BEAT THE HEAT

How to achieve thermal comfort during heat waves in Sweden, inspired by architecture in countries with a warmer climate.

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Master Thesis spring 2022

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ABSTRACT

Extreme weather due to climate change will become more common in Sweden. Researchers at SMHI (the Swedish Meteorological and Hydrological Institute) have estimated that heat waves that previously occurred every 20 years in Sweden durig the summer, can occur every three to five years at the end of the century (SMHI, 2013).

Apartments in Sweden is not adapted to theese high temperatures and will in many cases result inuncomfortable indoor climate. The elderly, young children, the sick and the disabled are particularly vulnerable to warmer indoor temperature and the issue has recently become a high priority among both property owners and authorities.

There are ways to cool a residential building mechanically, such as air-conditioning, but research indicates that large amounts of energy will be needed to gain thermal comfort with theese solutions, which rhymes poorly with set climate goals.

Therefore, we need to investigate other ways to counteract high indoor temperatures and see the issue from different perspectives at an early stage.

By investigating architecture in countries with a traditionally warm climate, focusing on materials, floor plans, building solutions and user habits, this Master Thesis aimed to research whether there are any methods or design strategies that can be implemented in Swedish housing construction.

The reference projects were selected freely based on design solutions and relevance, rather than from a specific country, wich enabled to investigate architecture in many different contexts.

In my reserach i found that there were similarities among the different reference projects, even though they were built 1000 of miles apart.

In many cases, the building design was so adapted to the conditions on the site that it was hard to transfer the strategies directly to a swedish context. While some strategies, like cross-ventilation and bright facade colors, could easily be applied.

Keywords : #passive ventilation #thermal comfort #solar shading #material #swedish housing

STUDENT BACKGROUND

Bachelor´s degree 2009-2012
Chalmers School of Architecture

Masters programme 2013-2015
Architecture and Urban design

Five years of practical experience from two architecture firms, working mainly with office buildings and housing.

During my master I have participated in the courses ”Design and planning for social integration”, ”Urban morphology and design” and ”Matter, space and structure”. At the same time, I have about five years of experience from two different offices, mainly focusing on housing in the early stages.
I have also been involved in the sustainability work at the architectural offices in my previous roles.

With the knowledge I gained by working with residential buildings, I will be able to draw conclusions and analyse my results from a broader perspective.

Through my choice of subject, I challenge myself as I am neither an expert on climate change and heat waves nor architectural history in countries with warm climates. But I will have the ability to connect the different parts based on my educational background, work experience and the genuine interest I have in the subject.

Regardless of the results, I will have broadened my understanding of how a warmer climate can be handled in housing planning and what the possible solutions might be.

TABLE OF CONTENT

1. INTRODUCTION

According to SMHI, a heat wave means that the outdoor temperature reaches 25º C at least five days in a row (SMHI, u.å).

In an apartment in an multifamily building, the indoor temperature will rise as the heat wave continues and in order to achieve a cooler indoor climate, both FHM and Boverket advise to air during the night, close windows during the daytime and pull down blinds. There is also a recommendation to open multiple windows to create cross drafts and better throughput of the air, as well as sleeping downstairs as the warm air rises upwards (FHM, 2021; Boverket, u.å)

For example, for an elderly person living in a single-sided apartment facing south, it is only possible to follow some of the first advices, which is also no guarantee that the apartment actually will be cooler.

If the apartment is the only accommodation, it also means a greater vulnerability for the resident because there are no alternatives but to stay in an environment with temperatures above healthy levels.

Aim

To evaluate strategies in other, traditionallt warmer, countries and apply them in a swedish context. The result of the investigation will lead to a designproposal of a multifamily house located in area in *Norrköping* called *Inre hamnen*.

1.2 Research questions

The question I ask is whether there are methods and design used in housing construction in warm countries, mainly from a historical perspective, that can be applied to housing in Sweden?

Sub question

• How will solutions that are intended to lower the temperature during the summer work during the winter?

• What are the obstacles to using the same design strategies in Sweden? Will it be compatible with fire safety regulations? With accessibility requirements?

1.3 Method

The method I have used is *Research for design*, and I have worked in parallel with reading reports and articles, performing traditional sketching, conducting interviews and discussed with people who have knowledge in relevant areas.

Literature

The material consists of books, articles, reports, previous Master Thesis and websites from authorities. There is a mix of both Swedish and foreign authors.

Interviews and discussions

The basis for Brazil is based on interviews carried out by a Brazilian architect as well as information from websites belonging to a Brazilian research project.

For guidance regarding fire safety in some of my proposals, I have had a dialogue with a fire engineer.

Workflow

It started with the awarness of the problem with heatwaves i Sweden. How did they handle it in other countries?

Choosed a site in Norrköping for my proposal of a multifamily house. The municipality had an ongoing process of developing i detailplan for housing

Did research on factors in urban planning and construction that might push the indoor temperatures higher during a heat wave.

Read articles and reports on vernacular architecture in countries with warmer climate.

Conducted an interview with an architect from Brazil in order to understand Brazilian strategies to handle high temperatures.

Doublechecked some of the strategies with a fire engineer and recieved an instant ”No” according to the fire regulations... Had to re-think.

After a lot of reading, I finally found five reports from different countries that adressed the topic I was studying and was extensive enough.

I divided the architectural strategies based on the scale, e.g the width of the streets or the colour of the facade.

I choosed to develop some of the strategies in a Swedish context.

I found a lot of similarities from the different countries and began to see a pattern.

The result of this journey is a proposal for a multifamily house that aims to find the balance between the sedish context and the design strategies developed in warm countries.

1.4 Delimitations

Extreme weather due to climate change will affect us in several ways. In addition to hot summers, we will probably have increased precipitation and a greater risk of flooding.
However, I choose to limit my Master Thesis to only deal with the issue of heat.

If some of the design strategies I found in the reference projects had very little to do with the indoor thermal comfort, I made a decision to not consider that strategy. It could for example be a floor that was placed high above the ground in order to avoid heavy flooding during the rain season.

It would have been poosible to focus on just one country, or one design strategy, and have a proposal on a more detailed level. Instead i choosed to have a broader perspective on the subject, taking all of the strategies I found into consideration.

With this overall view it was also possible to see patterns in my findings, something that would have been impossible if I focused on just one strategy, for e.g window sizes.

Even if the existing housing stock is relevant to the issue, I will limit the thesis by focusing only on new construction.

I will not focus my research on the landscape around the building, like topography, but I will take into consideration nearby buildings.

No detailed drawings or calculations.

2. OVERVIEW OF CLIMATE, REGULATIONS & IMPORTANT FACTORS

2.1 Climate

The summer of 2018 was one of the warmest since SMHI started collecting data. The heat resulted in a number of forest fires and severe drought and researchers suggest that it might be a glimpse of the future. For studies of future climate development, so-called RCP scenarios are used according to international standards, which are based on different assumptions about the amount of greenhouse gas emissions and changes in other climate-influencing factors (SMHI, 2019)

It also became clear that the society was not prepared for these types of weather conditions. (Hevele, Olsson, 2020). Warm years has dominated since 1988 and heat waves will be more common in the future (SMHI, 2018)

According to Hevele and Olsson (2020) we tend to spend 80-90 % of our time indoors, in industrialised countries. When the temperatures tend to rise outside it will have impact on the indoor climate, and the population in Sweden is in general not adapting very well to high temperatures (2020).

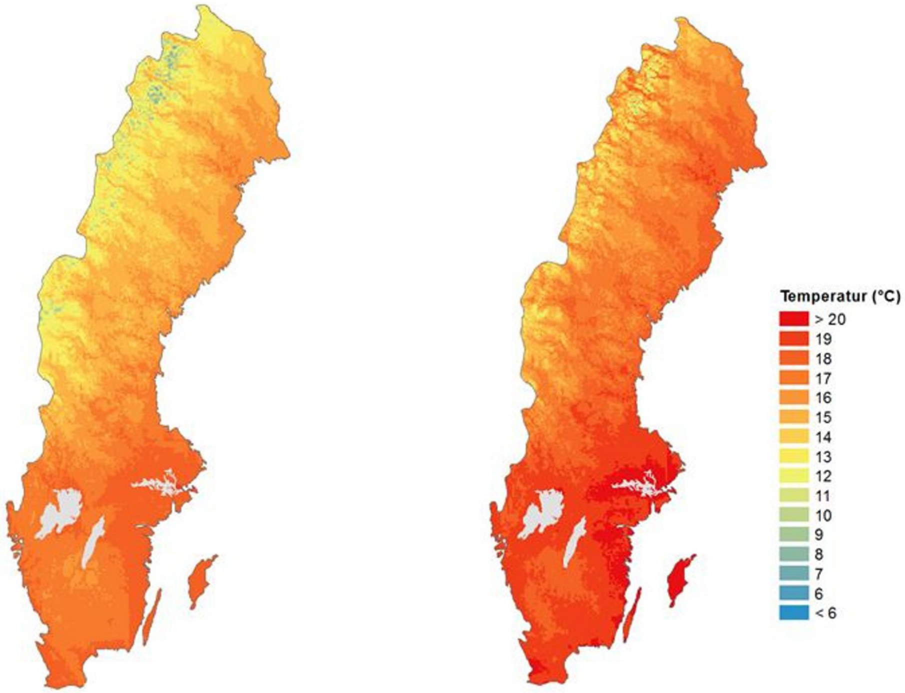


Fig. 1 (SMHI, 2019) Average temperature for future summers. The map on the left shows a scenario for a period around the turn of the century, where greenhouse gas emissions have been limited. The map to the right shows a scenario with continued increasing emissions (SMHI, 2019)

2.2 Regulations

In 2009, many years before before the worst heat wave in many years struck Sweden, came Boverket up with guidelines on the subject. In the report ”Build for tomorrow’s climate- Adaptation of planning and construction” they stated the following:

“Buildings and infrastructure that are being built today will remain for a long time. It is therefore important to take into account future heat waves as far as possible when planning and building. ”(s. 8, Boverket, 2009)

The National Board of Housing, Building and Planning’s building regulations (BFS 2011: 6:1) specify the technical requirements. A regulation states that ” Buildings and their installations shall be designed so that air and water quality as well as light, humidity, temperature and hygiene conditions will be satisfactory under the lifespan of the building and thus inconveniences to human health can be avoided”.

The only requirements regarding temperatures are set for which minimum indoor temperatures can be maintained in a building.

It states that buildings should be designed so that the temperature in the living zone and working rooms is at least 18 ºC and 20 ºC in hygiene rooms, care rooms, rooms for children in preschools and for elderly in service houses. No requirement for a maximum permissible temperature is set in the rules (BFS 2011: 6:42).

With regard to requirements for energy management, it is stated in regulations, among other things, that ”the need for cooling shall be minimized through construction and installation technical measures”. (BFS 2011: 9:51)

General advice to the regulation states that “to reduce the need for cooling in the building, measures such as the choice of window size and placement of windows, sun protection, sun protection glass, electrically efficient lighting and equipment to reduce internal heat loads, night cooling and cold accumulation should be tried in the building structure ”. (BFS 2011: 9:51)

"Buildings and their installations shall be designed so that air and water quality as well as light, humidity, ***temperature*** *and hygiene conditions will be satisfying under the lifespan of the building and thus inconveniences to human health can be avoided ".*
BFS 2011: 6

2.3 Factors to be considered

There are several factors that can raise the temperature further in addition to climate change and heat waves.

Urban heat islands

Building geometry and choice of building materials can create conditions for something called Urbana heating islands, which means that it can be warmer in a larger city than a smaller urban area. A city that has a circular shape is, for example, warmer than if it has an elongated shape (FHM, 2019)

Surrounding landscape is also a factor that affects whether the city creates a local, warm climate (Hevele & Olsson, 2021). The effect of the phenomenon is mainly noticeable at night, as the cooling during the afternoon and evening is slower than the surrounding landscape. This results in the city also retaining a large part of the heat absorbed during the day at night (FHM, 2019).

Building materials

Solar radiation can be absorbed or reflected depending on the building material. Dark and dense materials such as brick, asphalt and concrete are examples of materials that absorb and store heat for a longer period of time (FHM, 2019).

Vegetation

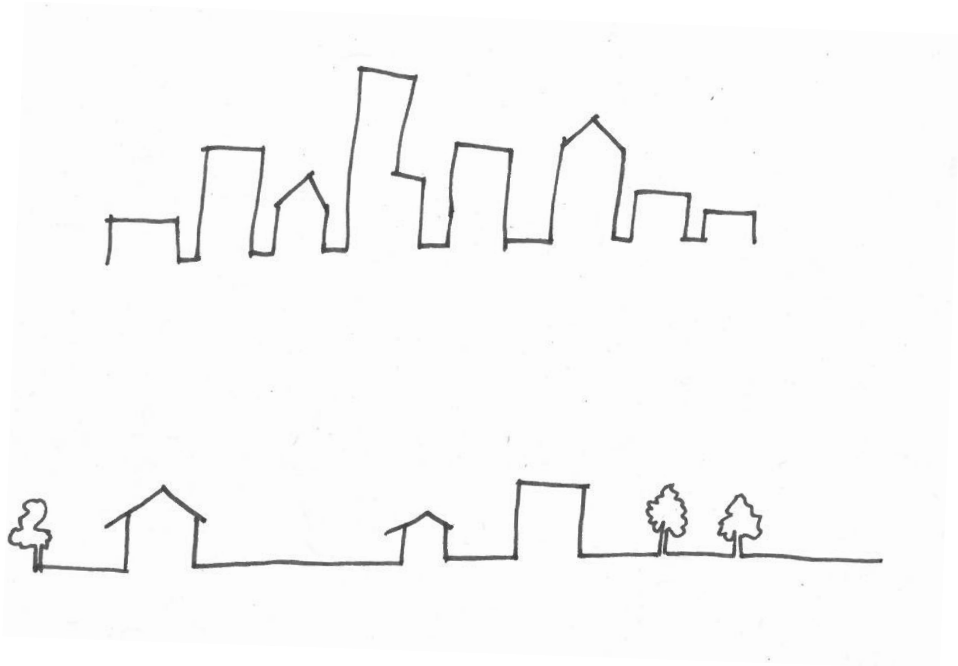
Trees and plants in the urban environment are so much more than just a beautiful addition. ”Transpiration” is the evaporation of water from plants, and gives a temperature-lowering effect (FHM, 2019).

Shading from trees and plants is also a cooling factor (2019). Another important reason why the green environment is crucial for lowering temperatures in urban environments is that it does not heat its surroundings in the same way hard-ground materials (Hevele & Olsson, 2021).

According to the Swedish Public Health Agency (2019), it is mainly larger contiguous vegetation and high vegetation that have an effect on temperature.

Water surfaces

The Public Health Agency also addresses water as a cooling factor in its report. Open water such as canals, streams, lakes and ponds have a dampening effect on temperature fluctuations. Regarding the cooling effect, there are a few studies that show that it has a limited effect, but the area is relatively unexplored.

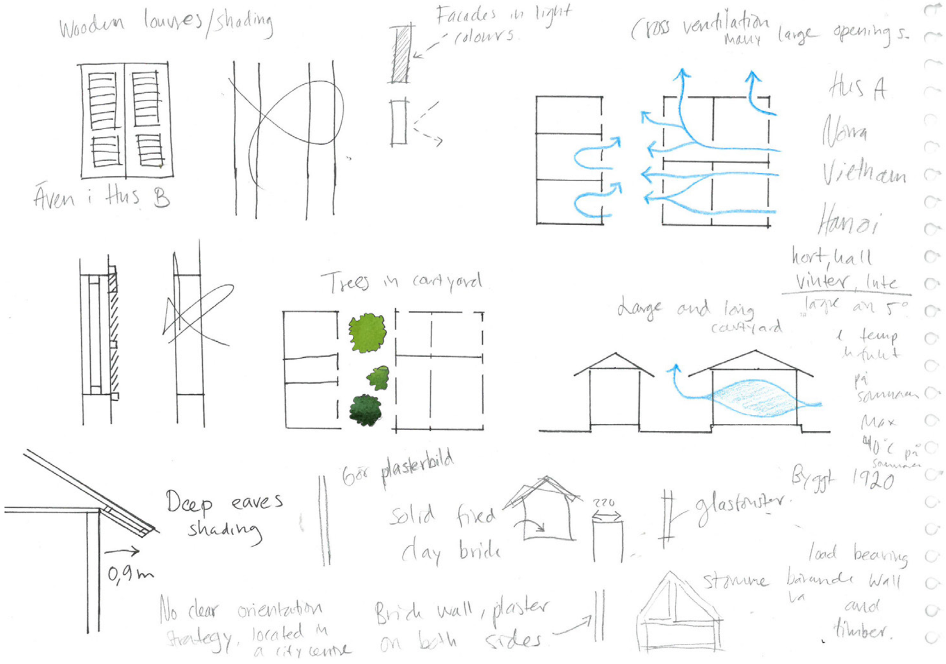
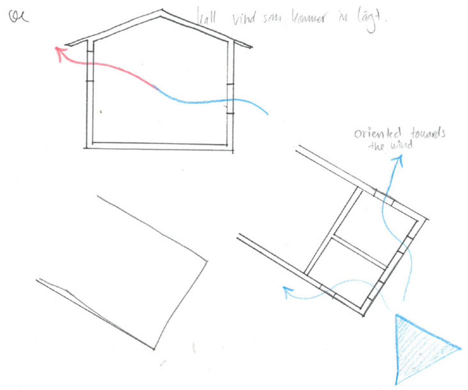
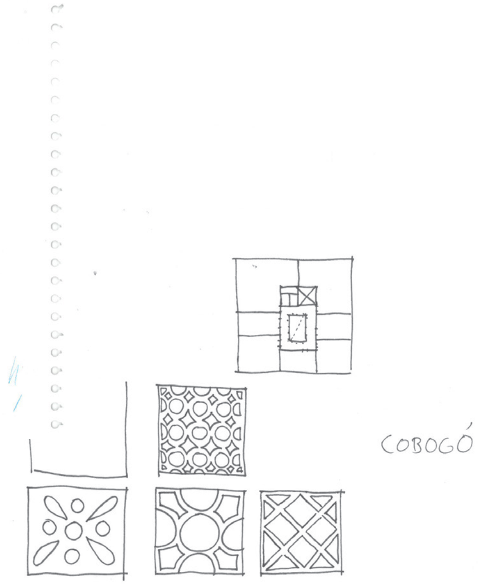
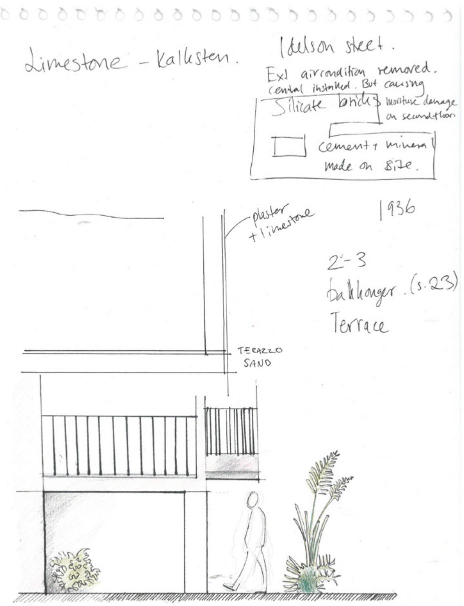
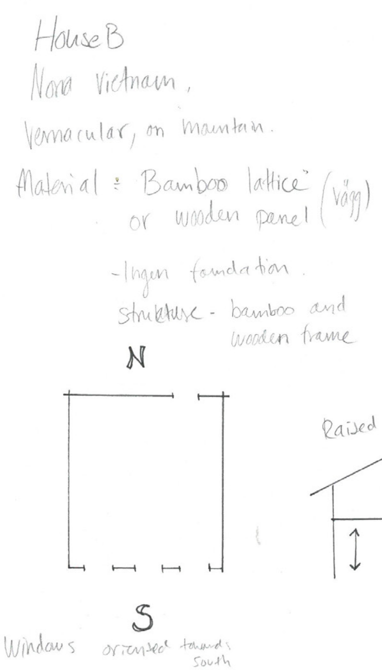
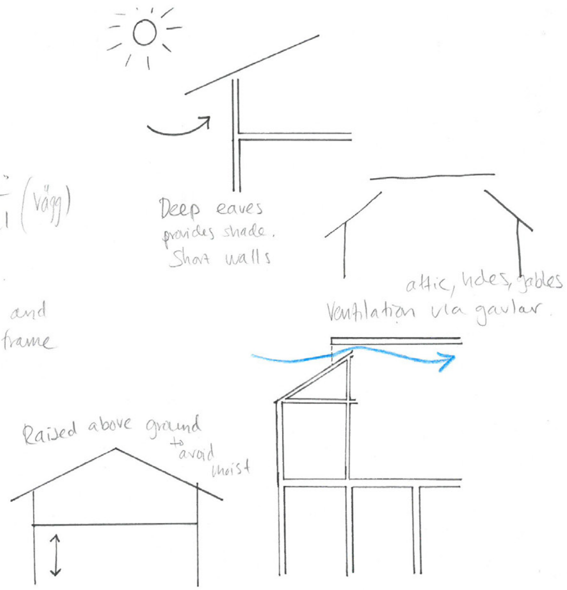
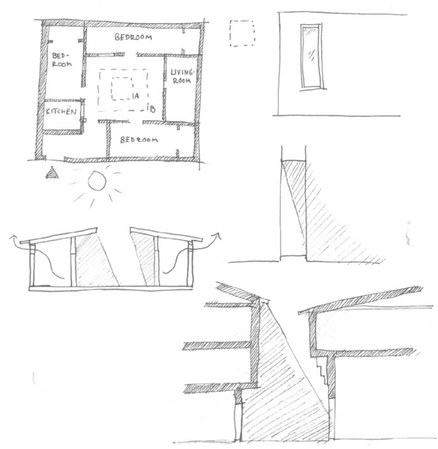


Urban heat islands?

According to the Public Health Agency's report, the effect of urban heat islands becomes stronger if the area is dense and large.

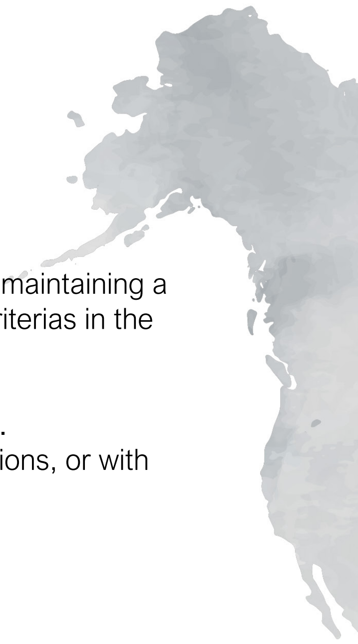
There is a great difference between a city that houses one million inhabitants and an small town with less than 1000 inhabitants. The larger city can be up to 8 degrees warmer than its surroundings, while the less populated town gets a temperature increase of about 2 degrees (FHM, 2019).

Image by author.


Wooden louves/shading
Facades in light colours
Cross ventilation
many large openings.
Hus A
Norra
Vietnam
Hanoi
Även i Hus B
Trees in courtyard
Large and long courtyard
Deep eaves
shading
0,9m
Gör plasterbild
Solid fired clay brick
Byggt 1920
load bearing
Brick wall, plaster on both sides
No clear orientation strategy, located in a city centre
and timber.

oriented towards the wind

COBOGÓ

Limestone - kalksten
Idelson street.
Silicate bricks
cement + mineral made on site.
plaster + limestone
1936
2-3
Terrace
TERAZZO
SAND

House B
Nora Vietnam,
Vernacular, on mountain.
Material : Bamboo lattice or wooden panel (vägg)
-Ingen fondation
Structure - bamboo and wooden frame
N
S
Windows oriented towards South

Deep eaves provides shade. Short walls
attic, hides gables
Ventilation via gavlar
Raised above ground to avoid moist

BEDROOM
KITCHEN
LIVING ROOM

3. EXPLORING DESIGN STRATEGIES

3.1 Five countries



Five countries from different continents have been selected to examine strategies for maintaining a comfortable indoor climate despite high temperatures outside. The most important criterias in the process of evaluating the references was:

1) The country/climate zone should have a higher average temperature than Sweden.
2) The strategies to lower indoor temperature must be based on passive design solutions, or with interventions from residents (like closing windows manually).

The following questions was also used as a guide in the process:

- In what climate is the solution used?
- Is the place humid or dry?
- Is the solution old or new?
- Does it require any energy supply?
- Is manual control or intervention from residents needed?
- What material is used?
- What is the result?

To get a variety of different strategies, I have chosen to investigate areas with hot and humid climates and hot and dry climates.

Tel Aviv, Israel. Climate: Hot and dry.
Turkey, Mardin. Climate: Hot and dry.
Algeriet, Kenadsa. Climate: Hot and dry.
Brazil. Climate: Hot and humid.
Vietnam. Climate: Hot and humid.


TURKEY
ISRAEL
ALGERIA
VIETNAM
EQUATOR
BRAZIL

3.2 The ”White City”, TEL AVIV, ISRAEL

History: Tel Aviv is located by the mediterranian in Israel, and was founded in April 1909, by a number of families. The nearby city Jaffa, estimated to be around 3000 years old, was becoming crowded and overpopulated and Tel Aviv became a modern suburban to the larger city.

The scottish city planner Sir Patrick Geddes was invited to elaborate a master plan for Tel Aviv. This was in 1925, and his plan was implemented six years later (BBSR 2015). According to historical researchers he wanted to ”(a) enabling the city to be aerated by ocean winds; and (b) the use of local construction materials and construction traditions”. The masterplan also contains large gardens and green spaces.

In 1932, the city continued to develop as jewish immigrants fled the european persecution and therefore increased the population. Architects were among the fleeing europeans and many of them were trained in the modern movement style: Bauhaus. The modern architecture style was adapted to suit Tel Avivs climate and resulted in an area with 4000 buildings with a clean, functional expression and plastered facades. ”The White city” was declared a UNESCO World Heritage Site in 2004. (tel-aviv-gov, 2022)

Population: Tel Aviv is now home for 3,9 million people. (tel-aviv-gov, 2022)

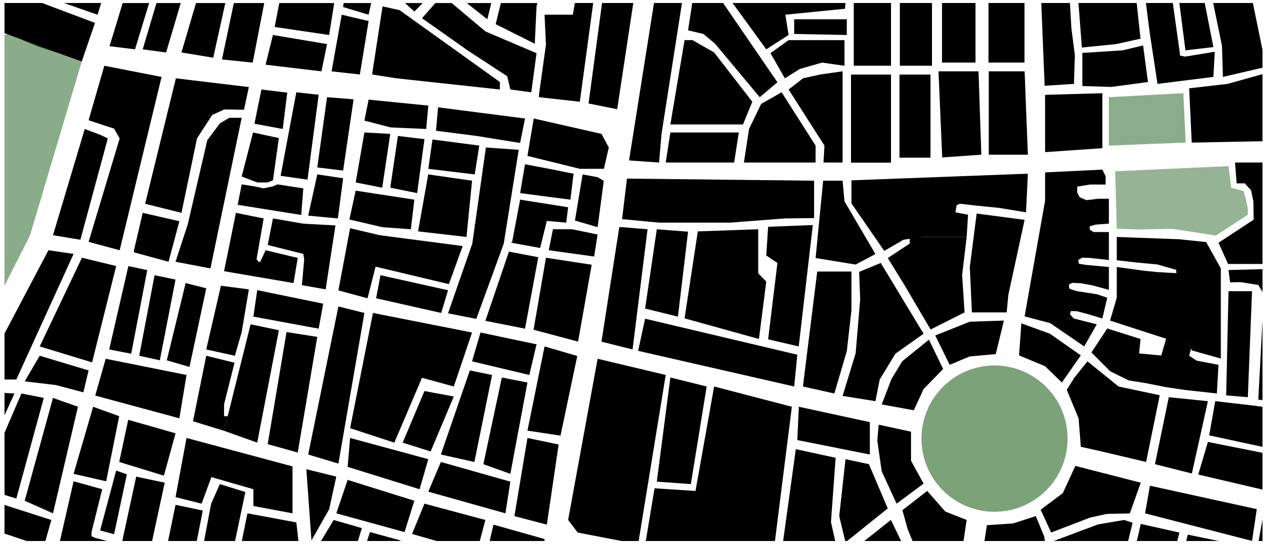
Tel Aviv is located in a supropical area, and the mean temperature in the summer is 27 °C (with daily highs to 35 °C) and 13 °C in the winter. The breeze during nights can lower the summer temp to 23 °C. The White city is designed to benefit by the wind by configuring the buildings in such ways as to allow cross ventialtion (BBSR, 2015).

The strategies presented on the following pages are based on the research from Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) (2015), titled: Tel Aviv White City-Modernist buildings in Israel and Germany.


Fig. 2. Tel Aviv


Fig. 3. Tel Aviv

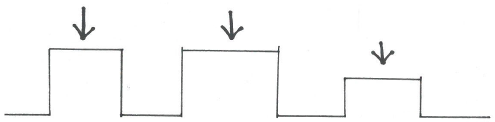

Fig. 4. Tel Aviv

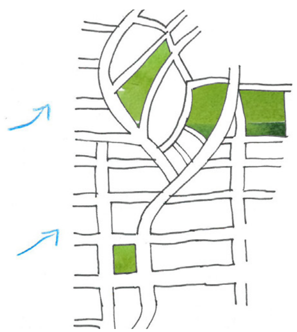

City structure, plan view. Image by author.

Architecture and strategies
Drawings by author.

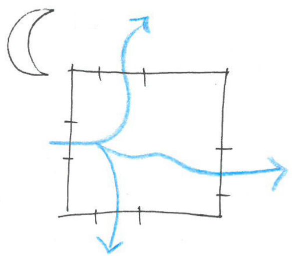
Accordning to reserach the architects planning the buildings in the White City had to take following into consideration (2015)

The numbers of floors are limited to enhance circulation of air.





Nocturnal cross-ventilation that reduces the heat that builds up during hot days



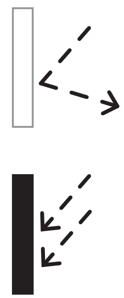
Material and colour

The ceilings and frames in most of the buildings are reinforced concrete, and other walls are made of lime sandstone. There are also examples of buildings made of silicate bricks (mineral and cement bricks fabricated on site) with a concrete flat roof and a concrete foundation. Many buildings have terazzo floor and staircases, wich is ideal for hot climates beacuse of its cooling properties and great thermal conduction.

The combination of solid materials and thick walls enables the buildings to have great thermal storage capacities. During summerdays, these elements store and absorb a large amounts of heat.

The "White City" is, in contrary to it's name, not so white. The facades are plastered in a broad range of bright colours: ochra, sandy beige, white, green and red and was intended to protect the masonry from erosion. Sand was a locally available material and was one of the influences for the colour range.

There is a large difference between the night and day temperature in Tel Aviv and the heat stored in the solid structures is removed during night by targeted nocturnal cooling. The interior walls absorb some of the heat from the solid structure and can therefore be used as a thermal buffert the next day.

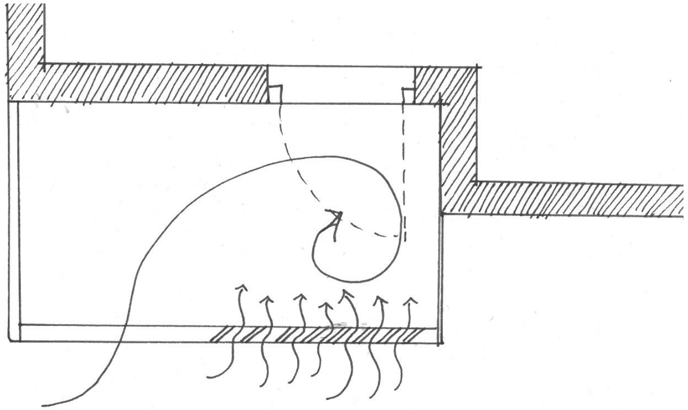


On a white facade, the sun can raise the temperaure to 40 °C. On a black facade it's almost 60 °C.

This can be of use during the winter in Tel Aviv, by removing the solar shades in front of balconies and windows and allowing the solar radiation to heat upp the spaces and creating a more comfortable ambient condition.

Balcony with vertical slats

Fig. 5. Tel Aviv, balcony



In order to bring fresch air into the buildings, vertical slats are capturing the breeze.

Cantilevered facade slabs

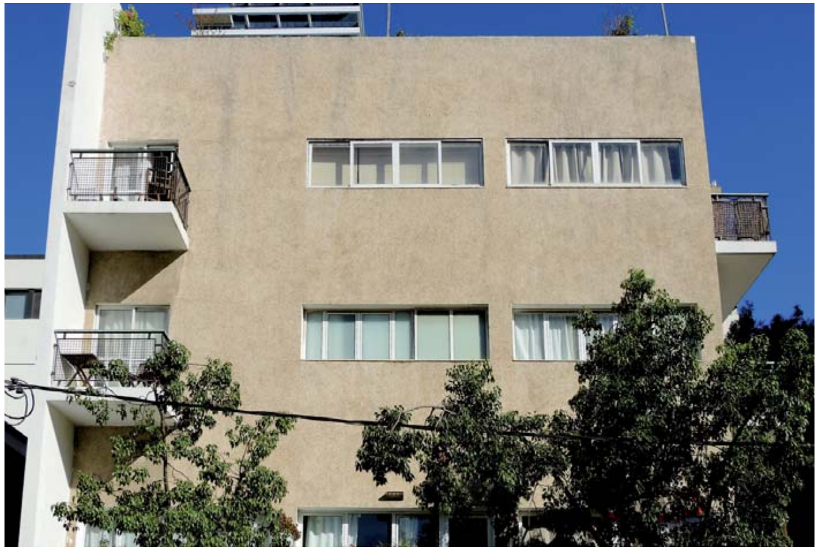
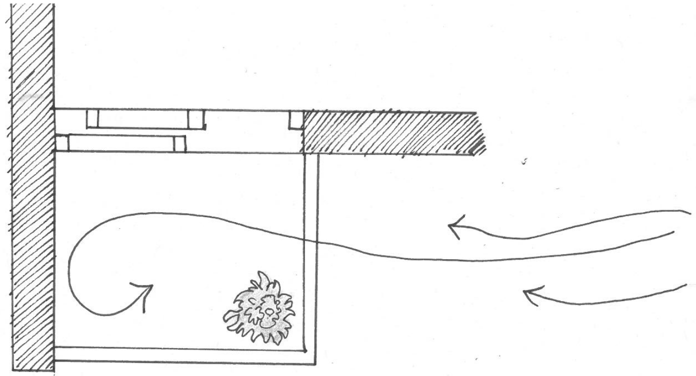


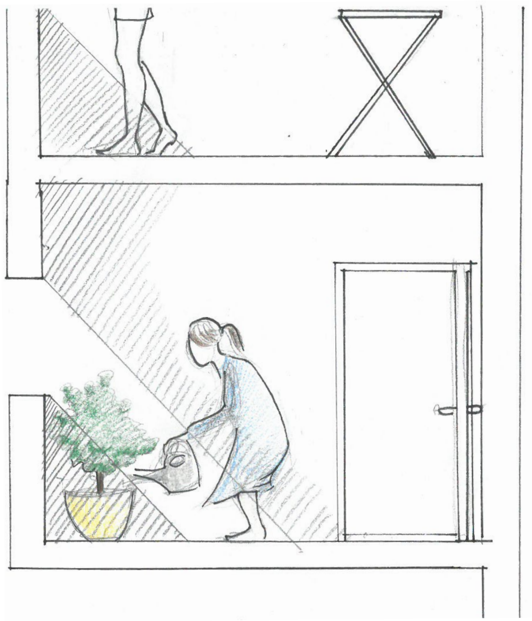
Fig. 6. Tel Aviv, facade slabs



Cantilevered facade slabs also has the function of catching the ozean breeze.

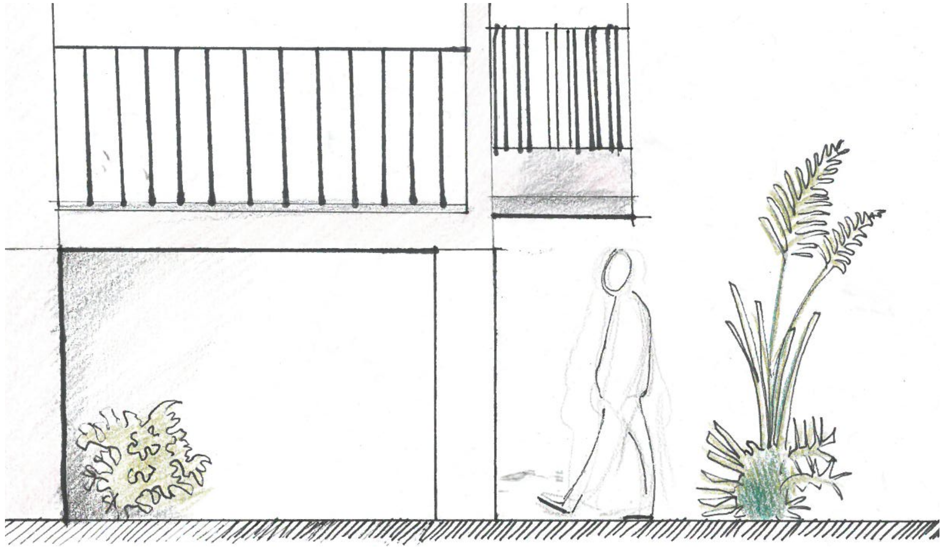
Balcony with wide skirting

Fig. 7. Balconies with wide skirting



Many houses has balconies with an extremely wide skirting, affording protection against the sun.

Pulled back facades and cantilever over entrances

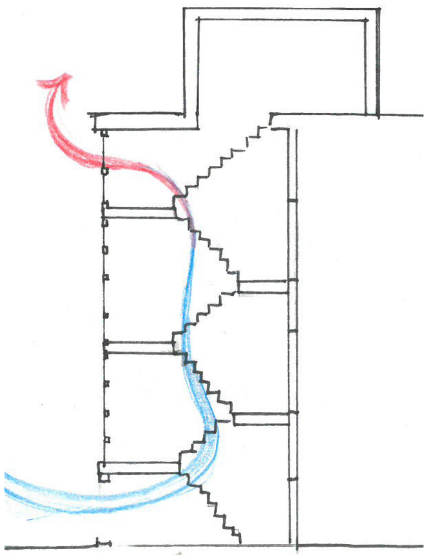


Facades that are pulled back from the streets provides shade and circulation of air. The result of this is a microclimate that is cooler in theese spaces.

Thermometer windows

Fig. 8. Tel Aviv, thermometor window

Fig. 9. Tel Aviv, thermometor window

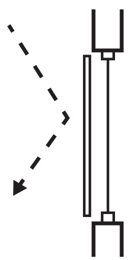


Thermometer windows creates vertical air movements and is used in the staircases.

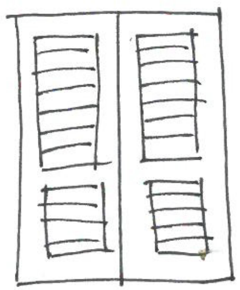
It removes heat very efficiently in a passive way through it's chimney effect when the windows are open at both the top and bottom.

Solar shading

Fig. 10. Tel Aviv, shading and blinds



Wooden roller blinds and awnings cre-ates shading, but it's functionality relies on the residents.



Wooden louvres is also a way to provide shade.

3.3 Mardin, TURKEY

History: It's more than 2000 years old and is very well preserved. The old town is mentioned under the UNSECO heritage list.

Population: 2012 it was around 90 000 people living here.

Average temperature during summer: The average temperature in July is 30 degrees, with a maximum average temperature of 42.5 degrees.

Average temperature during winter: In January the average temperature is 3.1 degrees and the lowest average temperature is 13.4 degrees.

The strategies in the next page is based on the work by Can Tuncay Akin (2020).

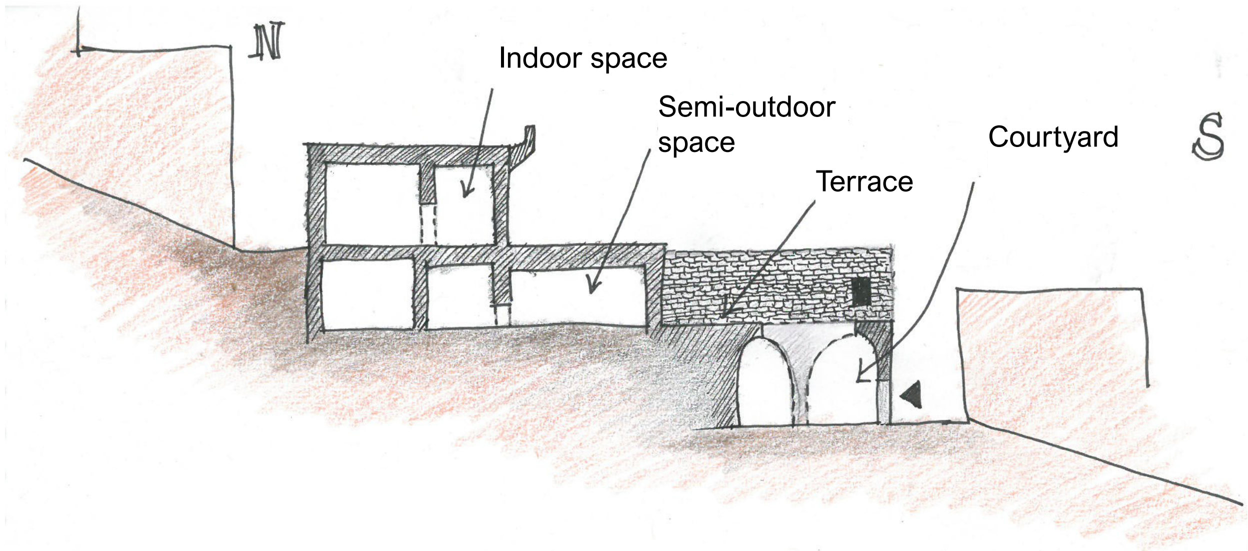
Fig. 11, Mardin

Fig. 12, Mardin

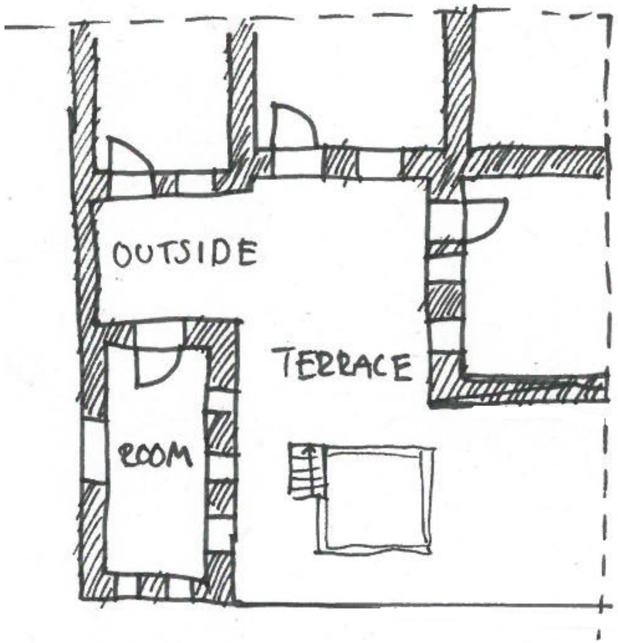
Fig. 13, Mardin

City structure, plan view. Image by author.

Architecture and strategies
Drawings by author.

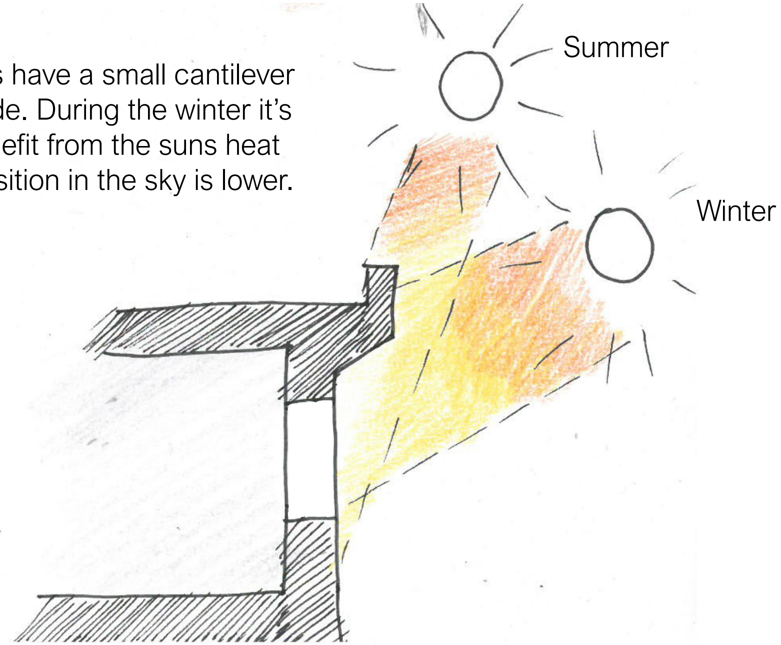


Micro climate zones
Many buildings are turnings towards south. The floorplans provide multiple opportunities for shade and different micro climate zones. The same room can be the most comfortable during different times of the year. The lower rooms are the warmest during winter and autumn and in july it is the room with best thermal comfort.

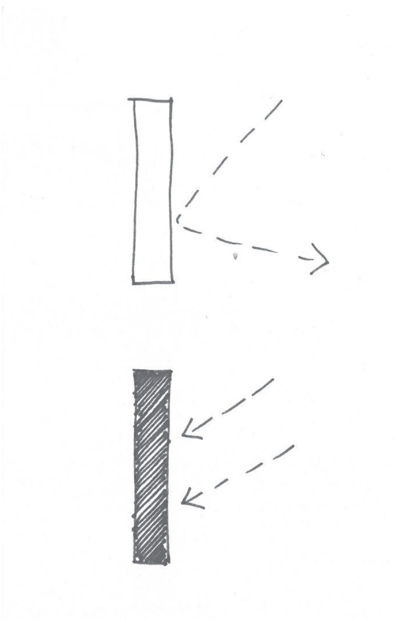


The building has a great number of doors and window openings in varying sizes wich enables cross-ventialtion.

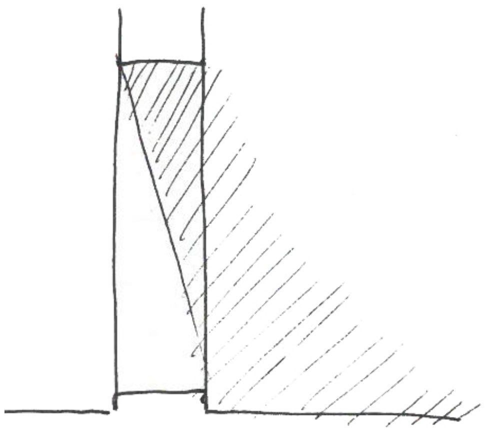
Some buildings have a small cantilever to provide shade. During the winter it's possible to benefit from the suns heat as the suns position in the sky is lower.



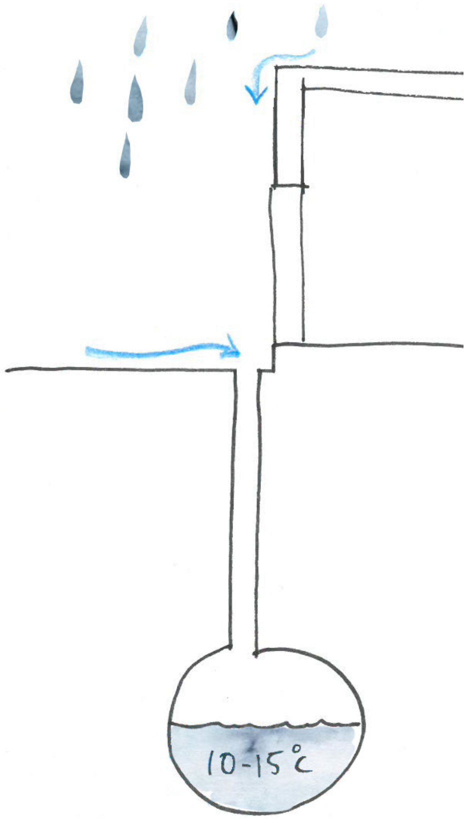
Bright facade colours
to reflect sun



Thick walls provides shade



Water is stored in wells located bwlow the buildings. Both rain and snow is stored this way, an provides the inhabitants with water through all four seasons. There is at least one well in all buildings, and the water is sprinkled on terraces and courtyards during the summer wich cools down the buildings and cretaes humidity.



3.4 Kenadsa, ALGERIA

History: The city is at least 700 years old. It is located in the bottow of a valley and is surrounded by fine sand in the north and west. It is also located by a cliff composed silica sandstone wich offers protection againts the climate.

Population: 13 942 people lived here in 2008.

Average temperature during summer: The average high temperature in July is 15 degrees.

Average temperature during winter: In January the average low temperature is aroun 15 degrees.

The strategies in the next page is based on the work by Khoukhi, M & Fezzioui, N (2012).

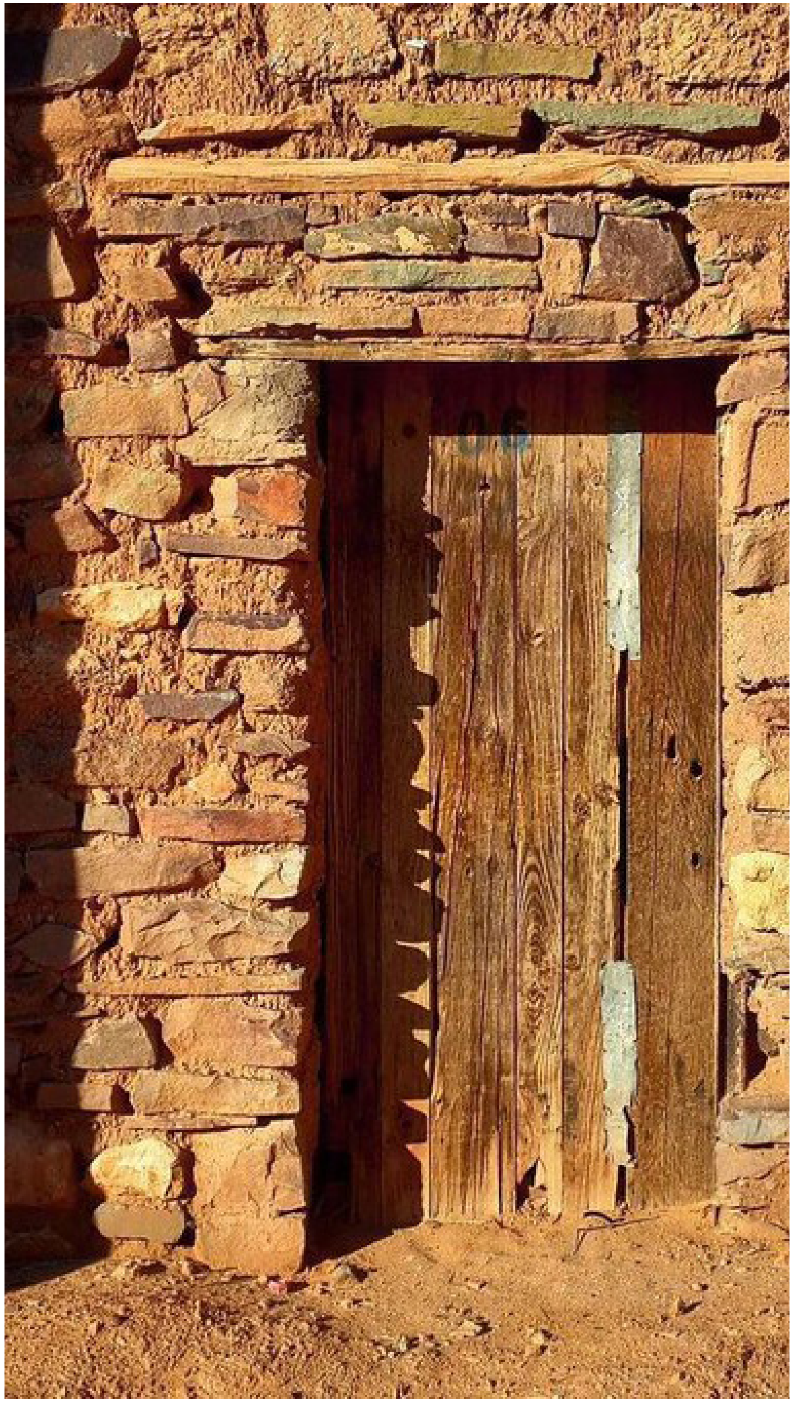


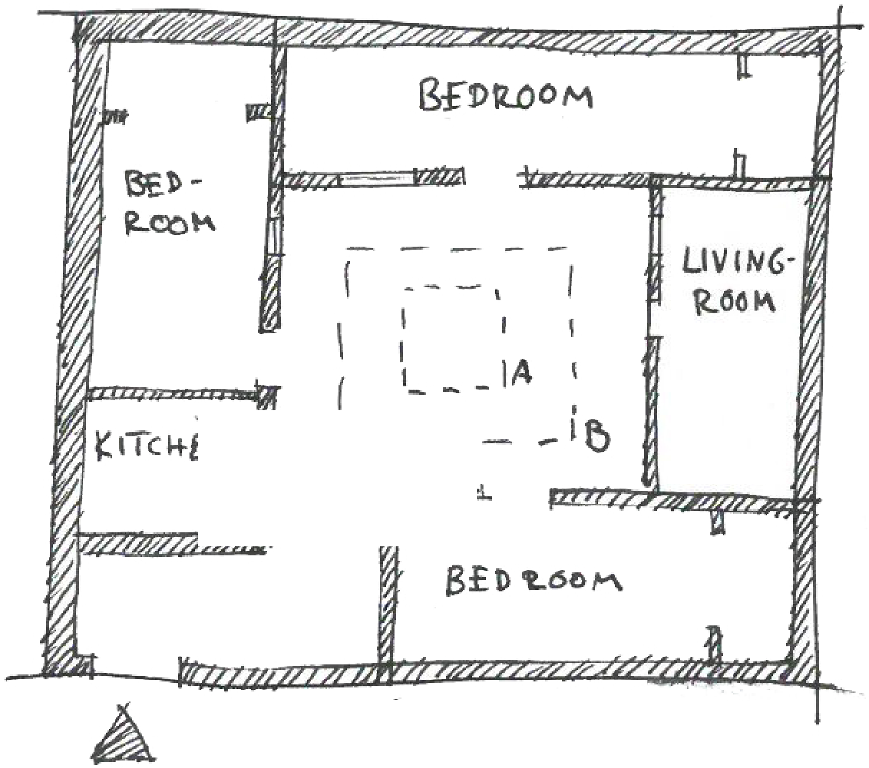
Fig. 14, Kenadsa

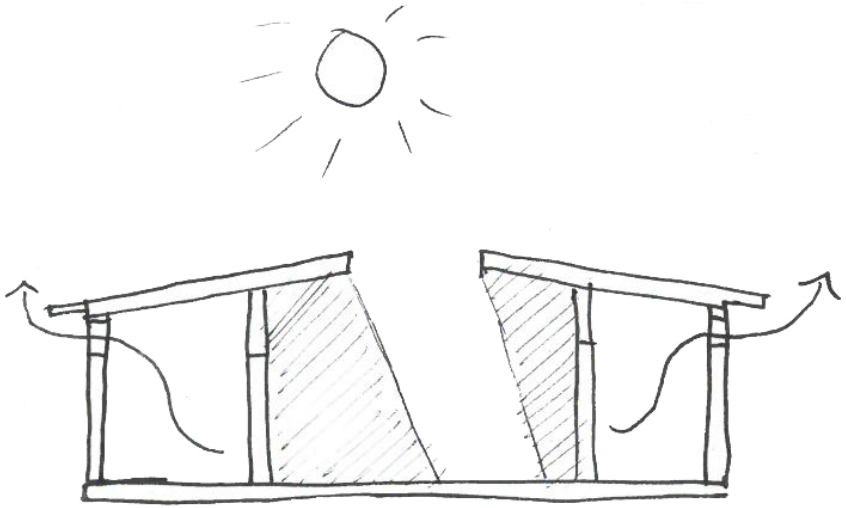
Fig. 15, Kenadsa

City structure, plan view. Image by author.

Architecture and strategies

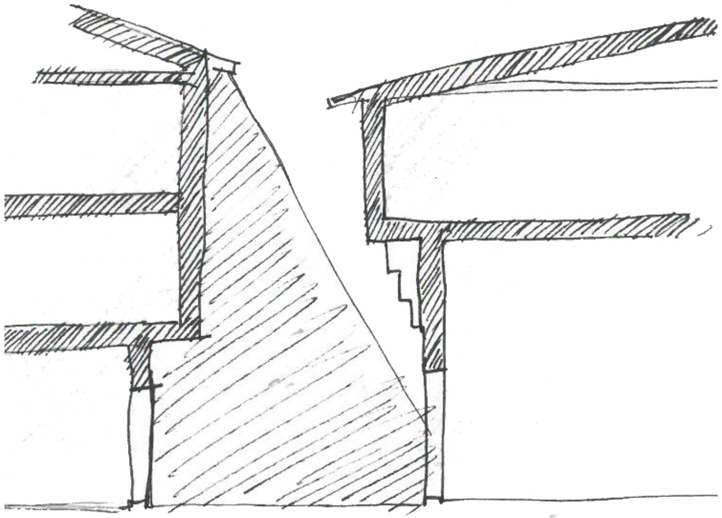
Drawings by author.



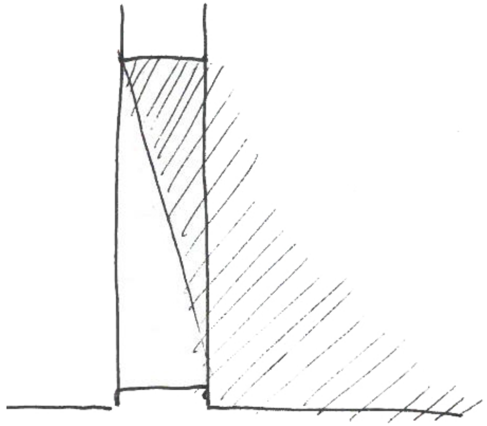


Typical floorplan in Kenadsa. The rooms are turning towards the atrium and the facades towards the streets are closed. Different sizes of the autrium were studied and showed that (A) enabled the building to have a lower indoor temperature than (B).

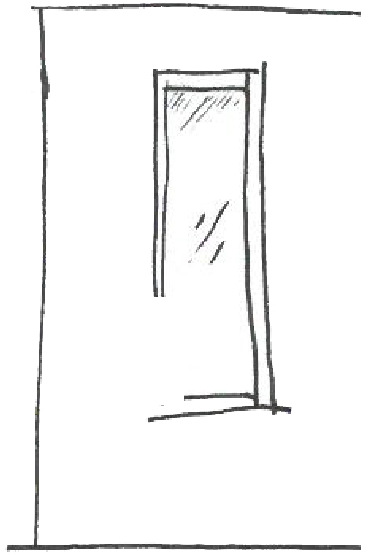
Cross ventialtion by small openings close to the roof.



Narrow streets and cantilevers provide shade.



Thick walls provides shade.



All windows in the building are high and narrow.

3.5 Belo Horizonte, BRAZIL

History: Belo Horizonte is located in the southeastern Brazil, and the city was first founded around 1897.

Population: 2,375,151 people lived here in 2010.

Average temperature during summer: The average temperature in July is 17,7 degrees, and is also the coldest month of the year.

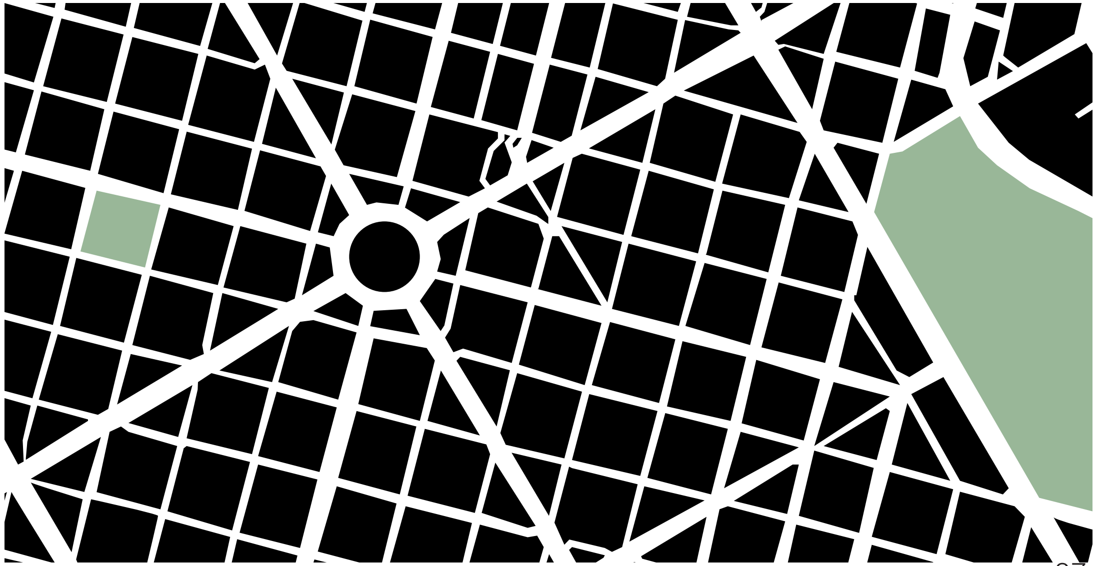
Average temperature during winter: In february the average temperature is around 22,8 and therefore the warmest month of th year. Average maximum temperatur in february is 27,5 degrees.

The strategies in the next page is based on an interview with brazilian architect E. Dinis (interview, 2022-04) currently living in Sweden. Many of the strategies can be found through the whole country, but many examples are from E. Dinis hometown.

Fig. 16, Belo Horizonte

Fig. 17, Belo Horizonte

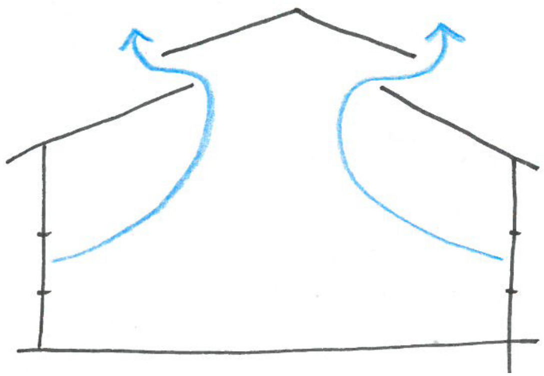
Fig. 18, Belo Horizonte



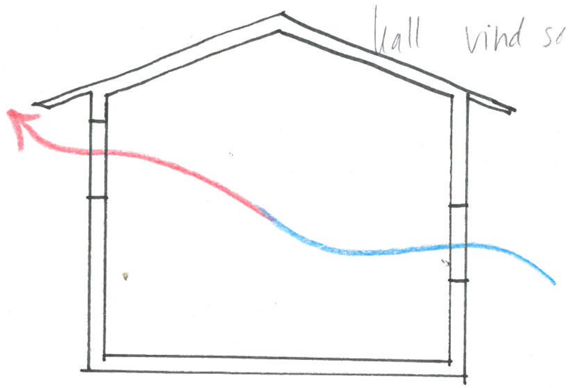
City structure, plan view. Image by author.

Architecture and strategies

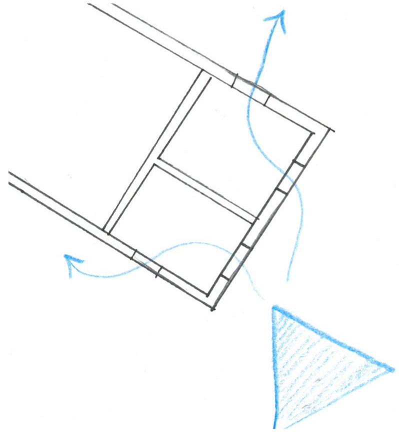
Drawings by author.



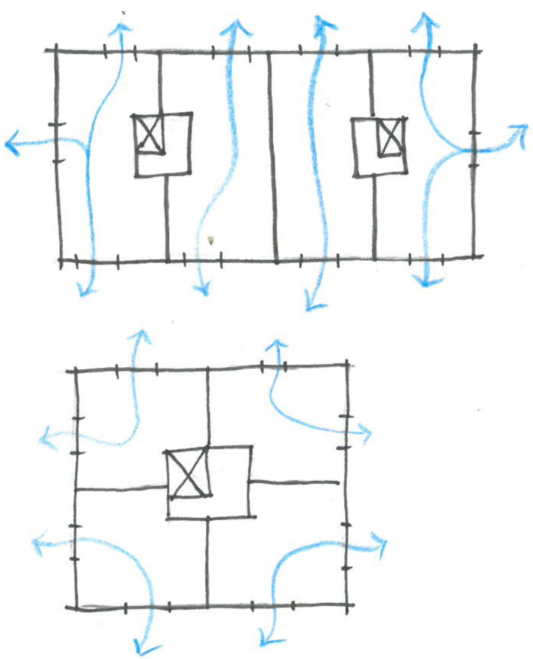
This is a type of vernacular architecture that was built before Brazil was colonized. Openings in the roof creates vertical airmovement.



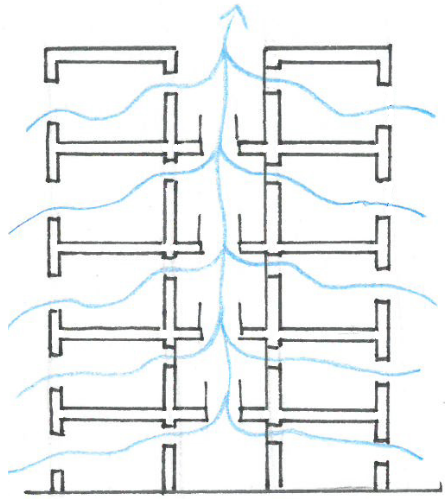
In the more modern architecture (from the beginning of the 19´th century), windows are placed on different hights to enhance the cross-ventilation and enable the warm air rise towards the ceiling and be aired out.



It is very common that the building are oriented with regard of the wind direction with their openings towards the wind.



Floor plans that enables
cross ventialtion



Cross ventliation through atriums

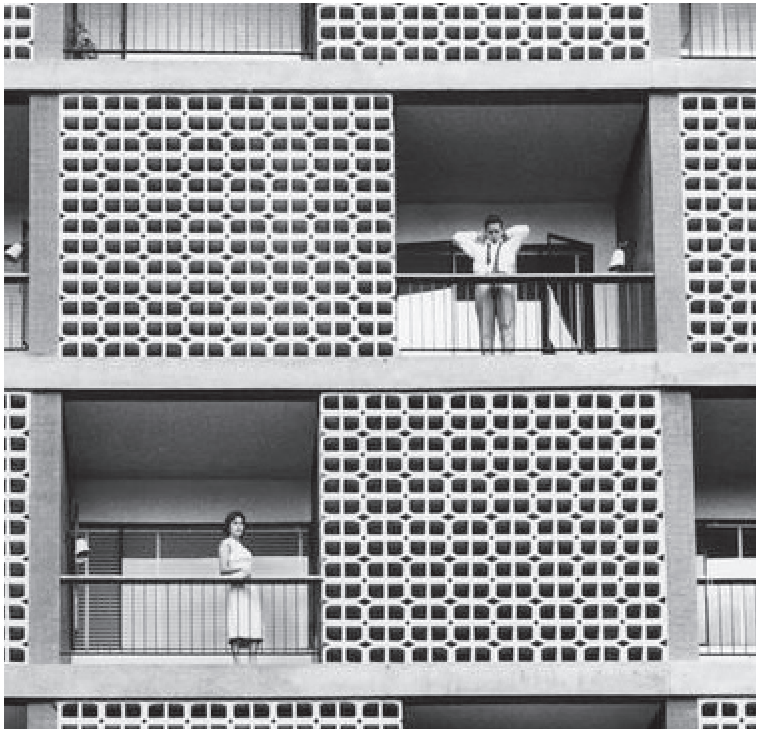
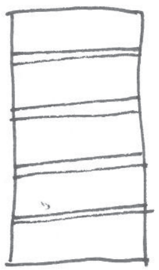


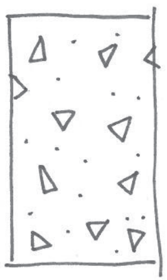
Fig. 19, Cobogó

Cobogó, perforated facade material and in Brazil it could for be used instead of an outer wall to increase the airflow in a laundry room for example.

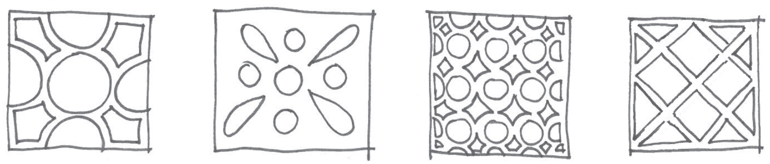
Adobe



Concrete



Example of patterns



3.6 Hanoi (urban) and Hoa Binh province (rural) VIETNAM

History: Hoa Binh province is located outside of Hanoi, and both areas are in the north of Vietnam. The reference building from Hanoi is built in 1920 and the vernacular building in in Hoabinh province has no availble source for the construction date, but reserach show that it is a housing style that has existed for centuries, but with a short life span of each house (Nguyen, A-T, Tran, Q-B & Tran D-Q (2011).

Population: 4,875,000 people lived in Hanoi in 2021.
In Hoabinh province was the population 854 131 in 2019.

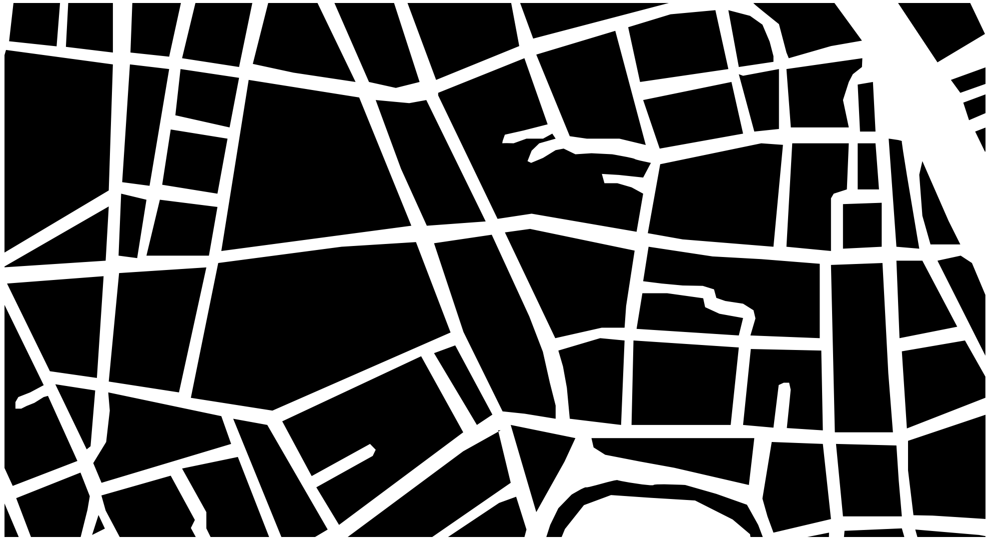
Average temperature during summer: The average temperature in Hanoi July is 29 degrees, with average highs of 33 degrees. Hoabinh province is nearby, but a very large area, so it is difficult to add information about the temperature based on the information from the reference project. For this master thesis I will just assume the temperature is similar to Hanoi.

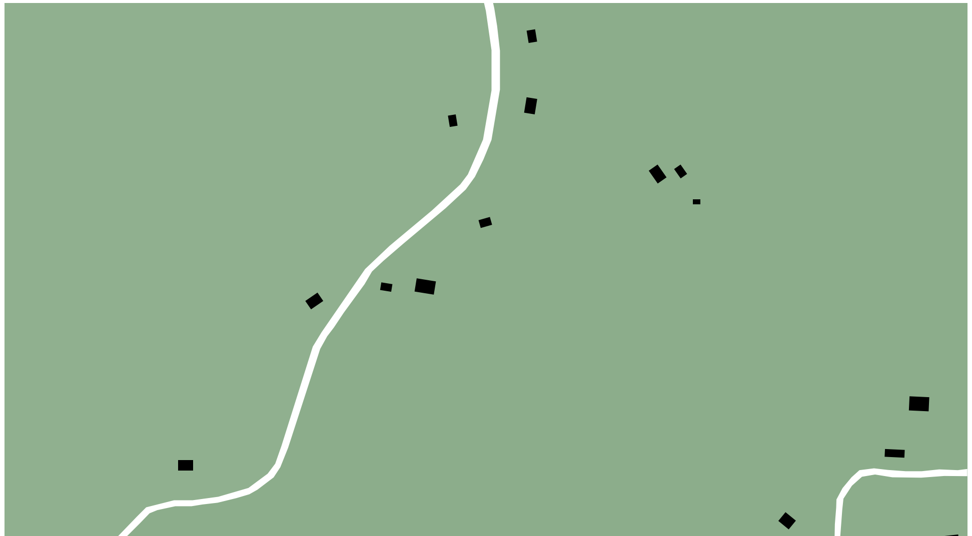
Average temperature during winter: In january is the average temperature around 17 degrees and therefore the coldest month of th year. Average maximum temperatur in january is 20 degrees.

The strategies in the next pages is based on an article by Nguyen, A-T, Tran, Q-B & Tran D-Q (2011).


Fig. 20, Hanoi

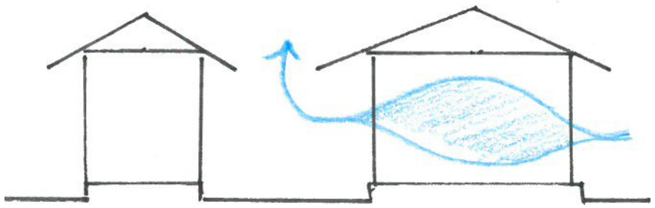

Fig. 21, Hoa Binh


City structure, plan view. Image by author.

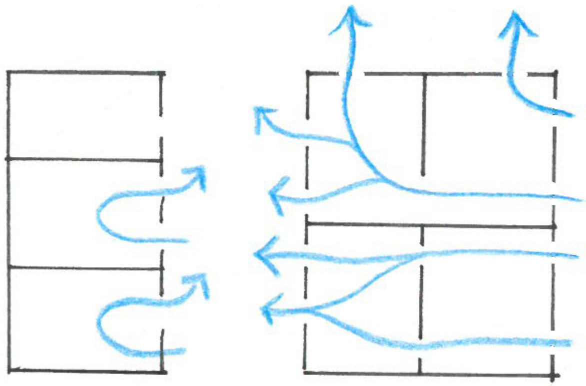

Landscape of Hoa Binh. Image by author.

Architecture and strategies, Hanoi City

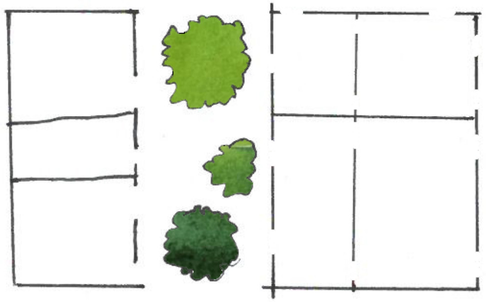
Drawings by author.



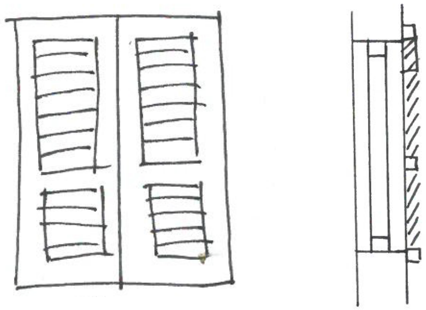
Large and long courtyards to enhance ventilation.



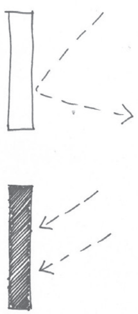
A large number of openings enables cross-ventilation. The openings are made of timber and glass.



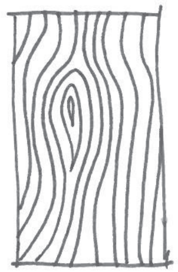
Trees in courtyard provides shade and moist.



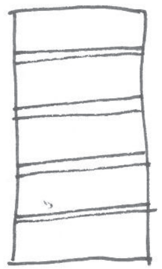
Openings with wooden louvres creates shading and reduces heat input.



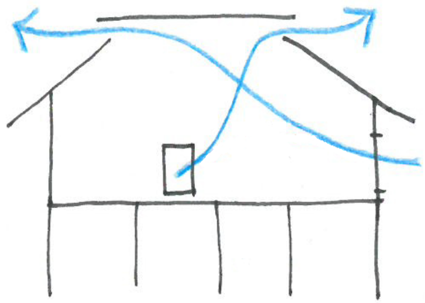
Bright facade colours reflects the sun.



The structure is made of timber.

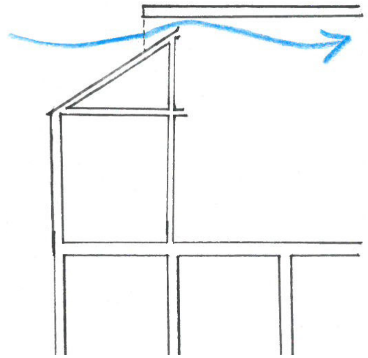


The walls are made of solid bricks and plaster on both sides.



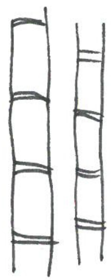
Cross ventilation is enabled through windows, doors, and openings on the gable.

The window openings are made of bamboo lattice.

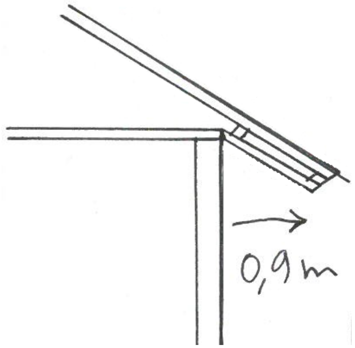


The attic is well ventilated by holes at the gables.

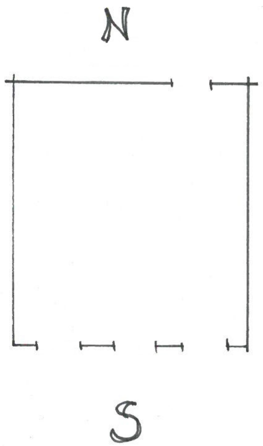
The structure is made of bamboo and a wooden frame.



The walls are made of a bamboo lattice or a wooden panel.



The building has deep eaves and short walls that will protect both walls and openings from the sun.



Windows oriented to the south.

3.7 Summary

Many of the countries had similarities in their strategies no matter if the climate was hot & humid or hot & dry.

Every strategy listed and in the previous pages is thoroughly described in articles and reserach, as well as the result. The only design feature that I had to make an assumption about is the ”Cobogo” in Tel Aviv. It is seen in pictures of the White City but there’s no information regarding it’s trait. In this Thesis it still has a place in the charts beacuse of the contribution to statistics.

Most frequent strategy

Vertical air movement together with cross ventilation can be seen in almost all the reference projects. Adobe or bricks is also among the most usual strategies.

To orient the building based on the wind was also common, as well as narrow streets and openings near the roof in order for the hot air to rise and then be ventilated.

Unusual strategies

The water wells could not be found in any of the other projects than Mardin, Turkey. One explanation could be that there is both heavy rains and even snow during the winter. And water is an excellent as a cooler during the summer.

Other features that could not be seen in so many other areas were the concept of ”catching the breeze” in Israel, cantilevered facades in Algeria and Bamboo in Vietnam.

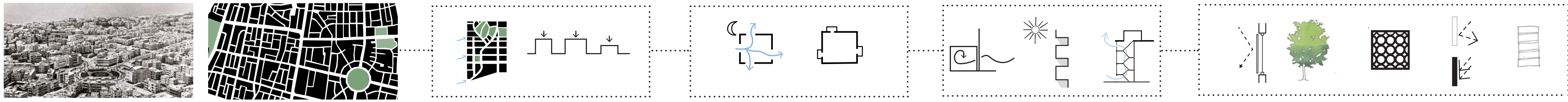
Reading instructions

Th first chart is showing the strategies divided by country, followed by information of the city/aerial structure and then strategies sorted by ”scale”.

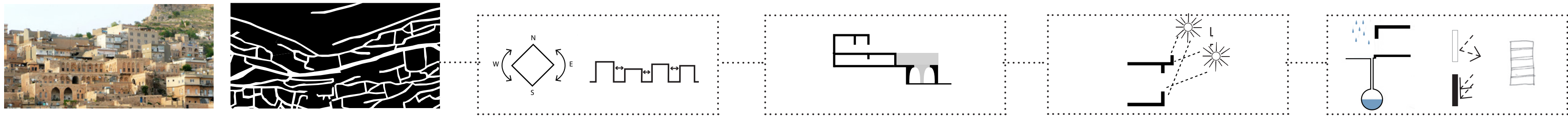
The second chart is collecting all strategies divided by how frequent they are, beginning with the most common.

	Country/ area	Typology	Building geometry Large scale	Plan strategies Medium scale	Vertical strategies Medium scale	Additions to the building Medium scale/ detailed level

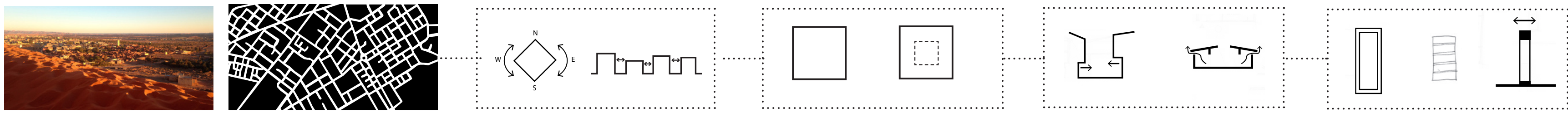
Israel
Tel Aviv, "White city"



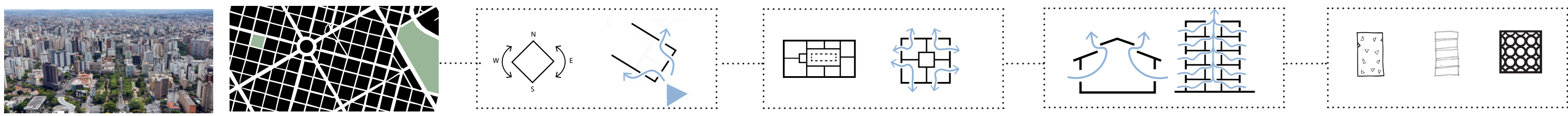
Turkey
Mardin



Algeria
Kenadsa

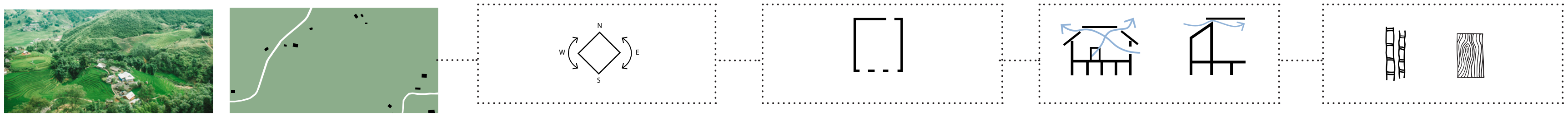


Brazil
Belo Horizonte

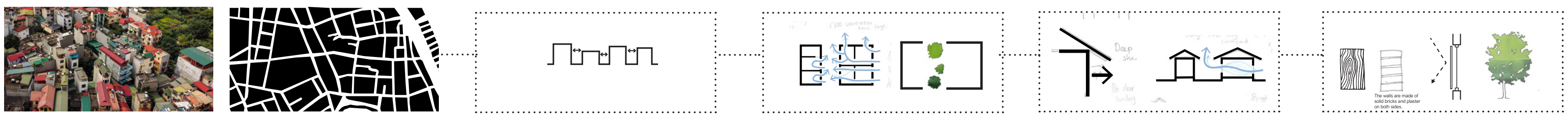


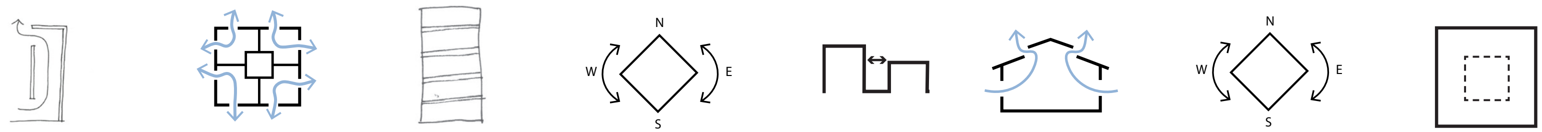
Vietnam

Rural area



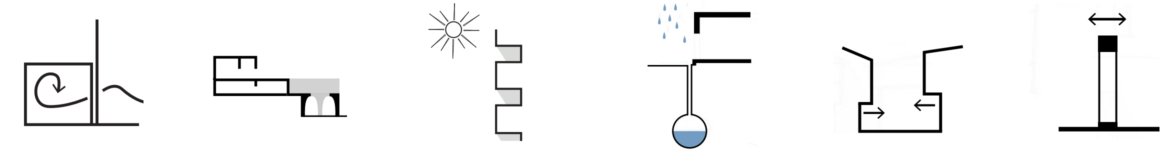
Urban area





	Vertical air movement	Cross-ventilation	Adobe/silicat bricks	Orientation based on the wind	Narrow streets	Openings near the roof	Orientation based on the sun	Atrium
TEL AVIV, ISRAEL								
MARDIN, TURKEY								
KENADSA, ALGERIA								
BRAZIL								
VIETNAM, RURAL								
VIETNAM, URBAN								

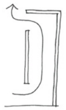
	Cobogó	Trees and vegetation	Eaves protecting from the sun	Blinders	Bright facade colours	Concrete	Bamboo	Closed facade with no windows
TEL AVIV, ISRAEL	■	■		■	■	■		
MARDIN, TURKEY			■		■			
KENADSA, ALGERIA								■
BRAZIL	■					■		
VIETNAM, RURAL			■					
VIETNAM, URBAN		■		■			■	

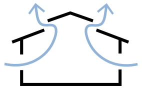


	Catching the breeze	Micro climate zones	Deep balconies	Water dwellings	Cantilever towards the streets	Thick walls
TEL AVIV, ISRAEL						
MARDIN, TURKEY						
KENADSA, ALGERIA						
BRAZIL						
VIETNAM, RURAL						
VIETNAM, URBAN						

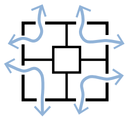
3.8 Strategies to implement in a swedish context

It is clear that some of the strategies are more common than other. My decision of what to bring into the design process has been selected by how frequent the strategy appears in the chart, but also out of curiosity to see how it could be applied in my proposal. Below, I will present the reasoning behind my design choices.

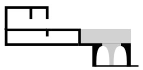

Vertical air movement


Openings near the roof

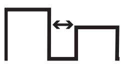
Vertical air movement as a strategy can be seen in all five countries. The design for this solution doesn´t look exactly that same in all reference projects, but the concept is similar. The challenge is to add this strategy in a multi family house with several more stories than many of the references. It is connected with the strategy of openings near the roof.


Cross-ventilation

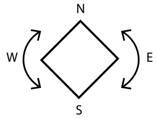
Cross-ventialtion is the second most common strategy in the chart and by planning the design of the floorplan it migth be easily applied.


Micro climate zones

I am curios to see if I can set up conditions in the apartment or in the building for micro climate zones.

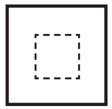

Narrow streets for shading

The width of the streets in at my choosen site is 13 meter, but I still want to see if the surrounding buildings is providing any shade.



Orientation based on the wind

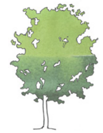
The directon of wind was very important for three of the references. I will investigate to see if can use the direction of wind at the site in Norrköping.


Atrium

The atrium was also used in three of the examples and I will try to implement it in my design.


Cobogó

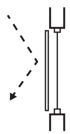
Cobogo could be seen in two references, Brazil and Tel Aviv, but it is a bit unclear how it is used in Tel Aviv. In Brazil it could be used instead of an outer wall to increase the airflow in for example a laundry room. I migth use it in a different way in my proposal, as of the weather conditions in Sweden during the winter where it would be non-practial to have perforated walls.


Trees and vegetation

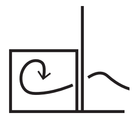
This strategy could only be seen in two of the examples, but in some cases the surrounding environment was very harsch and had very little natural vegetation.


Bright facade colours

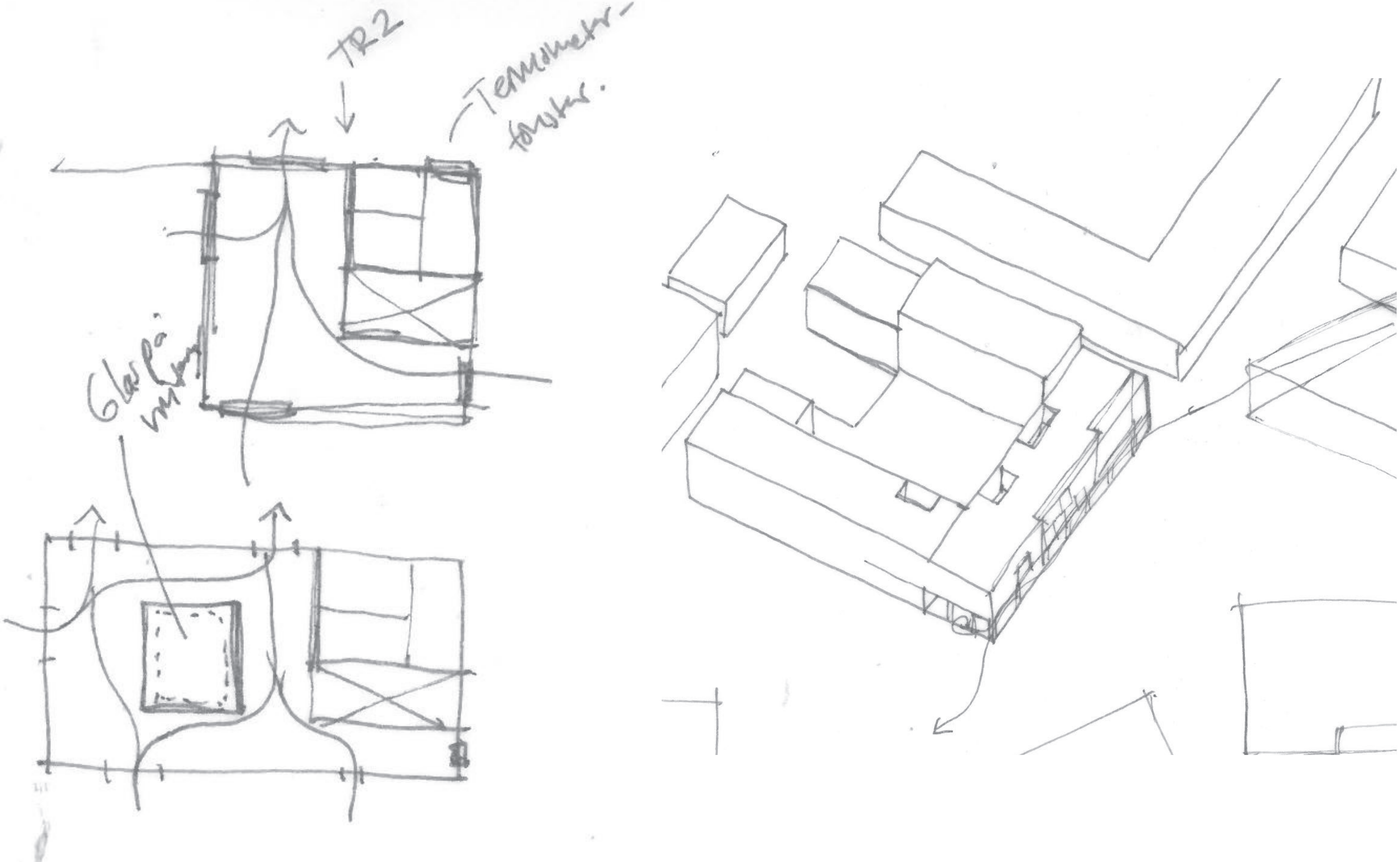
Reserach suggests that bright facade colours is absorbing less heat, and is therefore an important strategy to implement.


Blinders

Blinders could only be noticed in two references. But I noticed other startegys with a similar outcome, like deep eaves, and in the case of Algeria, no windows at all.


Catching the breeze

Catching the breeze was an important part of the strategies in Tel Aviv. It could be achieved by using pulled back facades, walls that was protruding from the facade and vertical slats/raster on balconies.



Drawings by author.

4. DESIGN PROCESS & PROPOSAL

4.1 Location and context

The choosen site for the multifamily house is located in area called ”Inre hamnen” near the city centre of Norrköping. The whole area is currently empty and is being prepared for schools, office buildings and almost 3000 apartments.

The municipality is currently developing a detailed plan for the site I have chosen, and I think it is interesting to adapt my proposal to the guidelines set by the municipality. See the next page for comments on the regulations.

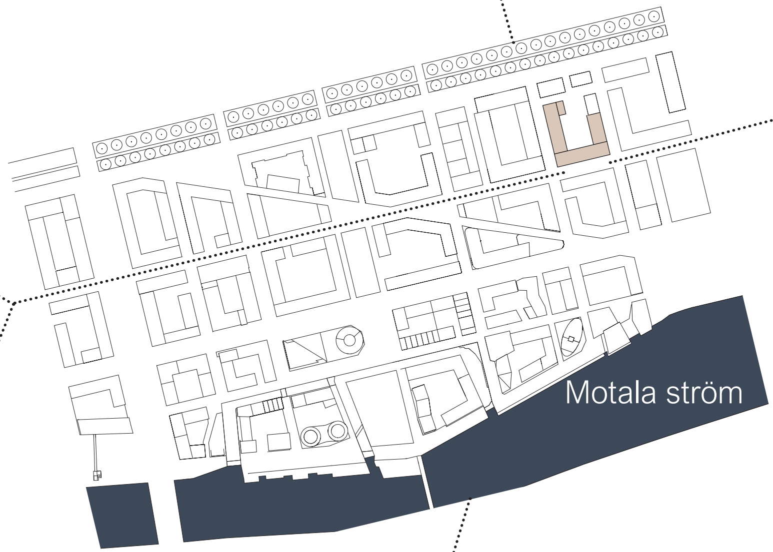
Weather and climate
In Norrköping, the average temperature for the whole year is 7.6 ° C. In July, the normal daytime temperature is 23 ° C and the highest average temperature during the day is 29 ° C. At night it drops to 12 ° C. The coldest month is January with a normal daytime temperature of 1, 3 ° C.

The prcipitation during a year is about 600 mm. The relative humidity in July is around 75%.

Norra promenaden is a one of three large avenues in Norrköping. The total numbers of threes in the avenues is around 1800 and is therefore an important green asset.

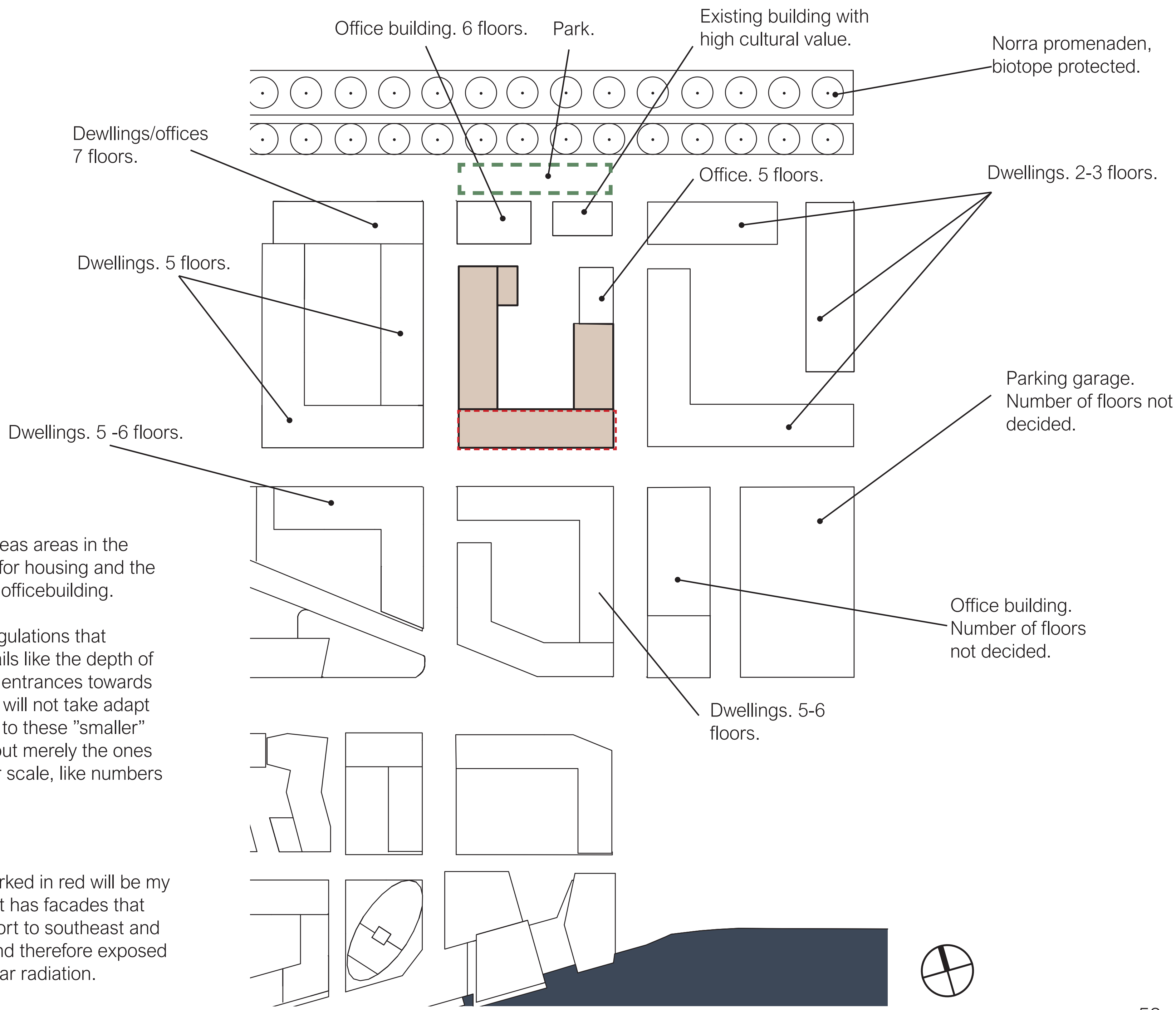
4,7 km to Bråviken.

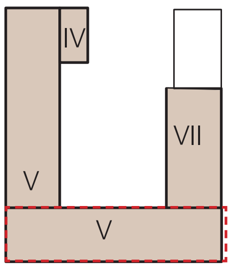
1,16 km to the Central station



1,69 km to Norrköping city centre

Motala ström is a river that flows through the city of Norr-köping all the way to Vättern. It´s aproximately 100 km long and has been an important part of the industrial area in Norrköping that took place between 1850 and 1970.





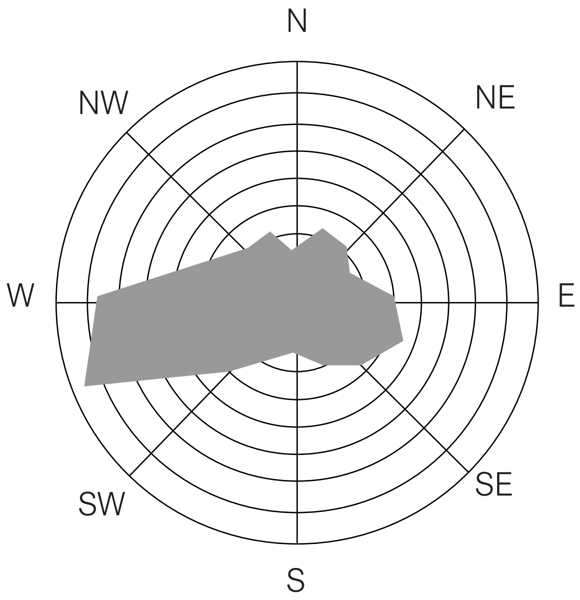
The beige areas areas in the detailplan is for housing and the white part is officebuilding.

There are regulations that dictates details like the depth of balconies or entrances towards the streets. I will not take adapt my proposal to these "smaller" regulations but merely the ones for the larger scale, like numbers of floors.

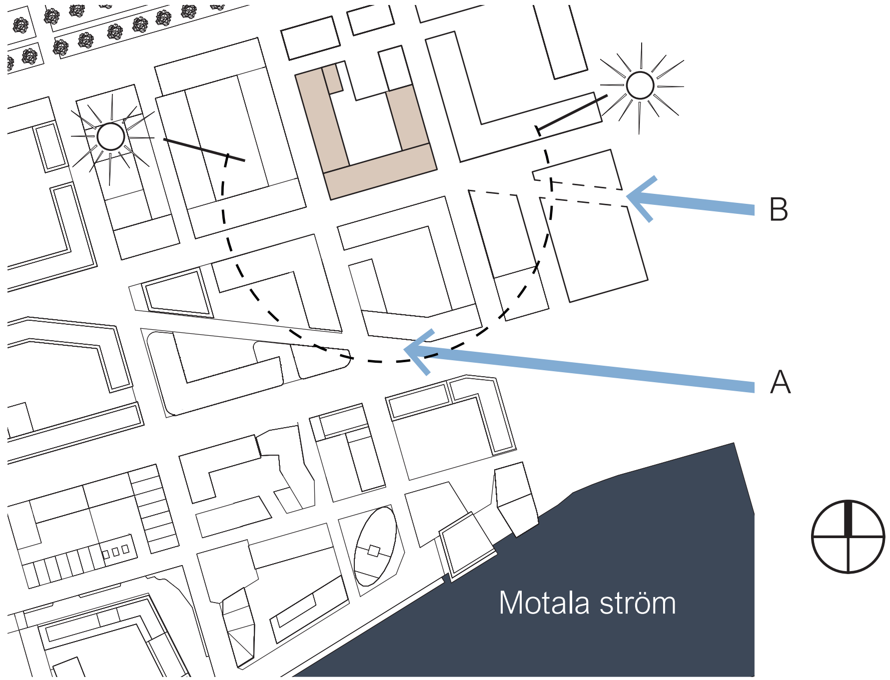
The area marked in red will be my main focus. It has facades that is oriented bort to southeast and southwest and therefore exposed to a lot of solar radiation.

4.2 Orientation of wind and sun

Strategies shown
Orientation based on the wind



The wind on the site in ”Inre hamnen” is mainly coming from south west/west during the winter. On the summer however the wind direction change and the winds are coming from east/ south east (The Foodprint Lab, 2016).



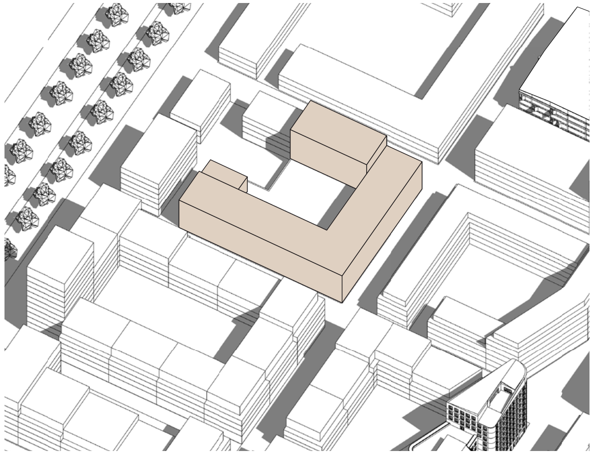
A) is showing how the wind will move through the urban landscape, where the detailed development plan already parted some of the blocks. In order to enhance the wind on my site I decided to split buildings further north, as shown in arrow B).

4.3 Solar study

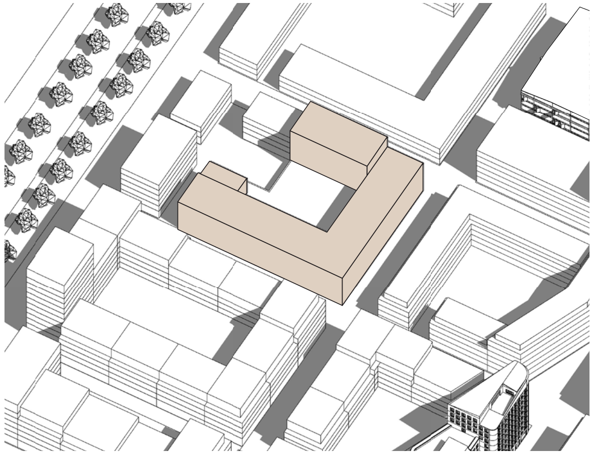
The width of the streets in the detailed development plan is 13 meter, wich makes it impossible for the surrounding buildings to provide any shade that would make difference during warmest hours.

Strategies shown (and out-ruled)
Narrow streets for shading

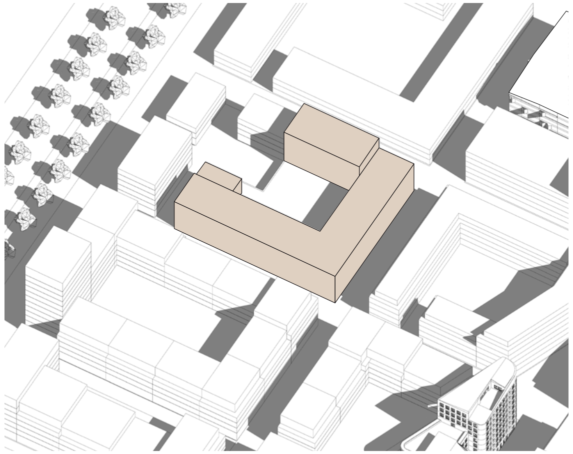
June 15/6 13:15



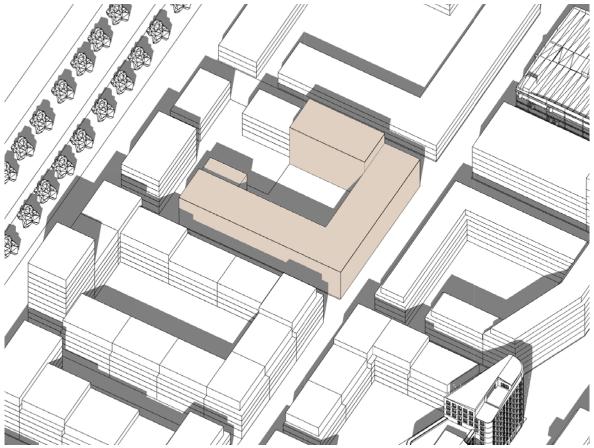
July 15/7 13:15



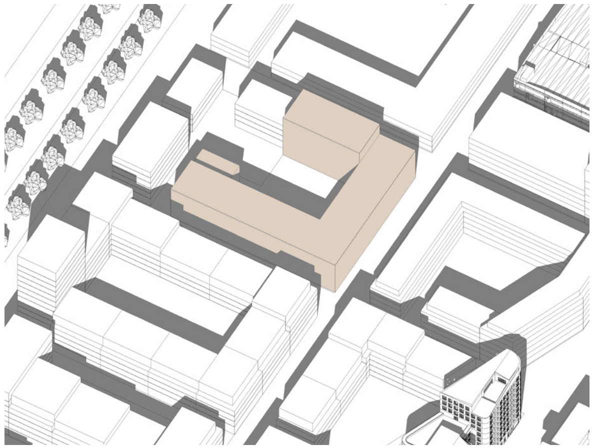
August 15/8 13:15



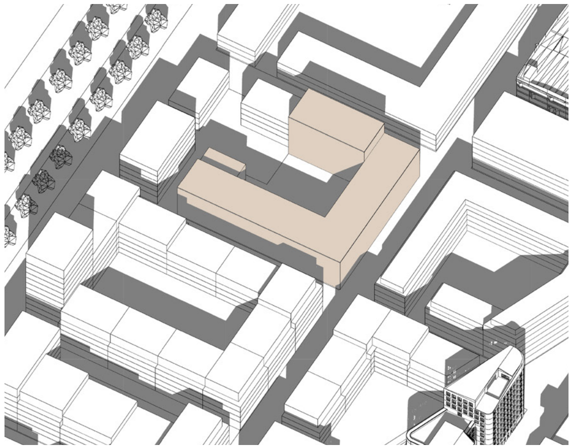
June 15/6 16:15



July 15/7 16:15



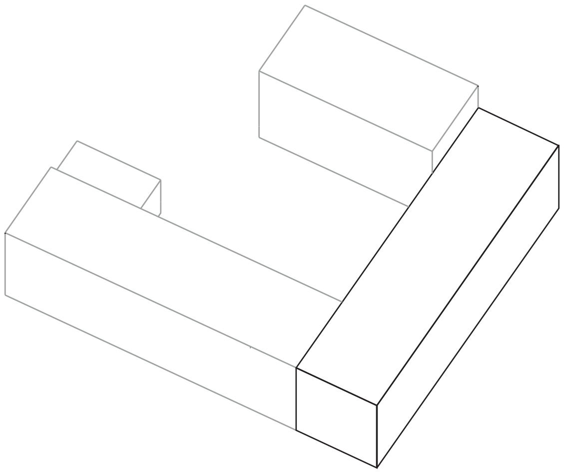
August 15/8 16:15



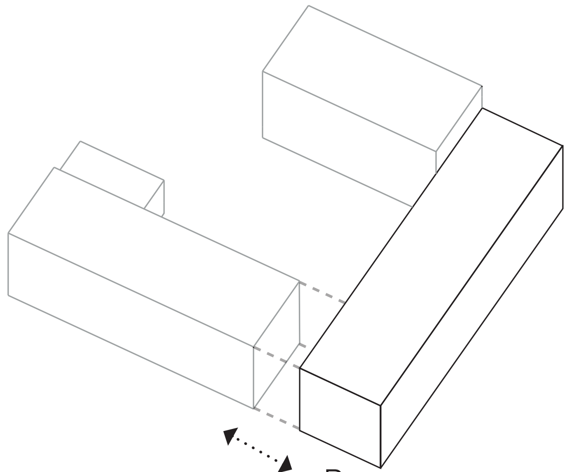
4.4 Design strategy to enable cross-ventilation

A). Part of the block that will be transformed
B). A gap is created in order to eaiser implement the strategy of cross-ventilation.
C). The block is divided in four parts, with a total of three stairwells.
D). The four parts is adjusted to create better conditions for cross-ventilation.
E). Some parts are lowered so that the outer, larger parts have more walls towards the open air. The top floor on the part furthest to the west will ha a diagonal shape in order to minimise the wall facing towards south.

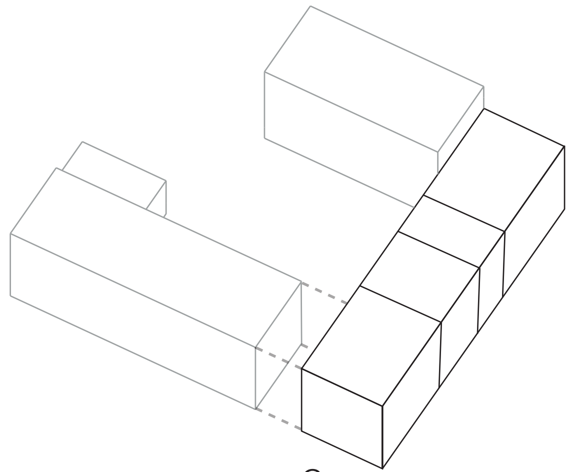
Strategies shown
Cross-ventilation



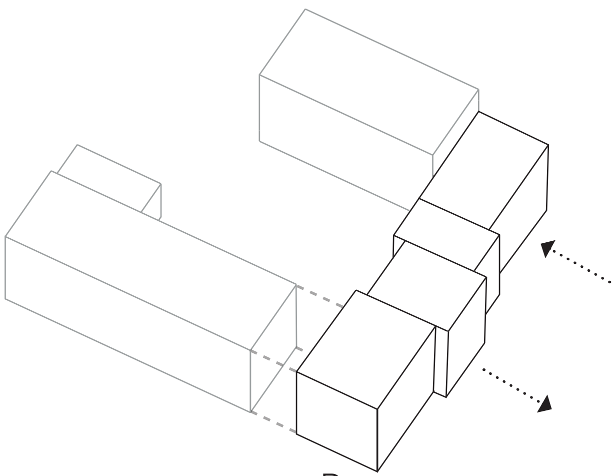
A



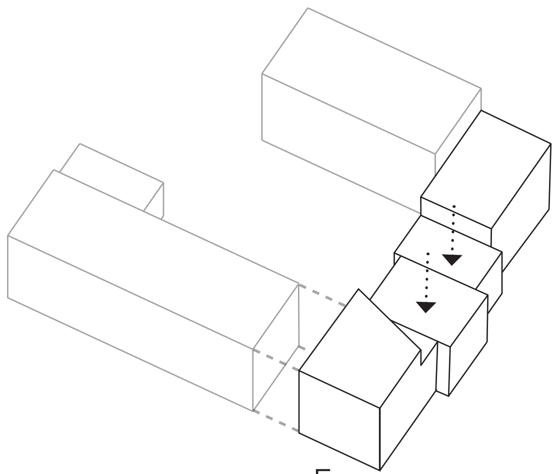
B



C



D

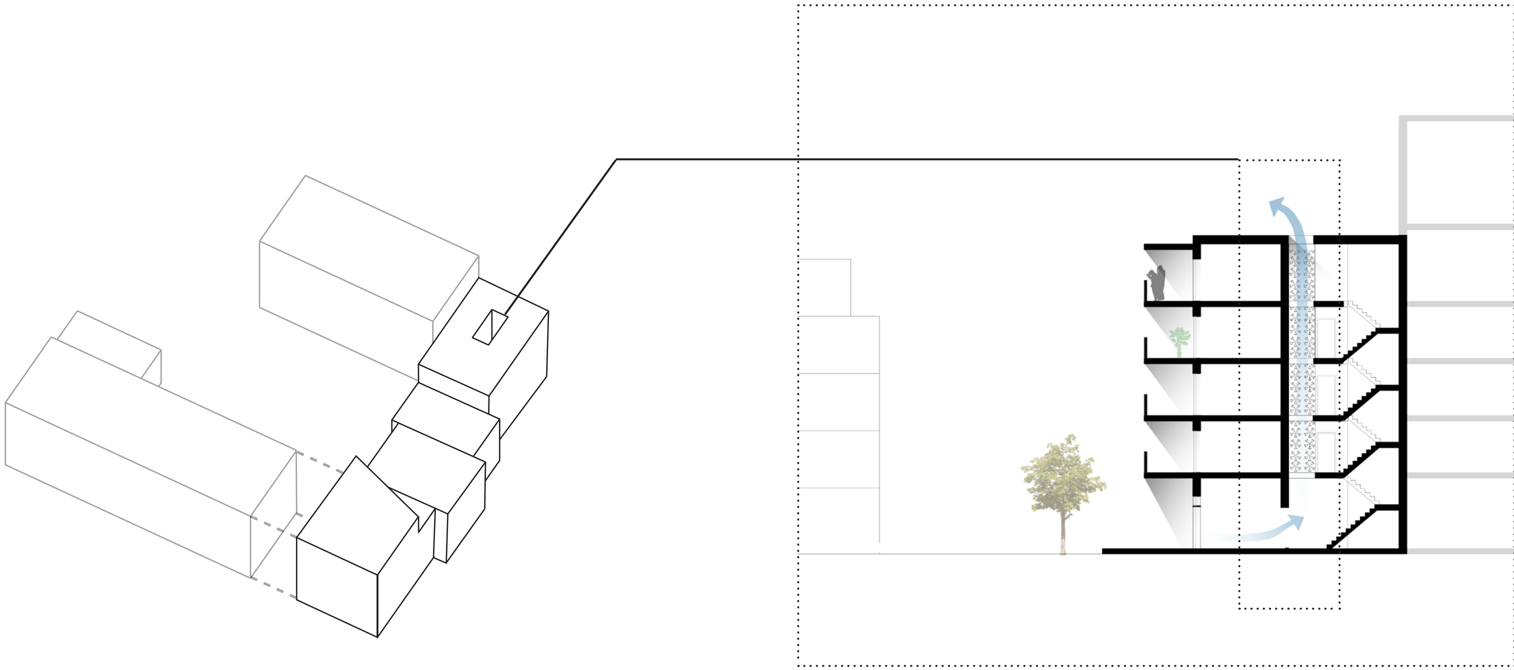


E

4.5 The addition of atrium/air shaft

Strategies shown
Atrium
Vertical air movement

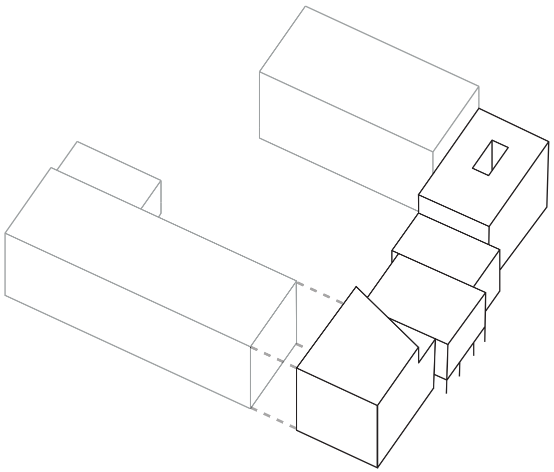
This solution is combining two strategies, and one of them is important according to previous chart: the vertical air movement. The atrium goes all the way up to the roof and will let the warm air rise up towards the opening.

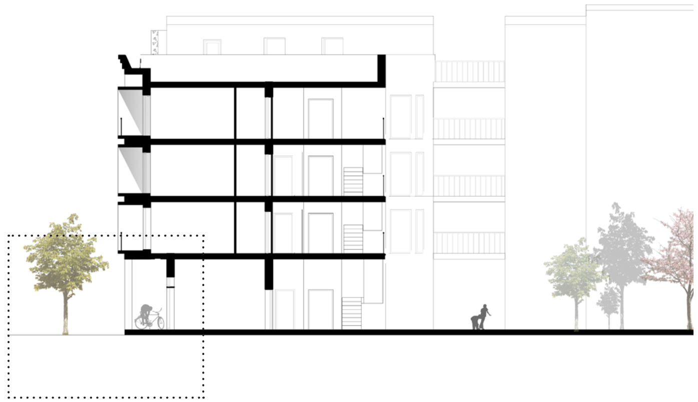


4.6 Catching the breeze

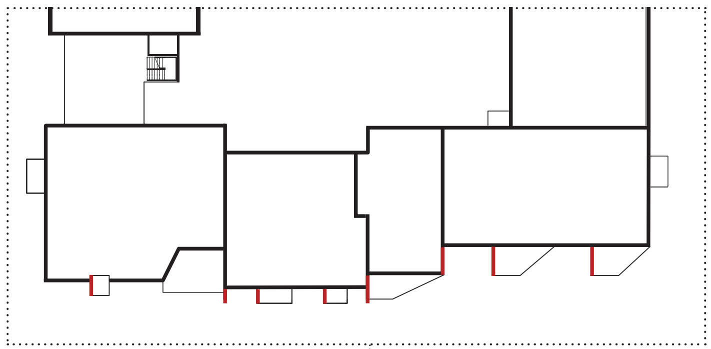
This strategy was not ver common according to the reference project, but it was a usual strategy in Tel aviv where the ocean wind was "catched" in different ways.

Strategies shown
Catching the breeze

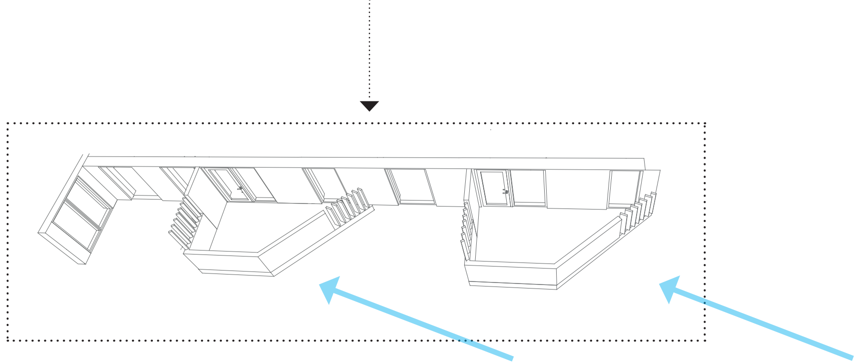




When the facades is pulled back in different levels it creates air eddies wich helps to lower the temperature in the streets.



Another solution is to stop the wind and let it circulate in smaller areas. In this case, the wind comes from the east during the summer. The balconies has therefore solid walls to stop the wind, and as shown in the picture below- vertical slats to let the air in to the balcony.



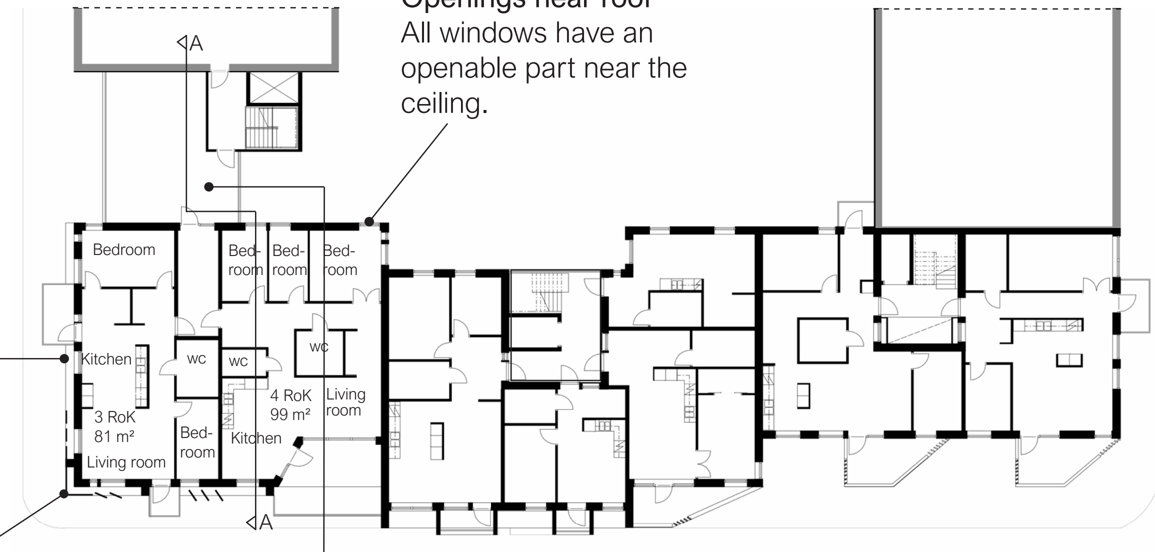
4.7 First floor & section A-A, part A

1:400/A4

Strategies shown
Micro climate zones
Openings near roof
Blinders
Cobogó
Cross ventilation

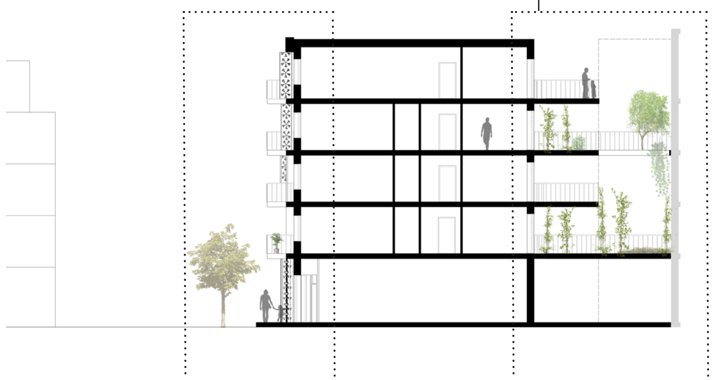
Openings near roof
All windows have an openable part near the ceiling.

Cross ventilation
The floorplans have windows towards many directions, and in different heights.



Part A

Blinders & Cobogo
Theese strategies are combinded, and the cobogo is transformed to function as a perforated solar shading.

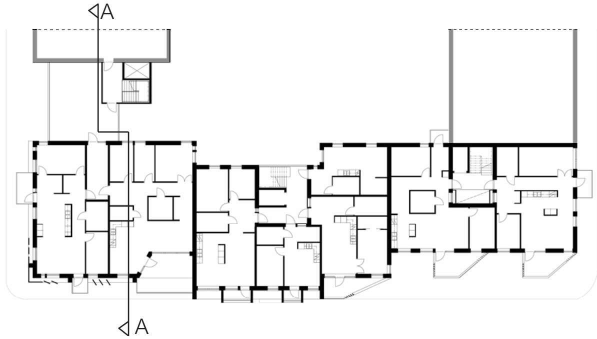


Micro climate zones
By creating a garden in many floors this will be an asset for the residents.

4.8 Detailed section A-A

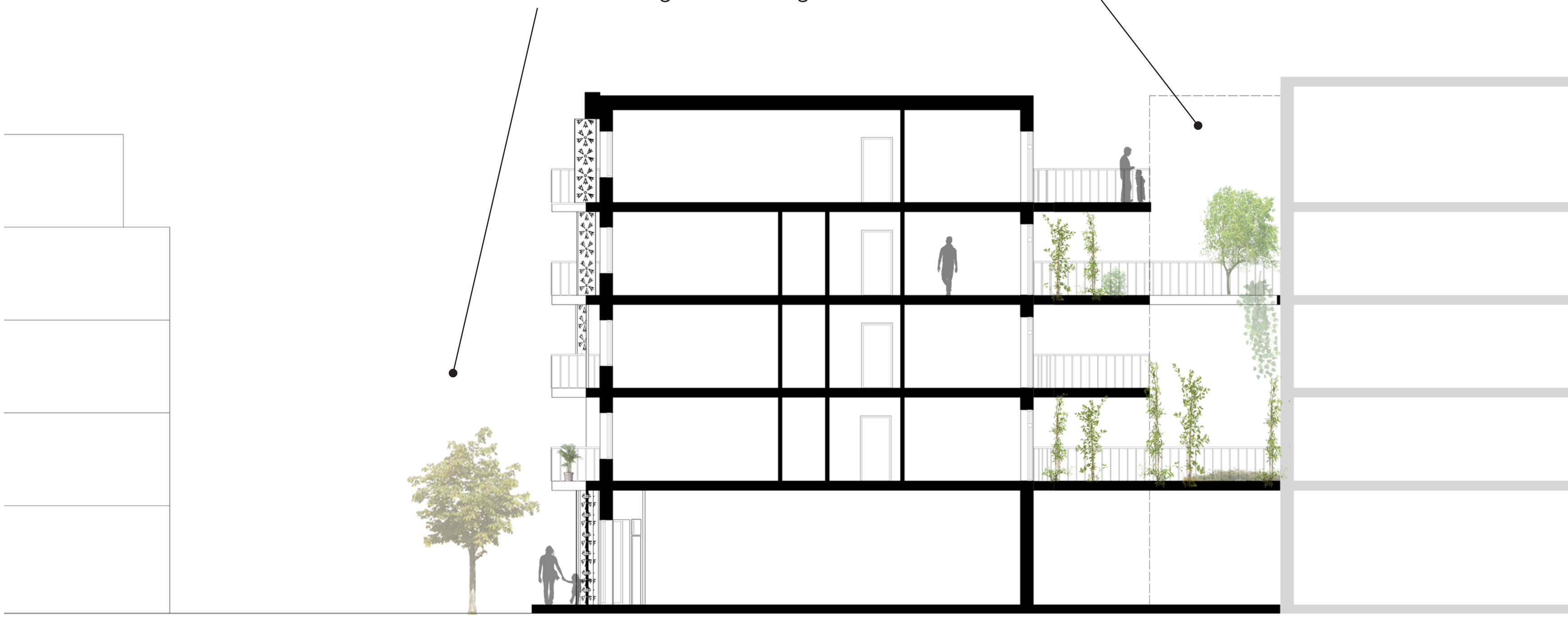
1:200/A4

Strategies shown
Vegetation



Vegetation
Threes and vegetation is added in a terrace that has openings in the slab on every other floorplan. This is to provide more room for the plants and also to enable both rain and sun to reach the vegetation.

Trees are also planted on the streets surrounding the building.

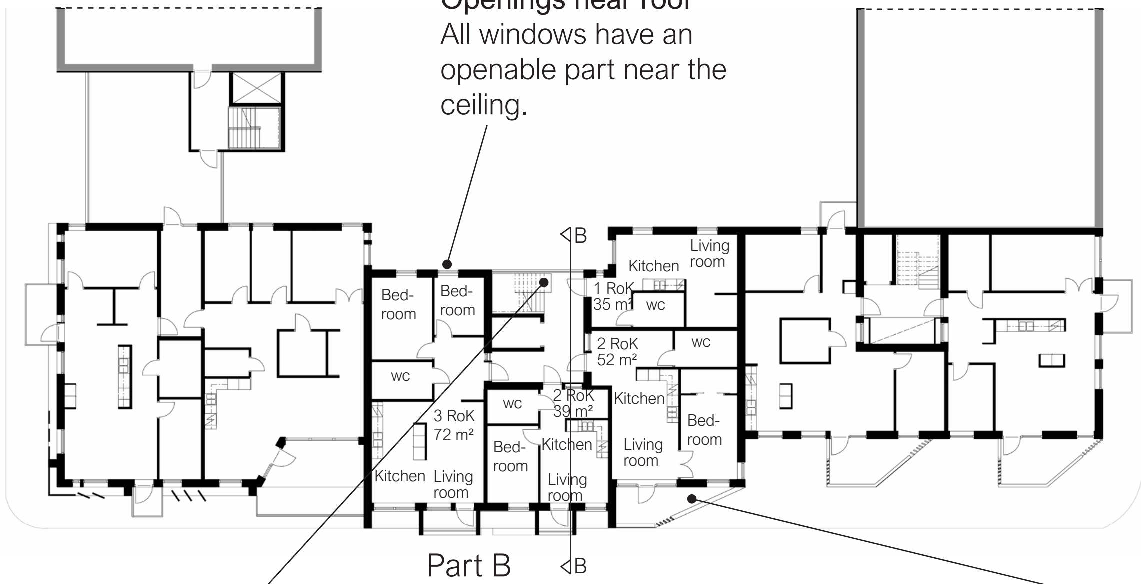


4.9 First floor & section B-B, part B

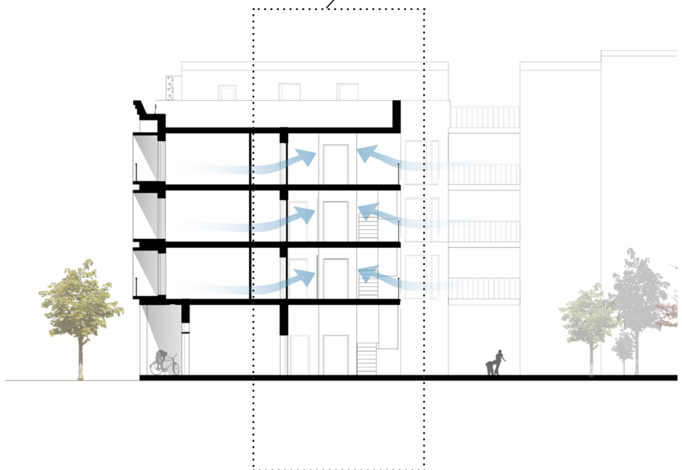
1:400/A4

Strategies shown
Openings near roof
Cross-ventilation
Catching the breeze

Openings near roof
All windows have an openable part near the ceiling.



Catching the breeze



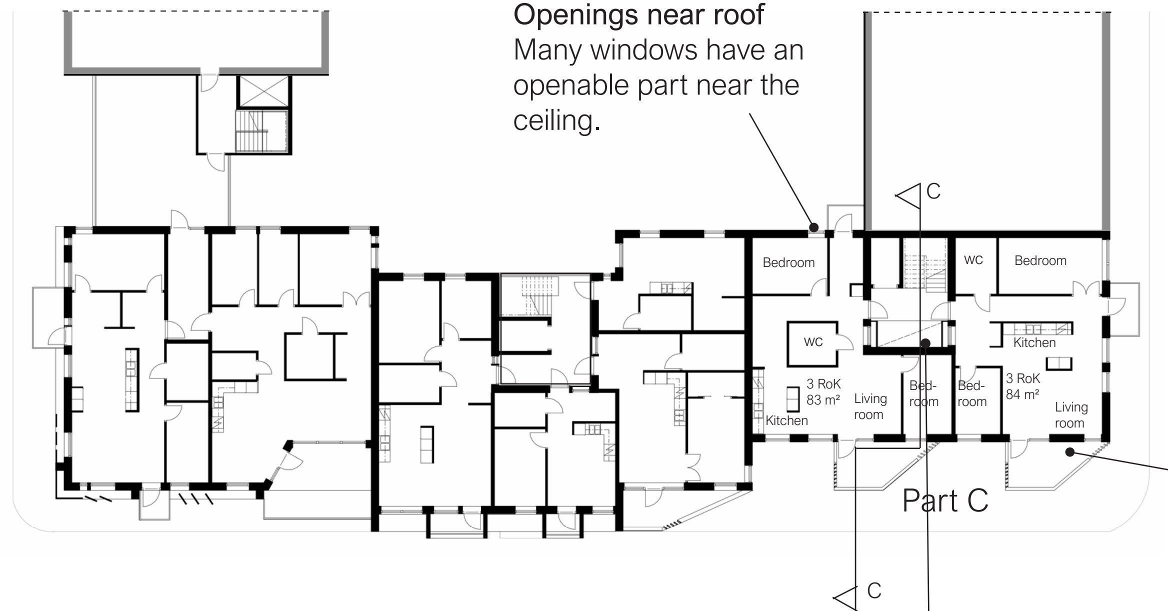
Cross-ventilation
All the apartments have openable windows towards the stairweill to enable cross-ventilation.
The stairwell has the same function as a exterior corridor so the air can circulate in to the building. Some of the apartments are single-sided and this is a solution to enable for cross-ventilation.

4.10 First floor & section C-C, Part C

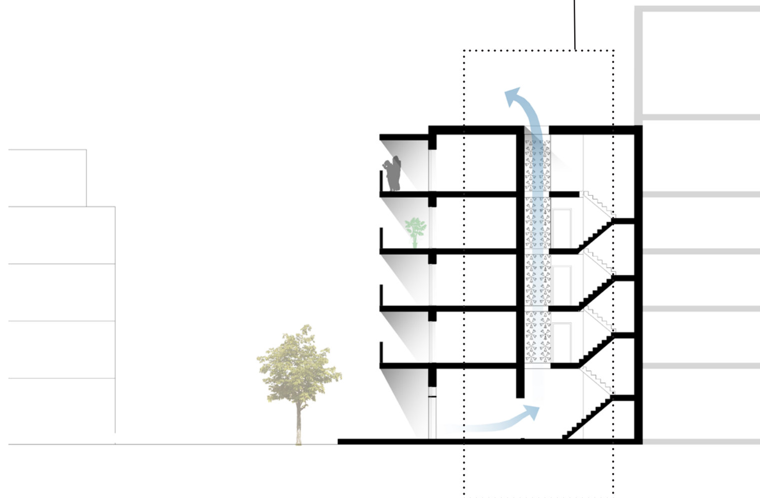
1:400/A4

Strategies shown
Atrium
Openings near roof
Cross-ventilation
Catching the breeze

Openings near roof
Many windows have an openable part near the ceiling.



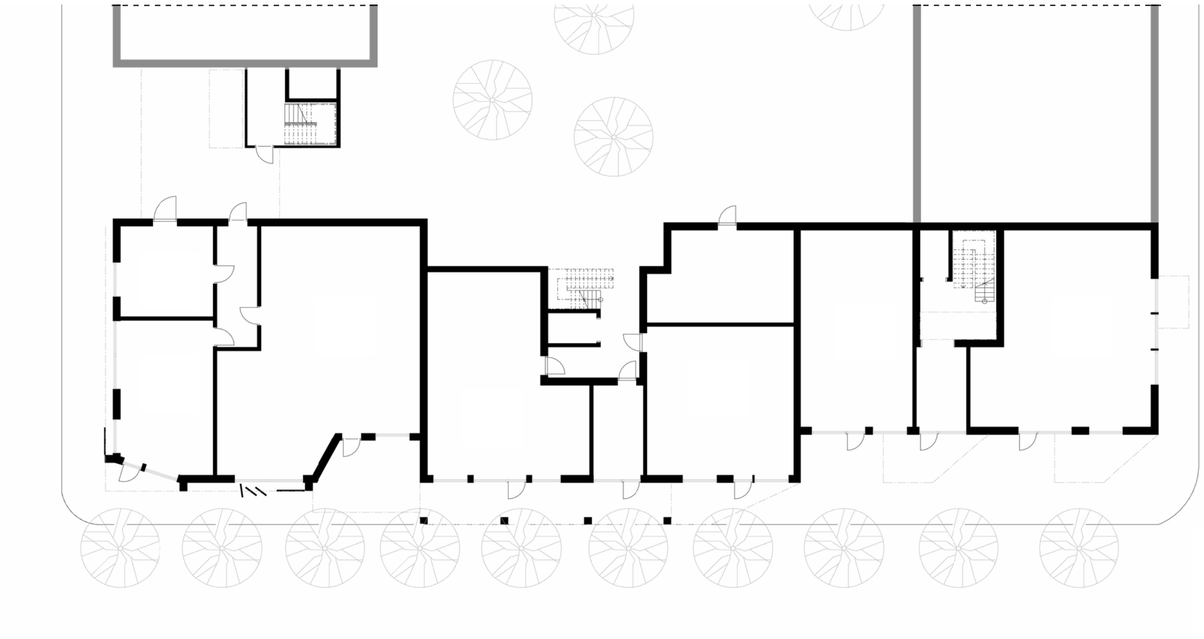
Catching the breeze



Atrium/air shaft/cross-ventilation
The atrium goes all the way up to the roof and will let the warm air rise up towards the opening. Air from windows towards the stair-well will also circulate up through this air shaft.

4.11 Ground floor

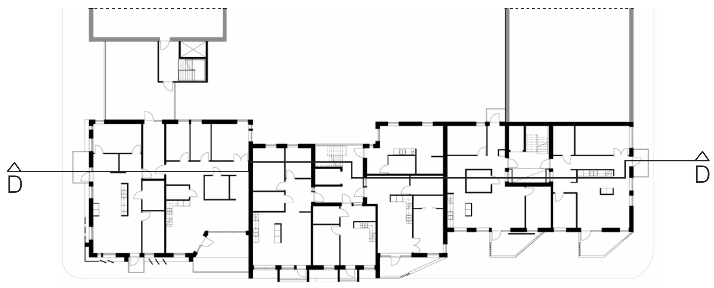
1:400/A4

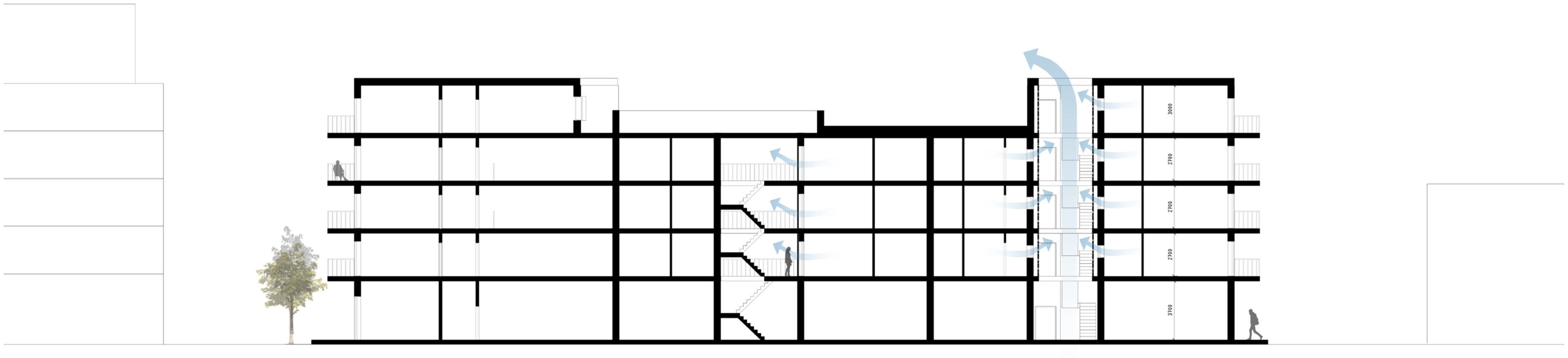


The floor contains premises and space for installations and waste containers.

4.12 Full section D-D

1:400/A4





4.13 Facades

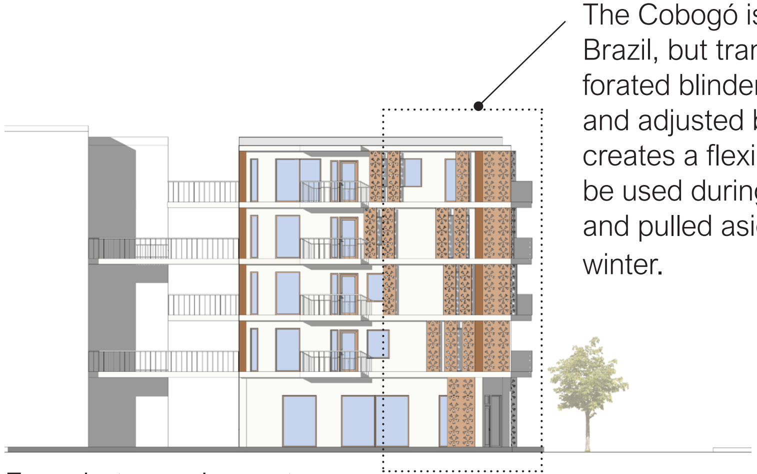
1:400 / A4

Strategies shown
Cobogo & Blinders
Bright facade colours

Bright facade colours
The use of bright colours was a common strategy. Most part of the facade is therefore plastered in a warm, white nuance. A light blue colours is also added together with details in beige.

Facade towards south

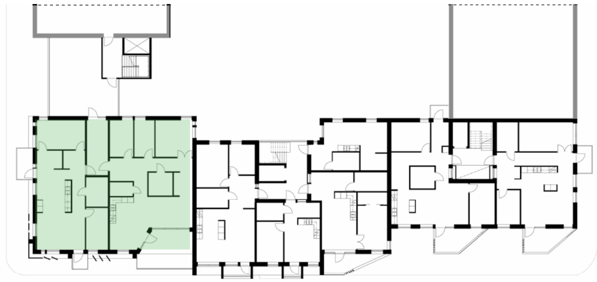
Cobogo & blinders
The Cobogó is not used as in Brazil, but transformed in to a perforated blinder that can be moved and adjusted by the residents. This creates a flexibility so that it can be used during the warmest hours and pulled aside during the dark winter.



Facade towards west

Facade towards north east

4.14 Axonometry, part A



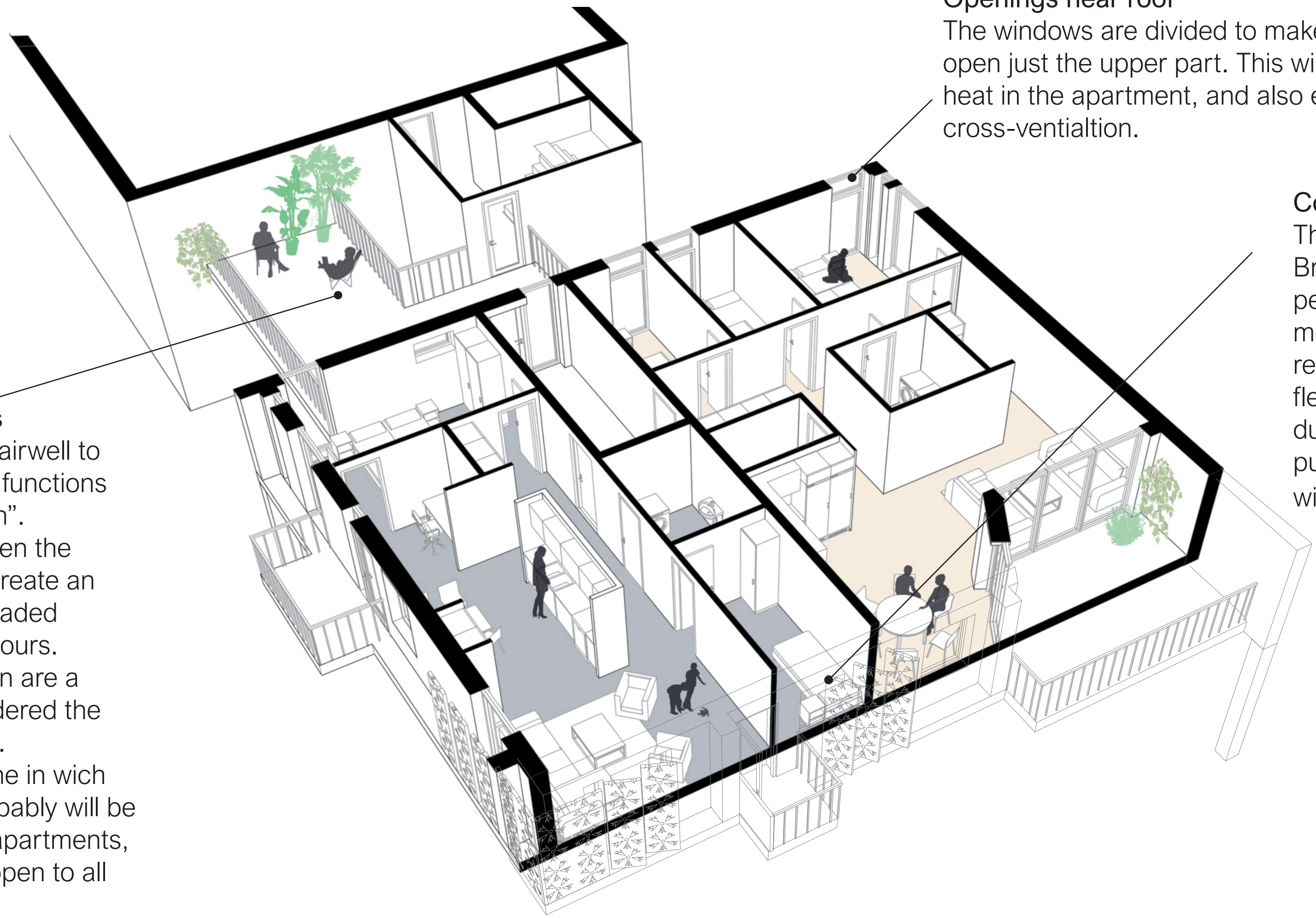
Part A

Strategies shown
Micro climate zones
Openings near roof
Cross-ventilation
Blinders
Cobogo

Cross-ventilation
The apartmens have multiple windows in different sizes. The windows are also oriented towards different directions wich enables the cross-ventilation.

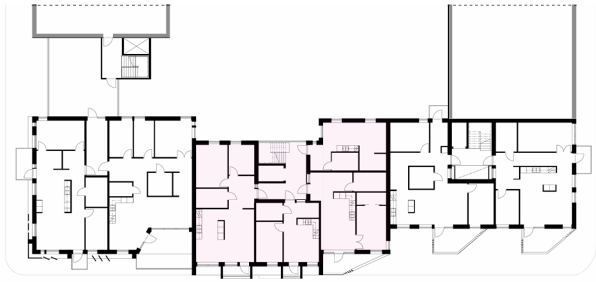
Openings near roof
The windows are divided to make it possible to open just the upper part. This will air out the heat in the apartment, and also enhance the cross-ventialtion.

Cobogo & blinders
The Cobogó is not used as in Brazil, but transformed in to a perforated blinder that can be moved and adjusted by the residents. This creates a flexibility so that it can be used during the warmest hours and pulled aside during the dark winter.



Micro climate zones
The path from the stairwell to the apartments also functions as a ”shadow garden”.
It’s location in between the building blocks will create an area that is partly shaded during the warmest hours.
Plants and vegetation are a cooling factor considered the evaporation of water.
This will create a zone in wich the temperature probably will be lower than in some apartments, and the terraces is open to all the residents.

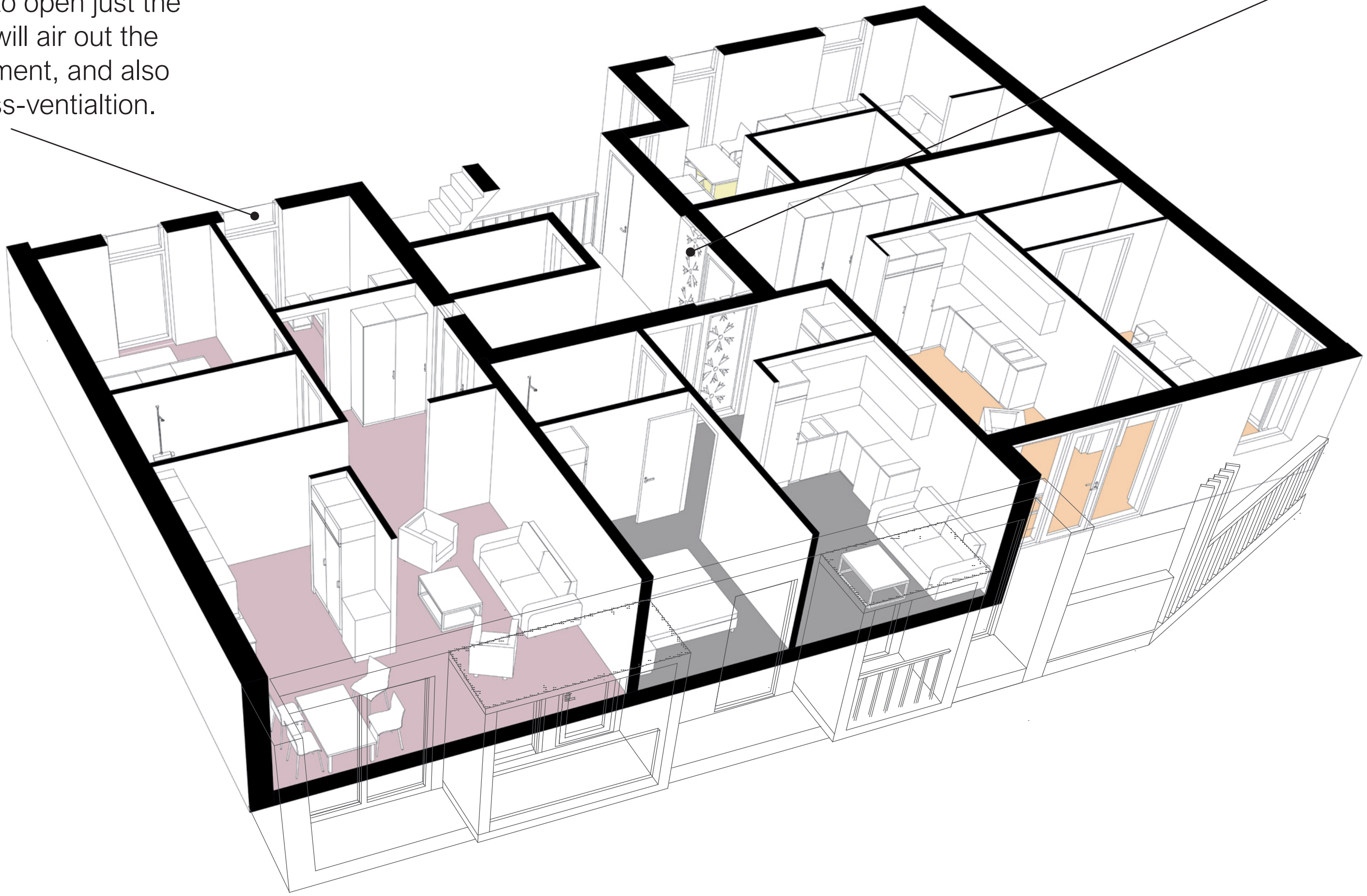
4.15 Axonometry, part B



Part B

Strategies shown
Openings near roof
Cross-ventilation
Catching the breeze
Cobogo

Openings near roof
The windows are divided to make it possible to open just the upper part. This will air out the heat in the apartment, and also enhance the cross-ventialtion.

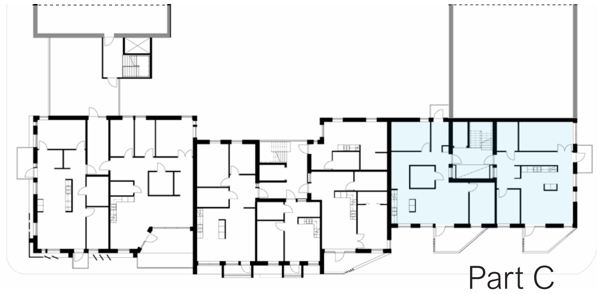


Cobogo & cross-ventilation
All the apartments have openable windows towards the stairweill to enable cross-ventilation. The stairwell has the same function as a exterior corridor so the air can circulate in the building. Some of the apartments are single-sided and this example is a way of showing how to find a solution for cross-ventilation.

The Cobogós is in this case used as visual protection in front of the windows.

4.16 Axonometry, part C

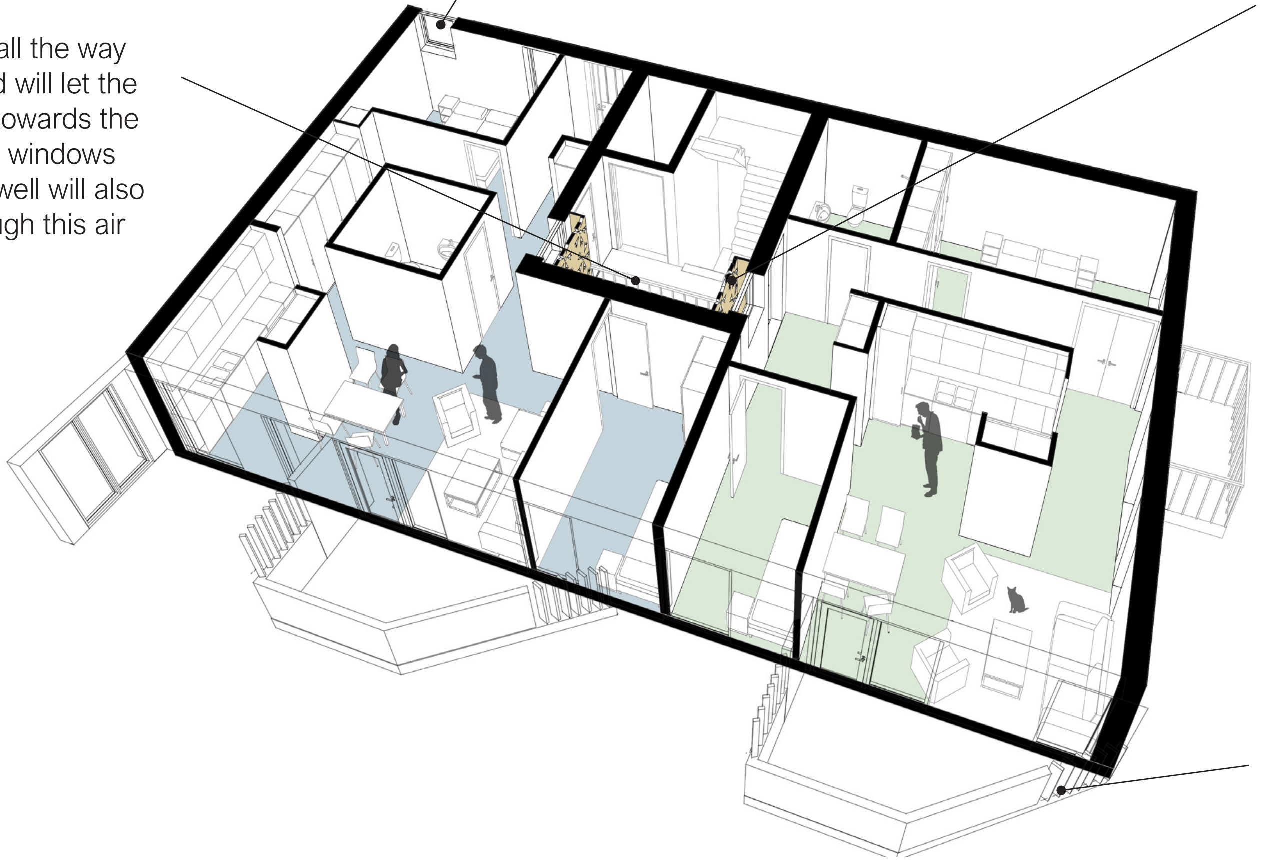
Strategies shown
Atrium
Openings near roof
Cross-ventilation
Catching the breeze
Cobogo



Openings near roof
The windows are divided to make it possible to open just the upper part. This will air out the heat in the apartment, and also enhance the cross-ventialtion.

Atrium/air shaft
The atrium goes all the way up to the roof and will let the warm air rise up towards the opening. Air from windows towards the stairwell will also circulate up through this air shaft.

Cobogo & cross-ventilation
All the apartments have openable windows to enable cross-ventilation. The Cobogós is in this case used as visual protection in front of the windows.



Catching the breeze
The vertical slats will let the winds from east flow in to the balcony and then be stopped by a solid wall, wich will create air eddies.

View from south

5. DISCUSSION

5.1 Conclusion

My main question was if there were methods and design used in housing construction in warm countries, mainly from a historical perspective, that could be applied to housing in Sweden.

After evaluating strategies from five different areas, I could see that some design strategies were clearly connected to specific conditions on the site, and it is therefore a complex task to transfer them directly in to a swedish context. Other strategies are easier to implement, either directly or in a re-designed form. The chart on the next page shows where in the process they can be applied.

What surprised me was that cross-ventilation and vertical airmovement was the most common strategy in all of the areas I investigated.
Together with dense material and ways of provide shading from the sun it seems to be solution that clearly works well. It is also something that can be applied in a swedish context without too much effort.

My sub questions were:

• How will solutions that are intended to lower the temperature during the summer work during the winter?

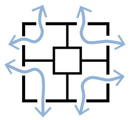
And:

• What are the obstacles to using the same design strategies in Sweden? Will it be compatible with fire safety regulations? With accessibility requirements?

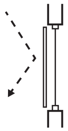
The answer to the first question is that most of the strategies will work both during the winter and the summer. When it comes to shading it would be best have a solution that stops the solar radiation even before it hits the window. It also needs to be flexible so that the light can pass through during the winter. I will discuss this further under ”Process & questions”. The cobogo can not be used exactly as in Brazil (perforated outer walls) but the concept could be transformed in to shading as in my proposal.

Regarding the second question there are no obvious obstacles concerning the accessibility requirements. But when it comes to fire safety regulations there are some problems with the strategies of the vertical air movement. Sweden has strict rules for vertical openings in the building that can lead to the circulation of smoke from a fire.

Strategies that ***could easily*** be implemented in an early stage of a project.



Cross-ventilation



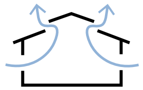
Blinders

Bright facade colours

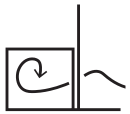
Trees and vegetation

Strategies that ***can*** be implemented in an a project but needs to be further investigated.

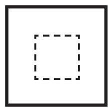
Vertical air movement



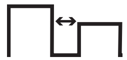
Openings near the roof



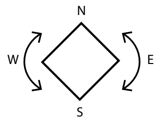
Catching the breeze



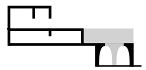
Strategies that ***can*** be implemented in a project but needs to be further investigated and in some cases must be considered veryv early in the process. Already in the poducing of a detailed development plan.



Narrow streets for shading



Orientation based on the wind



Micro climate zones

Cobogó

5.2 Process & questions

There were a couple of scenarios that I could see happen during the journey.

One alternative, and the one i was aiming for, was that my investigations and analyses resulted in an actual proposal for a residential building, where my ”findings” in building design could be applied and functioning in a Swedish climate and with the conditions that exist (various existing regulations in housing construction, for example).

The other scenario was the case were I discovered that it was not possible to translate any design strategies, since e.g., is too expensive, does not work during the winter, or is not compatible with Swedish fire- or accessibility requirements.
My reserach could then result in a mapping of the current situation and possible ways forward (where I have investigated and shown different ways of dealing with heat). The conclusions i made could still be an interesting addition in the debate where I contribute with a compilation from an architectural perspective.

I also had concerns regarding that I wouldnt find enough material and reference projects to base my research on.

Looking back at the process and the outcome, I can see that my fears about not finding enough research material were unfounded.

There are a number of research reports and previous theses on vernacular architecture and ways to create a good indoor climate in warm environments. It feels like I just scratched the surface, and had to limit the number of references in order to get ahead in the process.

In the process of applying the design strategies I found, new questions arose that I want to highlight and have a discussion about.

Light transmission

The Swedish winter is long and dark, and the light is therefore valuable to get into the apartments during this time of year. By using tall and large windows, the light input becomes large during this time of year, but this unfortunately also applies during the summer.

Through the large glass surfaces, a large amount of solar radiation enters during the summer months and raises the temperature in the apartment.

The reference projects show that it is common to shield the solar radiation even before it reaches the glass surface, and literature on the subject also proves this as a more effective solution than having internal blinds.

In the design proposal, I added ”Cobogó” as a shading strategy in front of the window. The ”Cobogo” has to be adjustetd manually by the residents. This means that if you forget to adjust the blinders before you leave for work e.g, you will have a warm apartment when you arrive home in the evening. There is however not only one solution to cool down the apartments in the proposal. Crossventilation and vertical air movements are other options that has been prepared for.

Vertical airflow

One of the most common strategies was to create vertical air flows, where hot air that rose upwards in the building could be ventilated through openings in the roof or openable windows in the stairwells, such as thermometer windows in Tel Aviv.

These vertical air flows in the stairwell with openings were difficult to solve in a Swedish context due to the fire regulations which are extensive when it comes to stairwells.

A question that arose during the project is whether the ceiling height in an apartment can play a key role in the use of this strategy. One way to create the opportunity for hot air to be transported upwards and then ventilated is to place openable windows high up in a room with generous ceiling height.

The next question that arises for how high the ceiling needs to be for the strategy work? It could be a matter of further investigation.

In addition, if the detailed plan only regulates the number of floors and not the height of the building, would it be possible to plan a higher number of deplux apartments in order to achieve a vertical air flow? This must of course be set against how much energy it takes to heat a deplux apartment in the winter versus a ”regular” apartment.

The context

During the cold winter months it can be beneficial to have the solar radiation through the windows as it will increase the temperature.

In one reference project, Mardin in Turkey, there were eaves that shaded the windows when the sun was high in the sky during the summer months.

In winter however, it is cold in this small mountain town, and since the sun's position is then lower, the radiation ends up under the eaves and the heat can enter through the window openings.
Because the houses are located on a hillside there is no near by building that can obstruct the winter sun.

For my design proposal, such a strategy would work poorly because the site is completely flat. There will also be a five storey building across the street that will stop the low incoming sun.

It is clear that many of the reference projects are adapted to the conditions of the site in all possible ways. If I would use the same way of thinking in Norrköping as in ancient Turkey I might come up with the conclusion that ”Inre hamnen” is not even a suitable place for dwellings.

The way in which city planner Sir Patrick Geddes planned Tel aviv in the early 19th century, where the direction of the wind played a major role in the streets and the location of the houses, would require that the questions about passive cooling methods are part of the general planning work. For example when the municipality produces a detailed development plan.

Are passive solutions enough?

In the reference projects from Vietnam and Tel Aviv, the authors ask themselves whether the passive solutions are sufficient, and come to the conclusion that during the highest heat peaks, technical solutions, such as air conditioning, will be necessary in order to achieve a comfortable indoor climate.

It is possible that technical solutions will be needed in Sweden as well, when our heat waves become longer and the heat peaks too high.
But we can create conditions for the houses to be able to cool down in a natural way as far as possible.

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