THE FORECAST OF TOMORROW

Exploring design strategies to develop a building withstanding future Swedish extreme weather

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Master´s Thesis in Architecture

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Supervisor: Kaj Granath

CHALMERS

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by Johanna Mattsson
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ABSTRACT

As a consequence of climate changes, new or unusual weather conditions at unpredicted locations already affects our everyday life and destroy buildings and homes faster than predicted. However, we still construct our buildings according to previous climate situation. We must face the consequences of climate change and change the way we build to adapt to the "new normal" where extreme heat, extreme cold, storm and frequent rain- as well as dry periods most likely will become reality.

Q1 - What extreme weather could occur in Sweden within 10-20 years?

Q2 - How can a small house be constructed to withstand the consequences of the climate crisis concerning extreme weather in Sweden?

Q3 - What impact would the findings to withstand future weather scenarios for a small house have on planning?

Solutions for each forecast already exist, however there is a gap when the scale from extreme heat to extreme cold is a fact, particularly for northern countries.

In this thesis a design proposal to withstand the negative consequences of climate change is developed. According to the IPCC reports, a realistic Swedish weather scenario is defined, and is the base when studying existing solutions of built references around the world for each criteria. Elements from the research phase is gathered as design strategies which in turn is translated and merged into a design proposal for four small residence buildings in a challenging urban area in Sweden. The site is handled as a microclimate aiming for self sufficiency.

My ambition is to achieve a result of existing solutions merged into an experimental design proposal that could be useful as discussion material for planners, architects and private stakeholders who are interested in the development of constructions adapted to the consequences of the climate change.

Keywords: Climate change, Extreme weather, Design strategies, Swedish context, Microclimate

STUDENT BACKGROUND

2021 Fall	**Master´s program in Architecture & Urban Design** Studio Healthcare 30 credits Chalmers University of Technology
2021 Spring	**Exchange program** Master´s program in Architecture & Urban Design 30 credits École Polytechnique Fédérale de Lausanne (EPFL)
2020 Fall	**Master´s program in Architecture & Urban Design** Studio Material & Detail 30 credits Chalmers University of Technology
2019-2020	**Architectural competitions**
2020 Spring	**Business economy** 22,5 credits University of Gothenburg
2019 Fall	**Rhetoric** 30 credits University of Gothenburg
2018-2020 Summertime	**Internship** Simrishamn planning architect
2016-2019	**Bachelor Architecture** Chalmers University of Technology

TABLE OF CONTENTS

CHAPTER I / INTRODUCTION

PURPOSE & AIM

Background

The negative consequences of climate changes are occurring faster than expected. "New" or unusual weather conditions at unpredicted locations already affects our everyday life and destroy buildings and homes faster than expected. In a Swedish context we anticipate to face extreme heat, extreme cold and heavy rain periods to mention a few. However, we still construct our buildings in a traditional manner and according to the previous climate situation. We must face the consequences of climate change and change the way we build to adapt to the "new normal" where heat, cold and frequent rain- as well as dry periods most likely will be an issue.

Solutions already exist in different long- and latitudes where climates and weather, that seems extreme to us in a northern perspective, is normal. The expected conditions in Sweden, however, differ from many other climates concerning a scale from extreme heat to extreme cold, and the stages in between.

This thesis investigates what possible extreme weather could occur in Sweden in the next 10-20 years, referring to the Intergovernmental Panel on Climate Change (IPCC) reports, SMHI (Sveriges meteorologiska och hydrologiska institut) and MSB (Myndigheten för samhällsskydd och beredskap).

Realistic extreme weather scenarios is identified, where different built references in the different stated conditions/climates is studied together with supporting literature for each reference project. Elements from the research phase is gathered as design strategies which then is translated and merged into a design proposal for four small residence in a challenging urban area in Sweden and will also be handled as a microclimate aiming for self sufficiency.

Research within this subject often relates to a 100-year perspective and is adjusted to suit within the 10-20 year perspective this thesis is based on.

There is a tradition of building environmentally friendly, but not yet a tradition of building climate adapted. Today a newly constructed building have a technical life span of 50 years adapted to the old climate situation. When climate is changing the lifespan will be remarkable shorter.

Aim

The ambition of this report is to achieve a result of existing solutions merged into a design proposal that could be useful for planners, architects and private stakeholders who are interested in the development of constructions adapted to the consequences of climate change.

The aim with the design proposal is to assist as a guideline and a library where the theory is translated and tested in a physical design. Elements and solutions can then be adapted for users in other circumstances, such as a bigger scale for example. The design proposal should be seen as a discussion material.

Most importantly I want to raise the question of climate change and I hope that by presenting the different weather scenarios an unwelcome message could reach important stakeholders to make a difference.

Research questions

Q1 *What extreme weather could occur in Sweden within 10-20 years?*

Q2 *How can a small house be constructed to withstand the consequences of the climate crisis concerning extreme weather in Sweden?*

Q3 *What impact would the findings to withstand future weather scenarios for a small house have on planning?*

METHOD

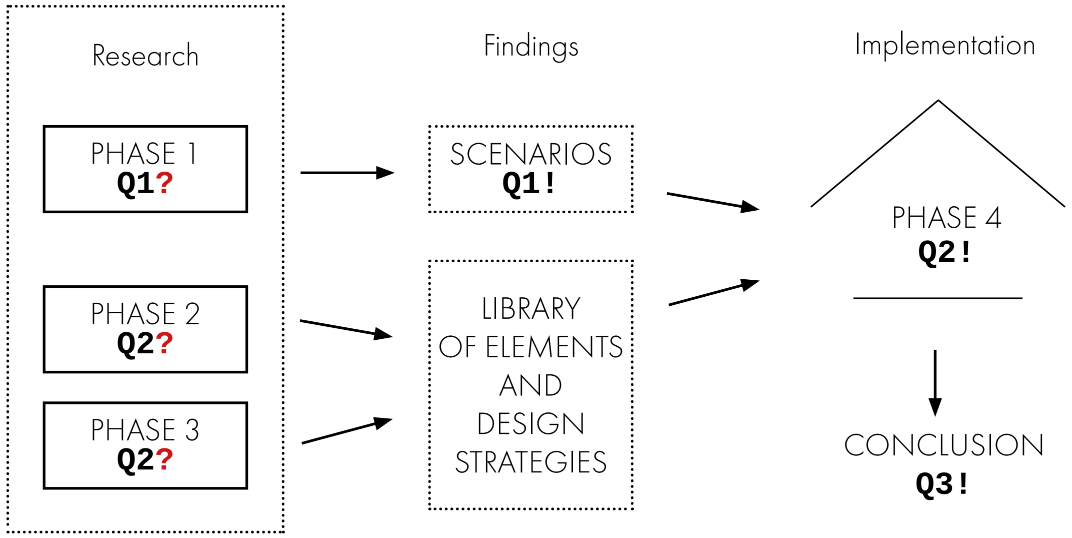
Phase 1: Research for design is used when gathering information about the climate situation and possible future weather scenarios. Six weather scenarios in a Swedish context is stated early in the report and is also an answer to Q1.

Phase 2: Research for design is used in this phase and consists of common low tech solutions for each weather scenario.

Phase 3: Research on design is used when studying reference projects for each scenario where findings together with findings in phase 2 is gathered in a "library". This is then used in the design proposal.

Phase 4: Research by design is used to directly test the gathered theory for each scenario, merged into a design proposal in a Swedish context.

Site visits and analysis is a big part of the method and used in an early stage of the process, as a base for the design proposal.



DELIMITATIONS

The program includes four dwellings, handled as a microclimatate and aiming for self sufficiency.

The research focus on low tech solutions.

Surroundings is of course taken into account for the design proposal, however universal wind solutions is being used.

The research is locally adapted to a site in Mölndal and its specific circumstaces.

The costs is not taken into acount more than striving for a compact living with low tech solutions. The approach to the subject is more experimental and focus on necessary adaptations.

A life cycle analysis is present but not in focus, this means the building strives to be as environmental friendly as possible with a small environmental footprint, however is not analysed in the report.

READING INSTRUCTIONS

Terminology

Extreme weather

In general e*xtreme weather* and *extreme climate* is both defined as *climate extremes* (Danijel et al., 2019).

The definition of *extreme* is complicated since it does not only define the event in itself, but also the effect on settlements and society of the event. (Danijel et al., 2019) In a weather perspective *extreme weather* varies globally and what is *extreme* in one region is *normal* in another. Therefore the term is quite sensitive and should be set in indivdual cases.

In this report the term ”extreme” will be used in a Swedish context and proceed from a Swedish normality.

Example: precipitation, temperature, hot/cold spells and wind (IPCC, 2021)

Natural disaster

Natural disasters is not a weather itself, but defined as ”an event caused by natural forces with a great impact on the natural physical environment and human lives” (NE, 2022). Often the source is caused by disturbance in the natural weather pattern. Hence natural disasters often is a consequence of extreme weather which in turn is a consequence of climate change. What kind of natural disasters that are likely to happen varies and depends on the local context.

Example: floods, droughts and landslides (IPCC, 2021)

CHAPTER II

SCENARIOS

PREDICTING THE FUTURE

”Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes.” (IPCC, 2021)

The consequences of climate change is global. The earth is today 1.1°C warmer in relation to before industrial time. (United Nations, 2021). This does not mean that the effect of global warming only means rising temperatures. In certain regions it does. Extreme weather conditions and natural disasters in different extent are all a result of the climate change. Stated in the 6th IPCC report, 2022, climate hazards are increasing faster than predicted in previous reports. The vulnerability of eco-systems and social communities are highlighted and defined as ”near-term risk areas” (IPCC, 2022).

In a Swedish context global warming have several potential outcomes and due to the coverage of various latitudes of the country, the consequences differ even within the country. The climate above the polar circle varies a lot from regions under the polar circle and the climate on the west- and east cost differentiates for instance. This thesis is mainly based on data of the southern part of Sweden.

With IPCC as a global perspective and the SMHI and MSB as locally supporting data this chapter present possible weather scenarios for the region around Gothenburg within the next 10-20 years.

According to SMHI and MSB following extreme weather- and climate scenarios will be more frequent in the area, which in this thesis is named as different scenarios.

Scenario I - Extreme heat
Scenario II - Extreme cold
Scenario III - Heavy Precipitation
Scenario IV - Drought
Scenario V - Storms
Scenario VI - Natural disasters

What differenciates Sweden and this region from many other parts of the world is the range from extreme heat to extreme cold.

The scenarios explicate Q1, *What extreme weather could occur in Sweden within 10-20 years?*. This chapter emphasizes the meaning of each scenario and what impact it has on a local scale in the Gothenburg area in Sweden.

SCENARIO I

Extreme heat

Extreme heat periods are predicted to be more frequent and longer lasting in Sweden. More tropical nights (when temperature is above 20°C during night), drought, wildfire and lower groundwater are all immediate effects of extreme heat which in turn has a direct influence on the society and the way we are living. (MSB, 2020). Global surface temperature is expected to rise and locally, within cities, the temperature will intensively increase known as the urban heat island effect. (IPCC, 2021). Rising temperature directly influence ecosystems, people, settlement and infrastructure (IPCC, 2022)

The urban heat island effect means that cities store and contribute to a locally warmer environment than its surroundings (MSB, 2020). Gothenburg is no exception and due to hard urban surfaces in pavement and building material, but also natural exposed rock faces, that is absorbing heat during the day and takes long time to release it, the temperature could rise exponentially. During warm periods dark and hard surfaces, such as asphalt, bricks and dark roofs, do not have enough time during night to release all the stored heat. This mean coming day will continue to build and store heat and not be able to release it, and the urban heat island effect and thermal comfort is an issue. (United Nations, 2020). In combination with daily activity and dense city planning, cities are extra sensitive to thermal change. Settlements generate heat during night time and with increasing need of cooling systems more energy is used, which enhance the contribution to the rising temperature within an urban heat island. (MSB, 2020).

The strongest effect of the urban heat island is rising temperatures during night time and the main causes are impervious surfaces, dark material, lack of greenery and dense city planning which does not allow wind to transport the heat from the city. The effect of rising temperatures in surroundings of cities will have an direct negative effect of the urban heat islands. With warmer surrounding, areas will not be able to contribute to the cooling of cities. (Danijel et al,. 2019)

Heat waves are predicted to increase as a natural consequence of the global warming. What is important to emphasize is that the frequency of heat waves does not follow the same curve as the change of average temperature. Heat waves will in many regions be more frequent than the increase of the average temperature (Danijel et al., 2019).

In line with the global warming maximum temperature in Fenno-Scandinavia during summer time is predicted to rise. (Danijel et al., 2019) The yearly average temperature in Gothenburg has increased from 7,7 to 8,9°C during the last 30 years and according to SMHI the temperature in Sweden increase twice as fast than the rest of the world. Snow have an insulating quality which leaves the ground cold longer, however with rising temperature the protective layer melts and the ground surface temperature rise faster. (SMHI, 2021)

Long periods of heat contributes to drought. Underneath trees the temperature is lower
Photo Mälarhusen

SCENARIO II

Extreme cold

Sweden has a historical experience of handling extreme cold. Hence this topic is not as new to this context as other scenarios. According to SMHI extreme cold temperatures will decrease in Scandinavia. However, even with global warming, extreme cold will still occur and the pattern will differentiate from current and past climate situation. Other extremes in combination with warm temperature and suddenly thermal changes could occur. (Danijel et al., 2019)

The more frequent precipitation during wintertime means, regionally, heavier and sudden snow loads. With stormy weather and the combination of different layers of cold and warm air within the atmosphere and cold ground surfaces, this could mean precipitation such as snow, wet snow, ice pellets and freezing rain. (Danijel et al., 2019).These events requires consideration of, particularly, roof construction and roof material.

With global warming, it is difficult to predict the future pattern within extreme cold. Exceptional events that does not follow the expected rising temperature during winter time is likely to increase. In general, extreme cold temperatures in a Swedish context is predicted to decrease. However, with this taken into account it is worth mentioning the winter 2021/22. In December Naimakka measured the lowest temperature related to the month since 1986 with -43,8°C. The same month the southern part of Sweden measured the largest amount of precipitation during 24 hours with 59 mm of snow. According to SMHI this is difficult to predict wether it is a consequence of climate change or just an exception in the weather pattern. (SMHI, 2022). Important to acknockledge is however that in a swedish context extreme cold temperatures with heavy precipitation will occur and will most certainly not follow the previous pattern.

CHAPTER II
SCENARIOS

Sweden has historical experience of building to survive extreme cold, particularly in the north, however the pattern is changing and suddenly cold weather can occur in the south
Photo from Åre

SCENARIO III

Heavy precipitation

According to the IPCC report, *Climate Change 2021 The Physical Science Basis - Summary for Policymakers*, heavy rain periods will increase globally as a consequence of climate change. For every increasing degree of the global warming, extreme daily heavy rain is predicted to increase with 7%. Globally, northern Europe has the highest value of predicted heavy precipitation caused by humans. IPCC further states that heavy precipitation will transpire during all seasons in northern Europe, which means different types of precipitation will occur.

The average yearly precepitation in Gothenburg has increased from 784 to 912 mm compared over a 30-year-period in Gothenburg. (SMHI, 2021) The average amount of precipitation days during one year in Mölndal is 12-15 days every month. (Meteoblue, 2022).

Flooding is mainly a result of heavy precepitation, however it could also occur from snow melt for instance, which will be an issue in the Fennoscandinavian countries. Another aspect with higher temperatures, is that an increase of *evapotranspiration* is predicted. Evapotranspiration denotes the sum of released moisture from soil, plants, surface water etc. released to the atmosphere (Nationalencyklopedin, 2021). The consequence of increased evapotranspiration means drier soil which makes the ground less pourous and enhances the water runoff. According to SMHI "such effects can increase the probability of flooding even without a change of precipitation." (Danijel et al., 2019).

IPCC further stress that the exact amount of rising sealevels is difficult to predict. However an approximate estimate is a rising of 0,5 metres in Sweden the year 2100.

Furthermore SMHI states that the risk of flooding in a, Fennoscandinavian, perspective is historically more likely to occur during spring season when snow is melting due to the rising temperature, however there is an increased risk of flooding during autum due to rain.

Cloudburst is another extreme that is likely to increase in the southern parts of Sweden and can cause flooding (Danijel et al,. 2019). This means occasions of extreme proportions of heavy rain in a very short time (Nationalencyklopedin, 2022).

According to the IPCC report (2022) the inland flooding in Europe has rapidly increased, and affected both settlements and infrastructure due to heavy precipitation. A previous example of flooding, caused by cloudburst in an area with impearmable urban surfaces, was in Gävle 2021. Within 24 hours, 161,6 mm of rain destroyed basements and infrastructure. (SMHI, 2021)

Heavy precipitation in Skillinge. A high amount of rain in a short time affect the agriculture.

SCENARIO IV

Drought

SMHI predicts that drought in the southern parts of Sweden will increase mainly due to a decrease of precipitaion in periods, regionally (Danijel et al., 2019). Stated in the 6th IPCC report, 2022, the water scarcity in Europe has increased due to climate changes, and in turn the level of agriculture production and marine life rapidly been negativly affected during the past years.

In the article *Climate Extremes for Sweden* (Danijel et al., 2019) four different classifications of droughts are described.

Meteorological drought is occuring as dry periods and the duration of the period, is higher in comparison to normal amount of dryness. (National Drought Mitigation Center, 2021) These periods can end fast, compared to hydrological drought which takes time to reset. (Danijel et al., 2019)

Hydrological drought is referring to low water content, such as low ground water, which mostly is an affect of long term periods of meterological drought. (Danijel et al., 2019)

Agricultural drought is an effect of meteorological and hydrological drought and is defined as periods when plants are affected. (Danijel et al., 2019)

Socioeconomic drought means supplies that societies rely on, such as electricity and food, is affected due to weather changes. In a swedish context this could mean lower water levels in rivers which as a consequence could lead to water energy limitations. (National Drought Mitigation Center, 2021)

As a consequence of heavy precipitation the soil moisture will be affected. In the southern parts of Sweden this means an increase of wet soil when global warming reaches 1.5 degrees and then switch to drier soil when global warming reaches 2 degrees. (IPCC, 2021). In general, heavy precipitation will affect parts of Europe differently with a drier south and more wet north (Danijel et al., 2019).

Stated in the sixth IPCC report (2022), the level of water supply is predicted to rapidly decrease and water related risks is predicted to rapidly increase, both in a near term (2021-2040) and mid to long term (2041-2100) scenario. This emphasizes the importance of taking care of heavy precipitaion periods to be able to handle dry periods.

The summer 2018 is a previous example when groundwater levels dried out to extraordinarily low levels, where both private and regional water supplies were affected in Sweden.

From the dry summer 2018, when meteorological- and hydrological drought caused agricultural drought
Picture Komstad

SCENARIO V

Storms

Storminess is a wide definition where *wind storms* often cause extremes like strong winds, heavy rain, hale and extreme snow fall. *Thunderstorms, tornadoes, hailstorms, ice storms, freezing rain, heat waves* and *cold spells* are all storms likely to occur more frequently in Sweden. (Danijel et al., 2019).

With large variation in temperature, a higher risk for storm is likely. Mid-latitude cyclones are predicted to be more occuring over the North Atlantic and will have an effect on Sweden during winter time, October to March, and could also be known as *winter storms*. The cyclones makes extreme winds, caused by changes in wind direction and wind speed in regions along the coast of Sweden. (Danijel et al., 2019).

Stressing that wind storm is one of the most harmfull and damaging future scenarios, IPCC also states that the increase of *extreme* wind speed is small, however still increasing. To emphasize this, a statement from an article by Devis et al. (2018) is important. They state that even though it is a small change in high wind speeds it will affect the average wind speed. This means an overall effect in the every day life when the outdoor environment becomes more challenging. An increase of wind speed can cause physical damage on buildings, infrastructure and humans, but also make the outdoor environment difficult to use.

The average wind speed in Gothenburg/Mölndal peaks in December, January and February to then decrease during spring and summer. The average maximum wind speed during January and February is 10,9 m/s, with a direction from south-west. (Meteoblue, 2022)

Strong wind is predicted to occur more often when cyclones over the North Atlantic most certantly will increase with the variation in temperature
Picture Örnahusen

CHAPTER II
SCENARIOS

SCENARIO VI

Natural disasters

Natural disasters are defined as natural events with drastic consequences on the society and environment. (Nationalencyklopedin, 2022). This could include previous mentioned scenarios like drought and storms, however is here chosen to be seperated as own scenarios due to their comprehensive increase in the context. Mentioned in this scenario are natural disasters that are not explained as thoroughly by SMHI, MSB and IPCC, but still have an increasing risk.

Earthquake

With changes of the ground water level and human activity such as digging, logging and exchange of soil material when building, smaller *earthquakes* could be more frequent. (MSB, 2020)

Erosion

Depending on topography, rising sea levels and ground material, more frequent *erosions* are also predicted to occur. This will mainly be visible in areas with sand as ground material (MSB, 2020)

Landslide

Landslide is predicted to be more frequent in Sweden and in the southern parts the probability of landslide will be larger during August-December. However, with climate changes the risk increases all year around and often relates to snow melts, frostbite and heavy rain periods. The most risky area of Sweden is Västra Götalands län, due to its high coast line and clay ground. (MSB, 2020). The whole city of Gothenburg is almost completely built on clay ground.

Wildfire

Extreme drought, particularly in combination with strong winds, drastically increases the risk of fire. This can get, and have got, enormous consequences for the nature and ecosystem with a direct risk for human lives. (Danijel et al., 2019)

Flood

Flooding is touched on in Scenario III where heavy precipitation could be the source of flooding in micro climates even in high located environments. However, rising sea levels due to melting glaciers will affect all environments along coastlines and rivers. According to SMHI the sealevel in Västra Götaland, year 2100 will rise 0,5 metres. In Gothenburg and Mölndal this will have devastating consequences, particularly around Göta älv and Säveån.

The year after a wild fire in Lenhovda, 2019

CHAPTER III

DESIGN STRATEGIES

SOLUTIONS FOR EACH SCENARIO

Following pages are gathered design strategies for each weather scenario. They are introduced by common solutions for each scenario based on traditions where the extreme scenario, seen from a Swedish perspective, is normal in another climate. Each scenario includes design strategies based on reference projects where useful elements are interpreted in illustrations.

Aiming for simple solutions, reference projects around the world are studied where certain expertise can be learnt from. Solutions in different types and scales are used when elements, building techniques and typologies are gathered and categorized. In the appendix to this thesis the main reference projects are gathered.

Many design strategies are contradictory to each other for the different weather scenarios. To help with priorotizing and to weigh strategies against each other the chapter is concluded by a matrix. This should work as a tool for the continuous phase, when implementing the design strategies to a building.

The design proposal should be seen as a discussion material to investigate what architectual qualities could, or should, be sacrifised, but also what new architectual qualities can be found when using new building techniques.

BUILDING FOR HEAT

Natural ventilation

In Sweden there is a history of cold weather and thereby a developed building tradition consisting of high insulated buildings. With the global warming, rising temperature and increase heat waves the traditional and contemporary building techniques will be an issue. The well insulated buildinges reject the heat for a while, however, with longer heat periods the indoor climate will be too warm and hot air will be trapped inside. Insulation prevents heat-release during night and a rising indoor temperature increases the use of additional airconditioning systems.

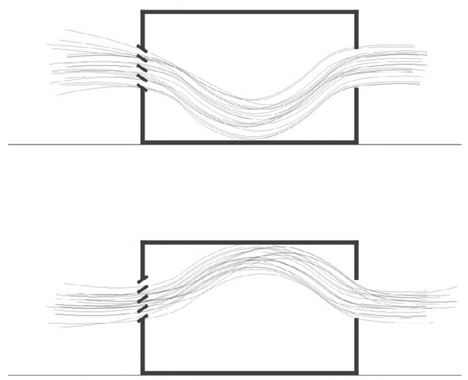
Natural ventilated buildings are standard and a developed strategy on continents like Africa, Asia, South America and Australia, hence illustrations are interpreted from *Building Beyond: A Trade School in Swaziland, Africa* (2012).

Natural ventilation means both wind and temperature fluctuations are used either to ventilate or lower the temperature.

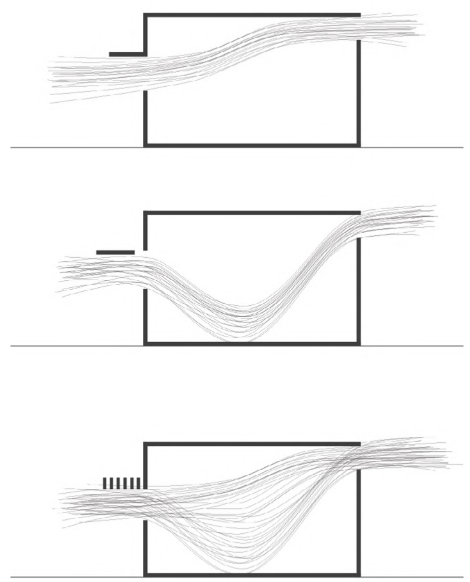
The most considerable when designing with natural ventilation is the fact that warm air rises and cold air drops. Hence out-takes should be placed high and in-takes lower. With small adjustments the design can force air to move in wished flows.

Sections

Wind direction



The angle of louvres forces the air up or down



Canopy over opening

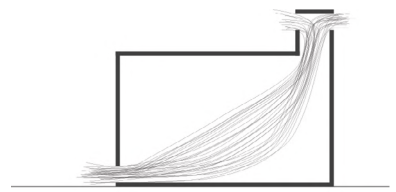
For maximum effect of passive cooling:

- the in-take should be smaller than the out-take if positioned opposite
- the in- and out-take should be the same size if offsetted
- adding a chimney-shaped out-take for suction effect
- openings should not be aligned in plan, rather shifted
- air should rather be pressed downwards for thermal comfort
- interior walls should not be too close to in-takes
- in-takes should be angled 30-45° from general wind angle
- longer, thin buildings with short facades towards east/west are preferrable

(Kwok & Grondzik, 2018)

Section

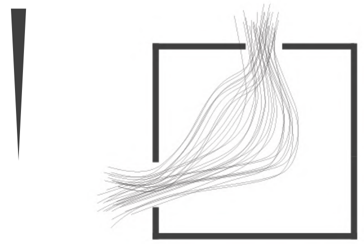
Wind direction



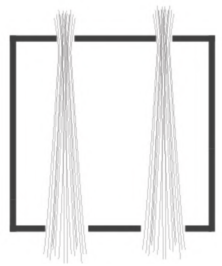
Wind tower for out-take

Plans

Wind direction



Cross ventilation should be used both in plan and in section



Smaller openings in in-take (in cases where cross ventilation is not used)

BUILDING FOR HEAT

Design strategies

To avoid an overheated indoor climate the main issues are solved from the outside. By shadowing the facade, adding greenery and open up for natural ventilation many problems are reduced.

By consciously use vegetation where it is suitable for its characteristics buildings can benefit from its shadow and wind protection. Not only do they clean the air from pollution, they bind soil, absorb water and release moisture to the atmosphere. Hence this is important to implement both in microclimates but also on an urban scale.

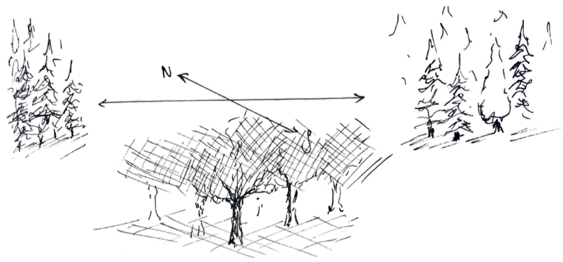
With openable walls and in-takes the indoor climate can be ventilated and natural breezes can, with help of water for instance, serve as airconditioning without any electricity.

On an urban scale the most considerable factors are the urban surfaces. With impermeable and dark surfaces the urban heat islands will continue to increase. Like solutions in the microclimate, almost everything is solved by vegetation, shadow and light materials.

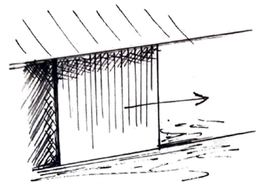
Inspiration can be taken from the Marika -Alderton house in Australia, built 1994, where large parts of the walls can be opened. A non-insulated building with a flexible floorplan makes the indoor climate comfortable and could be compared to a pavilion where the main coverage is shadowing from direct sun light.

Complications

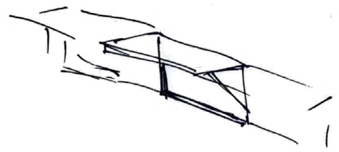
The increasing urban heat island effect is mainly caused by dark and impaveable surfaces, which partly are design strategies for extreme cold. This should be considered and reflected upon. In a climate where heat is seasonally a problem and urban heat islands tend to increase, dark and impermeable surfaces should never be used since the effect cause larger damage during summer than it helps during winter.



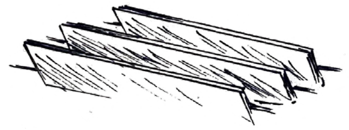
Evergreen vegetation towards east and west facade for shadow. Deciduous trees towards south facade to give light during winter time



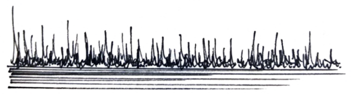
Sliding parts for flexibility and ventilation



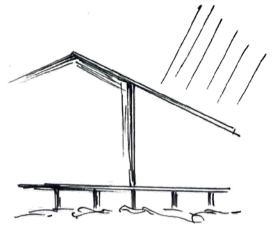
Openable in- and out-takes for natural ventilation



Louvres for shadow and directing wind.

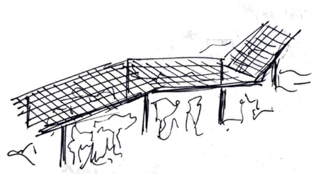


Green roofs decrease indoor temperature and release moist to atmosphere

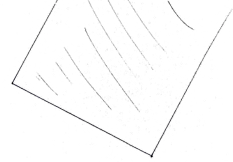


Separate sunshading elements or deep overhang for sun protection

Reinforced grass to break up hard surfaces

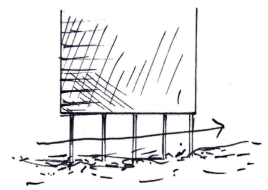


Permeable, lifted outdoor surfaces to minimize footprint and allow greenery underneath

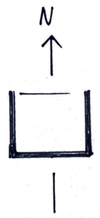


Bright surfaces to reflect solar rediation

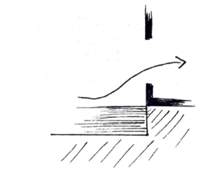
Vegetation for shadowing and moisture release. Temperature directly under tree can be 4°C cooler than surroundings



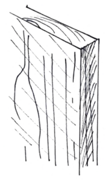
Lift up building to allow breezes underneath and to access wind for natural ventilation



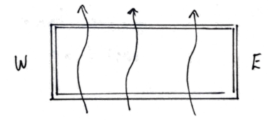
Optimal placement of windows towards north



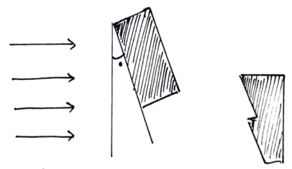
Water surfaces directly connected to an in-take for natural ventilation



Using materials, like timber, with low density (thermal mass) to not absorb heat



Long floor plan along west-east to enable natural ventilation



To get use of wind the angle of in-take should be maximum 30-45° to normal wind direction

BUILDING FOR COLD

Passive heating

Direct gain

The most efficient and basic way to heat a building is with direct gain systems. By taking advantage of the different sun angle during winter time a building can get direct solar radiation during winter and ensure shading during summer. (Kwok & Grondzik, 2018)

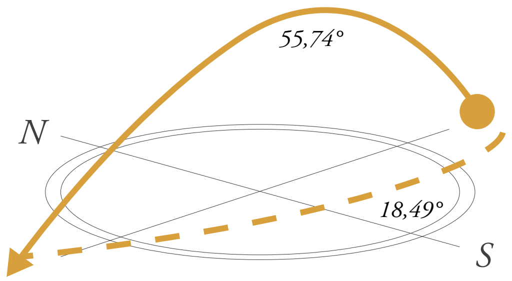
In a direct gain system thermal mass is used to absorb and store heat to release it in the indoor climate. For maximum effect the building axis should be placed along west-east and be complemented with a passive cooling system during summer time. Important to emphasize is also the necessity of large glazed areas towards south in this strategy, which is contradictory to cooling systems during summer time. The release of heat through glass during night time and cloudy winter days are also an issue. (Kwok & Grondzik, 2018)

Surfaces considered to absorb heat should preferably be a dark colour or consist of unpainted masonry to work as thermal mass. Reflective surfaces can help to redirect light in masony for instance. (Kwok & Grondzik, 2018)

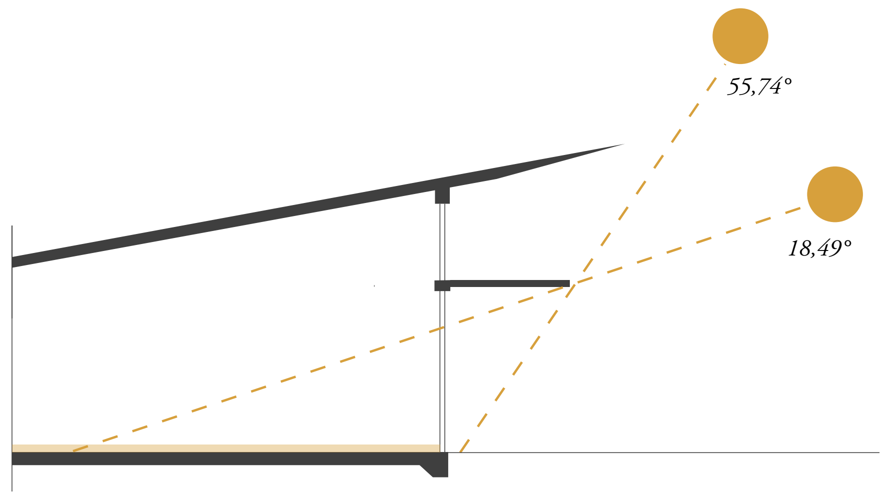
Indirect gain

An indirect gain system have three types of solutions where solar enegy is stored in different categories but with the same principal. Thermal storage can be used as Trombe walls, water walls or roof ponds.

Trombe walls consistis of masonry based walls, cladded with glass along the southern facade. Solar radiation heats the air between the two materials and moves through vents in top and bottom of the wall. Water walls and roof ponds work similarly but heat is transfered through water and on the roof. Roof ponds are regulated through movable insulation to avoid heat loss during night and to reverse the process during summer. (Kwok & Grondzik, 2018)

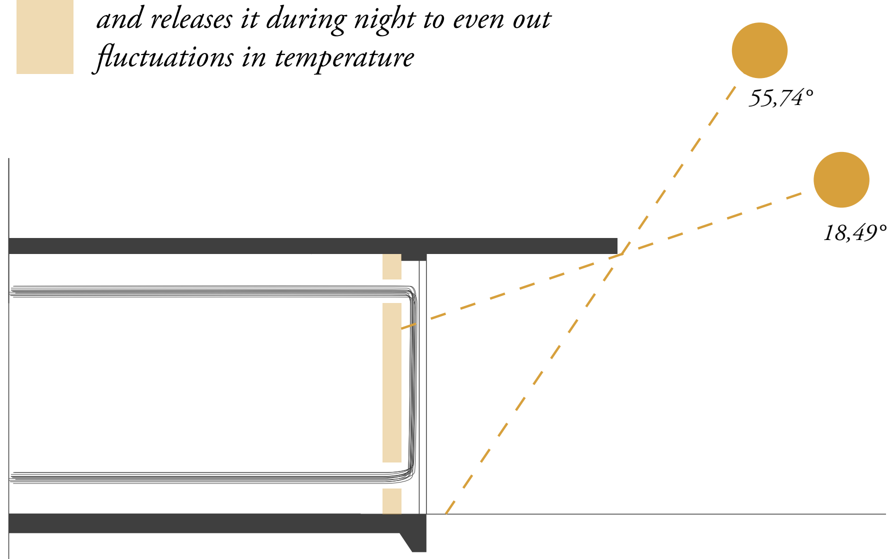


Sunpath, summer- & winter solstice at 57,7°N 12°E (Gothenburg, Sweden)



In a direct gain system, material (thermal mass) is used to store and transport heat

Thermal mass absorbs heat during the day and releases it during night to even out fluctuations in temperature



Indirect gain heating system use masonry as thermal mass with a distanced glazed cladding. The air heats up and moves into the building where it cools down and moves back to the glazed wall

BUILDING FOR COLD

Design strategies

When constructing for extreme cold the most essential factor is undeniably good insulation. Besides that, to reduce energy for heating, a compact and well considered placement of materials could make the building energy efficient. To use the different thermal masses of a material the heat can be stored and used for heating during night. Aiming for a low form factor is always desirable. This means that the relation between the total surface of the building and the volume of the building should be as small as possible to not lose energy.

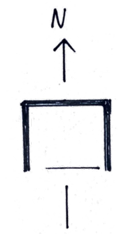
Extreme cold in combination with heavy precipitation and wind demands particular attention to roof material and construction. A steep roof angle is necessary to avoid unnessary heavy snow loads, not only for the weight but also to avoid water leak when snow melts. In case of ice pellets and freezing rain, the roof should be able to handle intense and directed ”point forces”.

With a weather protective shell, a flexible floorplan and moveable parts the building can be covered and protected during winter time and opened up in the summer. Inspiration of this can be found in Canada and New Zeeland for example where indoor and outdoor space change function depending on season. An increase of passive housing in the northern countries are also inspiring source of buildings that withstand extreme cold.

Complications

The problem when constructing in cold climates is the now increasing temperatures and longer summers when the well insulated buildings do not have any capacity to let warm air out. To terminate the increasing use of additional air conditioning systems the problem can be reduced in the constructing phase with strategies for extreme heat. A problem with merging solutions like this is the fact that one is based on non-insulated building and one is based on completely dense buildings. To add large openable in- and out take vents can make the indoor climate unbalanced, more difficult to seal and condensation can emerge.

Unfortunately many design strategies adapted for extreme cold are contradictory to strategies for extreme heat. However, by taking advantage of the shifting sun angles during different seasons and placement in the urban planning this can be avoided (illustrated on previous page).

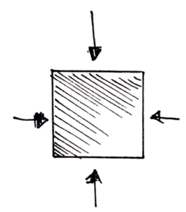


Optimal placement of windows towards south

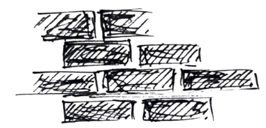
Steep roof angle to avoid heavy loads

Metal sheets as roof material makes snow slide off and avoid heavy loads

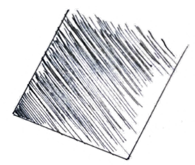
Possibilities for providing heat with natural sources, optimal place centered in building



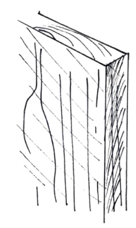
Narrow footprint to minimize heating



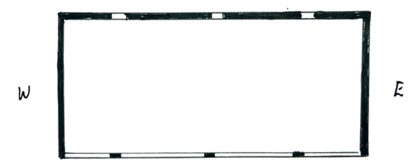
Bricks, concrete and adobe are examples of materials with good capacity to store heat (thermal mass). Usable in direct or indirect gaining systems



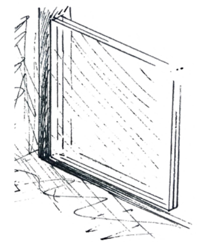
Dark surfaces to absorb heat from sun



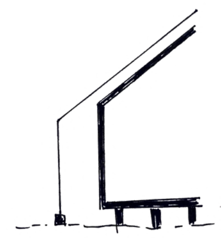
Using low thermal conductivity, but with a high heat-insulating capacity where there is direct contact with material, such as flooring.



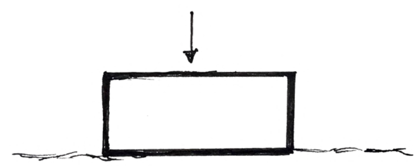
Small openings where direct- or indirect gain is not used to maximize insultion capacity



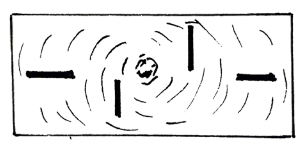
Tripple glazed windows for high insulation



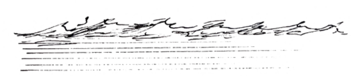
An outer shell without insulation protects the building and creates a semi outdoor space that could work as a buffert zone



Low ceiling hight to reduce volume



Centered heat provider and open floorplan to spread heat



Water have a good capacity to transport heat and could be used as themral mass in pipes or ponds

BUILDING FOR RAIN & DROUGHT

Caring for water

While water is essential for life, precipitation for a building can be dreadful. With new extremes, such as heavy rain periods, melting snow, rising water and flooding it is essential to find a strategy to handle water to be used during dry periods. Same amount of precipitation can affect microclimates differently, depending on its circumstances. Hence it is important for each microclimate to handle its water streams. Small changes in a small area can make the area survive flooding. (UN, 2020)

When taking care of water, horizontal surfaces have the biggest influence. Impervious surfaces are the main cause to why flooding occurs in microclimates. This is the same issue that cause the urban heat island effect, hence impervious surfaces should be reconsidered in every microclimate. (UN, 2020)

By comparing a natural enviroment with the same urbanized environment (illustrations) during extreme heat and extreme precipitation some conclusions can be confirmed. In the natural environment most precipitation is absorbed by the landscape and the run off is directed to the ocean.

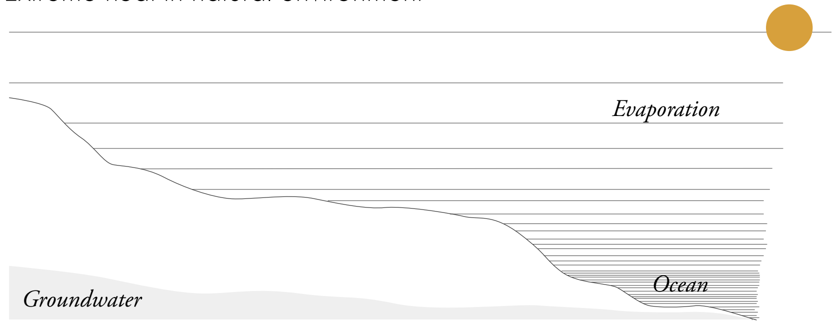
Due to the landscape being covered in hard and impervious surfaces, in the urbanized case, rain and run-off water is collected in the city. During extreme precipitation this means flooding and damaged buildings. To avoid this, hard surfaces, such as asphalt and concrete, should be removed to expose soil and to allow greenery. Where removing is not possible alternate materials such as reinforced grass could be an option. By exchanging materials to vegetation, water is absorbed and can be released during heat periods and in turn have a cooling effect to a larger area. The greenery also have a delaying effect. A complication of this is when soil get more dense and eventually could get similar characteristics as a hard surface material such as asphalt. Therefore green areas should carefully be thought through.

Depending on terrain, urban surfaces, roof material and roof angle water can be directed to wished directions and stored in reservoirs. These could either be partly exposed or hidden to be used during dry periods when ground water is low. The benefit with an exposed water surface directly connected to a building is the cooling effect during hot days or as passive ventilation.

CHAPTER III

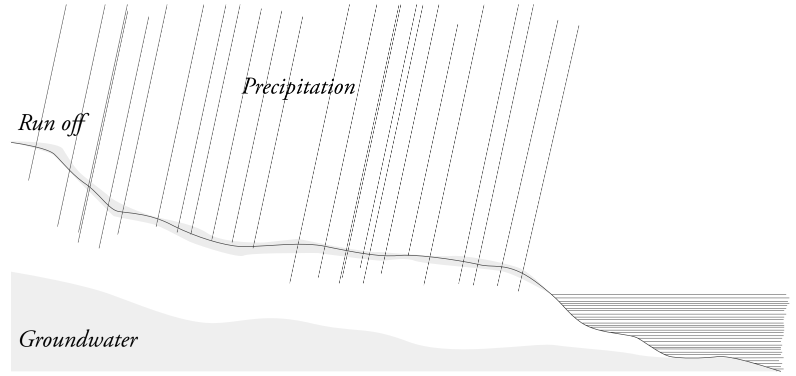
DESIGN STRATEGIES

Extreme heat in natural environment



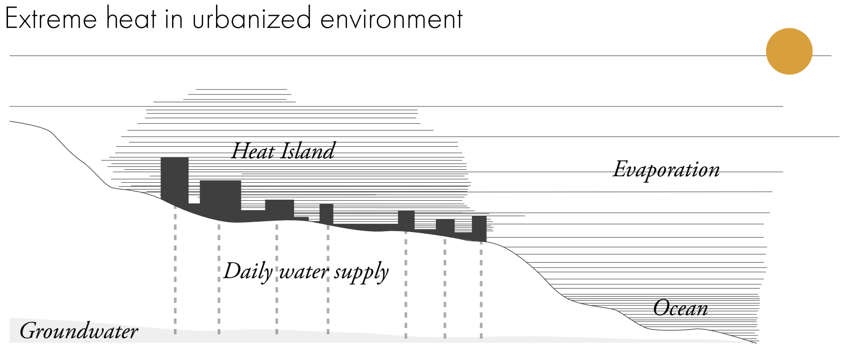
Evaporation from land and ocean. Groundwater gets lower. Greenery release moist and delay dry periods

Heavy precipitation in natural environment



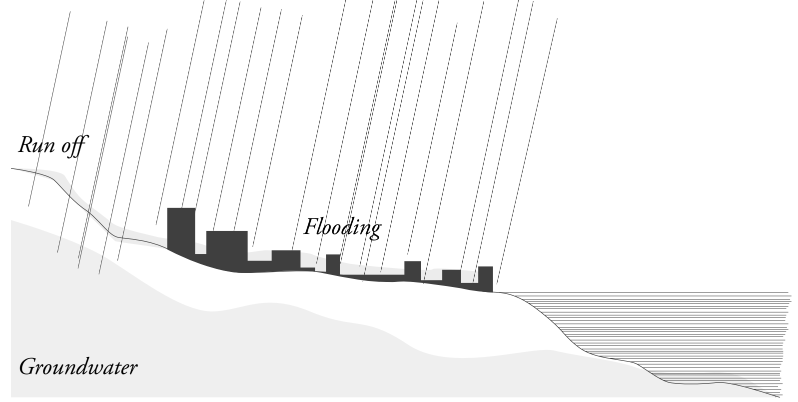
Run off water partly absorbs by vegetation. Groundwater level rises. Greenery delay flooding

Extreme heat in urbanized environment



Dark, impermeable urban surfaces heats the air within the city and is warmer than its surroundings. Groundwater gets very low

Heavy precipitation in urbanized environment



Impeavable urban surfaces collects water and locally flooding occurs. Groundwater level and sealevel rise

BUILDING FOR RAIN & DROUGHT

Design strategies

The most important statement according to strategies for rain- and dry periods is the fact that a big difference is not only made on the urban level, but also a small microclimate can make sure to avoid flooding and act self sufficiently.

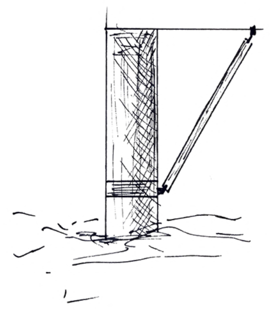
These strategies should work in parallel to each other since they belong to opposite extreme situations. By redirecting the water with draining systems and by gathering water to be used for increasingly dry periods the two extreme scenarios can get use of each other. In an ideal situation the gathered water is also used for passive cooling, stated in the strategies for extreme heat.

In risk zones where flooding and rising sealevels are present, building on stilts to make sure the lowest floor level is above predicted water level, should be standard. Buildings like this are traditionally constructed in Northern America and Cambodia to mention two.

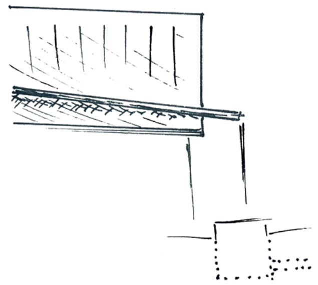
Important to acknowledge is that stilts should not only be used where rising water levels are threatening. With heavy precipitation, streams of water is created and by putting buildings on stilts the footprint is minimized. This brings up the possibilty for vegetation under the building which absorbs water and the foundation of the building avoids water damage. An excavated basement should be avoided, both for its own risk of damage but also for changes in ground material which enhance the risk of landslides and erosion.

Complications

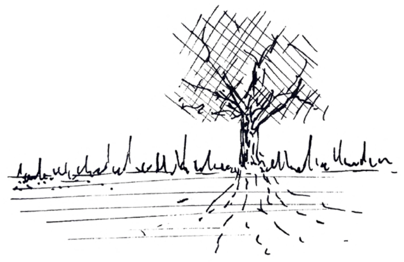
A conflicting factor with building on high stilts is the accessibility aspect. The rised entrance floor demands long and often steep staircases and are not accessible for everone. This is often handled by a longer ramp, however mostly in cases where the stilts are low and not in the areas with high risk of rising water level. To add an outdoor elevator is not an option in these cases since the risk of water damage is most certain a risk.



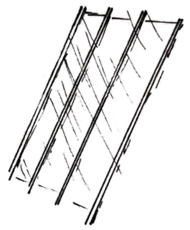
Building on stilts in concrete or metal to lift from flooding



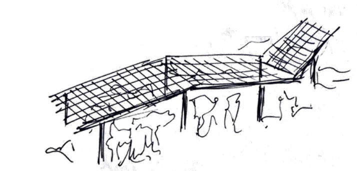
Large roof surfaces collects lots of water which can be directed to water reservoirs



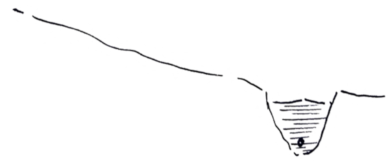
Permeable surfaces, such as soil and vegetation absorb rain and release moisture during dry periods



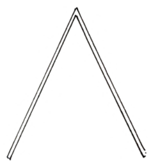
Metal sheets as roof material makes water stream down and avoid water damage



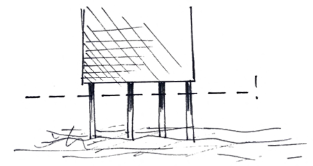
Permeable, lifted outdoor surfaces to minimize footprint and allow greenery underneath



Dike to collect water on an urban scale. Drainage to direct water to larger ponds to be used durig dry periods

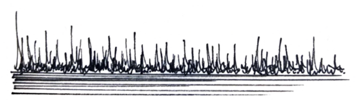


Steep roof angle to avoid water ponds and heavy loads on roof

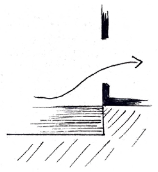


Where rising water levels are high risk the floor level should be above predicited water level

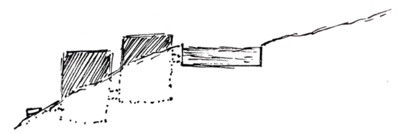
Reinforced grass to break up hard surfaces



Green roofs absorb water and release moist to atmosphere



By directing water to collections directly under in-take it can be used during hot and dry periods to cool air



Taking advantage of the two extremes by providing water reservoirs with collected rain water

BUILDING FOR STORM

General wind simulations

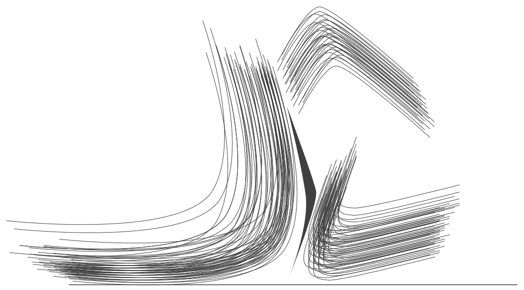
As storm and strong winds is likely to increase in many regions, it is essential to know what effect buildings have on wind direction and speed and what could minimize the risk of damage on buildings.

This topic will be elaborated in a general situation and not to a specific site for the information to be useful in other circumstances. The simulations are considered from only one wind direction, compared to a realistic scenario where wind have several directions, to give a general understanding of the influence of the wind. These shapes can therefore be interesting to applicate in the direction of the most common wind direction and placement of several buildings.

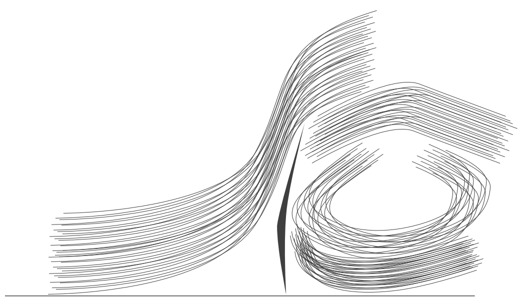
In urban environments wind is an essential factor to transport heat to avoid heat islands. In dense cities with high rised buildings, less wind can transfer the heat away and the result is rising temperature. Meanwhile the building in itself should have the capacaty to protect from wind and provide thermal comfort.

The following figures aim to illustrate what effect a building's shape can have to wind direction and speed and thereby show what impact the wind have on buildings. The illustrations are interpretated from text

Wind direction



Concave windprotection



Convex windprotection

CHAPTER III
DESIGN STRATEGIES

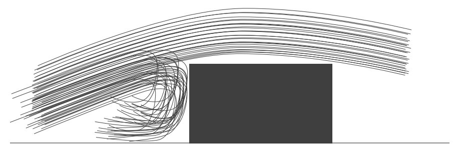
Wind direction

and diagrams in the report *Parametic Wind Design* (Lenka et al., 2018).

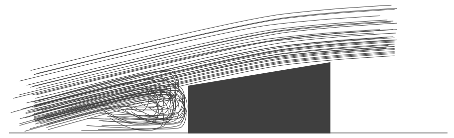
Architecture is a static part of a changing environment and unlike adapted aerodynamic design within industries like airforces there is a gap in adapted aerodynamic architecture. (Lenka et al., 2018). Where wind is vertically stopped, the static architetcure creates, often unwanted, wind swirls, where the vertical wall is the most exposed one to damage.

In narrow urban environments and funnel shaped air gaps, an increased wind speed can be formed and be the source to accelerated wind speeds and to damaging results. (Lenka et al., 2018). Illustrated in figure "concentration".

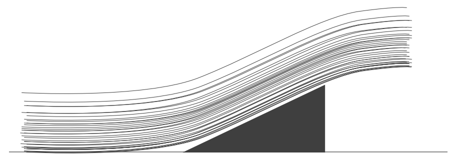
To avoid damage from heavy wind, important factors to consider is the orientation and foot print of the building, to avoid wind swirls by not stopping the wind. According to Lenka et al. (2018) the most optimal shape with minimal resistance of a building is illustrated to the right.



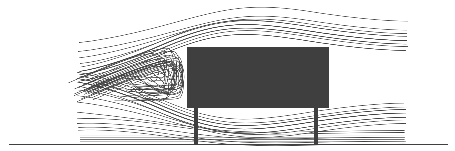
Block



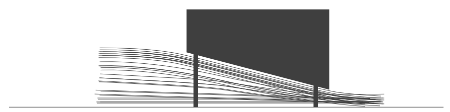
Slightly angled roof



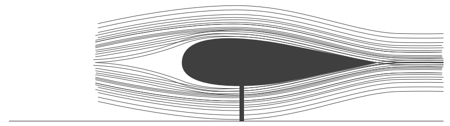
Slope angled roof



Lifted on stilts



Concentration



Minimal resistance

BUILDING FOR STORM

Design strategies

The design strategies adapted for storm have similarities to the strategies for natural disasters. The horisontal forces and vibration have to be taken care of and will be adressed in the next part.

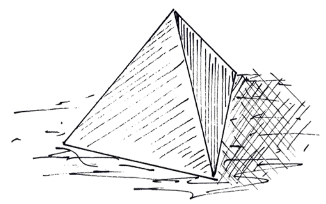
Particularly important for buildings in storm is to conceive a building with as minimal resistance as possible. To make this literally, it would be a space-ship-shaped building and not very livable. In reasonable terms the most important factors are a unified and dense building without any protruding part that can capture wind that destroys the building.

On an urban scale the most important aspect to consider is to not try to stop the wind but rather work with a stagging typology method. This is to prevent unwanted swirls and concentrated wind tunnels that could be more harmful than the original wind capacity. Outdoor shelter is also important in the urban planning where, for example, bus shelter could be redesigned to a less resistance shape and to make less impact on the wind direction. This is especially important in dense street views.

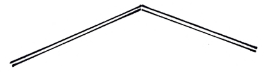
Globally, and regionally, many of these solutions are well developed and studied, especially along coasts and within archipelagos. For example, Iceland and Norway are countries known for its strong winds.

Complications

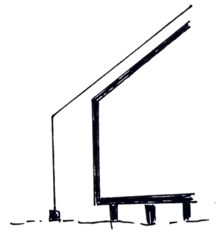
Many of these strategies are contradictory to the strategies for extreme heat where deep overhangs and big openings are optimal to protect from direct sun and receive breezes. When designing for storm the completely seamless joints are wishable and every opening should preferrably be aligned with the facade. To take into acount when winds mixed with heavy precipitation is a risk of water working against gravity, where water in this case can come from the side and even from underneath. This is a common scene on the west coast of Sweden. Again, one should strive towards the symmetric and compact building.



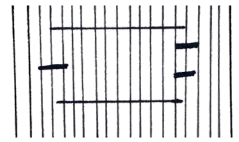
A triangular volume like a classic tent have a supportive and strong construction



30° angled roof to force wind go smootly over the building.

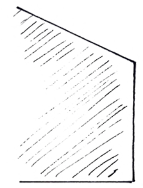


An outer shell in steel protects the building and creates a semi outdoor space

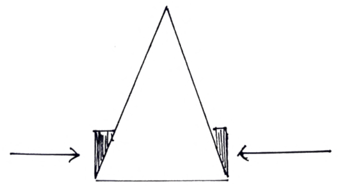


Possibility to completely close openings and protect windows where needed

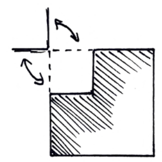
Stagged buildings in the urban planning allows wind to move between buildings



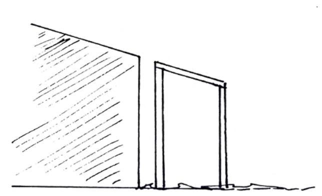
Avoid overhang to protect roof structure when wind comes from underneath



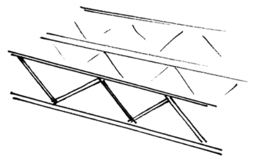
Entries from opposite directions means one is always more protected



Flexible space to be able to seal the building and make it uniform during storm

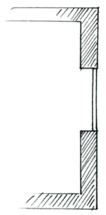


If shading is needed, a separate construcution can be used to "sacrifice" in a storm and protect the main building

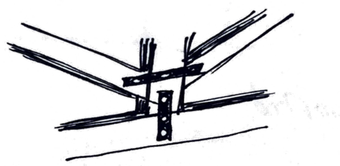


2- or 3 dimentional truss beams for stable construction

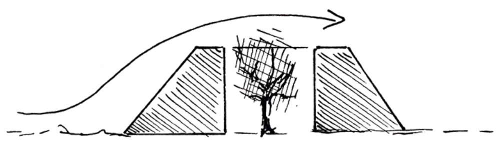
Outdoor shelters are important elements in exposed areas for human protection and should be shaped with minimal resistance to avoid changes in wind directions



Aligned surfaces to minimize resistance



Connections between elements should always be well implemented



An inner yard can serve as a covered space in places where wind is constantly present

BUILDING FOR NATURAL DISASTER

Vibration resiliant structure

Increasing landslides, strong wind and smaller earthquakes caused by increased precipitation, dry periods and erosion contributes to a higher risk of vibration in buildings. The main issue in areas with high risk of earthquakes, landslides and storm are the horizontal forces in a building caused by vibrations. Buildings made out of concrete, bricks or adobe are the most fragile ones due to its brittleness (UN Educational, 2014). Traditionally buildings in Sweden, as in many other regions, are constructed to mainly withstand vertical forces. Hence this part will focus on how to adapt a wooden structure to withstand horizontal forces.

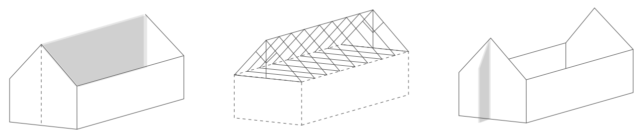
To withstand the vibrations in the ground the building should have the capacity to bend, sway and deform. This is called *ductility* or *high rigidity*. To handle ductility regular geometries in both plan and section is necessary since irregular shapes tend to break. Symmetry is always desirable in both volume and openings. In a rectangular shaped footprint the length (L) should be less than three times of the width (B): L<3B (UN Educational, 2014)

Timber is a flexible material and with a resiliant structure and connections, damage, such as cracks can be handled. To avoid heavy loads a light weight construction is preferable, which also supports a structure built in wood. (UN Educational, 2014)

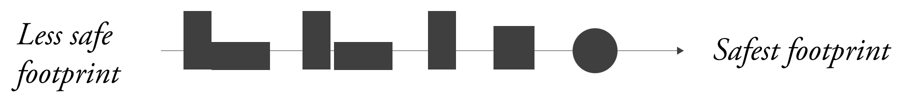
The most fragile components in a building tend to be the corners of openings, the triangular shape of the gable and the structure of the foundation. (UN Educational, 2014)

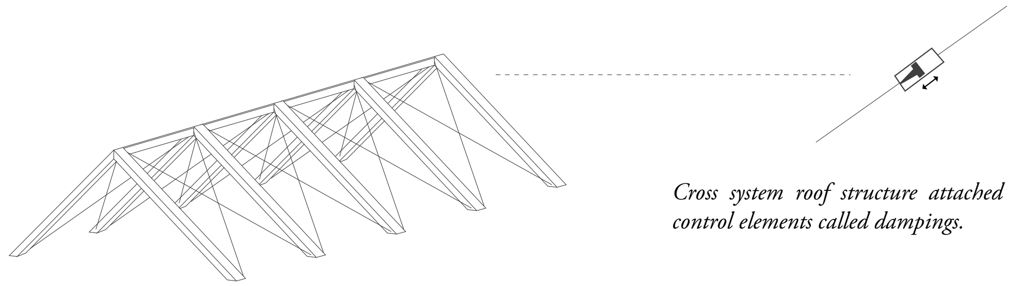
Following illustrations are inspired and interpreted from the article *Earthquake proof buildings* by Big Rentz (2019).

In a Swedish west-coast context, the risk of earthquakes is very low, however the vibration resiliant structure can be useful in other circumstances.

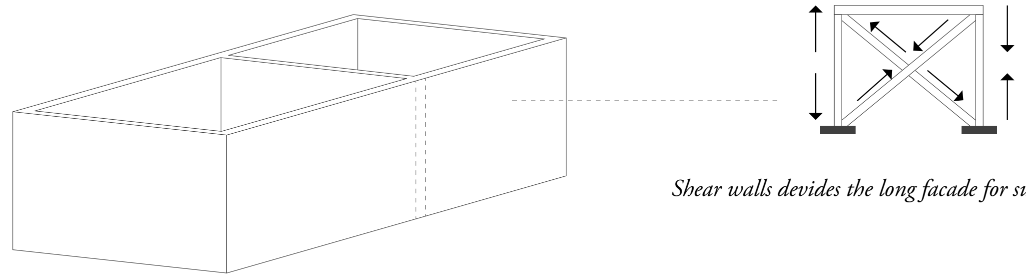


A gable should either be supported by a shear wall from the inside, connected with the roof structure or supported by a buttress from the outside. (BigRenz, 2019)

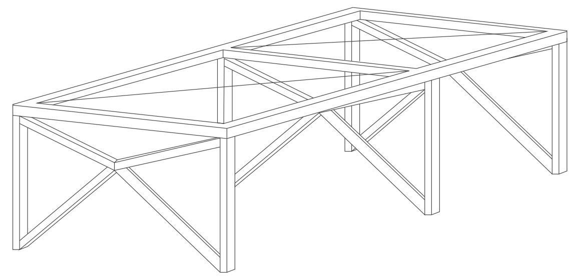




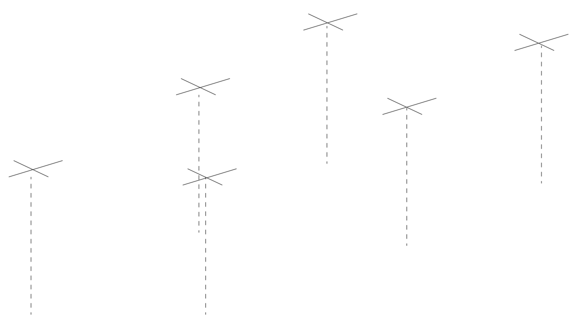
Cross system roof structure attached with vibration control elements called dampings.



Shear walls devides the long facade for support



A high space frame structure supported in all directions handles vibrations from the ground



Flexible stands to differentiate building from ground. Deeply connected to ground depending on the layers of soil. Optimal would be to isolated the stands from surrounding ground

BUILDING FOR NATURAL DISASTER

Design strategies

With climate changes and its alterations in weather patterns the frequency of natural disasters tend to increase. Particularly heavy precipitation and sudden changes in the amount of water in the ground landslides and erosion threatens to damage buildings. By human power the changes in ground material while excavating, the construction industry enhance the risk for landslides, particularly on the West Coast in a Swedish perspective. Erosions tend to occur in sandy areas, along the south coast.

Landslide

The most efficient way to prevent landslides is to plant vegetation with large root systems to bind the soil. Additionaly soil changes should be avoided and replaced by stilts, deeply anchored to solid ground material.

Being able to handle the vibrations and horizontal forces demands special features on the construction. All elements should be carefully attached to eachother supported in xyz led.

Wildfire

With longer and warmer summers the dry periods dries moist out from the ground and increase the risk of spreading wildfire.

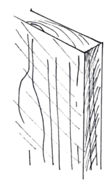
Devastating consequences can be a threat to both buildings and humans. Drought is difficult to avoid however small points can be taken to minimize the risk of wildfire.

With wood as construction material the charcoal from the burnt parts will, for some time, protect the structural capacity in the core, unlike steal which bends when heated. By dividing the floorplan into fire cells the risk of spreading fire within the building minimizes.

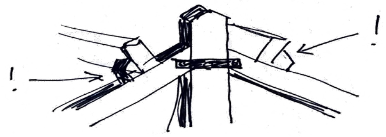
Complications

By using the same strategies as building for storm and cold, with a closable and dense building the main smoke can be isolated on the outside. By making a fireproof zone around the building fire can be prevented from spreading too close. However with strong winds and sparks from surroundings the fire can still reach far and impermeable surfaces should be avoided when considering strategies for extreme heat.

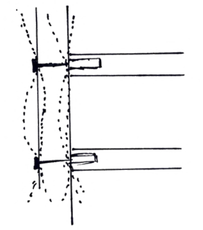
Fireproof zones often means impermeable and hard surfaces which is not desirable when designing for extreme heat and to avoid urban heat islands.

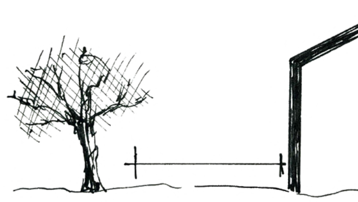


Wood is a flexible material and can adapt to vibrations

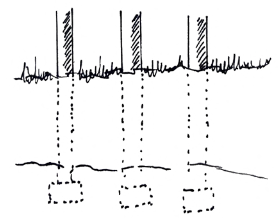


Small supports can make big differences when forces comes from many directions

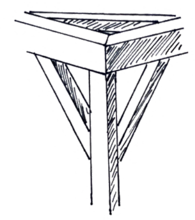




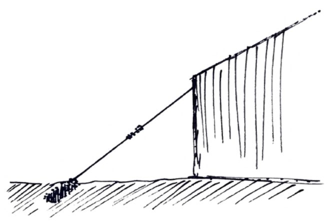
Zone of 1,5-10 metres around the house without flammable material like vegetation to protect from fire



Deep anchored stilts reached to stable ground to remain standing in a landslide

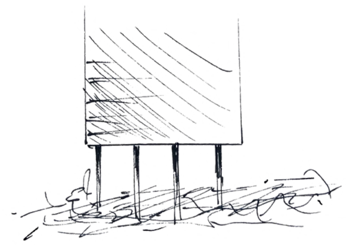


Horizontal floor slabs should be supported in xyz led



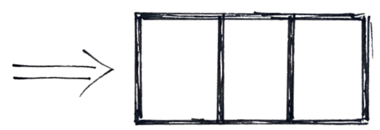
Whires with damping helps adjust the building adjust contradictory to vibratios

Vegetation binds soil and could avoid landslandes and erosion. The larger root system, the better effect

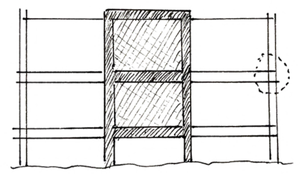


Building on stilts to leave ground as untouched as possible to minimize risk of landslide

Well dimensioned timber keeps its load-bearing capacity longer than steel when a layer of charcoal protects the core in case of fire



By dividing a plan into fire cells a wood building can work as a passive fire protection



A compact core of concrete or maisonry anchored in ground work as stabilizer and safety room. Flexible wooden structure is supported to the core

MERGING DESIGN STRATEGIES

Weighing strategies against eachother

The following spread shows a matrix on relevant design strategies for each scenario (y), weighted and compared to each weather aspect (x). The point of the matrix is to highlight the most important design strategies and to exclude strategies that could do more harm than be helpful during different circumstances. This is especially important when design strategies are contradictory to each other, mostly common for strategies for extreme heat versus extreme cold. The matrix gives an indicaton of what should be prioritized and not, but only for this specific combination of scenarios. The table is a tool that can be arranged differently by adding or removing scenarios when evaluating a different site.

The colours show a scale in five steps, from dark red to dark green. If a column have either the dark red or dark green the gathered colour will be directly influenced and show that colour. If one column have both extremes, the red one will weigh heavier and that strategy should not be used.

Each colour have a number which is added as a gathered number for each strategy. The gathered number and the gathered colour does not necessarily mean the same thing since if the two extremes are included the gathered colour will directly be influenced.

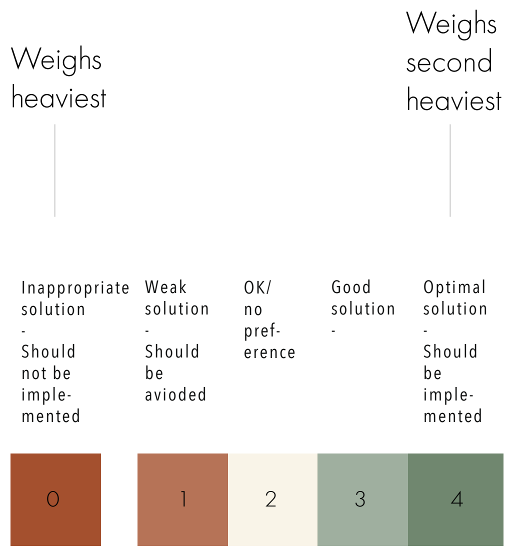
The gathered grade is the base of choosing strategies for the design proposal, and the more green strategies that are included in the design, the better. In the discussion of this report the design proposal will be evaluated by the matrix to grade the design proposal. The number can be useful when two similar design strategies have the same colour and different numbers. Then the design strategy with the highest number should be used.

The numbers are primarily useful when evaluating several projects and comparing them against each other. In theory, that would mean that the project with the highest number have the best solutions in the aspect of design strategies adapted for the weather scenarios on the specific site. This comparison only make sence if the parametres of two design proposals are the same, thus have the same risk factors on the y-led.

Some of the combinations does not make any sense, for example the design strategy ”dark surface”. This do not have any impact if there is a storm or landslide and get the white colour for ”no preference”

The row of ”indication” gives a picture if the solution is a standard in Sweden or not. This row is not included in the gathered grade but can be read together if wished.

CHAPTER III
DESIGN STRATEGIES



° NOT STANDARD

°° STANDARD

CHAPTER III
DESIGN STRATEGIES

	MATERIALS			ROOF						LANDSCAPE
	Wood	Concrete	Thermal mass	Metal roof	Large overhang	No overhang	Steep roof angle	Slightly tilted roof	Green roof	Dark surface
HEAT	In areas with low humidity	Release heat during night		If bright colour, ok	Sun-shading	Lack of shadow			Release moist	Absorbs heat
COLD	Good for insulation	Not optimal for insulation			Not opt. for heavy loads	Good to avoid heavy loads			Flat roof collects snow loads	Absorbs heat
PRECIPITATION	Not opt. to handle moist, but ok				Pref. with large roof to collect water	Not optimal to protect facade			Absorb water	
DROUGHT					Pref. for shadow around building				Absorb water, release moist	Should be avoided, increased heat
FLOOD										
STORM	Flexible	Preferable with dense material		Optimal, for little resistance	Could increase damage		Not optimal for wind resistance	Preferable for little resistance	Not optimal, "loose" material	
LANDSLIDE	Flexible construction	Not flexible but could work as stabilazor				Pref. with no outsticking parts	Not optimal, 30° is pref.	Dense shape preferable	Not optimal, "loose" material	
WILDFIRE	Still load bearing ICO fire if generous dimens.	Fire proof							Not optimal, flammable when drought	
Standardization	∘∘	∘∘	∘	∘	∘	∘	∘	∘∘	∘	∘∘
GATHERED GRADE	20	19	18	20	15	17	19	16	15	14

							DESIGN			
	Bright surface	Permeable surface	Impermeable surface	Vegetation	Non flammable zone	Staggered topology	Narrow volume	Symmetric and uniform volume	Completely dense	Outer shell
HEAT	Huge impact on UHI	Huge impact on UHI	Huge impact on UHI		Not optimal for shadow	Allow breezes	If possible to open upp, ok	Easier to applicate natural vetilation	If possible to open upp, ok	Could work as buffert zone
COLD			Absorbs heat	Rather small veg. to avoid shadow				Preferable to optimize heating		Good for insulation
PRECIPITATION			Should be avoided, risk of flooding	Absorb water	Permeable surfaces are wishable	Pref. to allow water flows			Prevent water coming in	Protect inner facade
DROUGHT	Preferable to not increase heat		Should be avoided, increased heat	Release moist	Permeable surfaces are wishable					
FLOOD			Should be avoided, risk of flooding	Absorb water	Permeable surfaces are wishable	Pref. to allow water flows				
STORM				Not opt. with large trees. Low veg. ok						
LANDSLIDE		Allow vegetation	Not optimal to bind soil	Nec. to bind soil				Pref. to avoid cracks		
WILDFIRE		Good with gravel	Pref. around building	Fire risk.		Preferable to avoid spread				Could work as buffert zone
Standardization	∘∘	∘∘	∘	∘∘	∘	∘	∘∘	∘∘	∘	∘
GATHERED GRADE	19	26	9	25	17	23	20	21	22	17

				CONSTRUCTION				DETAILS			
	Long floor-plan W-E	Open floor-plan	Fire-cells in floor-plan	Dense concrete core	Support in all directions	Deep anchored construction	Building on stilts	Sun-shading	Seperate shading constructions	Openable vents	Water reservoir
HEAT	Optimal for vent.		Not optimal for natural ventilation	Comb. with thermal mass, good			Important for ventilation				Optimal for passive ventilation
COLD	Not opt. but ok, square more suitable		Not optimal for spreading heat	Comb. with thermal mass, good	Pref. for heavy loads		Bad for insulation	Nothing should cover winter sun	Nothing should cover winter sun	Works, if well insulated	Not optimal for freezing. Protected, ok
PRECIPITATION					Pref. for heavy loads					Works, if well insulated	Necessary, taking care of water
DROUGHT							Pref. to avoid impeavable surfaces	Pref. to avoid heat	Pref. to avoid heat		
FLOOD											
STORM	Works with short side against wind	Shear wall needed from side to side			Nec. to handle xyz forces		Pref. to allow wind underneath	Outsticking part should be avoided		Works, if well insulated	
LANDSLIDE	Works with max. range 1:3	Shear wall needed from side to side			Nec. to handle xyz forces		High space frame structure	Outsticking part should be avoided		Works if small openings	Digging should be avoided
WILDFIRE		Fire cells					Not optimal to spread fire				Nec. to provide water
Standardization	∘∘	∘∘	∘	∘	∘	∘	∘	∘∘	∘	∘	∘
GATHERED GRADE	17	15	15	17	22	19	22	18	21	17	24

CHAPTER IV

CONTEXT

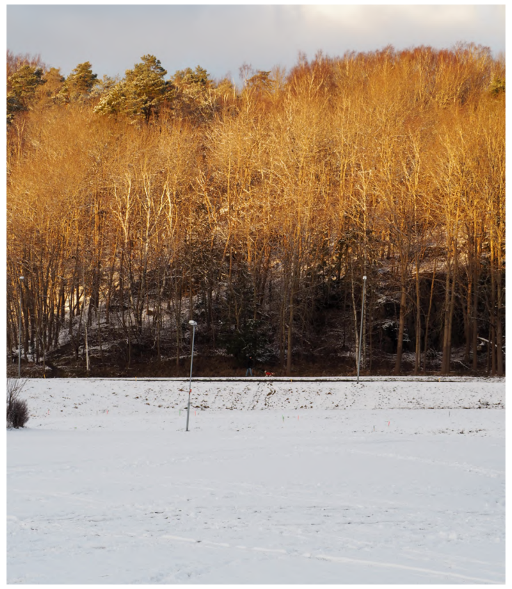
AXGATAN, MÖLNDAL

The site is located by the foot of the south part of Änggårdsbergen. It is currently within an ongoing process of a plan area by the municipality of Mölndal. The program of the site includes apartment buildings and is directly attached to an area with townhouses in two floors towards east, and an existing alotment area towards west. Further west is a residential area consisting of one-family homes in 1-2 floors.

Closeby are everyday facilities, such as grocery stores, dentist, hair dresser, preschool, outdoor gym, some restaurants etc. The site is connected within the urban area but still has closeness and is surrounded by nature.

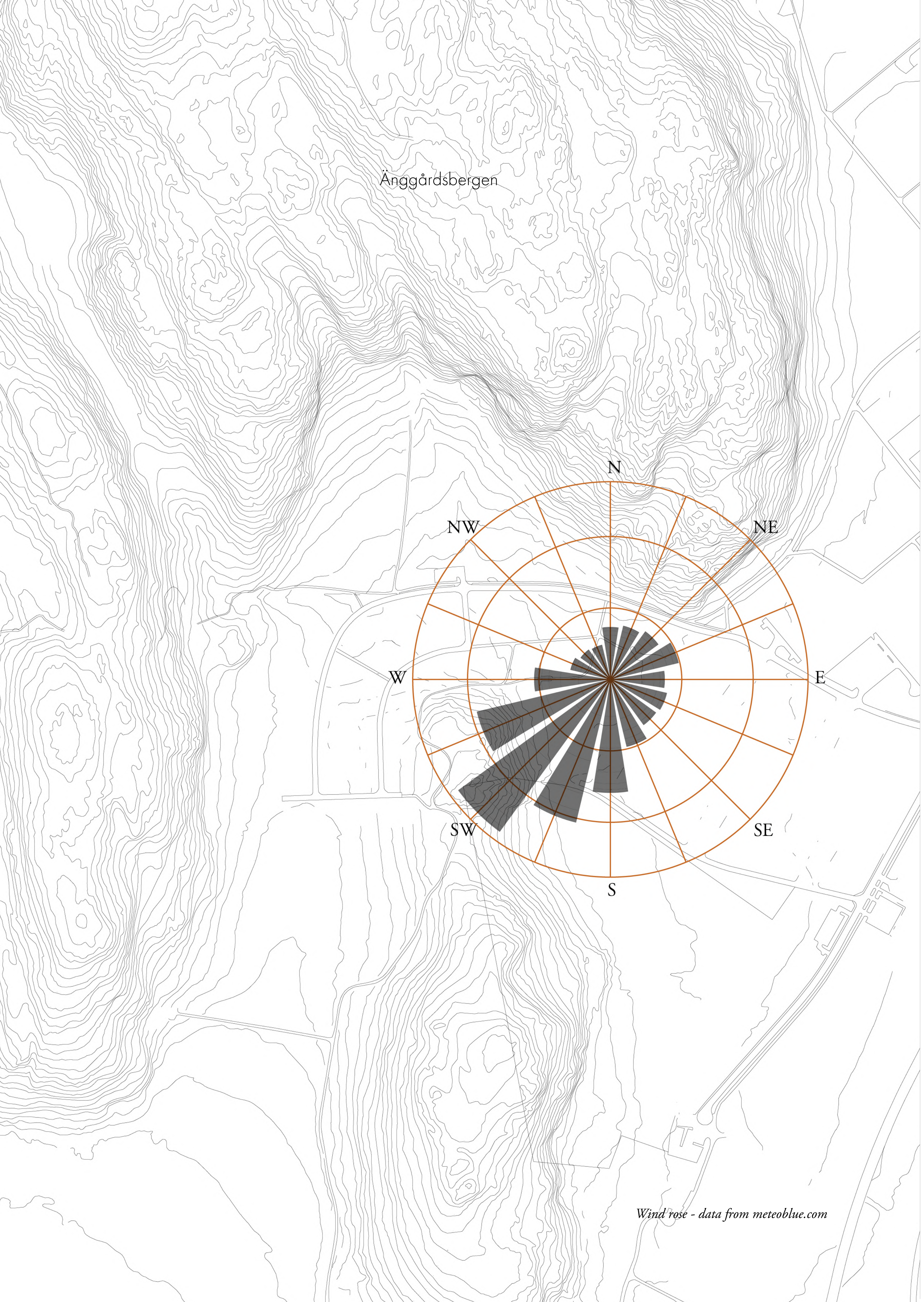
The reason to select this site is partly because of its relevance of currently being planned, but mainly because of its risk factors, referring to the stated extreme weather scenarios in this report. It may not be in the risk zone of rising sea levels, however circumstances regarding the closeness to Änggårdsbergen is predicted to have impact on the site. Following pages is a site analysis based on the extreme weather scenarios.

The site photos are taken in Febraury 2022 around 3 p.m. indicating the site being shadowed at this time.



View from site towards north

View from site towards west

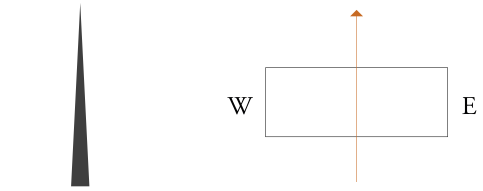


Wind rose - data from meteoblue.com

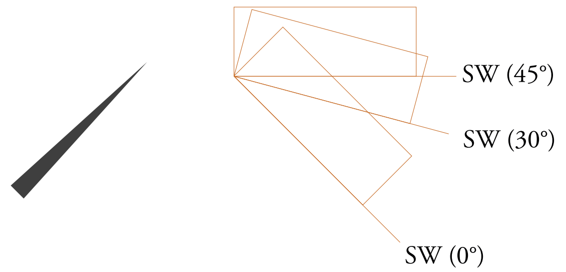
WIND STUDIES

Site analysis

Wind direction *Orientation range*

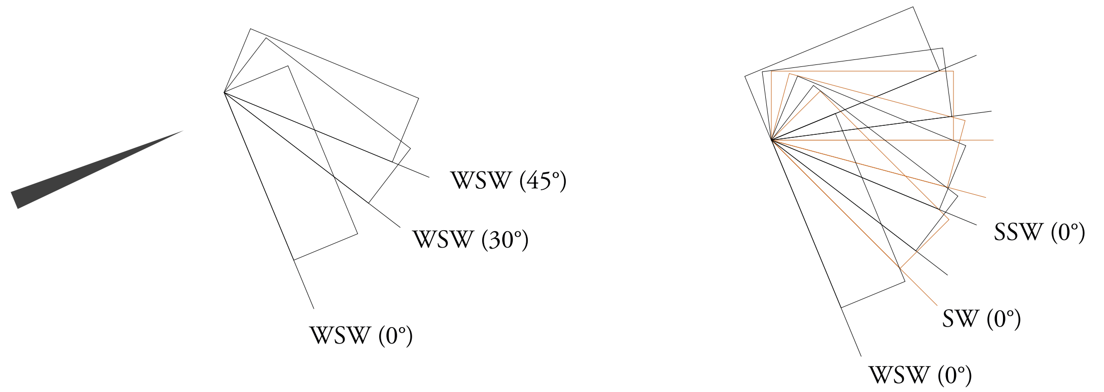


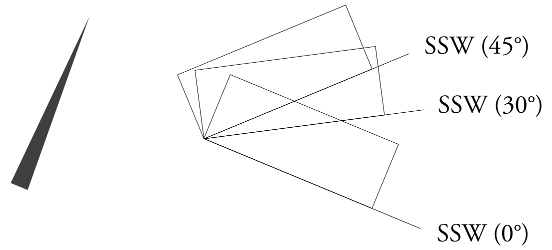
Desired orientation for extreme heat and extreme cold, maximum proportion 1:3 for storm and natural disasters, according to design strategies



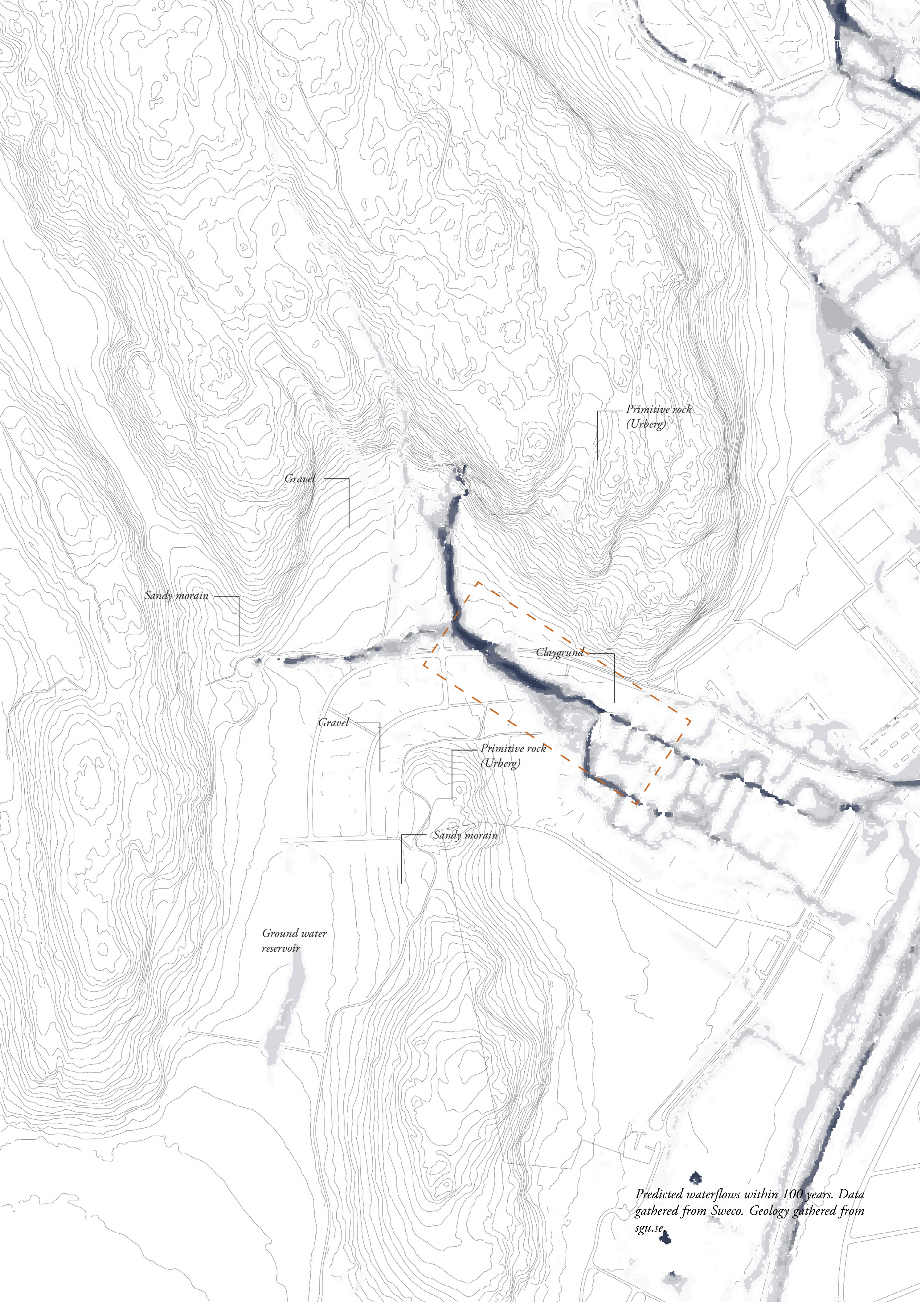
Most common wind direction from South-West (Eklanda, Mölndal). Due to the smaller mountain south-west to the plot the wind redirect slightly from the surrounding area, but the wind rose will still be used as it is.

Maximum range, 30-45°, from wind direction for natural ventilation.





Above diagram shows the merged range of desired orientation per wind direction. Optimal orientation would be close to the orange marks, adapted for the most common wind direction.



Predicted waterflows within 100 years. Data gathered from Sweco. Geology gathered from sgu.se

WATERFLOWS AND GEOLOGY

Site analysis

Within a 100-years-perspective the predicted increasing precipitation, particular with heavy rain periods in a short time, lots of run-off water will be gathered in a flow towards the site. This due to the high points in Änggårdsbergen, where valleys and springs collects water and direct it towards the site.

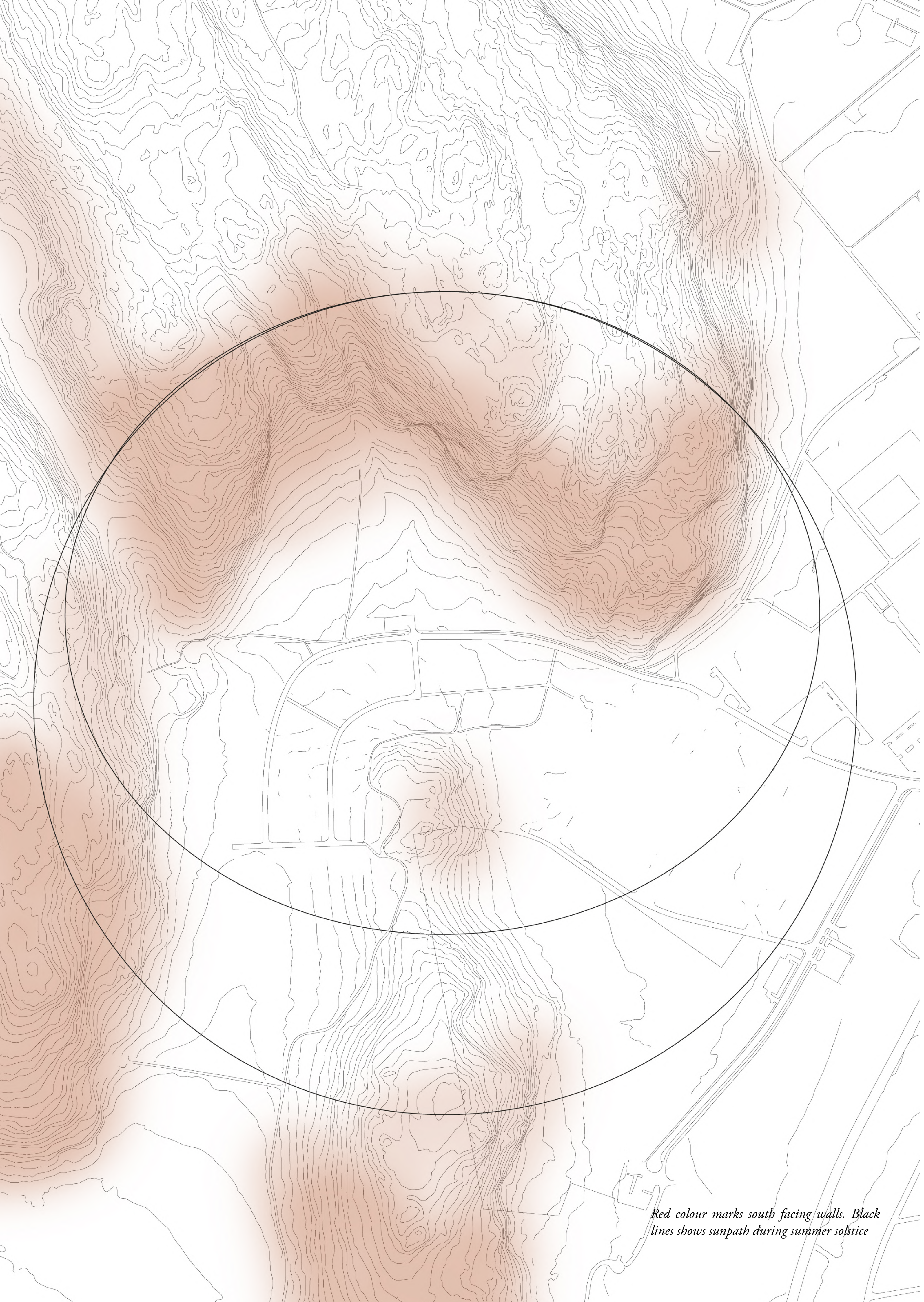
While Änggårdsbergen mostly consists of primitive rock under layer of vegetation, less water can be absorbed directly and run-offs during heavy rain will be more frequent.

The main ground material in the area around and within Gothenburg consist of clay ground, which could be a risk of landslides in combination with increased precipitation as previously announced (chapter II).

According to old investigations by SGU this site is not directly announced as a risk zone, but rather the areas around Götaälv and Säveån. However, the site is currently (May 2022) under a geotechnical investigation by Mölndal municipality to tell if action should be taken to handle stormwater. This will also establish potential landslide risk of the site. The marked zone consists of a clay ground predicted to a depth of 20-30 meter (Sgu.se, 2022). Just alongside the plot the run-off water could partly defect the ground in case of heavy rain. Notised is also collected water on the north side of the site, probably in the trails of the vehicle used during the geotechnical investigation, according to the city planning office, Mölndal municipality. The neighbouring plot consist of cultivation lots and is already today collecting ponds of water during heavy rain, due to its slightly sinked location.

During heavy precipitation periods a decrease of daylight due to cloud coverage will be an issue.

Rising sealevel will not have an impact on the site within the given time-period due to the high location. The site is located 25 meters above sealevel.



Red colour marks south facing walls. Black lines shows sunpath during summer solstice

EXPOSED SUN AREAS AND DROUGHT

Site analysis

With Änggårdsbergen as a nature reserve dry periods will have high impact on the moist level. South tilted rock faces will dry out faster due to the sun exposion. This increase the risk of wildfire in the area and could have a direct risk on the site. Already wildfire is an issue in the area. During July 2021 an area of 1500 sqm was destroyed by a wildfire (GP, 2021).

The ground water level on the site is considered as "fairly good extracting possibilities" by SGU. This means the ground water level is not very high yet not very low. Hence, flooding is not a high risk due to rising ground water. During periods with lack off precipitation the ground water level can get very low and cause drought as a consequnce.

Other circumstances applies on the ground water reservoir south-west to the plot where flooding and a direct impact on water supplies can be caused during rain- and dry periods.

During winter time the site is baerly exposed to the sun. The small mountain in the middle and the westerly mountain provides shadow due to the low sun angle during wintertime from early afternoon to sunrise. This makes direct and indirect gaining systems only useful during forenoon, which could be considered as not gaining enough for being worth using the method on this specific site.

CHAPTER V

DESIGN PROPOSAL

TRANSLATING THEORY INTO DESIGN

"Societal choices and actions implemented in the next decade determine the extent to which medium and long-term pathways will deliver higher or lower climate resilient development." (IPCC, 2022)

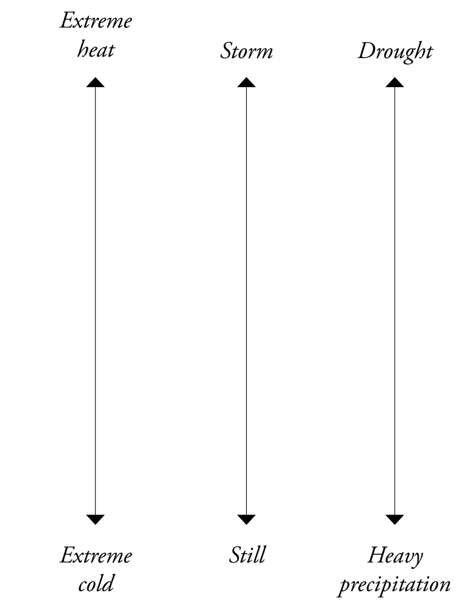
The aim with this chapter is to interpret the theory into a design proposal which should be seen as a discussion material. The ambition is to initiate a discussion about how the development of future living situations can look like, what architectual qualities we need to sacrifice and what new qualities we can discover when rethinking the way we build to reach thermal comfort.

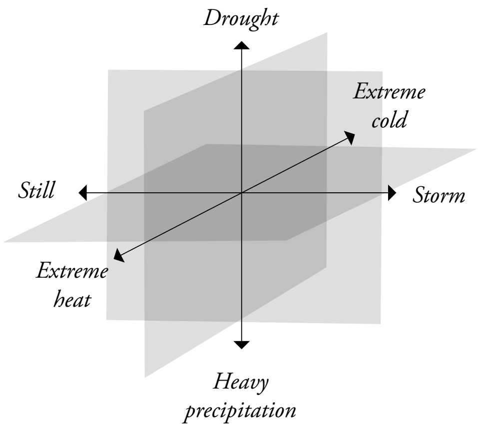
The matrix of design strategies has been the base when sketching on the design proposal to tell which design strategies should be priorotized and which ones should be avoided. In combination with the site analysis this has given the result of the proposal.

Each design strategy has been evaluated and tried out in the sketching process to see what combinations could work in this specific microclimate.

In the discussion of this report the design proposal is evaluated, based on the previous mentioned design strategies and its adaptation to the new climate situation and weather scenarios stated by IPCC, SMHI and MSB. Solutions in the design proposal could rise, or answer, questions, weather we are willing to change the way we are living, contruct our buildings and plan our cities to reach the global goals and to take responsibility in the level of individual, societal and regional choices.

THE SCALE OF EXTREMES



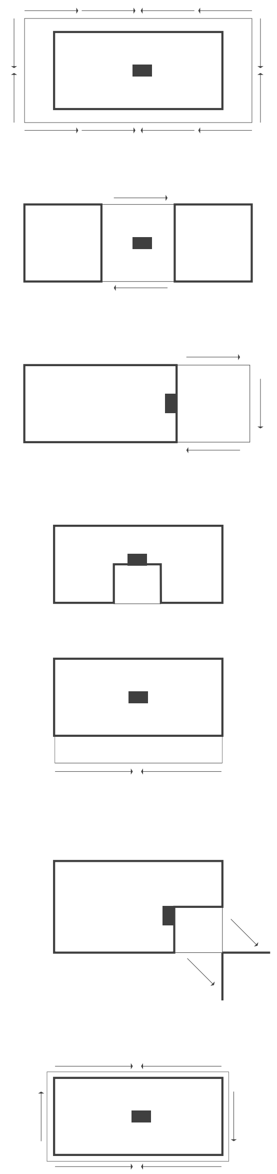


Taken into account that some extremes will never happen at the same time, makes the possibility of solutions more managaeble. Extreme heat and extreme cold, storm and stillness, drought and heavy precipitation, will never happen simultaneously. Hence they can be placed in opposite directions of a scale and in turn be combined in a diagram, illustrated to the left. The bottom diagram illustrates possible combinations of extremes. The origo could be seen as a normal state for each site where the extremes are subjective depending on the existing environment. Scenario VI, natural disasters, is not directly implemented in the diagram since it often is a consequence of one of the mentioned extremes.

Design strategies that are contradictive to eachother in this diagram should be implemented in opposite sides of the scale. This enhance a flexible building looking different during different weather.

METHOD

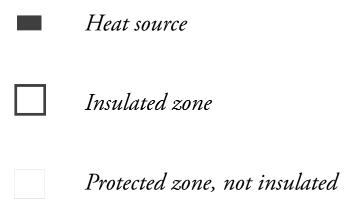
Zoning for flexibility



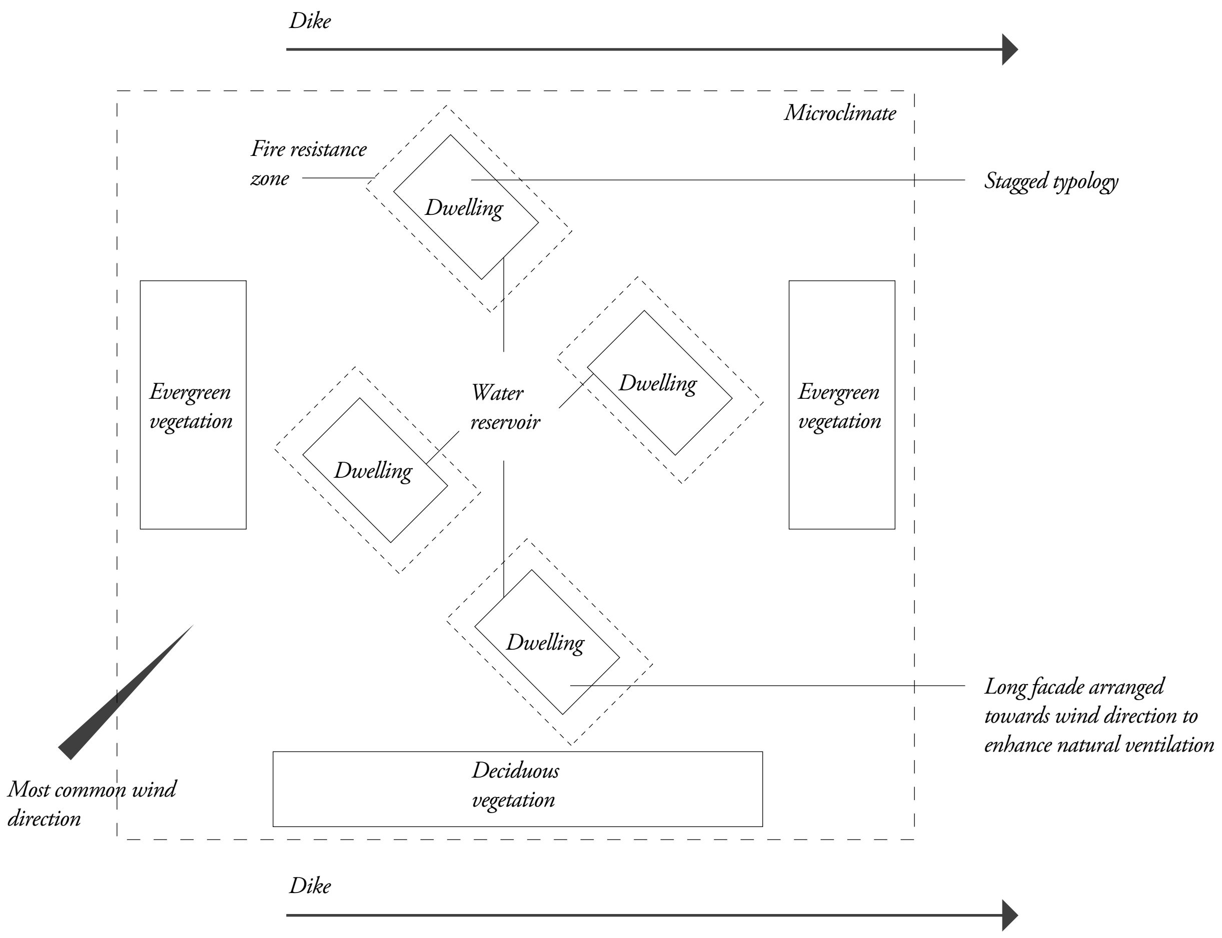
By zoning the building with different layers of insulated and non-insulated buffert zones, solutions to the extreme scenarios can be achieved. This is already well implemented in some regions around the globe were the climate varies, mostly where rain- and dry periods seasonally repeats. With this method the buffer zone could be included in fire and wind protection and also protect from direct sunlight during summer and to avoid heat leakage during winter.

The diagrams to the left show different common or less common solutions of flexible buffert zones where a combination of types will be applied to this design proposal to be able to handle all extremes on the site.

The ”protected zone” is non insulated and mainly works as a direct weather cover to protect the inner structure.



PROGRAM MICROCLIMATE



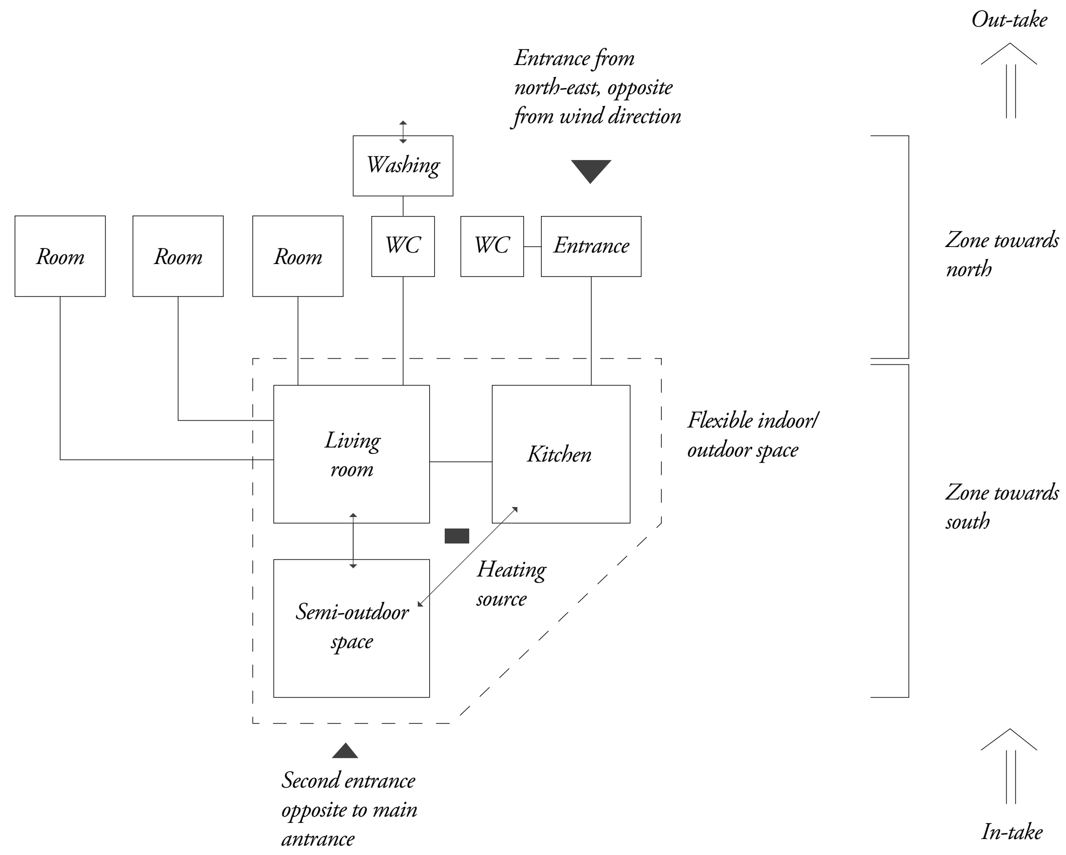
The program includes four dwellings, on Axgatan in Mölndal. The plot is approximately 2,700 sqm and will in this report be handled as a microclimate, aiming for self sufficiency. To handle run-off water from Änggårdsbergen suggested dikes is included in the program to redirect water towards larger water reservoirs. The idea is to be able to attach several water collectors to collect water on a bigger scale useful for the municipality during dry periods.

Evergreen vegetation towards east and west and deciduous vegetation towards south provides shadow during summer and allows sun during winter.

A stagged typology let wind pass through the area and also allow breezes to reach all dwellings during extreme heat.

A shared water reservoir could work as a common passive cooling system.

PROGRAM DWELLING



The program above applies on all four dwellings on the site. The main entrance should face the opposite facade of the most common wind direction to be protected. An additional entrance opposite to the main entrance provides covarage when wind changes direction.

Social rooms face south and have directly connection to outdoor spaces, aiming to be flexible and considered as either indoor or outdoor space depending on season and weather.

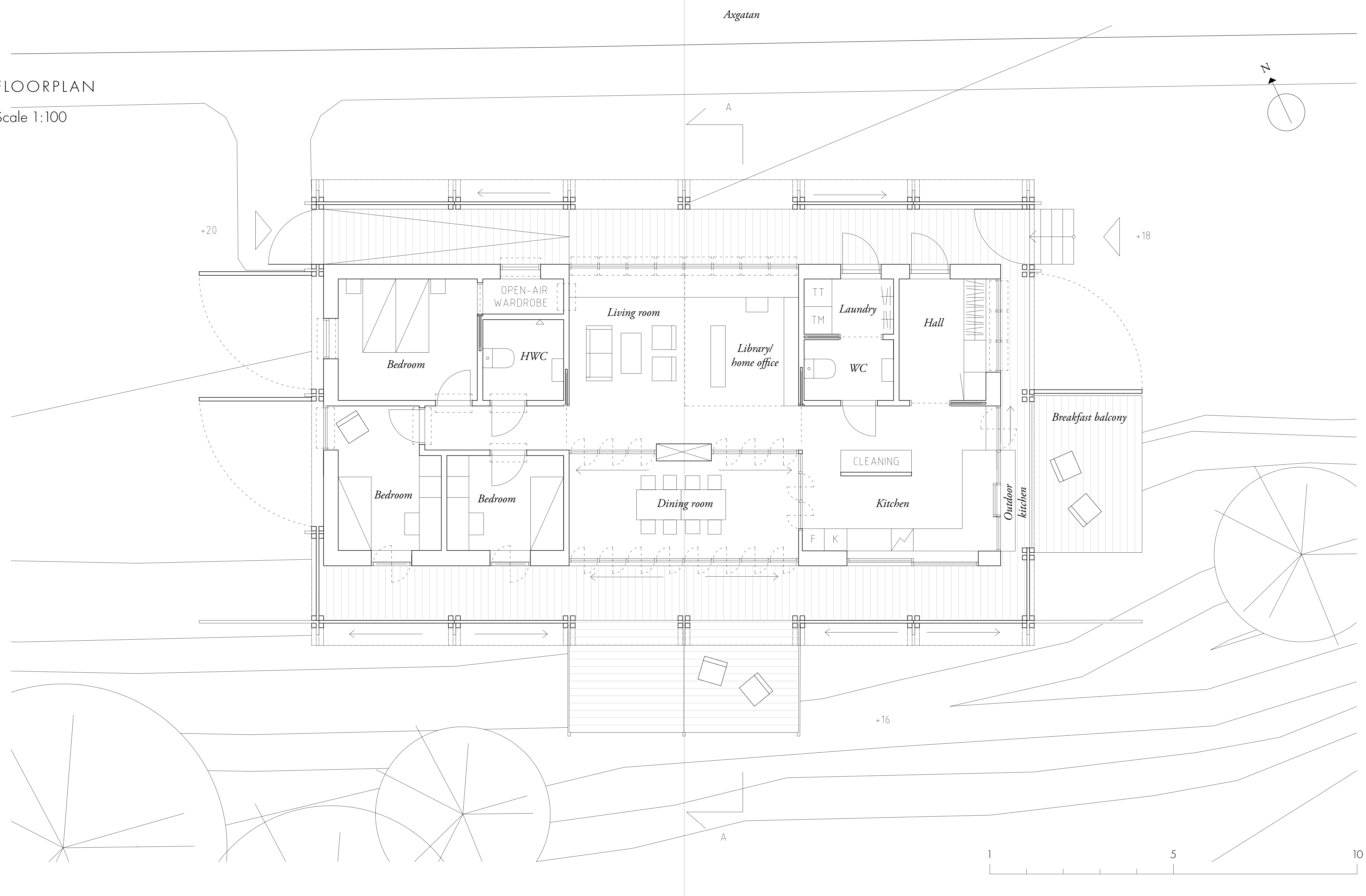
SITEPLAN

Scale 1:1000

CHAPTER V
DESIGN PROPOSAL

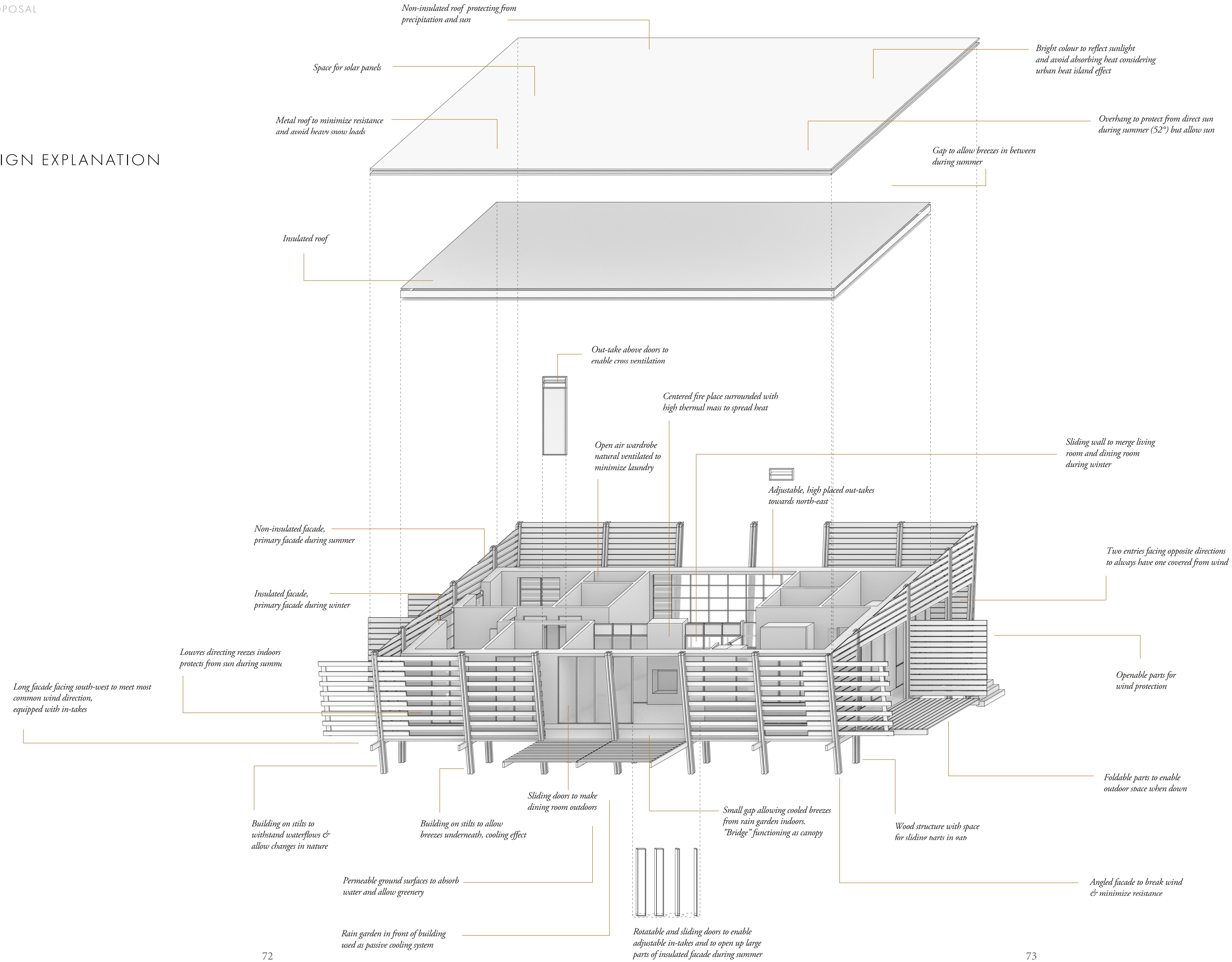
FLOORPLAN

Scale 1:100



CHAPTER V
DESIGN PROPOSAL

DESIGN EXPLANATION



PLAN AND SECTION

Description

Site plan

A rain garden runs between the buildings, which works as a water reservoir to take care of heavy rain flows and run off water from Änggårdsbergen. During summer it provides the buildings with a passive cooling system.

Each building is put on stilts to allow different water levels to vary. By lifting it up from the ground it makes a minimal footprint on the site, and allows grass and vegetation to grow underneath. This also minimizes the impermeable surfaces on the site and makes the ground absorb more water to avoid flooding. Large trees are planted in the rain garden to provide with shadow and to bind the soil, in case of risks of landslides. Alongside the site, dikes are proposed for a larger area, where the predicted run off water from Änggårdsbergen is gathered in a large water reservoir for the municipality to use.

A stagged typology is used to allow breezes inside the microclimate and to be able to reach all buildings.

Floorplan and section

The building is directed with the long side towards the most common wind direction. This is where the in-takes for the natural ventilation is placed. Openable vents over indoor doors provides the building with a continous air flow, if wished. The dining room, living room and kitchen is openable in different ways to be able to be used during different seasons as indoor- or outdoor spaces.

An open air wardrobe, inspired from the project HSB-living lab, is used as an example of simple architectural solutions. Stated by the HSB-living lab, Swedes tend to wash their clothes too frequently. By using outdoor air to ventilate the closet, the clothes can hang in a protected area while ”freshened up”.

Two entrances are positioned in opposite directions to one another to always have one covered from wind.

The dining room and living room are provided with glassed, sliding doors to the south, vents to the north and a folding wall in between. This make the space possible to changable and qualitative during all seasons. The library and living room are facing Änggårdsbergen with large glassed parts to let light from north in meanwhile framing the view of the mountain.

CHAPTER V
DESIGN PROPOSAL

SECTION A-A

Scale 1:200

FACADES

Description

Concept

The main idea with the building is the double facade, which is foldable and slidebale in different directions.

The outer part is non-insulated and protect against precipitation, sun and storm and is the primary facade during summer. The inner part is insulated and is used as the primary facade during the rest of the year.

Normal day

During a ”normal day”, one probably want large window areas uncovered to the view and light. The facade module can then be put together and slided away to open up the view, while some parts are folded down to become outdoor balconies.

Storm

With the increased risk of storm in a Swedish context, the risk of damaged buildings are higher. Hence, the building can be completely dense and covered by the outer shell when folding up balconies and sliding walls in front of openings. This scenario is only used during high risk warnings, and only one or two days at time.

Extreme heat

During summer the outer shell works as the primary facade while large parts of the insulated facade could be opened up. The facade module can then be slided with every second plank alongside the facade. This provides the indoor climate with shadow but still let breezes in, in the gaps. The rain garden, further cools the building down to avoid additional air conditioning systems. Balconies are folded down over the rain garden where one get in close contact to the surrounding vegetation.

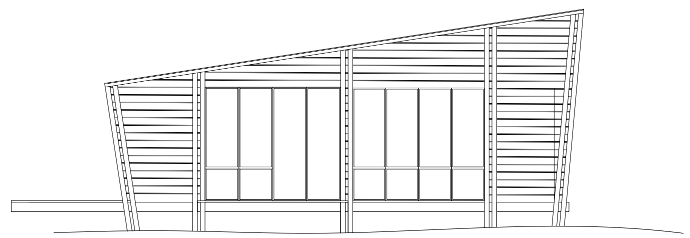
Some parts of the walls can be folded out to use as a wind cover on the breakfast balcony for example.

Material

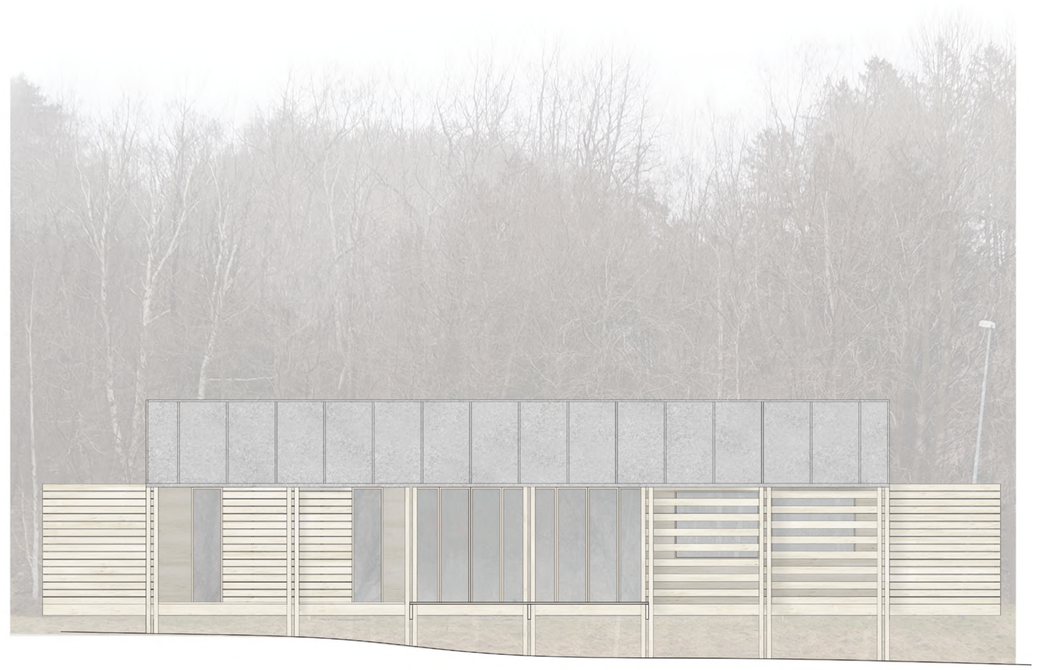
Both facades are in wood, where the inner one is cross laminated timber. Large parts of the inner walls, facing the common areas, are glazed to open up against the nature and rain garden.

FACADE “NORMAL DAY”

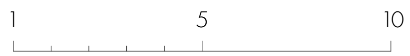
Scale 1:200



Facade towards south-east

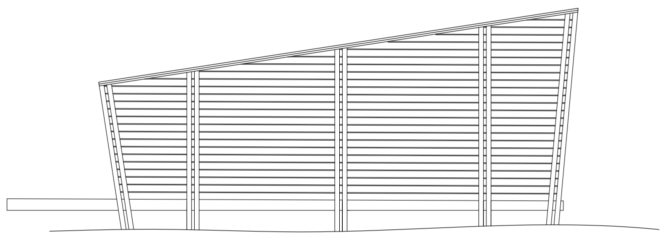


Facade towards south-west

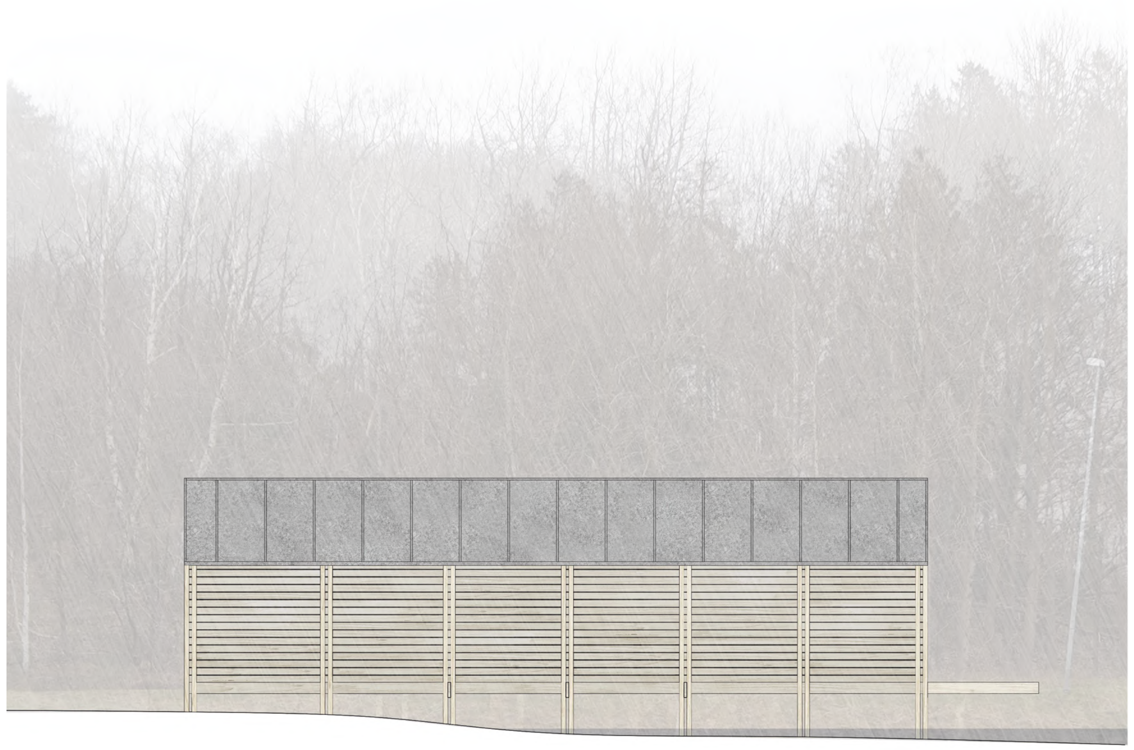


CHAPTER V
DESIGN PROPOSAL

FACADE STORM
Scale 1:200



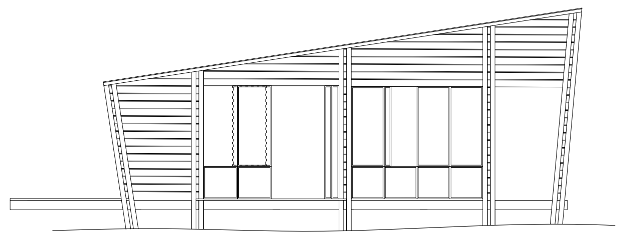
Facade towards south-east



Facade towards south-west

1 5 10

FACADE EXTREME HEAT
Scale 1:200



Facade towards south-east

Facade towards south-west

1 5 10

DETAIL SECTION

Description

Foundation

By building on stilts, rised above ground the building is protected from flooding. The wooden construction is distanced above ground when attached to the plinths. The depth of the soil on the site is 10-20 metres. To handle potential landslides poles are drilled to meet the rock.

The rain garden will change with different water levels and mainly contains of vegetation that manage high water environments.

In the lowest section a drainage pipe assures the water level to be stable and additional water is collected i a water reservoir possible to be used during dry periods.

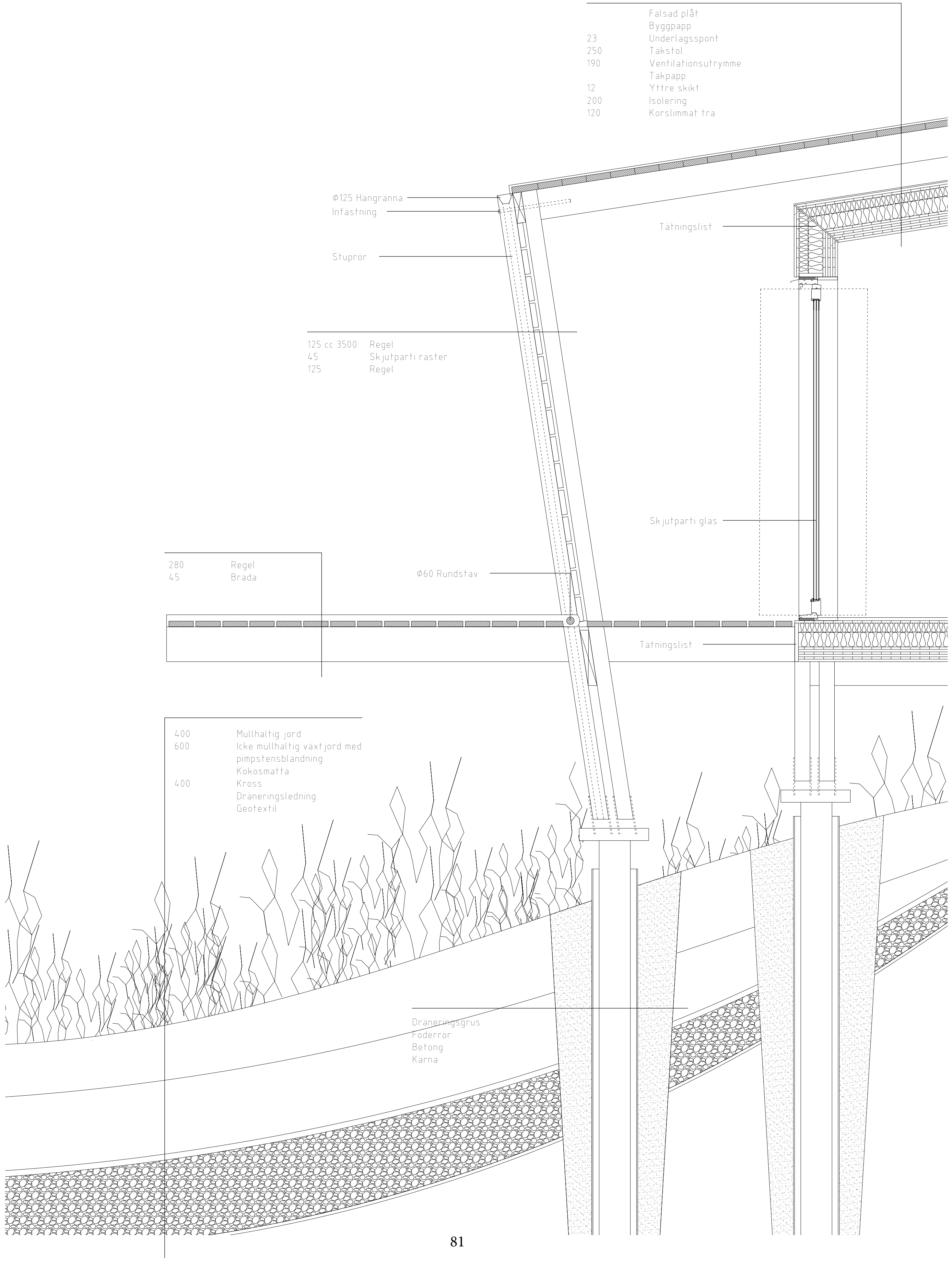
Construction

The building is divided in two structures, the outer one in a post and beam structure to be able to handle and adapt to vibrations during storm and potential landslides. The inner constrcution is self supported, consisting of cross laminated timber.

The outer roof is non insulated and light weighted to protect from weather while the inner volume is insulated to handle cold temperatures.

CHAPTER V

DESIGN PROPOSAL

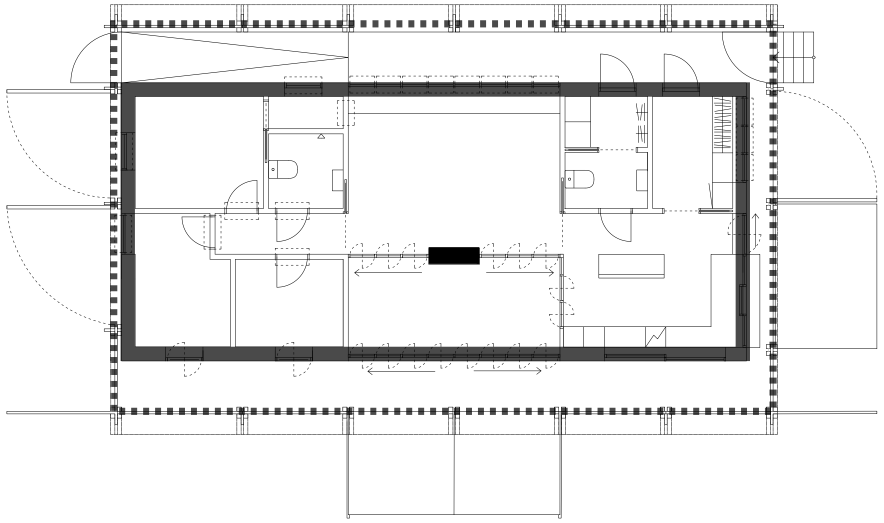


Zones

Heat source

Insulated zone

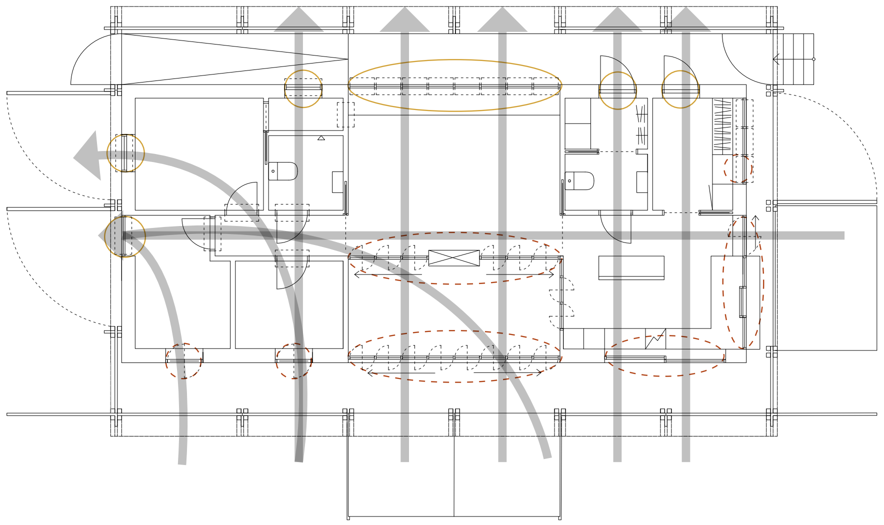
Protected zone, not insulated



Natural vetilation

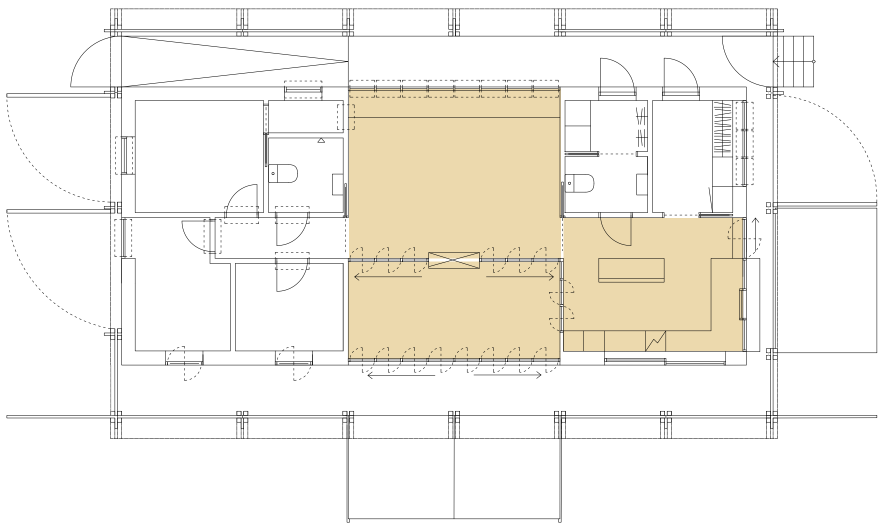
Out-take

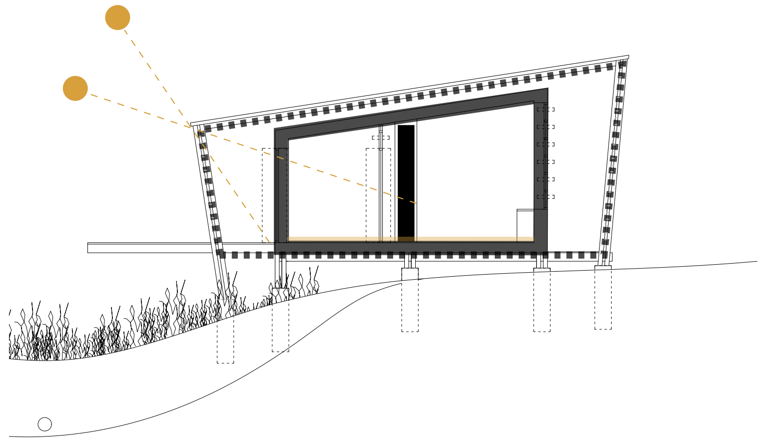
In-take



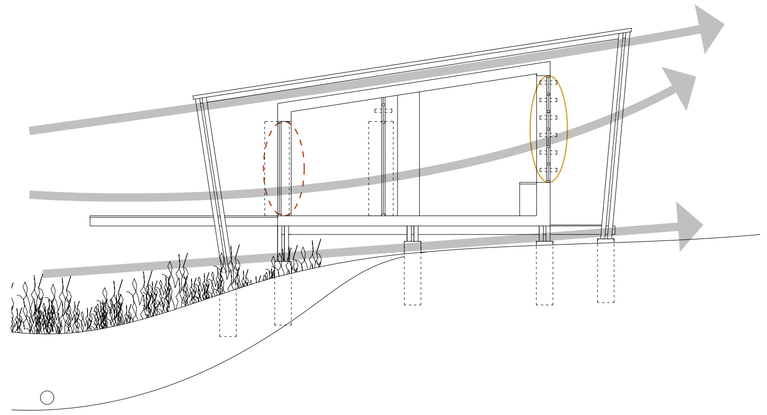
Flexible outdoor/ indoor zones

Space that could be outdoors and indoors





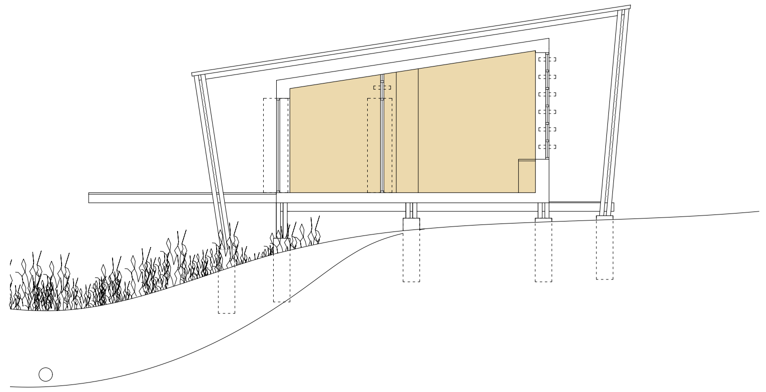
The outer shell works as a protective layer for precipitation, wind and sun and works as a primary facade during summer. The inner shell is insulated and works as the primary facade during winter.



Water reservoir, passive cooling

Cross ventilation is used in plan and section to allow breezes from different directions to cool the building down.

Breezes underneath the building cools the building down. In-takes directed to the most common wind direction is assigned lower and the out-takes to north-east is assigned higher.



Public rooms are openable with possibility to change between seasons. During winter the living room and dining room can be merged into a bigger social room.

Kitchen becomes partly outdoor kitchen towards "breakfast balcony"

CHAPTER V
DESIGN PROPOSAL

PREPARING FOR STORM

View from Axgatan towards west. Illustrating buildings prepared for storm

CHAPTER V
DESIGN PROPOSAL

LATE SUMMER EVENING

View from walking path towards north. Illustrating buildings during a warm summer evening when the outer shell is used as the primary facade.

CLOUDY DAY

View towards west from Axgatan. Illustrating a "normal day"

HOME OFFICE

View towards Änggårdsbergen from library / living room during fall, towards north

"As architecture and the weather are each a product of nature–culture relations, they inform, affect and alter each other in a complex developmental process that is never one way. Critical awareness of the weather, its causes and effects, is a valuable basis for design because, in all stages of building, it recognises architecture's dependence on its immediate and wider environments."

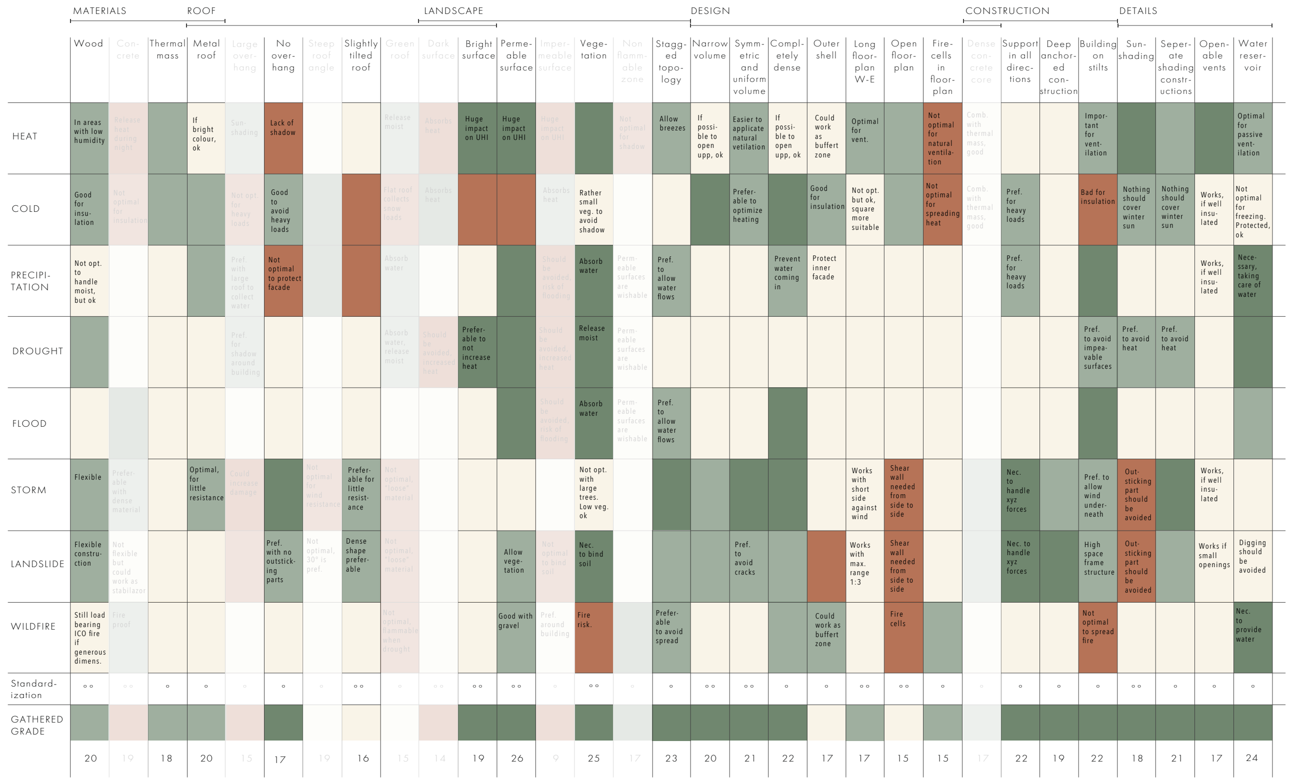
- Jonathan Hill, *Weather Architecture (p. 320*, 2012)

CHAPTER VI

DISCUSSION

EVALUATION

Based on design strategies



Achieved or partly achieved design strategies in the design proposal is seen "clear". The covered design strategies are not used. Total grade: 454

The aim with the design proposal is partly to investigate what architectual qualities we need to sacrifice to be able to handle the new climate, but also to see what new architectual qualities we can find when rethinking the way we are building.

The design proposal should be seen as a discussion material, additional to the theory, when discussing qualitative living spaces in relation to the changing climate.

The following part is an evaluation of the design proposal, based on the design strategies in the matrix presented in this thesis. When mentioning a design strategy it is marked in bold.

Materials and landscape

The design proposal is a **wooden construcion**, **supported in all directions**, to be able to handle vibrations and horizontal forces. A **metal roof** in **bright colour** to minimize the absorption of heat during the day is facing south-west and can be equipped with solar panels. All materials, particularly horizontal, are chosen to minimize the contribution to the urban heat island effect, which is an aspect that, in this thesis always is priorotized. The rain garden is a tool that function as a **passive cooling system** and **water reservoir** which absorb water and release moist to the atmosphere during night. All **impermeable surfaces**, such as asphalt and concrete, are avoided in the landscape architecture. In the parking area and walking paths, **reinforced grass** is used to minimize impermeable surfaces and still include as much greenery as possible. **Delay beds**, or dikes, are handling water on a bigger scale with a proposed communal water reservoir.

Vegetation function as an important role in many of the scenarios; to give shadow and release moist when temperature is high, binding soil in case of landslides, provide with **permeable surfaces** when heavy precipitation and to give protection against wind and storm. All of these factors make vegetation a priority and thereby weighs heavier than the design strategy to use a **fireproof zone** around the buildings, in case of wildfire.

The rain garden contributes with living qualities at the same time as it has the main function of handling the different scenarios. The buildings are arranged with a **stagged typology** where it let breezes in during summer, and the rain garden cools down the indoor climate. By tilting the facade strong wind breaks and is redirected over and under the building, meanwhile the stagged typology let the wind through to avoid creating wind swirls.

Roof

The roof is **slightly tilted** towards south to allow indoor hot air to escape towards north. The disadvantage with a slightly tilted roof is mainly the handling of heavy snowloads during winter, however the solution with **natural ventilation** is prioroized above that aspect in this proposal.

The shape of the roof makes the building asymmetric in the short led, which is contradictory to the design strategy to use a **symmetric volume** to survive natural disasters such as earthquakes and landslides. In this project that design strategy is not priorotized since the risk of landslides and earthquakes on this site is predicted as very low.

Footprint and volume

The building has a **rectangular footprint** within the **relation 1:3** to make the volume as dense and compact as possible and is rised on **stilts** to avoid creating wind swirls and to avoid being flooded. The construction is **deeply anchored** to handle vibratios and horizontal forces. With the folding **outer shell** the design strategy of both a ”**completely dense volume**” and an ”**open building**” is achieved. The inner flexible rooms makes the **floorplan open** and spacious and at the same time creates some **fire cells** when closed. Necessary for the bedrooms is the possibility to completely close the doors. By adding an out-take above each indoor door gives an opportunity to still ventilate the building. **Openable vents** are recurring in the building with in-takes toward south-west and out-takes towards noth-east.

The outer facade and **overhang** function as **sunshading** during summer, yet allow winter sun to reach indoors most of the year. The floorplan then extends and blurs out the lines of indoors and outdoors.

The building is directed with the long side **perpendicular to south-west**. This according to the most common wind direction to be able to use natural ventilation, and at the same time aiming for the design strategy to arrange the building **along west to east**.

Centred in the building is a **fire place** to contribute with heat during cold months using material with high **thermal mass** to spread the heat. The overhang provides with sunshading during summer and let sun in during winter.

Gathered grade

The evaluated design proposal gives a result where the gathered colour is always green or yellow, and never red. Hence, one could state that the design proposal is approved by the matrix.

The next step

One way to illustrate the relation between what is necessary and what is desirable could be to make the chart three-dimentional, by adding one axis. This did not fit into the scope in this thesis, however, by imagining a third axis where every day living qualities (z) is weighted against each scenario (y) and each design strategy (x), one could imagine this could contribute to an interesting discussion and possible new answers.

CONCLUSION
Summary & reflection

Design strategies for extreme weather

As climate is changing scientists emphasize the importance of taking predicatble and unpredictable weather extremes into account. In a Swedish context this means increasing periods of extreme heat, extreme cold, heavy precipitation, drought, storm and natural disasters. To be able to handle these extreme events we need to rethink the way we construct our buildings. By studying solutions in global reference projects we can learn and adapt our building techniques, urban planning and detail work to be able to handle the new climate situation.

The gathered design strategies for each extreme weather is meant to work as a library for different stakeholders. While every context and microclimate is different, combined design strategies for each context should be analysed and used. The table presented and summarized in the end of chapter III is a tool to weigh the strategies against each other and will look different for each project. This helps to choose design strategies in advance and to evaluate the project in recede.

The aim with the second part of this thesis was to test the theory in a design proposal and to evaluate from a practical example.

Reflection

The thesis question (Q1) *What extreme weather could occur in Sweden within 10-20 years?* is answered in the first chapter and is shortly concluded; increasing periods of extreme heat, extreme cold, heavy precipitation, drought, storm and natural disasters.

The second question (Q2), *How can a small house be constructed to withstand the consequences of the climate crisis concerning extreme weather in Sweden?,* is partly answered by the design strategies, but mainly by the design proposal in chapter V. Important for the design proposal is an established site analysis. This provides argument when evaluating which design strategies to use for the certain site. Hence the design proposal could be defined as an example of ”form follows function”.

The main challenge with merging all design strategies to a design proposal is to handle the fluctuations of temperatures during different seasons, as a unique Swedish scenario. By using openable in- and out takes, flexible open areas and double facades this could be worked around. Aspects, such as what humidity does to a wooden building in an insulated space during summer, did not fit in the scope in this thesis, however would be necessary to study in a continuous phase.

The third question (Q3), *What impact would the findings to withstand future weather scenarios for a small house have on planning?,* is meant to be continous discussed with the design proposal as a base.

By learning from this, the most important aspect in urban planning is to treat different zones as microclimates. These should in turn be able to work self suffient considering water, drought and fluctuations in temperatures. Water reservoirs in different scales should be considered when planning in municipalities, but also in smaller neighbourhoods and individual dwellings. Periods of drought and water restrictions is predicted to continue to increase and by collecting the water during predicted increasing precipitation periods we can buffert and even out the differences. Rain gardens and ”delay beds” alongside streets and walking paths takes care of water, which will avoid floodings from heavy precipitation periods in micro climates. The importance of taking care of water could not be emphasized enough.

The main issue with rising temperatures in urban areas is the urban heat island effect, mentioned briefly in this thesis. Hence design strategies that provides heat to the surroundings, mostly design strategies for extreme cold, should be strictly reflected upon. Using dark surfaces and impermeable surfaces which absorbs heat should therefore be avoided in an urban climate, where they are more harmful than helpful in the different scenarios.

A known problem in urban heat islands are the barriers, created by buildings, which prevents wind and breezes to move and cool down the outdoor air. By stagging buildings instead of blocking air flows this could be solved. Increasing wind tunnels when blocking air flows in another space should also be evaluated when planning neighbourhoods.

By shadowing dark surfaces with trees and vegetation urban surfaces can keep the temperature down and not absorb heat during the day. Temperatures underneath trees are always a couple degrees lower than its surroundings. Large trees in turn binds soil and stable the ground to avoid landslides and erosion. These aspects strongly supports the fact that greenery should be priorotized in urban planning.

When planning for buildings in a larger scale than a single family home, knowledge from this design proposal can be taken. Elements, such as a double facade and sun shading elements could be adapted in a larger building. Balconies, living room and dining room should be more flexible and work as outdoor/indoor space if the facade is more flexible. This would make the indoor climate more enjoyable in appartments during summer time, where the situation today is problematic with increasing indoor temperature. With the Swedish well insulated buildings, the warm air gets trapped inside. Instead additional cooling systems are added. When planning for new buildings, it should be a standard to avoid additional cooling systems. A flexible facade and a passive cooling system could be a solution in many situations.

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APPENDIX

THE FORECAST OF TOMORROW

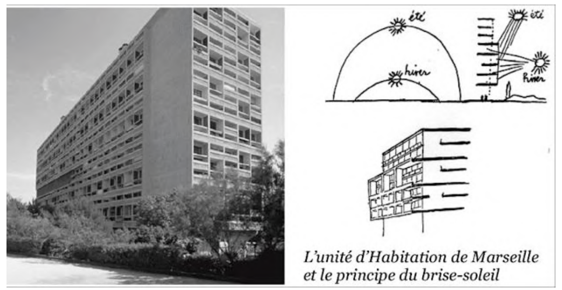
Exploring design strategies to develop a building withstanding future Swedish extreme weather

Johanna Mattsson

BUILDING FOR HEAT

Reference projects

Marika-Alderton house
Australia, 1994
Architect Glenn Murcutt



Type Berlin
Berlin - Charlottenburg, 1957
Architect Le Corbusier

Windcatchers of Yazd
Iran

House of the desert
Goraffe desert, Spain, 2018
OFIS Architecture

Villa d'Este
Tivoli, Italy, 1550-1572
viator.com

BUILDING FOR COLD

Reference projects

Skýli
Iceland, 2016
Utopia Arkitekter

Princess Elisabeth
Antarctic, 2009
International Polar Foundation

Même
Hokkaido Japan, 2011
Kengo Kuma & Associates

High House
Quebec Canada,
Delordinaire

Equippment building
Riksgränsen, Sweden
Photo from 2022

Cottage
Narvik, Norway
Photo from 2022

BUILDING FOR RAIN AND DROUGHT

Reference projects

Family home on stilts
Inle Lake, Myanmar

4.3 Skt. Kjelds kvarter
Copenhagen Denmark, 2012
Municipality of Copenhagen, SLA

The Treehouse
Belgium, 2012
Baumraum

BUILDING FOR STORM

Reference projects

Straume
Ålesund Norway, 2016
Knut Hjeltnes

Allmannajuvet Zinc Mine Museum
Sauda Norway, 2016
Peter Zumthor

BUILDING FOR NATURAL DISASTER

Reference projects

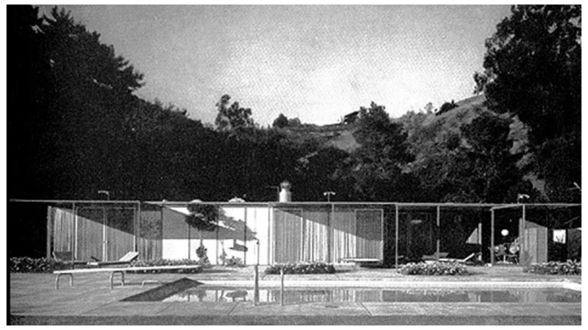
Japanese Pagoda
Miyajima Japan

Hurricane proof building
Usa

FLEXIBLE BUILDING

Reference projects

Chamberlain cottage
Wayland, USA. 1941
Marcel Breuer
Photography: Robert M. Damora



Fields House / Case study house n°18
Beverly Hills, USA. 1956-58
Craig Ellwood

Walker Guest House
Florida, USA. 1952
Paul Rudolph
Photography: Ezra Stoller

Garden House
Eindhoven, Netherlands. 2016
Caspar Schols
Photography: Jorrit 't Hoen

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