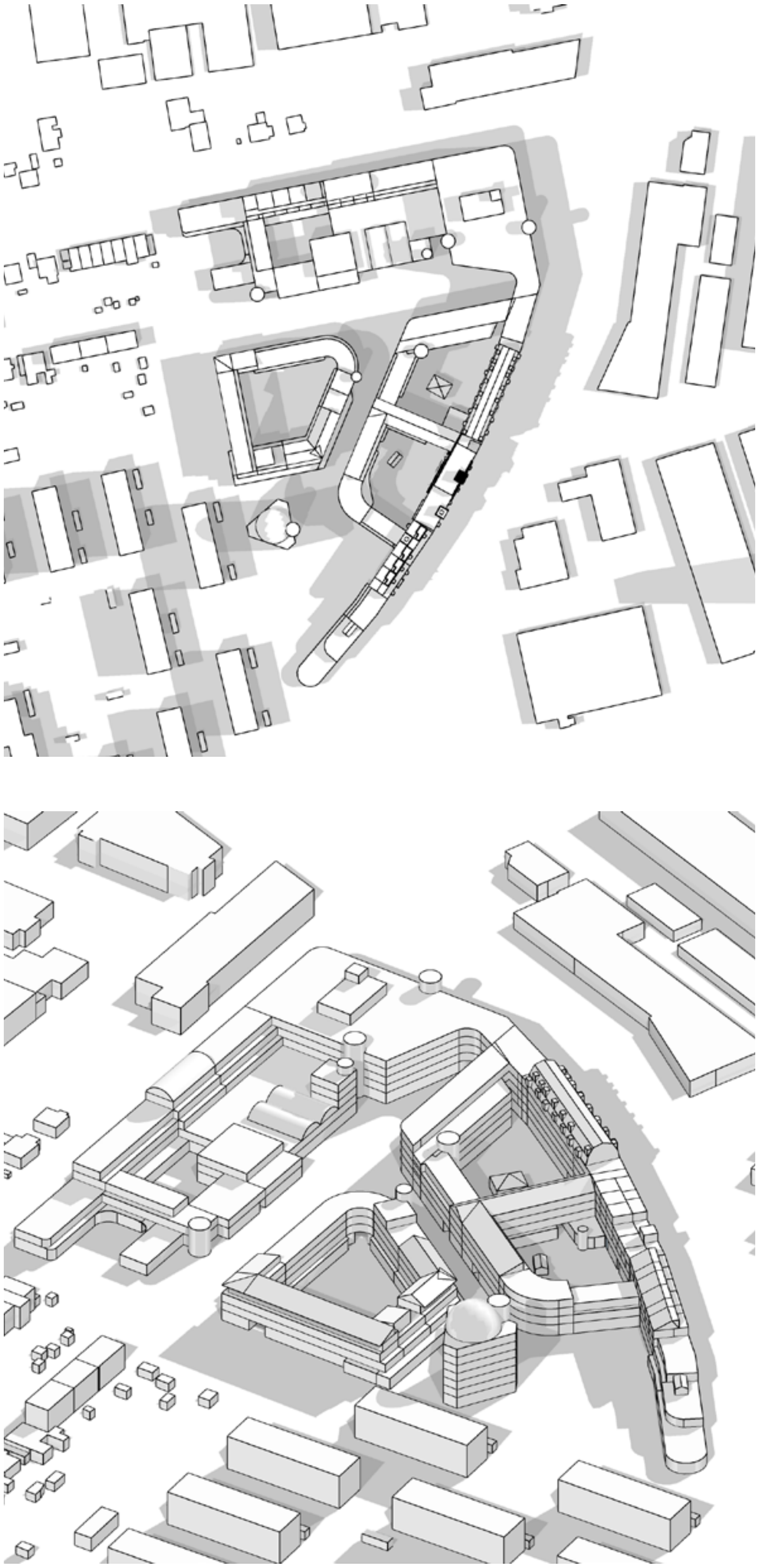


Larger building blocks, large space between buildings.

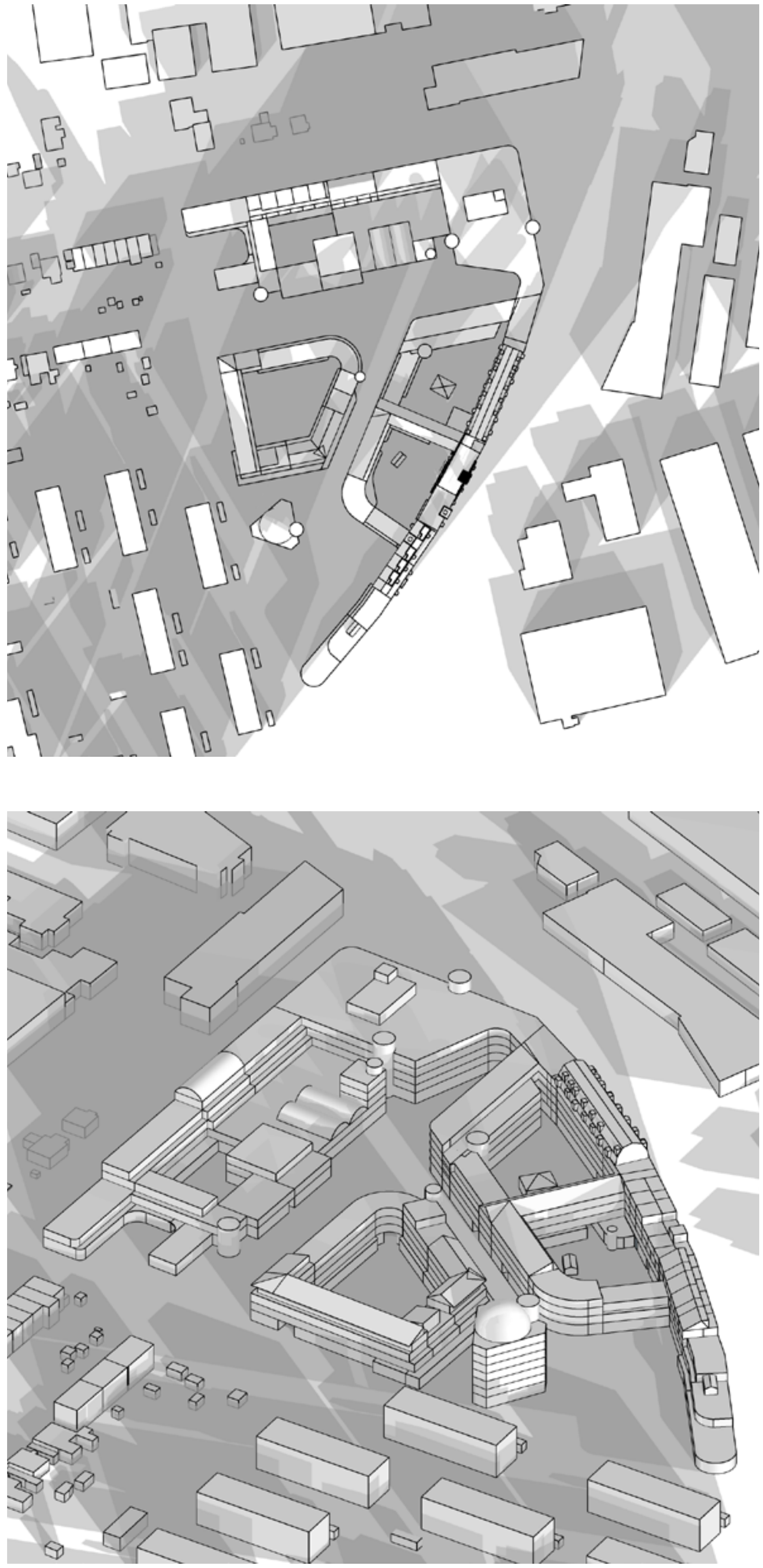
2-5 storeys



Building blocks with occasional point-buildings.



Shadows at summer, 07:00, 13:00, 16:00



Shadows at winter, 10:00, 14:00, 16:00

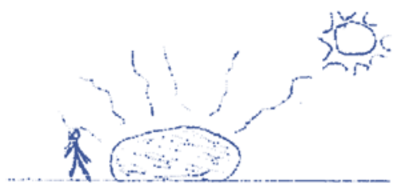
Sun hours and daylight optimization

In a dense city with large building heights and narrow streets one of the main issues is to gain enough sunlight for the area to be nice to occupied. Both outdoor spaces and indoor spaces needs sun radiation and daylight. The sun is used for multiply purposes, both for vision, working light and enjoyment, but an important is the passive energy which is necessary to gain energy efficient buildings.

The building regulation states in general factors concerning:

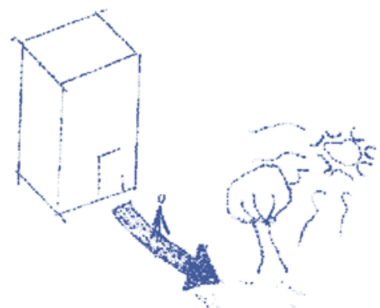
Daylight in workplaces:	2% Daylight factor at working stations (Glass area is 10% of floor area) (Arbejdstilsynet, 2010)
Daylight in living room:	300 lux, approx. 3% daylight factor (Glass area is 10% of floor area) (BR18)
Energy frame for residential:	30 kWh/m^2 each year. This means that the rest have to be found in passive strategies (BR18).

Below are listed some of the strategies one can work with in a urban scale to accommodate for solar radiation and daylight both in outdoor spaces and in indoor space, these are developed by Henning Larsen Architect in collaboration with Realdania (Henning Larsen Architect, 2012).

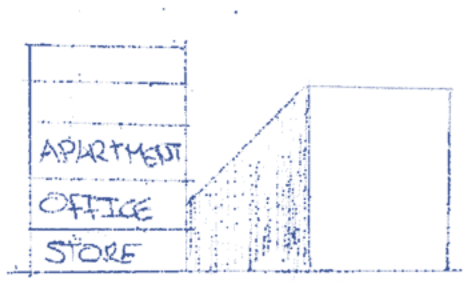


Using thermal heat in the outdoor spaces.

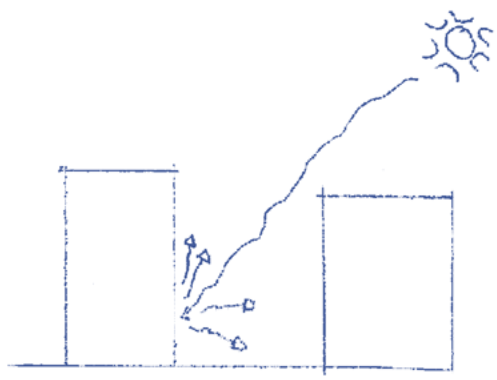
Creating spaces for different use with different solar conditions



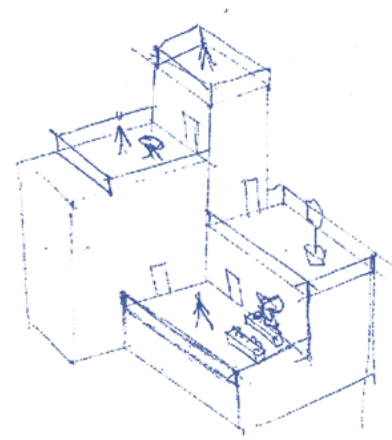
Easy acces to large outdoor and solar areas



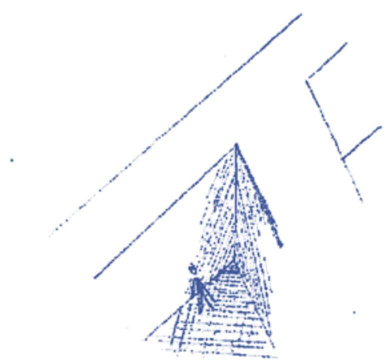
Placing functions which dont need much daylight at the ground floor

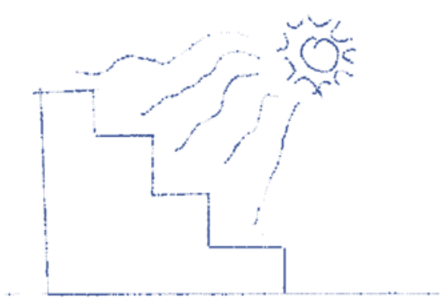


Using light, and reflective materials to let light reflect

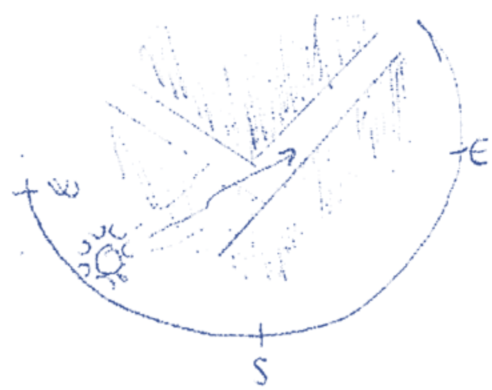


Rooftarrases and tarasses for oriented towards south

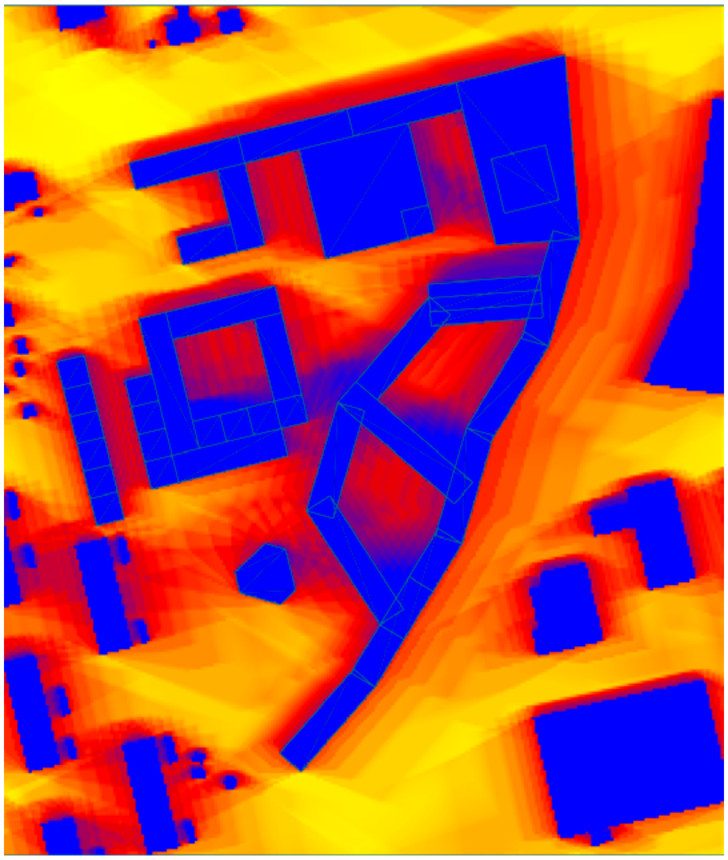




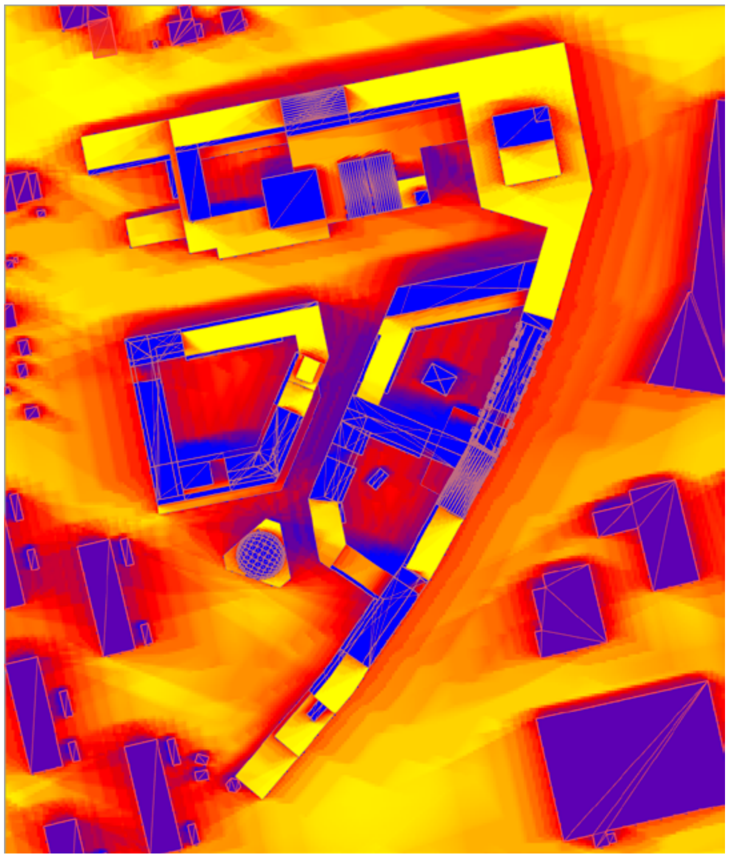
Letting buildings step back to allow sunlight enter apartments below



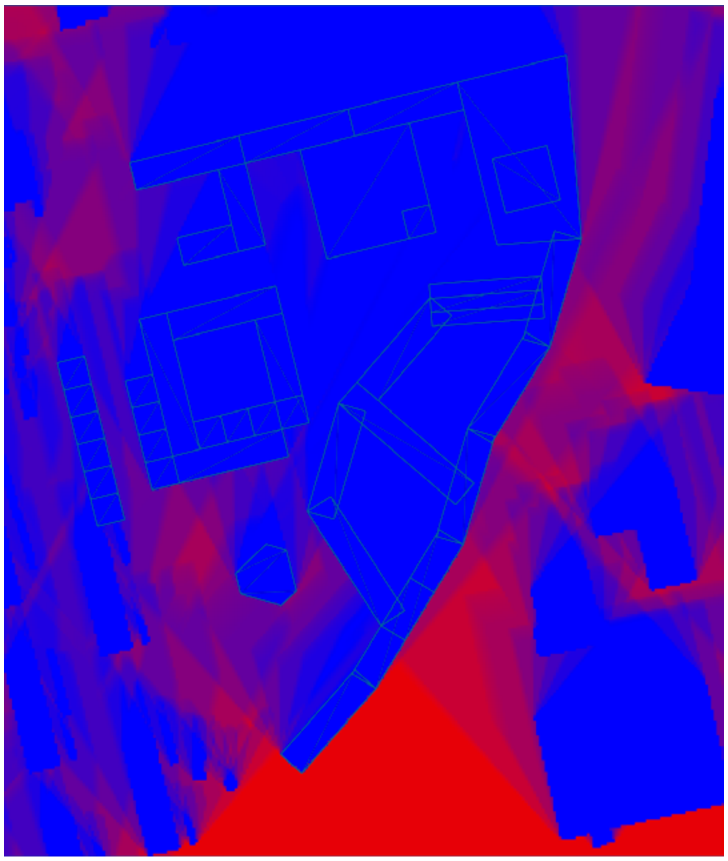
Orienting roads and buildings so that most of the facade is towards south



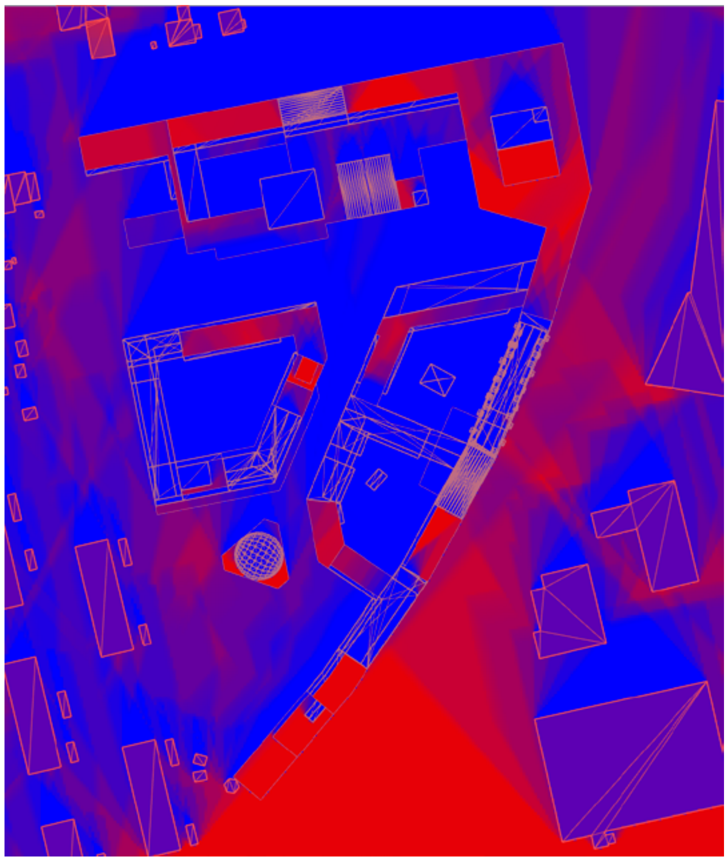
SUN LIGHT HOURS IN JULI CONJECTURE 1



SUN LIGHT HOURS IN JULI AFTHER IMPLYING INITATIVES



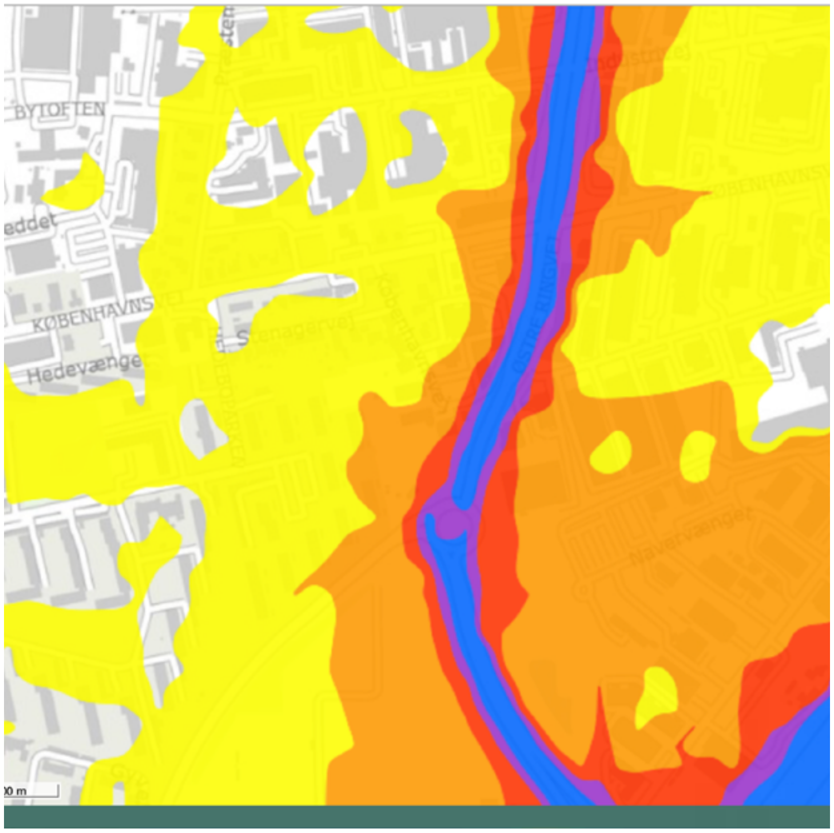
SUN LIGHT HOURS IN DECEMBER CONJECTURE 1



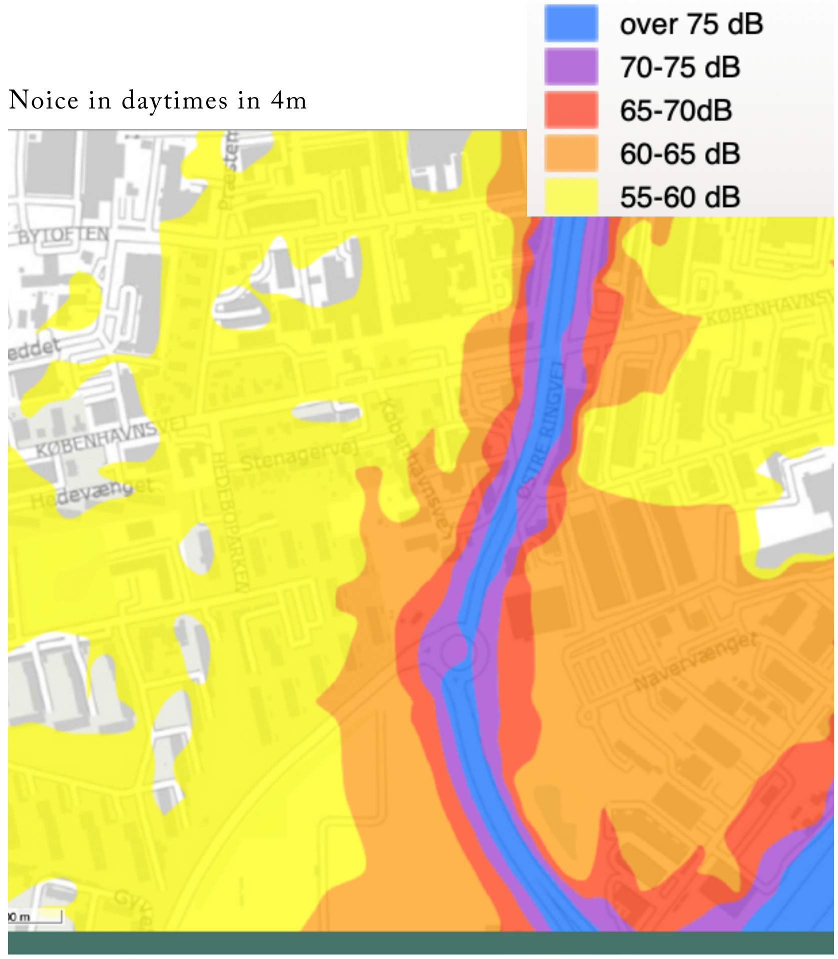
SUN LIGHT HOURS IN DECEMBER AFTHER IMPLYING INITATIVES

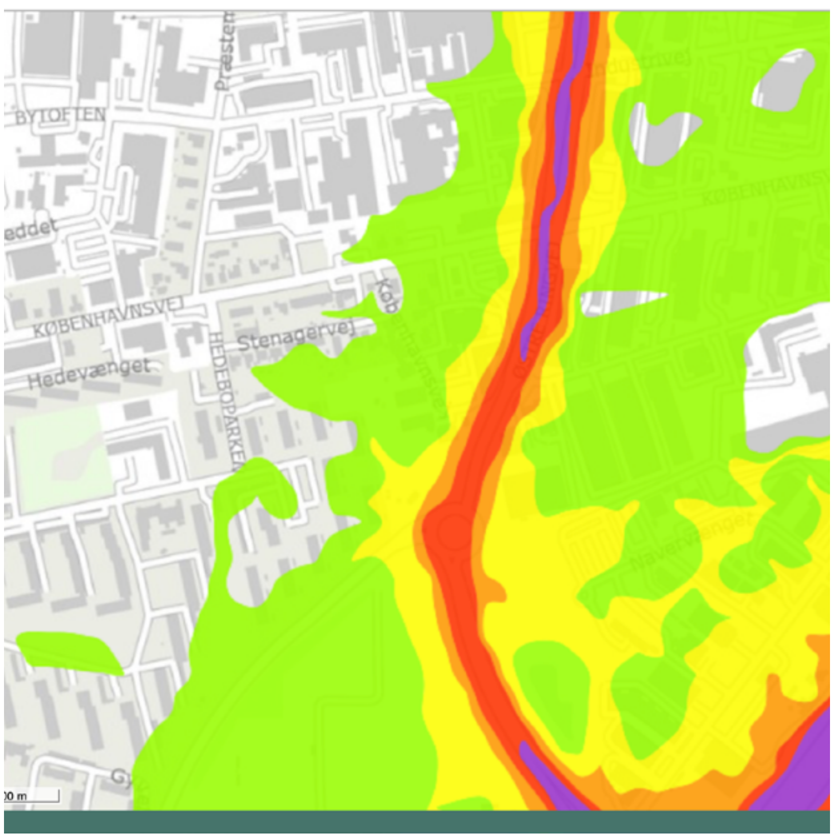
The investigations of solar radiation is a process of back and forth, where density creates shadows in outdoor spaces and only a few means can be done to decrease the shadow. Most importantly is to order buildings in such a distance that they only in a few hours a day limit the radiation on facades of the building next to. The awareness of shadow areas and placing of roof tops gives a setting for designing and investigating a urban landscape more profound.

Noice in daytimes in 1.5m

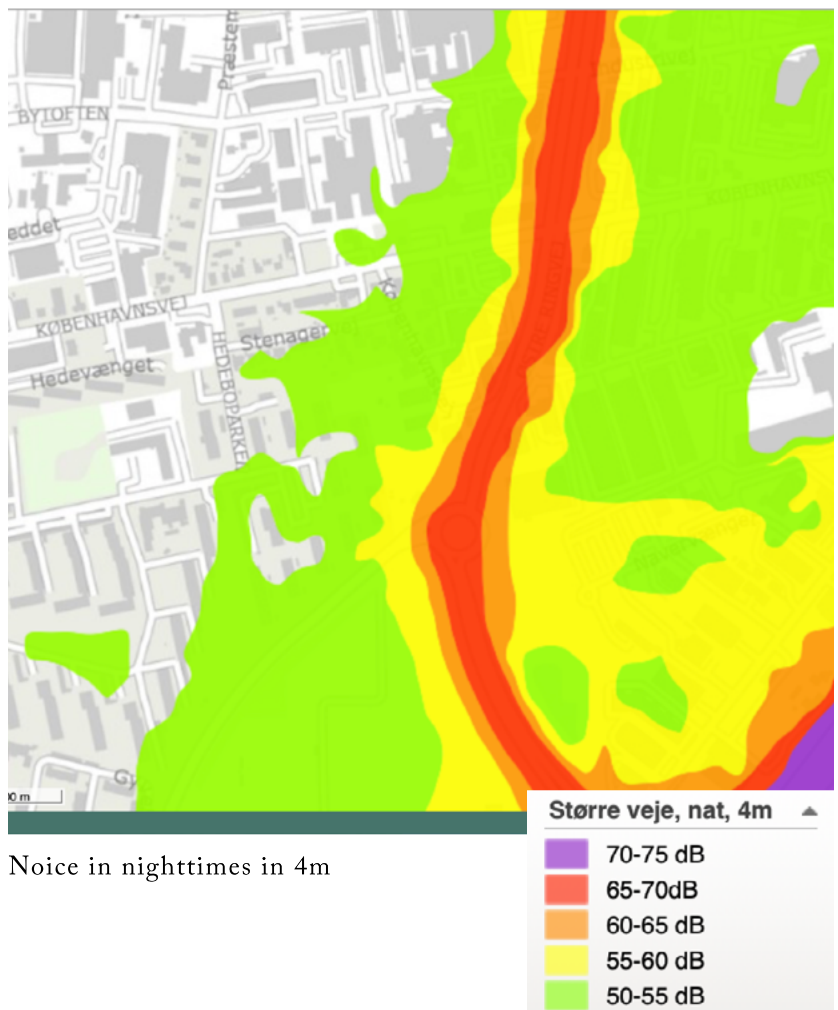


Noice in daytimes in 4m





Noice in nighttimes in 1.5m



Noice in nighttimes in 4m

Områdetype	Grænseværdi L_{den}
Rekreative arealer i landområder, sommerhusområder, campingpladser mv.	53 dB
Boligområder, børneinstitutioner, skoler og uddannelsesin-stitutioner, beboelse for ældre hospitaler mv. Kolonihaver, rekreative arealer og parker	58 dB
Hoteller, kontorer mv.	63 dB

Tabel 3.1. Danske vejledende grænseværdier for støj fra vejtrafik udtrykt som L_{den} [23].

Tabel from Vejdirktoratet Denmark

Boliger – Tabel 2.2 Støj indendørs fra trafik

Lydbestemmelserne gælder ikke for sommerhuse

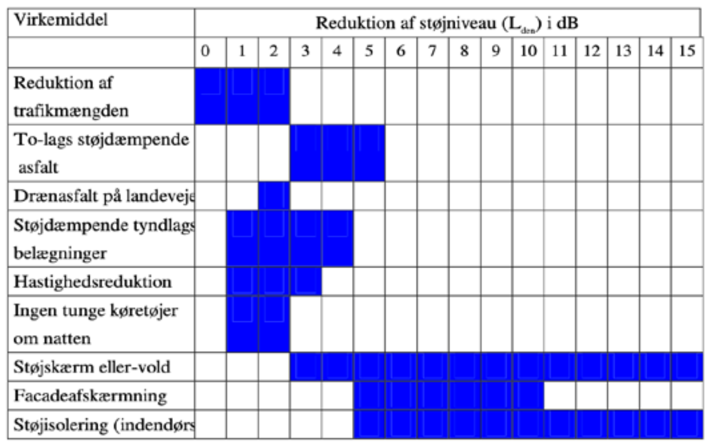
Lovgivning	**Støjbelastning ude** **Veje: L_{den} ≤ 58 dB** **Jernbaner: L_{den} ≤ 64 dB**	**Støjbelastning ude** **Veje: 58 dB < L_{den} ≤ 68 dB** **Jernbaner: L_{den} > 64dB**	**Støjbelastning ude** **Veje: L_{den} > 68 dB**
BR18 [1), 4)] [1], [2]	L_{den} ≤ 33 dB med lukkede vinduer	L_{den} ≤ 33 dB med lukkede vinduer	L_{den} ≤ 33 dB med lukkede vinduer
Supplerende vejledning *Planlovgivning* *- Veje* [5)] [7]	*Ingen krav*	*Byfornyelse mv.* [2)] *Veje: L_{den} ≤ 46 dB* *med åbne vinduer* [3)]	*Der bør ikke planlægges for boliger* [6)]
Supplerende vejledning *Planlovgivning* *- Jernbaner* [5)] [8]	*Ingen krav*	*Byfornyelse mv.* [2)] *Jernbaner: L_{den} ≤ 52 dB* *med åbne vinduer* [3)]	

Noter

1) BR18 henviser til DS 490 om lydklassifikation af boliger, lydklasse C, med grænseværdien for L_{den} gældende for de enkelte trafikstøjkilder hver for sig.
2) Byfornyelse, huludfyldning o.l. i eksisterende boligområder samt områder for blandede byfunktioner i bymæssig bebyggelse.
3) Specielle løsninger er nødvendige.
4) Grænseværdierne gælder i møblerede rum med eventuelle udeluftventiler i åben position.
5) Grænseværdierne gælder i møblerede rum.
6) Lokale bestemmelser kan omfatte boliger ved en udendørs støjbelastning over 68 dB.

Tabel from the danish building regulation

Figur 4. Overslag over normal støjmæssig effekt af forskellige virkemidler. Det skal specielt bemærkes, at der foregår en løbende forskning og udvikling af støjreducerende vejbelægninger.



Tabel from miljøministeriet Denmark

Noise reducent design

The large roads, both Københavnsvej and Østre Ringgade obesely gives disadvantage for the liveability of an area. In general the noise level of almost the whole area is above the limit for allowed noise on facades. This means that proviso have to be considered to hinder unwanted an unforeseen problems. It is important to notice that the noise levels are lower at night than in daytime, but proviso is taken according to a worst case scenario.

In general the following legislations are defined from the danish building regulations:

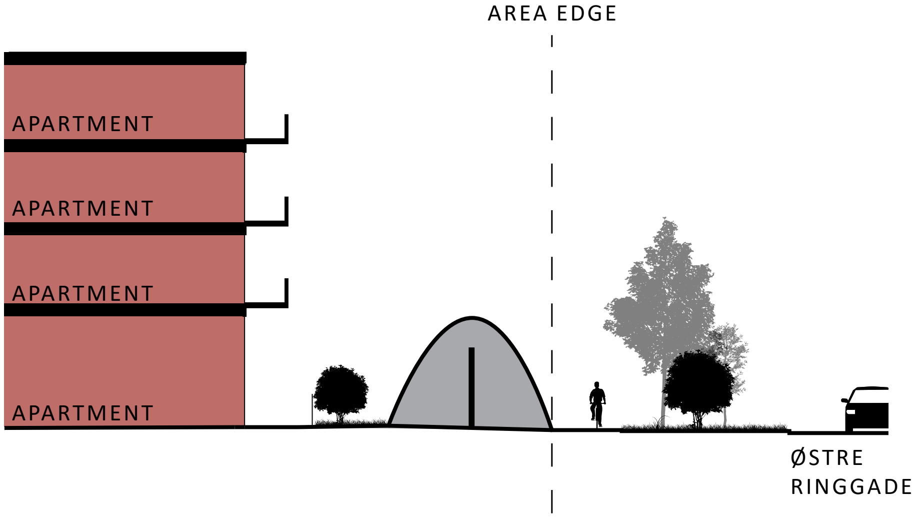
Apartments:
Allowed noise on façade: 58dB
Allowed noise inside apartments: 33 dB (With closed windows)

Offices:
Allowed noise on façade: 63dB
Allowed noise inside apartments: 38 dB (With closed windows)

Below are listet some of the common used solutions for noise handeling in architecture, these are validatet through their effect, economic cost and their posibility for implementation with in the design proposal.

Strategies	*Description* (Støj fra veje, 2007)	*Effect* (Støj fra veje, 2007)	*Economic costs* (Støj fra veje, 2007)	Implementation
Reducing traffic quantity	By making new roads or increasing them in size	0-3 dB	High	Don't require much for the site but have large requirements from the municipality.
Noise damping asphaltt	Special asphalt can be used to reduce noiset	2-5dB	Hight	Don't require much for the site but have large requirements from the municipalityt
Speed reductiont	By reducing speed limit with 10 km/h you gain a reduction at 2,5dBt	1-2dB	Low	Don't require much for the site but the effect of this compared to the annoyance might be disjoint.
Noise screen or mound	A large wall or mound (2-4 meters high)t	3-15dB	Medium	Don't require much for the site, but might detach the site from its surroundings.
Façade screen	A exterior glass screen which reduces the noise	5-10dB	Medium	Requires a aesthetic consideration for the facades.
Noise insulation	Choosing insulation, material and windows which reduces the noise	5-40dB	Medium	Don't requires a lot for the buildings but might increases the cost limits for the buildings.
Distance to the road	Noise decreases with 3 dB every time distance to the road is double	3dB at every 6m (Can be increased by vegetation)	Medium	Creates a unusable space between buildings and road which could be problematic.
Apartment layout	Only having a few living rooms next to noise facade		Low	Requires extra considerations when programming the plan layout.

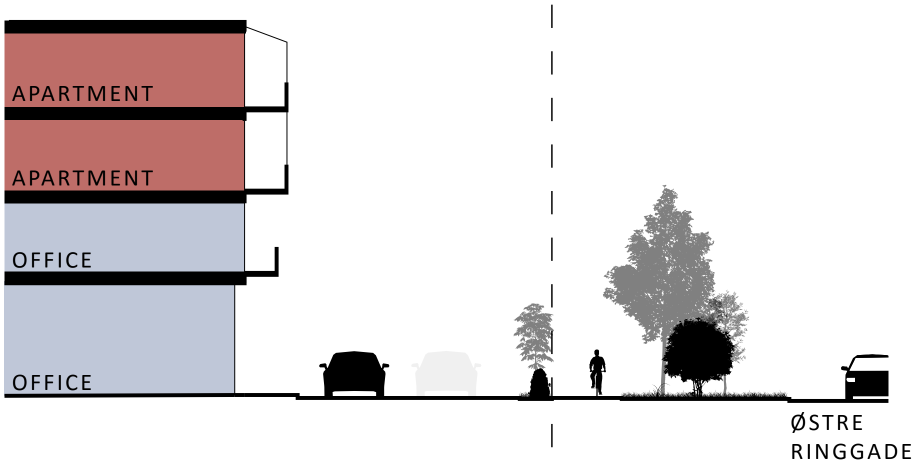
Through investigations of below are listed three ways of accommodating for the noise level at Østre Ringgade (75dB). Each of the princip sections combine multiply solutions to obtain the legislations of apartments and offices. Only the initiatives which are placed inside the area edge has been taken into consideration.



Using a noise screen and mound, distance to the road, and noise insulation

Pros:
Through this method you gain, theoretically the most noise reduction through the use of natural means, this allows for apartments to be placed both in the roof floor and ground floor of the building.

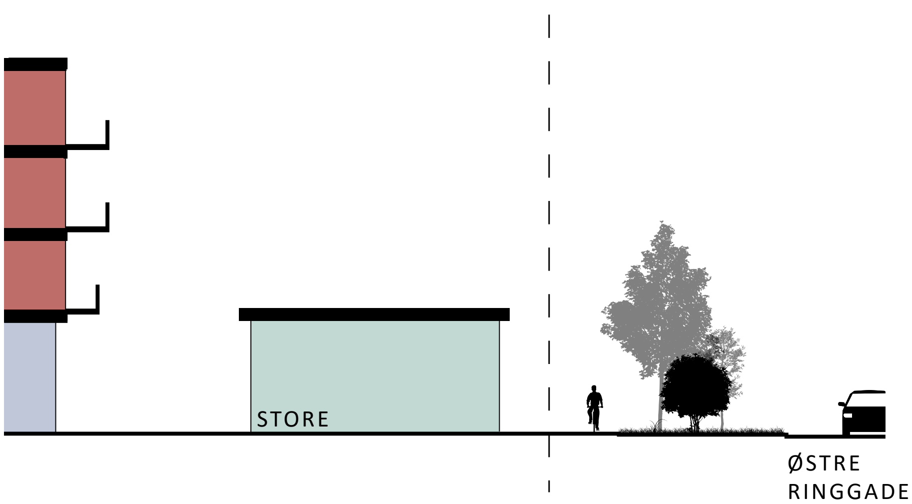
Cons:
The large mound and noise screen creates a detachment to the surrounding areas, and there might be a large space of land which is uninhabitable because of this.



Using distance to the road, noise insulation, program layout and façade screen

Pros:
By addressing most of the noise at the façade of the building the space in front of the building is left for functional use. This allows for functions which do not necessary requires low noise to be set aside like ally functions. Further more one are, depside of the noise, in a closer relation to the surroundings and offices might have possibility to attract customers and letting the enter closely to the office.

Cons:
Occupants might me annoyed by the extra level of glass that they have to manage when needing fresh air.



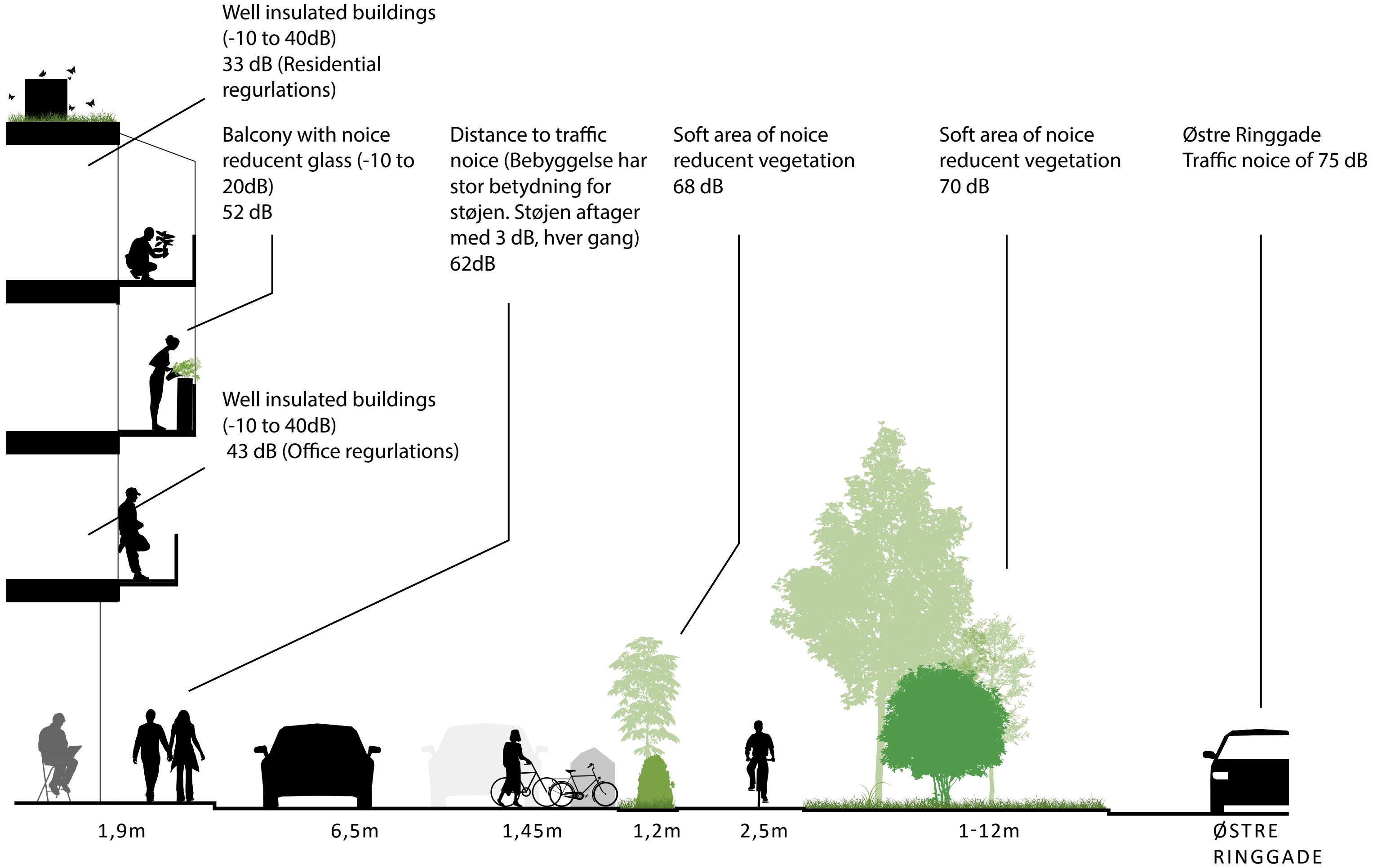
Using distance to the road and a building as noise screen

Pros:
This reduces the noise on the façade without using any extra costs on noise solutions whiles it creates a space for stores which easily can attract customers.

Cons:
This requires a lot of space the stores towards the area edge uses a lot of space and the buildings coming afterwards have to keep large distance. Furthermore, this, as the noise screen, could create a feeling of detachment.

This invistigation shows that there are multiply ways of handeling the noise problem at the large roads. It is important that the space on the ground is used to its fulles so that there is space for internal quality between the buildings. This means that the buildings should be places as far to the edge as possible so that most of the area is usable and nice to occupie.

THE ALLEY



Well insulated buildings
(-10 to 40dB)
33 dB (Residential regurlations)
Balcony with noice reducent glass (-10 to 20dB)
52 dB
Distance to traffic noice (Bebyggelse har stor betydning for støjen. Støjen aftager med 3 dB, hver gang)
62dB
Soft area of noice reducent vegetation
68 dB
Soft area of noice reducent vegetation
70 dB
Østre Ringgade
Traffic noice of 75 dB
Well insulated buildings
(-10 to 40dB)
43 dB (Office regurlations)
1,9m
6,5m
1,45m
1,2m
2,5m
1-12m
ØSTRE
RINGGADE

Month Average - Energy Concumption

Month Average Calculation

AALBORG UNIVERSITET
ARCHITECTURAL ENGINEERING

Rev. 17-04-2012 by JN

Building data

Roomtemperatur in case of heating [°C]	20
Roomtemperatur in case of cooling [°C]	25
Ground temperature [°C]	7,6
Net area [m²]	2568
Gross area [m²]	3424
Heated build-up area (footprint) [m²]	3424
Service life [hours/week]	168
Relative service life	1,000

Weather data

Choose destination
Copenhagen

If comments not are shown
they can be activated under "view"

Noise reducent design

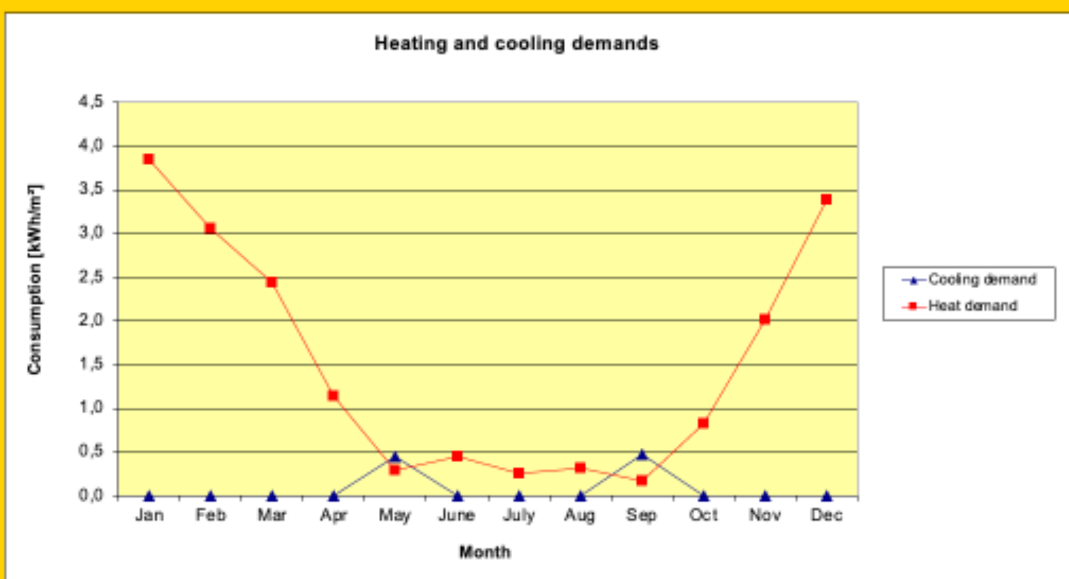
Heating and cooling demands of the building

Month	Number of days	Cooling demand kWh/m²	Heat demand kWh/m²	Ventilation loss W/K	Utility factor	Solar gain kWh	Internal gain kWh	Gains caused by tu>ti kWh	Heat loss with winter temp. kWh	Heat loss with summer temp. kWh
Jan	31	0,0	3,8	774	0,935	1815	12722	0	26755	33268
Feb	28	0,0	3,1	774	0,916	2838	11491	0	23609	29492
Mar	31	0,0	2,4	774	0,872	4268	12722	0	23179	29693
Apr	30	0,0	1,1	774	0,758	5837	12312	0	17659	23962
May	31	0,5	0,3	774	0,551	7420	12722	0	12082	18595
June	30	0,0	0,4	2787	0,614	7197	12312	0	13518	27068
July	31	0,0	0,3	2787	0,538	7049	12722	0	11511	25513
Aug	31	0,0	0,3	2787	0,567	6831	12722	0	12057	26059
Sep	30	0,5	0,2	774	0,506	4926	12312	0	9305	15609
Oct	31	0,0	0,8	774	0,728	3385	12722	0	14548	21061
Nov	30	0,0	2,0	774	0,869	1983	12312	0	19329	25632
Dec	31	0,0	3,4	774	0,928	1229	12722	0	24536	31049
SUM		***1***	***18***			***54579***	***149796***	***0***	***208089***	***307000***

Result

Energy consumption for heating pr m² floor area [kWh/m² yr]	18,2
Energy consumption for cooling pr m² floor area [kWh/m² yr]	0,9
Total energy consumption pr m² floor area [kWh/m² yr]	19,1

For comparison...	**Dwellings**	**Offices**
Energy class 2010	53,0	71,8 kWh/m² yr
Low energy class 2015	30,3	41,3 kWh/m² yr
Building class 2020	20,0	25,0 kWh/m² yr



Ventilation

Ventilation rate, summer

Service hours [l/s m²]	0,90
Outside service hours [l/s m²]	0,25
Average ventilation rate [m³/s]	2,31

Ventilation rate, winter

Service hours [l/s m²]	0,25
Outside service hours [l/s m²]	0,25
Average ventilation rate [m³/s]	0,64

Ventilation loss, summer [W/K]	2787	=Bv,summer
Ventilation loss, winter [W/K]	774	=Bv,winter

Characteristics of the building

Constructions towards outdoor

A m^2	Description	U W/m^2K	Bu W/K	
550	nordvæg	0,12	66	
0	østvæg	0	0	
30	vestvæg	0,12	3,6	
500	sydvæg	0,12	60	
850	tag	0,11	93,5	
			0	
			0	
			0	
			0	
Specific heat loss, constructions towards outdoor [W/K]			223,1	= Bu,con

Windows

A m^2	Direction	U W/m^2K	Bu W/K	g-value [-]	f(beta) [-]	f(shade) [-]	f(shadow) [-]	f(glass) [-]	Fsun [-]
240	N	1,2	288	0,5	0,9	0,7	0,7	0,75	0,165375
	NE		0						0
0	E	0	0	0	0	0	0	0	0
	SE		0						0
300	S	1,2	360	0,5	0,9	0,65	0,7	0,75	0,1535625
	SW		0						0
10	W	1,2	12	0,5	0,9	0,9	0,9	0,75	0,273375
	NW		0						0
	Skylight		0						0
Specific heat loss, windows [W/K]			660	= Bu,win					

Specific heat loss, outdoors, total [W/K]:	883,1	= Bt (=Bu,con+Bu,win)

Floor

A m^2	U W/m^2K	Bu W/K	
850	0,11	93,5	
		0	
		0	
		0	
		0	
Specific heat loss, floor [W/K]		93,5	= Bu,floor

Heat capacity

Heat capacity [Wh/K m²]	40
Time constant	37,3
a	3,3

Internal heat loads

Hour	Person load W	Ligthing W	Other W	Total W	
1	5100	0	12000	17100	
2	5100	0	12000	17100	
3	5100	0	12000	17100	
4	5100	0	12000	17100	
5	5100	0	12000	17100	
6	5100	0	12000	17100	
7	5100	0	12000	17100	
8	5100	0	12000	17100	
9	5100	0	12000	17100	
10	5100	0	12000	17100	
11	5100	0	12000	17100	
12	5100	0	12000	17100	
13	5100	0	12000	17100	
14	5100	0	12000	17100	
15	5100	0	12000	17100	
16	5100	0	12000	17100	
17	5100	0	12000	17100	
18	5100	0	12000	17100	
19	5100	0	12000	17100	
20	5100	0	12000	17100	
21	5100	0	12000	17100	
22	5100	0	12000	17100	
23	5100	0	12000	17100	
24	5100	0	12000	17100	
Total	122400	0	288000	410400	
Average	5100	0	12000	17100	=Φi

Pr. m² floor area	Person load W/m²	Ligthing W/m²	Other W/m²	Total W/m²
Average	1,99	0,00	4,67	6,66

Help for internal loads

Heat from persons:	Activity level met	Total W/person	Sensible heat W/person	Number of persons	Sensible, total W
	1,2	118	76	8	609

Ligthing: General	Level: lux	Incandescent ligh W/m² g.a.	fluorescent W/m² g.a.	Lowenergy W/m² g.a.	Choose power W/m² g.a.	Ligthing total, W
	200	52	16	8	8	27392

24-Hour Average - Thermal comfort

Calculation of 24-hour average temperature

AALBORG UNIVERSITET
ARCHITECTURAL ENGINEERING

Project:
Apartment A

Description of the room

If comments not are shown
they can be activated under "view"

Constructions towards outdoors

Nr	Surface	A m^2	U W/m^2K	Bu W/K	
1	Ydervæg	17,00	0,13	2,21	
2				0,00	
3				0,00	
4				0,00	
5				0,00	
	Total	17,00		2,21	= Bu,con

Windows towards outdoors

Nr	Surface	Number stk	A m^2	U W/m^2K	Bu W/K	Orient degree	Inclination 90/45/0	g-value [-]	f(beta) [-]	f(shade) [-]	f(shadow [-]	f(glass) [-]	Fsun [-]
1	Vindue	1	2,20	1,20	2,64	180	90	0,50	0,90	0,60	0,80	0,75	0,16
2	Dør	1	1,90	1,20	2,28	180	90	0,50	0,90	0,30	0,80	0,75	0,08
3	Vindue smal	1	1,10	1,20	1,32	180	90	0,50	0,90	0,70	0,70	0,75	0,17
4					0,00								0,00
5					0,00								0,00
	Total	3	5,20		6,24	= Bu,win							
	Total specific heat loss towards outdoors, Bt				8,45	= Bt = Bu,con+Bu,win							

Constructions towards ground and surrounding rooms

Nr	Surface	A m^2	U W/m^2K	Br W/K	tr °C	Br*tr W	
1	Wall	30,00	0,34	10,20	20,00	204,00	
2				0,00		0,00	
3				0,00		0,00	
4				0,00		0,00	
5				0,00		0,00	
	Total	30		10,20		204,00	=Σ Br*tr
	Total specific heat loss towards ground and surrounding rooms,			10,20	= Br		

Ground temperature for area chosen under destination i
7,6 °C

Ventilation

	Type	Air change h^{-1}	Room volum m^3	Air flow m^3/s	Density kg/m^3	Heat kap. J/kgK	BL W/K	
1	Ventilation	2,30	62,40	0,040	1,2	1006	48,13	
2	Infiltration	0,10	62,40	0,002	1,2	1006	2,09	
	Total	2,4		0,042			50,22	
	Total specific heat loss for ventilation, BL						50,22	= BL

Control
Total air flow
litre pr. m^2 floorarea
1,7

Heat accumulation

	Choose heat accumulation	Therm. cap W/K pr m^2	Floor area m^2	Ba W/K	
1	Extra light	6	25,00	150,00	
	Samlet specifik varmeakkumulering Ba			150,00	= Ba

Description of chosen inner structure

Light walls, floors and ceilings. e.g.skeleton with boards without any heavy structures.

Internal heat loads

Project:

Apartment A

Internal heat loads

Time	Personbelast W	Belysning W	Andet W	Sum W
1	80	0	20	100
2	80	0	20	100
3	80	0	20	100
4	80	0	20	100
5	80	0	20	100
6	80	0	20	100
7	80	0	20	100
8	0	0	20	20
9	0	0	20	20
10	0	0	20	20
11	0	0	20	20
12	0	0	20	20
13	0	0	20	20
14	0	0	100	100
15	0	0	100	100
16	120	80	100	300
17	120	80	100	300
18	120	100	100	320
19	120	100	100	320
20	120	100	100	320
21	120	100	100	320
22	120	0	100	220
23	80	0	100	180
24	80	0	20	100
Sum	1560	560	1280	3400
Middelværdi	65	23	53	142 =Φi
Max. timeværdi	120	100	100	320 =Φimax
Min. timeværdi	0	0	20	20 =Φimin

Pr. m² gulvareal	Personbelast W/m²	Belysning W/m²	Andet W/m²	Sum W/m²
Middelværdi	2,60	0,93	2,13	5,67
Max. timeværdi	4,80	4,00	4,00	12,80
Min. timeværdi	0,00	0,00	0,80	0,80

Calculations

Go to sheet RESULT

External loads

Choose destination

Copenhagen

Choose month

July

Outdoor temp: 24-hour av	21	°C	= tu
variation	12	°C	= Δtu

Solar gain windows	Area m2	Orientation degree	Inclination degree	Fsun [-]	Φs W	Φsmax W
1	2,20	180	90	0,16	70	237
2	1,90	180	90	0,08	30	102
3	1,10	180	90	0,17	36	121
4	0,00	0	0	0,00	0	0
5	0,00	0	0	0,00	0	0
Total solar gain in room					137	461

Help for internal loads

Heat from persons:	Activity leve met	Total W/person	Sensible he W/person	Number of p	Sensible, tot W
	1,2	118	76	2	152

Ligthing: general	Level: lux	Incandescen W/m² g.a.	fluorescent W/m² g.a.	Lowenergy W/m² g.a.	Choose pow W/m² g.a.	Ligthing i alt W
	100	26	8	4	8	200

Results

Project:

Apartment A

Choosen month:	July	tu =	21	°C

If the ventlation air has same temperature as outdoor air

24-hour average	ti =	24,9	°C
Temperature variation	Δti =	5,4	°C
Max. Temperature	timax =	27,6	°C

$$t_i = \frac{B_t t_u + \sum B_r t_r + B_L t_L + \Phi_i + \Phi_s}{B_t + \sum B_r + B_L}$$

$$\Delta t_i = t_{imax} - t_{imin} = \frac{\Delta \Phi_K}{B_t + \sum \mathbf{B_r} + B_L + B_{akk}}$$

$$\Delta\Phi_k = \Delta\Phi_{k1} + \Delta\Phi_{k2}$$

$$\Delta\,\Phi_{k1} = \frac{2}{3}[(\Phi_i + \Phi_s)_{max} - \Phi_{i,min}]$$

$$\Delta\Phi_{k2} = \Delta t_u(\mathbf{B}_{u,vin} + \mathbf{B}_L)$$

Additional calculations

If the ventilation air has the same temperature as the outdoor 24-hour average temperature

24-hour average	ti =	24,9	°C
Temperature variation	Δti =	2,8	°C
Max. Temperature	timax =	26,3	°C

Calculation where the ventilation air has a constant inlet temperature which is Δt = 2 °C lower than the outdoor 24-hour average temperature

If the ventilation air has a constant temperature of 19 °C

24-hour average	ti =	23,4	°C
Temperature variation	Δti =	2,8	°C
Max. Temperature	timax =	24,8	°C

Calculation of CLT element with C14

Payload

$G_{nyt.flade} := 1.5 \frac{kN}{m^2}$ — Load of payload for housing, DS/EN 1991-1-1 FU:2015, Table 6.2

$G_{nyt} := G_{nyt.flade} \cdot b_x = 3.3 \frac{kN}{m}$ — Line-load of Payload

Load combinations ULS

Dominant self-load

$K_{FI} := 1.1$ — Consequence class 3 (CC3), DS/EN 1990 FU:2013, Table A1.2

$P_{dead} \cdot 1.2 \cdot K_{FI} = 2.814 \frac{kN}{m}$ — Common load combination, Træinformation, Table 1.1

Dominant payload

$P_{dead} \cdot 1 \cdot K_{FI} = 2.345 \frac{kN}{m}$ — Common load combination, Træinformation, Table 1.1

$G_{nyt} \cdot 1.5 \cdot K_{FI} = 5.445 \frac{kN}{m}$ — Common load combination, Træinformation, Table 1.1

Internal stresses

$M_{y.d.max} := 24.10\ kN \cdot m$ — Internal bending stress from ROBOT

$M_{y.d.min} := -11.26\ kN \cdot m$ — Internal bending stress from ROBOT

Design resistance

$k_{mod} := 0.8$ — Modification factor for payload, Træinformation, Table 1.9

$f_{m.L.k} := 14\ MPa$ — Strength of outer lamella (C30), Træinformation, Table 1.3

$f_k := 1.1 \cdot f_{m.L.k}$ — Bending strength of CLT, Træinformation, Table 1.5

$\gamma_1 := 1$ — Partial coefficient for CLT, Træinformation, (1.11)

$\gamma_m := 1.3 \cdot \gamma_1$ — Partial coefficient, Træinformation, (1.11)

$f_{m.d} := k_{mod} \cdot \frac{f_k}{\gamma_m} = 9.477\ MPa$ — Design resistance, Træinformation, (1.9)

Material stiffness

$E_{x.0.L.C18} := 7000\ MPa$ — Elasticity of outer lamella (C30), Træinformation, Table 1.3

$E_{0.i} := 1.05 \cdot E_{x.0.L.C18} = (7.35 \cdot 10^3)\ MPa$ — Elasticity for CLT, Træinformation, (1.9)

$E_{x.0.L.C16} := 8000\ MPa$ — Elasticity of outer lamella (C30), Træinformation, Table 1.3

$E_{0.i.3} := 1.05 \cdot E_{x.0.L.C16} = (8.4 \cdot 10^3)\ MPa$

$E_{x.0.L.C14} := 7000\ MPa$

$E_{0.i.5} := 1.05 \cdot E_{x.0.L.C14} = (7.35 \cdot 10^3)\ MPa$

$E_{x.90.L} := 230\ MPa$ — Elasticity for CLT, Træinformation, (1.9) / Elasticity of outer lamella (C30), Træinformation, Table 1.3

$E_{90.i} := 1.05 \cdot E_{x.90.L} = 241.5\ MPa$ — Elasticity for CLT, Træinformation, (1.9)

Center of gravity

$E_1 := E_{0.i} = (7.35 \cdot 10^3)\ MPa$	$t_1 := 40\ mm$	$O_1 := 230\ mm$
$E_2 := E_{90.i} = 241.5\ MPa$	$t_2 := 30\ mm$	$O_2 := 195\ mm$
$E_3 := E_{0.i} = (7.35 \cdot 10^3)\ MPa$	$t_3 := 40\ mm$	$O_3 := 160\ mm$
$E_4 := E_{90.i} = 241.5\ MPa$	$t_4 := 30\ mm$	$O_4 := 125\ mm$
$E_5 := E_{0.i} = (7.35 \cdot 10^3)\ MPa$	$t_5 := 40\ mm$	$O_5 := 90\ mm$
$E_6 := E_{90.i} = 241.5\ MPa$	$t_6 := 30\ mm$	$O_6 := 55\ mm$
$E_7 := E_{0.i} = (7.35 \cdot 10^3)\ MPa$	$t_7 := 40\ mm$	$O_7 := 20\ mm$

$E_{ref} := E_1 = (7.35 \cdot 10^3)\ MPa$

$$Z_{s.x} \quad \frac{\sum \frac{E_i}{E_{ref}} \cdot t_i \cdot O_i}{\sum \frac{E_i}{E_{ref}} \cdot t_i}$$

Træinformation (2.1)

$$Z_{s.x} := \frac{\left(\frac{E_1}{E_{ref}} \cdot t_1 \cdot O_1\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2 \cdot O_2\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3 \cdot O_3\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4 \cdot O_4\right) + \left(\frac{E_5}{E_{ref}} \cdot t_5 \cdot O_5\right) + \left(\frac{E_6}{E_{ref}} \cdot t_6 \cdot O_6\right) + \left(\frac{E_7}{E_{ref}} \cdot t_7 \cdot O_7\right)}{\left(\frac{E_1}{E_{ref}} \cdot t_1\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4\right) + \left(\frac{E_5}{E_{ref}} \cdot t_5\right) + \left(\frac{E_6}{E_{ref}} \cdot t_6\right) + \left(\frac{E_7}{E_{ref}} \cdot t_7\right)} = 125\ mm$$

Internal design stress

$\sigma_{m.x}(Z_{s.x}) := \frac{E_i}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot Z_{s.x}$ or $\sigma_{m.x}.max := \frac{M_{y.d.max}}{I_{x.net}}$ — Træinformation (2.7) or (2.8)

$$I_{x.net} \quad \sum_{i=1}^{7} \left(\frac{E_i}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_i^3 + \frac{E_i}{E_{ref}} \cdot b_x \cdot t_i \cdot a_i^2\right)$$

Inertimoment, Træinformation (2.4)

$a_i \quad |O_i - Z_{s.x}|$ — Distance between the thicknes of the layer and the center of gravity, Træinformation (2.2)

$a_1 := |O_1 - Z_{s.x}| = 105\ mm$

$a_2 := |O_2 - Z_{s.x}| = 70\ mm$

$a_3 := |O_3 - Z_{s.x}| = 35\ mm$

$a_4 := 125\ mm - 125\ mm = 0\ mm$

$a_5 := |O_5 - Z_{s.x}| = 35\ mm$

$a_6 := |O_6 - Z_{s.x}| = 70\ mm$

$a_7 := |O_7 - Z_{s.x}| = 105\ mm$

$$\begin{aligned} I_{x.net} := & \left(\frac{E_1}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_1^3 + (9.702 \cdot 10^{-4})\ m^4\right) + \left(\frac{E_2}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_2^3 + \frac{E_2}{E_{ref}} \cdot b_x \cdot t_2 \cdot a_2^2\right) \\ & + \left(\frac{E_3}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_3^3 + \frac{E_3}{E_{ref}} \cdot b_x \cdot t_3 \cdot a_3^2\right) + \left(\frac{E_4}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_4^3 + \frac{E_4}{E_{ref}} \cdot b_x \cdot t_4 \cdot a_4^2\right) \\ & + \left(\frac{E_5}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_5^3 + \frac{E_5}{E_{ref}} \cdot b_x \cdot t_5 \cdot a_5^2\right) + \left(\frac{E_6}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_6^3 + \frac{E_6}{E_{ref}} \cdot b_x \cdot t_6 \cdot a_6^2\right) \\ & + \left(\frac{E_7}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_7^3 + \frac{E_7}{E_{ref}} \cdot b_x \cdot t_7 \cdot a_7^2\right) = (2.225 \cdot 10^9)\ mm^4 \end{aligned}$$

Moment of resistance

$$w_{x.net} \quad \frac{I_{x.net}}{MAX(|Z_{s.x}| \cdot |T - Z_{s.x}|)}$$

Træinformation (2.6)

$|Z_{s.x}| = 125\ mm$

$|T - Z_{s.x}| = 135\ mm$

$w_{x.net} := \frac{I_{x.net}}{135\ mm} = (1.648 \cdot 10^7)\ mm^3$

$\sigma_{m.x.max} := \frac{M_{y.d.max}}{w_{x.net}} = 1.462\ MPa$ $\quad \sigma_{m.x.min} := \frac{|M_{y.d.min}|}{w_{x.net}} = 0.683\ MPa$ — Internal design stress, Træinformation (2.8)

$\sigma_{m.x}Z_{s.x} := \frac{E_7}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot Z_{s.x} = 1.354\ MPa$ $\quad \sigma_{m.x}Z_{s.x.min} := \frac{E_7}{E_{ref}} \cdot \frac{|M_{y.d.min}|}{I_{x.net}} \cdot Z_{s.x} = 0.633\ MPa$ — Internal design stress in a layer, Træinformation (2.8)

Validation of CLT element

$\frac{\sigma_{m.x.max}}{f_{m.d}} = 0.154$ $\quad \frac{\sigma_{m.x}Z_{s.x}}{f_{m.d}} = 0.143$ $\quad \frac{\sigma_{m.x.min}}{f_{m.d}} = 0.072$ $\quad \frac{\sigma_{m.x}Z_{s.x.min}}{f_{m.d}} = 0.067$

Torsion

$V := 23.47\ kN$ $\quad f_{v.rul} := 3.5\ MPa$

$f_{v.rul.d} := k_{mod} \cdot \frac{f_{v.rul}}{\gamma_m} = 2.154\ MPa$

$S_3 := \frac{E_3}{E_{ref}} \cdot b_x \cdot t_3 \cdot a_3 = 0.003\ m^3$

$\tau_{v.rul.k5} := \frac{S_3 \cdot V}{I_{x.net} \cdot b_x} = 0.015\ MPa$

$S_4 := \frac{E_4}{E_{ref}} \cdot b_x \cdot t_4 \cdot a_4 = 0\ m^3$

$\tau_{v.rul.k5} := \frac{S_4 \cdot V}{I_{x.net} \cdot b_x} = 0\ MPa$

$S_5 := \frac{E_5}{E_{ref}} \cdot b_x \cdot t_5 \cdot a_5 = 0.003\ m^3$

$\tau_{v.rul.k5} := \frac{S_5 \cdot V}{I_{x.net} \cdot b_x} = 0.015\ MPa$

$S_6 := \frac{E_6}{E_{ref}} \cdot b_x \cdot t_6 \cdot a_6 = (1.518 \cdot 10^{-4})\ m^3$

$\tau_{v.rul.k6} := \frac{S_6 \cdot V}{I_{x.net} \cdot b_x} = (7.279 \cdot 10^{-4})\ MPa$

$S_7 := \frac{E_7}{E_{ref}} \cdot b_x \cdot t_7 \cdot a_7 = 0.009\ m^3$

$\tau_{v.rul.k7} := \frac{S_7 \cdot V}{I_{x.net} \cdot b_x} = 0.044\ MPa$

$\frac{\tau_{v.rul.k7}}{f_{v.rul.d}} = 0.021$ $\quad \frac{\tau_{v.rul.k5}}{f_{v.rul.d}} = 0.007$ $\quad \frac{\tau_{v.rul.k6}}{f_{v.rul.d}} = 3.38 \cdot 10^{-4}$

In case of fire

Reducing of strength

$f_{d.fi} := \boxed{k_{mod.fi}} \cdot \frac{f_{20}}{\gamma_{M.fi}}$

$k_{mod.fi} := 1$ — CLT handbook, pp. 137

$f_{m.L.k} := 14\ MPa$

$f_{20} := 0.8 \cdot f_{m.L.k} = 11.2\ MPa$ — Bending strength of material

$\gamma_{M.fi} := 1$ — CLT handbook, pp. 137

$f_{d.fi} := k_{mod.fi} \cdot \frac{f_{20}}{\gamma_{M.fi}} = 11.2\ MPa$ — CLT handbook, pp. 137

Reducing Cross section

$\beta_0 := 0.65 \frac{mm}{min}$ — standard reduction time for wood, CLT Handbook

$t := 90\ min$ — CLT handbook, pp. 137

$d_{char.0} := \beta_0 \cdot t = 58.5\ mm$ — Burnt material at the time t

Effective cross section

$$H_{clt} := 260\ mm$$

$$d_0 := \frac{H_{clt}}{6} + 2.5\ mm = 45.833\ mm$$ CLT Handbook, Table 7.5

$$H_{ef} := H_{clt} - d_{char.0} - d_0 = 155.667\ mm$$

Calculation strength with after 90 min of fire

Material stiffness

$$E_{x.0.L} := 7000\ MPa$$ Elasticity of outer lamella (C30), Træinformation, Table 1.3

$$E_{0.i} := 1.05 \cdot E_{x.0.L} = (7.35 \cdot 10^3)\ MPa$$ Elasticity for CLT, Træinformation, (1.9)

$$E_{x.90.L} := 230\ MPa$$ Elasticity of inner lamella (C30), Træinformation, Table 1.3

$$E_{90.i} := 1.05 \cdot E_{x.90.L} = 241.5\ MPa$$ Elasticity for CLT, Træinformation, (1.9)

Center of gravity

$$E_1 := E_{0.i} = (7.35 \cdot 10^3)\ MPa \quad t_1 := 40\ mm \quad O_{1.fire} := 125\ mm$$
$$E_2 := E_{90.i} = 241.5\ MPa \quad t_2 := 30\ mm \quad O_{2.fire} := 87.5\ mm$$
$$E_3 := E_{0.i} = (7.35 \cdot 10^3)\ MPa \quad t_3 := 40\ mm \quad O_{3.fire} := 55\ mm$$
$$E_4 := E_{90.i} = 241.5\ MPa \quad t_4 := 30\ mm \quad O_{4.fire} := 15\ mm$$

$$E_{ref} := E_1 = (7.35 \cdot 10^3)\ MPa$$

$$Z_{s.x} \quad \frac{\sum \frac{E_i}{E_{ref}} \cdot t_i \cdot O_i}{\sum \frac{E_i}{E_{ref}} \cdot t_i}$$ Træinformation (2.1)

$$Z_{s.x} := \frac{\left(\frac{E_1}{E_{ref}} \cdot t_1 \cdot O_{1.fire}\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2 \cdot O_{2.fire}\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3 \cdot O_{3.fire}\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4 \cdot O_{4.fire}\right)}{\left(\frac{E_1}{E_{ref}} \cdot t_1\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4\right)} = 89.068\ mm$$

Internal design stress

$$\sigma_{m.x}(Z_{s.x}) := \frac{E_i}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot Z_{s.x} \quad \text{or} \quad \sigma_{m.x}.max := \frac{M_{y.d.max}}{I_{x.net}}$$ Træinformation (2.7) or (2.8)

$$I_{x.net} \quad \sum_{i=1}^{7} \left(\frac{E_i}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_i^3 + \frac{E_i}{E_{ref}} \cdot b_x \cdot t_i \cdot a_i^2\right)$$ Inertimoment, Træinformation (2.4)

$$a_i \quad |O_i - Z_{s.x}|$$ Distance between the thicknes of the layer and the center of gravity, Træinformation (2.2)

$$a_1 := |O_{1.fire} - Z_{s.x}| = 35.932\ mm$$
$$a_2 := |O_{2.fire} - Z_{s.x}| = 1.568\ mm$$
$$a_3 := |O_{3.fire} - Z_{s.x}| = 34.068\ mm$$
$$a_4 := |O_{4.fire} - Z_{s.x}| = 74.068\ mm$$

$$I_{x.net} := \left(\frac{E_1}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_1^3 + \frac{E_2}{E_{ref}} \cdot b_x \cdot t_1 \cdot a_1^2\right) + \left(\frac{E_2}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_2^3 + \frac{E_2}{E_{ref}} \cdot b_x \cdot t_2 \cdot a_2^2\right) + \left(\frac{E_3}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_3^3 + \frac{E_3}{E_{ref}} \cdot b_x \cdot t_3 \cdot a_3^2\right) + \left(\frac{E_4}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_4^3 + \frac{E_4}{E_{ref}} \cdot b_x \cdot t_4 \cdot a_4^2\right) = (1.416 \cdot 10^8)\ mm^4$$

Moment of resistance

$$w_{x.net} \quad \frac{I_{x.net}}{MAX(|Z_{s.x}| \cdot |T - Z_{s.x}|)}$$ Træinformation (2.6)

$$|Z_{s.x}| = 89.068\ mm$$
$$|H_{ef} - Z_{s.x}| = 66.599\ mm$$

$$w_{x.net} := \frac{I_{x.net}}{89.068\ mm} = (1.589 \cdot 10^6)\ mm^3$$

$$\sigma_{m.x.max} := \frac{M_{y.d.max}}{w_{x.net}} = 15.163\ MPa \quad \sigma_{m.x}Z_{s.x} := \frac{E_3}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot \left(a_3 + \frac{40\ mm}{2}\right) = 9.205\ MPa$$ Internal design stress, Træinformation (2.8)

$$\sigma_{m.x.min} := \frac{|M_{y.d.min}|}{w_{x.net}} = 7.085\ MPa \quad \sigma_{m.x}Z_{s.x.min} := \frac{E_7}{E_{ref}} \cdot \frac{|M_{y.d.min}|}{I_{x.net}} \cdot Z_{s.x} = 7.085\ MPa$$ Internal design stress in a layer i Træinformation (2.8)

Validation of CLT element

$$\frac{\sigma_{m.x.max}}{f_{d.fi}} = 1.354 \quad \frac{\sigma_{m.x}Z_{s.x}}{f_{d.fi}} = 0.822 \quad \frac{\sigma_{m.x.min}}{f_{d.fi}} = 0.633 \quad \frac{\sigma_{m.x}Z_{s.x.min}}{f_{d.fi}} = 0.633$$

Torsion

$$V := 23.47\ kN \quad f_{v.rul.20} := 0.8 \cdot 3.5\ MPa$$

$$f_{v.rul.d.fire} := k_{mod} \cdot \frac{f_{v.rul.20}}{\gamma_m} = 1.723\ MPa$$

$$S_1 := \frac{E_1}{E_{ref}} \cdot b_x \cdot t_1 \cdot a_1 = 0.003\ m^3$$

$$\tau_{v.rul.k1} := \frac{S_1 \cdot V}{I_{x.net} \cdot b_x} = 0.238\ MPa$$

$$S_2 := \frac{E_2}{E_{ref}} \cdot b_x \cdot t_2 \cdot a_2 = (3.4 \cdot 10^{-6})\ m^3$$

$$\tau_{v.rul.k2} := \frac{S_4 \cdot V}{I_{x.net} \cdot b_x} = 0\ MPa$$

$$S_3 := \frac{E_3}{E_{ref}} \cdot b_x \cdot t_3 \cdot a_3 = 0.003\ m^3$$

$$\tau_{v.rul.k3} := \frac{S_3 \cdot V}{I_{x.net} \cdot b_x} = 0.226\ MPa$$

$$S_4 := \frac{E_4}{E_{ref}} \cdot b_x \cdot t_4 \cdot a_4 = (1.606 \cdot 10^{-4})\ m^3$$

$$\tau_{v.rul.k4} := \frac{S_4 \cdot V}{I_{x.net} \cdot b_x} = 0.012\ MPa$$

$$\frac{\tau_{v.rul.k1}}{f_{v.rul.d.fire}} = 0.138 \quad \frac{\tau_{v.rul.k2}}{f_{v.rul.d.fire}} = 0 \quad \frac{\tau_{v.rul.k3}}{f_{v.rul.d.fire}} = 0.131 \quad \frac{\tau_{v.rul.k4}}{f_{v.rul.d.fire}} = 0.007$$

Calculation of optimized CLT

Loads external loads

Self-load/dead-load

$\rho_{12.k} := 380 \, \frac{kg}{m^3} \cdot g = 3.727 \, \frac{kN}{m^3}$ — Characteristic density for C30 wood, Træinformation, Table (1.3)

$T := 0.26 \, m$ — Thickness of element

$b_x := 2.2 \, m$ — Width of element

$P_{dead} := \rho_{12.k} \cdot T \cdot b_x = 2.132 \, \frac{kN}{m}$ — Line-load of dead-load

Payload

$G_{nyt.flade} := 1.5 \, \frac{kN}{m^2}$ — Load of payload for housing, DS/EN 1991-1-1 FU:2015, Table 6.2

$G_{nyt} := G_{nyt.flade} \cdot b_x = 3.3 \, \frac{kN}{m}$ — Line-load of Payload

Load combinations ULS

Dominant self-load

$K_{FI} := 1.1$ — Consequence class 3 (CC3), DS/EN 1990 FU:2013, Table A1.2

$P_{dead} \cdot 1.2 \cdot K_{FI} = 2.814 \, \frac{kN}{m}$ — Common load combination, Træinformation, Table 1.1

Dominant payload

$P_{dead} \cdot 1 \cdot K_{FI} = 2.345 \, \frac{kN}{m}$ — Common load combination, Træinformation, Table 1.1

$G_{nyt} \cdot 1.5 \cdot K_{FI} = 5.445 \, \frac{kN}{m}$ — Common load combination, Træinformation, Table 1.1

Internal stresses

$M_{y.d.max} := 24.10 \, kN \cdot m$ — Internal bending stress from ROBOT

$M_{y.d.min} := -11.26 \, kN \cdot m$ — Internal bending stress from ROBOT

Design resistance

$k_{mod} := 0.8$ — Modification factor for payload, Træinformation, Table 1.9

$f_{m.L.k} := 18 \, MPa$ — Strength of outer lamella (C30), Træinformation, Table 1.3

$f_k := 1.1 \cdot f_{m.L.k}$ — Bending strength of CLT, Træinformation, Table 1.5

$\gamma_1 := 1$ — Partial coefficient for CLT, Træinformation, (1.11)

$\gamma_m := 1.3 \cdot \gamma_1$ — Partial coefficient, Træinformation, (1.11)

$f_{m.d} := k_{mod} \cdot \frac{f_k}{\gamma_m} = 12.185 \, MPa$ — Design resistance, Træinformation, (1.9)

Material stiffness

$E_{x.0.L.C18} := 9000 \, MPa$ — Elasticity of outer lamella (C30), Træinformation, Table 1.3

$E_{0.i} := 1.05 \cdot E_{x.0.L.C18} = (9.45 \cdot 10^3) \, MPa$ — Elasticity for CLT, Træinformation, (1.9)

$E_{x.0.L.C16} := 8000 \, MPa$ — Elasticity of outer lamella (C30), Træinformation, Table 1.3

$E_{0.i.3} := 1.05 \cdot E_{x.0.L.C16} = (8.4 \cdot 10^3) \, MPa$

$E_{x.0.L.C14} := 7000 \, MPa$

$E_{0.i.5} := 1.05 \cdot E_{x.0.L.C14} = (7.35 \cdot 10^3) \, MPa$

$E_{x.90.L} := 230 \, MPa$ — Elasticity of outer lamella (C30), Træinformation, Table 1.3 / Elasticity for CLT, Træinformation, (1.9)

$E_{90.i} := 1.05 \cdot E_{x.90.L} = 241.5 \, MPa$ — Elasticity for CLT, Træinformation, (1.9)

Center of gravity

$E_1 := E_{0.i} = (9.45 \cdot 10^3) \, MPa$ $t_1 := 40 \, mm$ $O_1 := 230 \, mm$

$E_2 := E_{90.i} = 241.5 \, MPa$ $t_2 := 30 \, mm$ $O_2 := 195 \, mm$

$E_3 := E_{0.i.3} = (8.4 \cdot 10^3) \, MPa$ $t_3 := 40 \, mm$ $O_3 := 160 \, mm$

$E_4 := E_{90.i} = 241.5 \, MPa$ $t_4 := 30 \, mm$ $O_4 := 125 \, mm$

$E_5 := E_{0.i.5} = (7.35 \cdot 10^3) \, MPa$ $t_5 := 40 \, mm$ $O_5 := 90 \, mm$

$E_6 := E_{90.i} = 241.5 \, MPa$ $t_6 := 30 \, mm$ $O_6 := 55 \, mm$

$E_7 := E_{0.i} = (9.45 \cdot 10^3) \, MPa$ $t_7 := 40 \, mm$ $O_7 := 20 \, mm$

$E_{ref} := E_1 = (9.45 \cdot 10^3) \, MPa$

$$Z_{s.x} \quad \frac{\sum \frac{E_i}{E_{ref}} \cdot t_i \cdot O_i}{\sum \frac{E_i}{E_{ref}} \cdot t_i}$$

Træinformation (2.1)

$$Z_{s.x} := \frac{\left(\frac{E_1}{E_{ref}} \cdot t_1 \cdot O_1\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2 \cdot O_2\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3 \cdot O_3\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4 \cdot O_4\right) + \left(\frac{E_5}{E_{ref}} \cdot t_5 \cdot O_5\right) + \left(\frac{E_6}{E_{ref}} \cdot t_6 \cdot O_6\right) + \left(\frac{E_7}{E_{ref}} \cdot t_7 \cdot O_7\right)}{\left(\frac{E_1}{E_{ref}} \cdot t_1\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4\right) + \left(\frac{E_5}{E_{ref}} \cdot t_5\right) + \left(\frac{E_6}{E_{ref}} \cdot t_6\right) + \left(\frac{E_7}{E_{ref}} \cdot t_7\right)} = 126.044 \, mm$$

Internal design stress

$\sigma_{m.x}(Z_{s.x}) := \frac{E_i}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot Z_{s.x}$ or $\sigma_{m.x}.max := \frac{M_{y.d.max}}{I_{x.net}}$ — Træinformation (2.7) or (2.8)

$$I_{x.net} \quad \sum_{i=1}^{7} \left(\frac{E_i}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_i^3 + \frac{E_i}{E_{ref}} \cdot b_x \cdot t_i \cdot a_i^2\right)$$

Inertimoment, Træinformation (2.4)

$a_i \quad |O_i - Z_{s.x}|$ — Distance between the thicknes of the layer and the center of gravity, Træinformation (2.2)

$a_1 := |O_1 - Z_{s.x}| = 103.956 \, mm$

$a_2 := |O_2 - Z_{s.x}| = 68.956 \, mm$

$a_3 := |O_3 - Z_{s.x}| = 33.956 \, mm$

$a_4 := 125 \, mm - 125 \, mm = 0 \, mm$

$a_5 := |O_5 - Z_{s.x}| = 36.044 \, mm$

$a_6 := |O_6 - Z_{s.x}| = 71.044 \, mm$

$a_7 := |O_7 - Z_{s.x}| = 106.044 \, mm$

$$I_{x.net} := \left(\frac{E_1}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_1^3 + (9.702 \cdot 10^{-4}) \, m^4\right) + \left(\frac{E_2}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_2^3 + \frac{E_2}{E_{ref}} \cdot b_x \cdot t_2 \cdot a_2^2\right) + \left(\frac{E_3}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_3^3 + \frac{E_3}{E_{ref}} \cdot b_x \cdot t_3 \cdot a_3^2\right) + \left(\frac{E_4}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_4^3 + \frac{E_4}{E_{ref}} \cdot b_x \cdot t_4 \cdot a_4^2\right) + \left(\frac{E_5}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_5^3 + \frac{E_5}{E_{ref}} \cdot b_x \cdot t_5 \cdot a_5^2\right) + \left(\frac{E_6}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_6^3 + \frac{E_6}{E_{ref}} \cdot b_x \cdot t_6 \cdot a_6^2\right) + \left(\frac{E_7}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_7^3 + \frac{E_7}{E_{ref}} \cdot b_x \cdot t_7 \cdot a_7^2\right) = (2.199 \cdot 10^9) \, mm^4$$

Moment of resistance

$w_{x.net} \quad \frac{I_{x.net}}{MAX(|Z_{s.x}| \, . \, |T - Z_{s.x}|)}$ — Træinformation (2.6)

$|Z_{s.x}| = 126.044 \, mm$

$|T - Z_{s.x}| = 133.956 \, mm$

$w_{x.net} := \frac{I_{x.net}}{135 \, mm} = (1.629 \cdot 10^7) \, mm^3$

$\sigma_{m.x.max} := \frac{M_{y.d.max}}{w_{x.net}} = 1.48 \, MPa$ $\sigma_{m.x.min} := \frac{|M_{y.d.min}|}{w_{x.net}} = 0.691 \, MPa$ — Internal design stress, Træinformation (2.8)

$\sigma_{m.x}Z_{s.x} := \frac{E_7}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot Z_{s.x} = 1.381 \, MPa$ $\sigma_{m.x}Z_{s.x.min} := \frac{E_7}{E_{ref}} \cdot \frac{|M_{y.d.min}|}{I_{x.net}} \cdot Z_{s.x} = 0.645 \, MPa$ — Internal design stress in a layer, Træinformation (2.8)

Validation of CLT element

$\frac{\sigma_{m.x.max}}{f_{m.d}} = 0.121$ $\frac{\sigma_{m.x}Z_{s.x}}{f_{m.d}} = 0.113$ $\frac{\sigma_{m.x.min}}{f_{m.d}} = 0.057$ $\frac{\sigma_{m.x}Z_{s.x.min}}{f_{m.d}} = 0.053$

In case of fire

Reducing of strength

$$f_{d.fi} := k_{mod.fi} \cdot \frac{f_{20}}{\gamma_{M.fi}}$$

$k_{mod.fi} := 1$ — CLT handbook, pp. 137

$f_{m.L.k} := 18 \, MPa$

$f_{20} := 0.8 \cdot f_{m.L.k} = 14.4 \, MPa$ — Bending strength of material

$\gamma_{M.fi} := 1$ — CLT handbook, pp. 137

$f_{d.fi} := k_{mod.fi} \cdot \frac{f_{20}}{\gamma_{M.fi}} = 14.4 \, MPa$ — CLT handbook, pp. 137

$f_{m.L.k.3} := 16 \, MPa$

$f_{20.3} := 0.8 \cdot f_{m.L.k.3} = 12.8 \, MPa$

$f_{d.fi.3} := k_{mod.fi} \cdot \frac{f_{20.3}}{\gamma_{M.fi}} = 12.8 \, MPa$

Reducing Cross section

$\beta_0 := 0.65 \, \frac{mm}{min}$ — standard reduction time for wood, CLT Handbook

$t := 90 \, min$ — CLT handbook, pp. 137

$d_{char.0} := \beta_0 \cdot t = 58.5 \, mm$ — Burnt material at the time t

Effective cross section

$H_{clt} := 260 \, mm$

$d_0 := \frac{H_{clt}}{6} + 2.5 \, mm = 45.833 \, mm$ — CLT Handbook, Table 7.5

$H_{ef} := H_{clt} - d_{char.0} - d_0 = 155.667 \, mm$

Calculation strength with after 90 min of fire

Material stiffness

$E_{x.0.L} := 9000\ MPa$ — Elasticity of outer lamella (C30), Træinformation, Table 1.3

$E_{0.i} := 1.05 \cdot E_{x.0.L} = (9.45 \cdot 10^3)\ MPa$ — Elasticity for CLT, Træinformation, (1.9)

$E_{x.0.L.3} := 8000\ MPa$

$E_{0.i.3} := 1.05 \cdot E_{x.0.L.3} = (8.4 \cdot 10^3)\ MPa$

$E_{x.90.L} := 230\ MPa$ — Elasticity of inner lamella (C30), Træinformation, Table 1.3

$E_{90.i} := 1.05 \cdot E_{x.90.L} = 241.5\ MPa$ — Elasticity for CLT, Træinformation, (1.9)

Center of gravity

$E_1 := E_{0.i} = (9.45 \cdot 10^3)\ MPa$ $\quad t_1 := 40\ mm$ $\quad O_{1.fire} := 125\ mm$

$E_2 := E_{90.i} = 241.5\ MPa$ $\quad t_2 := 30\ mm$ $\quad O_{2.fire} := 87.5\ mm$

$E_3 := E_{0.i.3} = (8.4 \cdot 10^3)\ MPa$ $\quad t_3 := 40\ mm$ $\quad O_{3.fire} := 55\ mm$

$E_4 := E_{90.i} = 241.5\ MPa$ $\quad t_4 := 30\ mm$ $\quad O_{4.fire} := 15\ mm$

$E_{ref} := E_1 = (9.45 \cdot 10^3)\ MPa$

$$Z_{s.x} \quad \frac{\sum \frac{E_i}{E_{ref}} \cdot t_i \cdot O_i}{\sum \frac{E_i}{E_{ref}} \cdot t_i}$$

Træinformation (2.1)

$$Z_{s.x} := \frac{\left(\frac{E_1}{E_{ref}} \cdot t_1 \cdot O_{1.fire}\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2 \cdot O_{2.fire}\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3 \cdot O_{3.fire}\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4 \cdot O_{4.fire}\right)}{\left(\frac{E_1}{E_{ref}} \cdot t_1\right) + \left(\frac{E_2}{E_{ref}} \cdot t_2\right) + \left(\frac{E_3}{E_{ref}} \cdot t_3\right) + \left(\frac{E_4}{E_{ref}} \cdot t_4\right)} = 91.247\ mm$$

Internal design stress

$$\sigma_{m.x}(Z_{s.x}) := \frac{E_i}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot Z_{s.x} \quad \text{or} \quad \sigma_{m.x}.max := \frac{M_{y.d.max}}{I_{x.net}}$$

Træinformation (2.7) or (2.8)

$$I_{x.net} \quad \sum_{i=1}^{7} \left(\frac{E_i}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_i^3 + \frac{E_i}{E_{ref}} \cdot b_x \cdot t_i \cdot a_i^2\right)$$

Inertimoment, Træinformation (2.4)

$a_i \quad |O_i - Z_{s.x}|$

$a_1 := |O_{1.fire} - Z_{s.x}| = 33.753\ mm$

$a_2 := |O_{2.fire} - Z_{s.x}| = 3.747\ mm$

$a_3 := |O_{3.fire} - Z_{s.x}| = 36.247\ mm$

$a_4 := |O_{4.fire} - Z_{s.x}| = 76.247\ mm$

Distance between the thicknes of the layer and the center of gravity, Træinformation (2.2)

$$I_{x.net} := \left(\frac{E_1}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_1^3 + \frac{E_2}{E_{ref}} \cdot b_x \cdot t_1 \cdot a_1^2\right) + \left(\frac{E_2}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_2^3 + \frac{E_2}{E_{ref}} \cdot b_x \cdot t_2 \cdot a_2^2\right) + \left(\frac{E_3}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_3^3 + \frac{E_3}{E_{ref}} \cdot b_x \cdot t_3 \cdot a_3^2\right) + \left(\frac{E_4}{E_{ref}} \frac{1}{12} \cdot b_x \cdot t_4^3 + \frac{E_4}{E_{ref}} \cdot b_x \cdot t_4 \cdot a_4^2\right) = (1.376 \cdot 10^8)\ mm^4$$

Moment of resistance

$$w_{x.net} \quad \frac{I_{x.net}}{MAX\left(|Z_{s.x}| \cdot |T - Z_{s.x}|\right)}$$

Træinformation (2.6)

$|Z_{s.x}| = 91.247\ mm$

$|H_{ef} - Z_{s.x}| = 64.42\ mm$

$$w_{x.net} := \frac{I_{x.net}}{89.068\ mm} = (1.545 \cdot 10^6)\ mm^3$$

$$\sigma_{m.x.max} := \frac{M_{y.d.max}}{w_{x.net}} = 15.602\ MPa \qquad \sigma_{m.x}Z_{s.x} := \frac{E_3}{E_{ref}} \cdot \frac{M_{y.d.max}}{I_{x.net}} \cdot \left(a_3 + \frac{40\ mm}{2}\right) = 8.758\ MPa$$

Internal design stress, Træinformation (2.8)

$$\sigma_{m.x.min} := \frac{|M_{y.d.min}|}{w_{x.net}} = 7.29\ MPa \qquad \sigma_{m.x}Z_{s.x.min} := \frac{E_7}{E_{ref}} \cdot \frac{|M_{y.d.min}|}{I_{x.net}} \cdot Z_{s.x} = 7.468\ MPa$$

Internal design stress in a layer i Træinformation (2.8)

Validation of CLT element

$$\frac{\sigma_{m.x.max}}{f_{d.fi}} = 1.083 \qquad \frac{\sigma_{m.x}Z_{s.x}}{f_{d.fi.3}} = 0.684 \qquad \frac{\sigma_{m.x.min}}{f_{d.fi}} = 0.506 \qquad \frac{\sigma_{m.x}Z_{s.x.min}}{f_{d.fi.3}} = 0.583$$