NORDIC MICROCLIMATE RESPONSE

A STUDY ON MICROCLIMATE DESIGN AND ITS IMPACT ON SEASONAL LIFE IN THE COASTAL TOWN OF ÅKREHAMN, NORWAY

SOPHIA SPOCK

LUND
UNIVERSITY

SUDes
Sustainable Urban Design

ASBM01: Degree Project in Sustainable Urban Design, May 2024 Lund University,
Sweden Faculty of Engineering,
Lund Institute of Technology Department of Architecture and the Built Environment
Sustainable Urban Design Master's program
All Artwork and Photographs are Done by the Author Uness Referenced Otherwise.

NORDIC MICROCLIMATE RESPONSE

A STUDY ON MICROCLIMATE DESIGN AND ITS IMPACT ON SEASONAL LIFE IN THE COASTAL TOWN OF ÅKREHAMN, NORWAY

Author
Sophia Spock

Supervisors
Teresa Arana Aristi, Lecturer SUDes, LTH

Erik Johansson, Associate Professor, Senior Lecturer,
Housing Development and Management, LTH

Examiner
Lars-Henrik Ståhl PhD, Professor, Head of Unit, LTH

Jury
Jenny B. Osuldsen Partner and Senior Landscape Architect, Snøhetta and Professor in Landscape Architecture at the University of Life Sciences Ås, Norway

Peter Siöström Senior lecturer, Department of Architecture and Built Environment at Lund

ACKNOWLEDGEMENTS

I would like to thank the many people who have helped me undergo this journey. I would like to especially express my appreciation for my supervisors, Teresa Arana Aristi and Erik Johansson. They have been very helpful in developing the concept from an initial idea to a design proposal, and I have valued their expertise tremendously when it came time to process and analyze the project's data and communicate the information of this thesis in my drawings. I would also like to thank all my professors and classmates from the SUDes program at Lund University. I have learned a lot from our time together, and it has been very inspiring to learn from each other's backgrounds and perspectives. Last but not least, I would like to thank my friends and family for their support and encouragement.

I really appreciate it.

TABLE OF CONTENTS

INTRODUCTION

01

This project explores the way design can adapt existing local areas to be better suited to their changing climates. In doing so it analyzes the current and seasonal climate conditions of Scandinavian towns such as Åkrehamn, Norway. Using available sun, wind, and weather data, the design is evaluated with climate modeling software to help visualize the climate conditions that the thesis aims to work with. From this analysis, the project researches and develops strategies to help mitigate the impact of seasonal changes in the town microclimate. As the town continues to grow this adaptability is also a valuable aid for the town's community driven centers and connections.

To do so, the project establishes a deployable toolbox of climate strategies and intervention methods that will be placed on the site strategically based on the climate modeling findings. The interventions will have various performance scales, including large-scale building placements and smaller seasonal methods. Doing so allows for multiple levels of seasonal interactions as people move within and use the space throughout the year. By focusing on year round adaptability, my thesis explores how a town might further engage with its microclimate as it develops to create public spaces that remain pleasant and lasting overtime.

In doing so, it aims to answer the following questions:

How can microclimate analysis help identify vulnerable areas in local centers?

How can climate responsive design strengthen local centers and thier connections?

How can we apply climate strategies to create pleasant and lasting public spaces that respond to seasonal climate and movement?

WHAT IS CLIMATE RESPONSIVE DESIGN?

Climate Responsive design is an approach to architecture and urban design that emphasizes the design's relationship with its local environment and microclimate conditions (Chauhan, Priya). In doing so, this design process aims to increase the comfort of places by improving the site's local microclimate, so that it is more suited to the seasonal needs of the local residents and climate.

However, to fully understand climate responsive design we must also understand what the microclimates they are responding to are. A microclimate is defined as being "the suite of climatic conditions measured in localized areas near the earth's surface which include temperature, light, wind speed, and moisture" ("Microclimate."). In the context of urban design a microclimate might refer to streets or squares, which connect to influence the range of outdoor comforts we experience in a local area like a town or city. When used together with climate responsive design, these smaller climate conditions can be studied seasonally, allowing us to understand how the microclimate changes and how our design responses might impact the way people use the space.

A glossary is included on the following pages to help identify additional terms about the microclimate and its relation to climate responsive design.

"Being the ones who design the city, we need to be aware of the consequences of our designs on the way people experience the microclimate"

(Lenzholzer, Sanda)

WHY DOES IT MATTER?

In the 21st century we face an increasingly changing climate. As Jonas Gahr Støre, the current Prime Minister of Norway has stated, ***"the impact of climate change is already here. The world needs to act together to reduce global warming"*** ("Norway."). As urban designers and architects, a large part of addressing climate change is making sure we are designing for urban and local microclimates. The climate is changing, but by taking those changes into account at a site specific scale, and allowing room for adaptability as well as seasonal spaces or movements in our projects, we can still create public spaces that are valuable for their communities.

As designers we are uniquely situated to mitigate climate change's overall impact on our built environment, because so much of our local microclimates is influenced by the buildings surrounding it. This includes building heights and positions, materials used, the placement of trees and other vegetation, and even additions to buildings like awnings or rain shelters (Lenzholzer, Sanda). By incorporating climate analysis into our initial design phases, we can gain a better understanding of the challenges and opportunities of the site, which in turn can help us to create spaces that are better suited to a location's climate and inhabitants.

A large part of this process is understanding how to respond to the local microclimate in the design process. Because the microclimate impacts how people feel in a space, it thus has a large impact on how often the space is used. People tend to gather where they are most comfortable, so public spaces that have pleasant sunlight, gentle winds, and access to shelter and drainage in the case of rain, get more use than spaces with strong winds, too much or too little sun, or unpleasantly damp environments. Understanding this creates more comfortable spaces for people to live in, and, by designing with the site's microclimate specifically in mind, helps us to create spaces that will remain pleasant and lasting as they respond to the conditions around them.

GLOSSARY

Climate
The general weather conditions of a region. This includes sunlight, precipitation, wind speeds and temperatures.

Microclimate
The collection of climate factors around a site that impact how the outdoor area feels to people in it. These factors include sun, wind and rain in multiple variations. Microclimate differs from climate because it is responding to the conditions of a specific area, which can be influenced by the built environment.

Mitigation
Mitigation is the act of reducing the intensity of something. In regards to climate it means to reduce the impact the climate has on the built environment around it.

Urban Sprawl
Urban sprawl is when urban areas continue spreading outwards instead of densifying at a central location. It often happens surrounding large scale urban developments, but can also occur around smaller towns and is usually made up of low density single family homes.

Ground Cover
Refers to the surface materials being used on the site. Permeable surface materials like gravel, pavers, or even greenery help to add drainage to the site while impermeable surface materials like asphalt and concrete cause water run off when it rains.

Solar Equinox
The midpoint of the solar year. These are the days when the day and night are even and occur on March 21st and September 21st.

Summer Solstice
The height of the solar year. This is the day when the sun is up the longest and occurs on June 21st.

Winter Solstice
The shortest day of the year. This is the day with the shortest amount of sun in the northern hemisphere and occurs on December 21st

SITE ANALYSIS

02

While the concept of climate responsive design is increasingly important throughout the world, it is also an incredibly site specific topic. Climate is changing everywhere, but the ways we respond to it vary based on the unique needs and struggles of the microclimates we are mitigating. Because of this, this project will be focused along a singular site, though it is important to remember that the processes of site analysis and toolboxes of climate intervention strategies can be helpful in any climate condition.

When we talk about climate and the built environment, most of the discussion today is dominated by the idea of reducing microclimate effects in cities that are already experiencing negative climate impacts (Olgyay, Victor). While this is indeed important, Nordic microclimate Response focuses on how climate analysis can be incorporated from the early stages of a town's development to help mitigate the need for greater intervention later. It is much easier and more effective for a municipality to improve the microclimate of vulnerable public spaces throughout its development process, rather than waiting till the end. This can be done by identifying and incorporating climate strategies from the initial planning stages, so they can be used to support the town's design goals and visions as it develops.

Specifically, This project is located around the town of Åkrehamn, Norway. Åkrehamn is a coastal town on the southwest coast of Norway with a population of approximately 7500 people. It is located in the Karmoy region between the larger regional cities of Bergen and Stavanger, and is close in proximity to the more local city of Haugesund. Åkrehamn is well positioned for the task of incorporating climate strategies in the early stages of town development, as it is currently noted as a local center for the Karmoy region, meaning it is expected to increase in density over the next several years. By strategically placing additions to Åkrehamn's built environment, we can use climate-responsive design strategies alongside traditional site analysis to locate and create public spaces that will remain pleasant

ÅKREHAMN, NORWAY

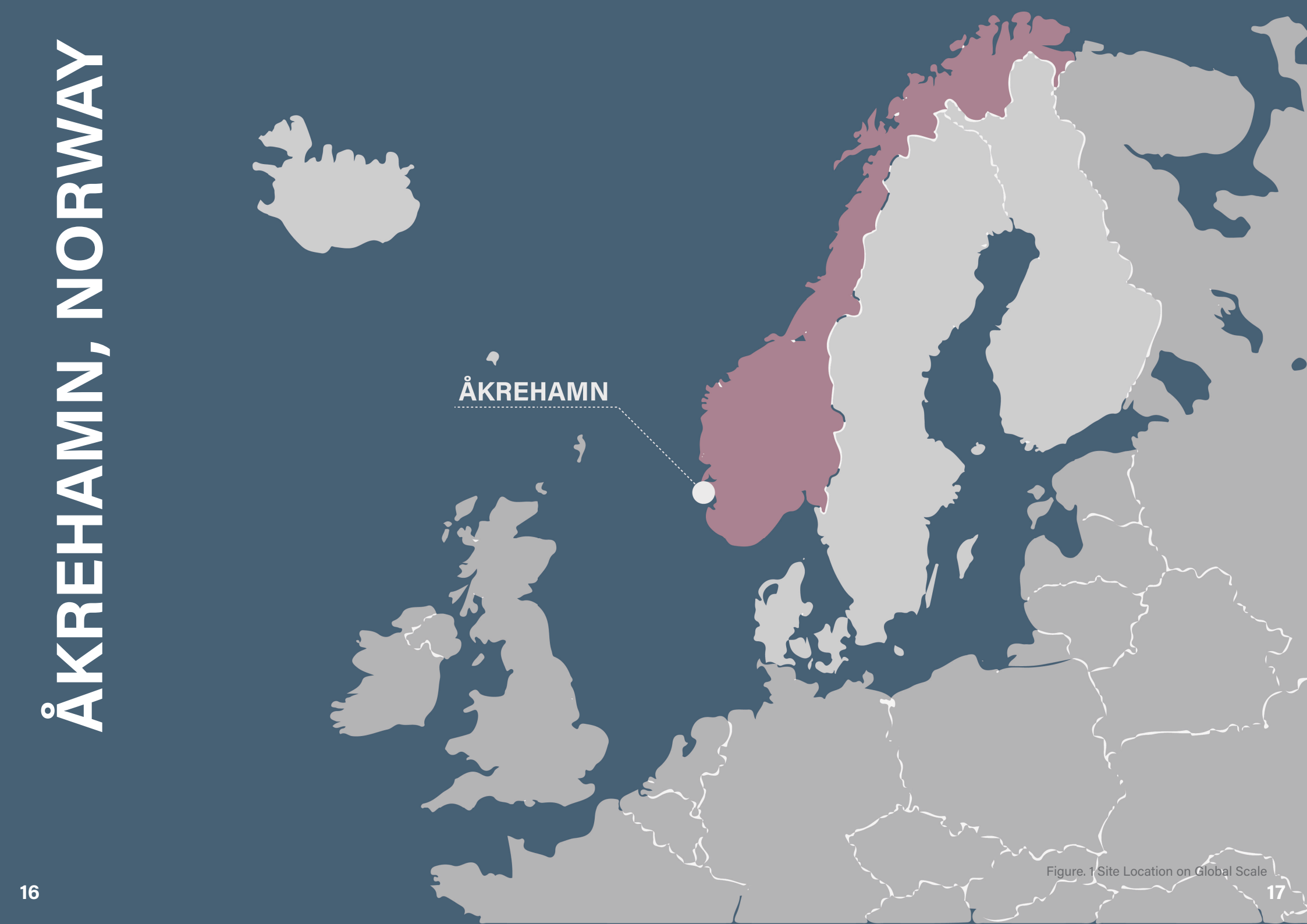


Figure. 1 Site Location on Global Scale

The Southern Fjords of Norway are known for having a particularly varied climate, with harsh winds and rainy weather, and its coastal cities are no exception. Located in the south west region of Norway, Åkrehamn is located in one of the rainiest portions of Norway, with an average of 1840 mm of precipitation throughout the year. This precipitation occurs mainly during the fall and winter seasons, and is increased by coastal proximity ("Seasons and Climate in Norway.").

The southwestern coast of Norway also faces uniquely seasonal wind conditions. The predominant wind in the summer is a cold coastal wind, while the winter features a warmer wind from the south ("IEM :: Site Wind Roses."). This means that, while the wind remains strong throughout the year, it changes directions seasonally, so various strategies must be used when mitigating the wind's impacts on the local microclimates.

This sense of seasonal wind conditions follows a similar trend to Norway's seasonal solar access. Like most Scandinavian cities, towns in the Fjords of Norway have a dramatic difference in sun access throughout the year based on their distance to the equator ("Climate of Norway."). This causes very long days in the summer, and very short days in the winter, which must also be addressed with different seasonal design strategies.

Paired together, the seasonality of the winds, precipitation, and solar access make the south western coastal cities of Norway a good choice for studying climate patterns and interventions because they establish a hierarchy of seasonal weather patterns that can be addressed through design.

"In Fjord Norway the weather is constantly changing. Don't be surprised if you get rain, sun, wind and even snow in the same day"

("Seasons and Climate in Norway.")

Figure. 2 South Western Fjord Climate Collage

REGIONAL LOCATIONS

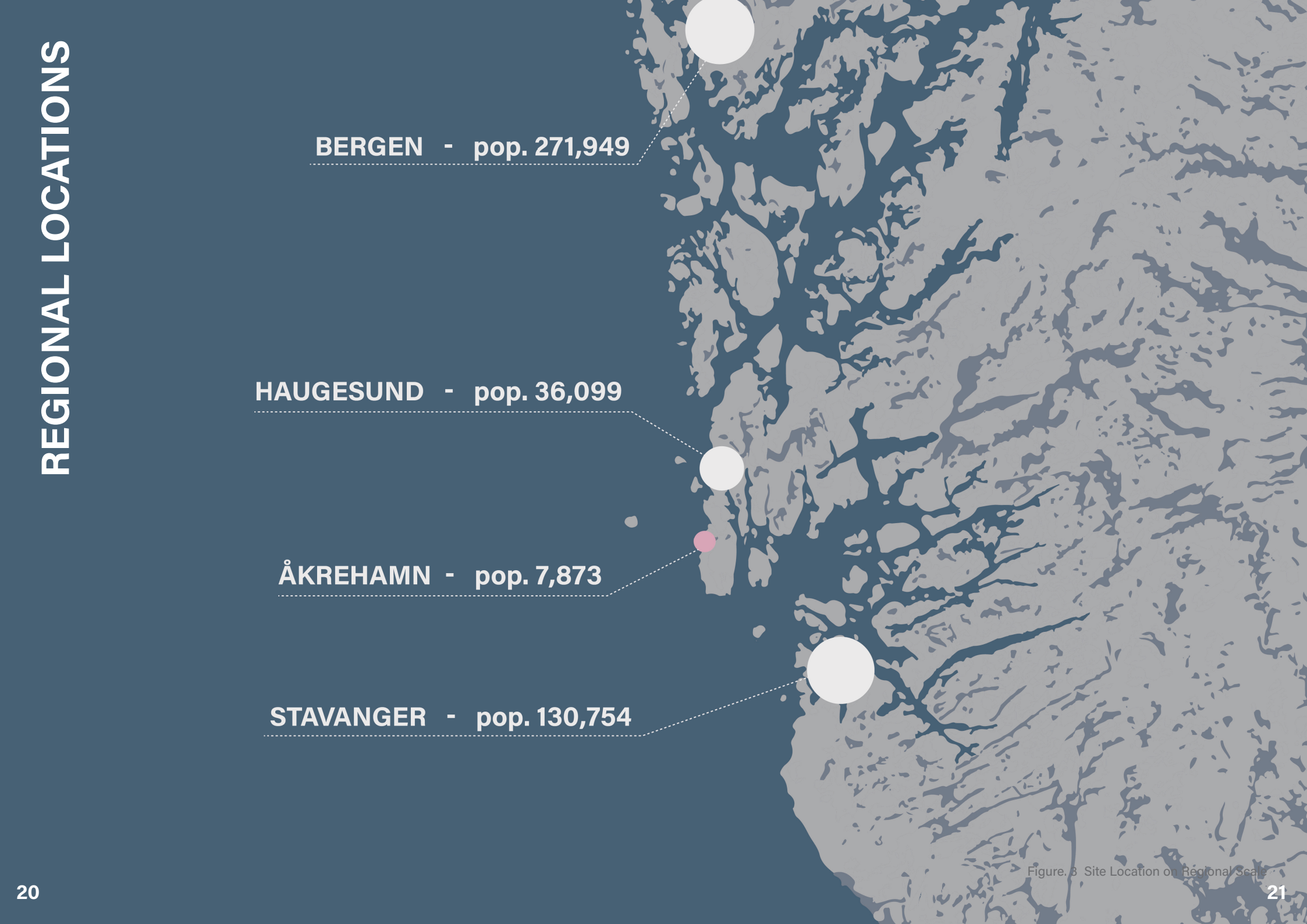


Figure. 8 Site Location on Regional Scale

LOCAL CONTEXT

The Karmoy region of Norway is characterized by beautiful natural landscapes, and "The residents feel a great deal of pride in the beautiful landscape surrounding [them]" (Europan 17). However, as the urban areas of the region have grown, accessing these green spaces has become harder, and they have become more isolated. Because of this, creating better connections between the natural areas is important for the area. Additionally, many areas of the region were developed post automobile, and are characterized by sprawl, which has been indicated in pink in the adjacent map. These spaces are mostly occupied by single family residential dwellings, and are low in population density.

Unlike some of the other regional centers established in the Karmoy region, Åkrehamn is located along the coast, causing it to have stronger coastal wind conditions that impact its microclimate. It is also located between two significant natural and hiking areas, Ørnahaugen Gapahuk and Åkrasanden, which means connecting these green spaces is an important concept for the town. This sense of green connection also has the ability to improve the local microclimate, making it a valuable design strategy to consider moving forward. However, encouraging and connecting these green spaces requires a shift away from the sprawling, car-centric characteristics of the region. Instead, promoting growth around Åkrehamn's city center would reduce the issue of sprawl, and addressing the microclimate to promote walkability instead of car-dependency would help establish it as a local center for the region.

"In the regional plan, Åkrehamn has received the status of local centre, meaning that the town can be densified with housing, business and retail."
(Europan 17)

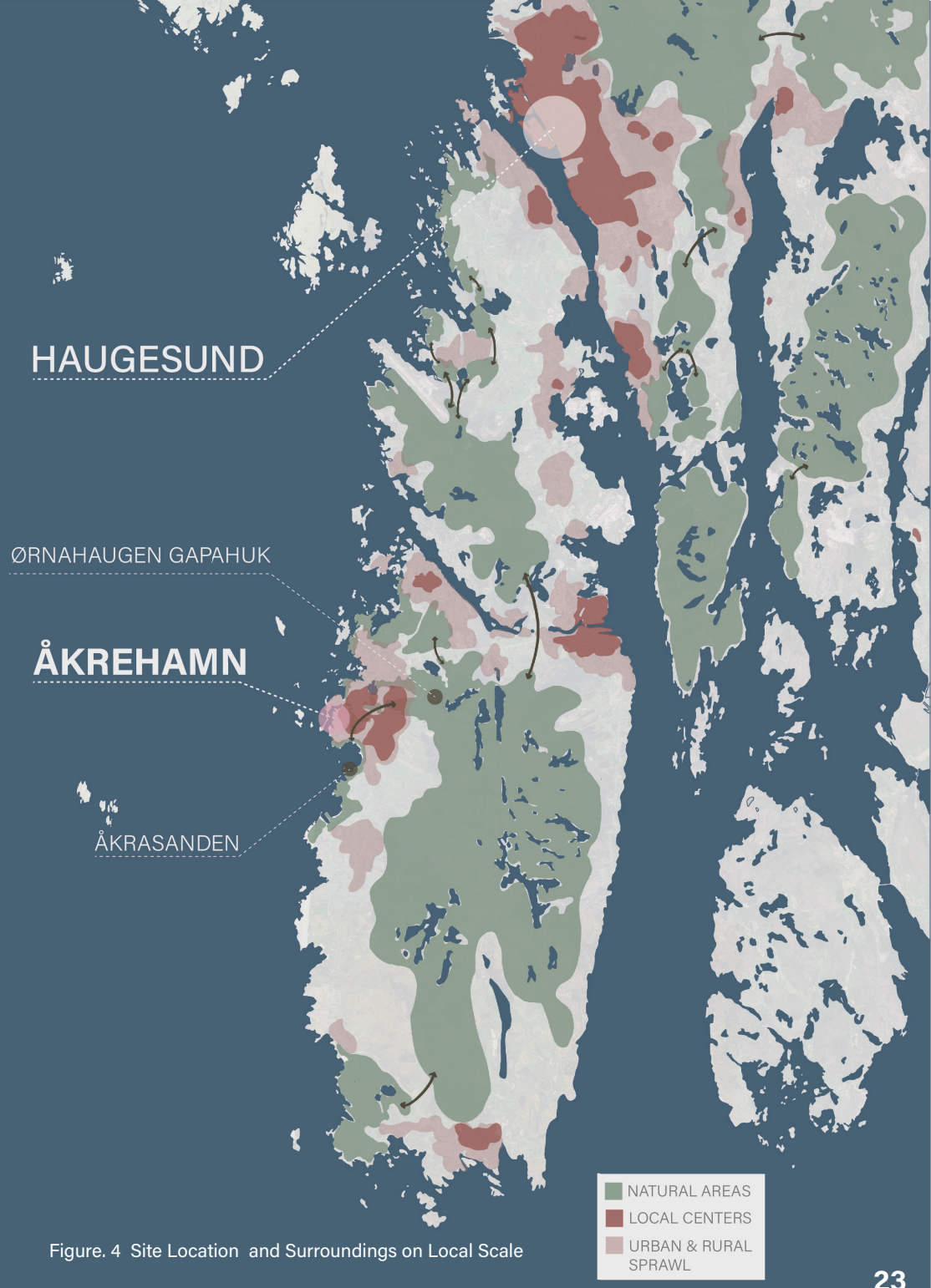


Figure. 4 Site Location and Surroundings on Local Scale

"The name Åkrehamn is made up of the words for field (åker) and harbour (hamn)... Åkrehamn grew from farms characterised by large fields as well as good access to the sea and fishing spots"

(Europan 17)

"The historic centre is by the older fishing harbour, while since the 1950s, new development has spread along the main road passing through the town." (Europan 17) In this historic image of the site from the 1960's we can see the divide between the settlements along Åkrehamn's harbor and the main road located further inland. Between these two spaces was historically mostly occupied by farmland, but became more populated residentially and commercially over time untill it was was recognized as a city in 2002. (Europan 17)

Figure. 5 Satalite Image of Åkrehamn from 1965 (Europan 17)

Figures. 6-10 Historical Image of Åkrehamn from 1965 (Europan 17)

In Åkrehamn we can see the initial town development along the sea. Initially, this caused buildings to be constructed right along the water's edge, which established the existing town harbor area. As cars began to be introduced, throughout the 20th century, this development trend shifted, and the city started growing farther inland. This encouraged growth, but reduced the town's historic connection with the sea (Europan 17).

Figure. 7

Figure. 8

Figure. 9

Figure. 10

CURRENT SITE

"Åkrehamn is formally classified as a town, but does not feel like one. It lacks a clear urban structure, and has no discernable centre."

(Europan Norway.)

In the current satellite image of Åkrehamn many areas are residential. While some of this is multifamily, most of it is detached single family housing, which has encouraged further urban sprawl along the area (Europan 17). Additionally, there is a significant amount of paved areas for parking and roadways, which has further encouraged the car-oriented, rather than walkable development of the town. This has led to there not being a clear town center, which impacts Åkrehamn's ability to provide areas of walkable community interaction, or establish a center to focus development.

Figure. 12 Satalite Image of Åkrehamn from 2020 (Google Earth)

Figures. 13-17 Current images of Buildings and Conditions in Åkrehamn (Europan 17)

In the present day we can see how Åkrehamn has grown from the 1960's and how that growth has moved from the harbor area towards the inland street. Pictured on the right include images of the historic town houses that are built closely together, the town's cultural center and library, The expanse of parking and pavement that has been added, and the town park.

Figure. 14

Figure. 15

Figure. 16

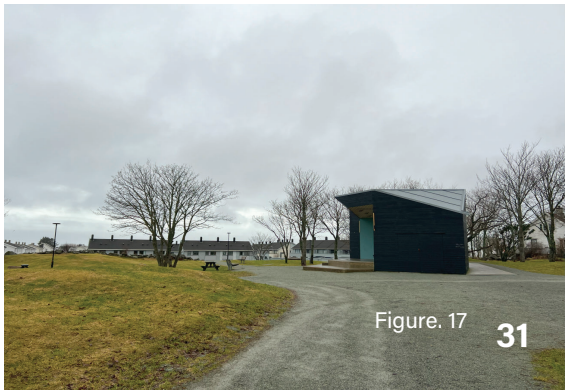


Figure. 17

History

"The area has several cultural monuments and cultural environments of value" (Europan 17) There are buildings from several eras in Åkrehamn, including older wooden buildings from the late 1800's and more recent mixed use buildings from the 20th century. places with historic value should be disturbed as little as possible.

Harbor

"Access to the sea varies...." (Europan 17) Areas where the harbor is accessible have been outlined in figure 1. There are not many places available near the town center, so these connections should be expanded.

Commercial

"Businesses and services are spread out a little, but are mainly organised along the county road" (Europan 17) The county road is outlined in dark gray on figure one. There is currently not much clear connection between the country road and the sea.

Public Space

"Public and general functions are partly scattered..." (Europan 17) There is a concentration of public spaces around the outlined town center, but creating a clearer distribution would help with the town's development into a local center.

Streets + Parking

"A pedestrian in the city will find it difficult to locate uninterrupted footpaths and routes that are safe to travel by foot" (Europan 17) Much of Åkrehamnis designed for driving, so creating connections within the town center that prioritize people is important.

Building Typologies

"A very high proportion of the homes in Åkrehamn are detached houses... It is expected that there will be increased demand for apartments in the city centre, close to important services and amenities" (Europan 17). As Åkrehamn continues to develop into a local center, there should be a focus on mixed use and on low level multifamily housing so it can blend with its surroundings.

Landscape

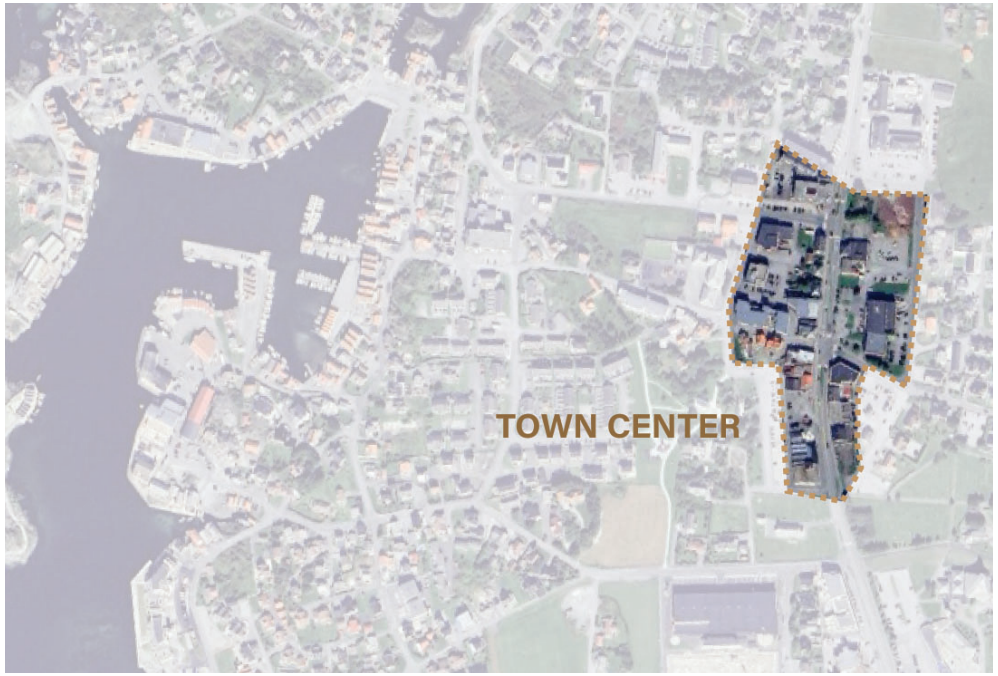
"The park in Åkra is a green lung...that [is] valuable for biodiversity." (Europan 17) Retaining and expanding the green connections between the town center and the

Figure. 18 Context Map of Åkrehamn

As Åkrehamn develops into a local center it has been involved with Europan 17, and is looking to answer the following questions;

> ***"How can the site be developed to create an attractive town centre?" and "How can we create high-quality and inclusive outdoor areas and urban spaces?"*** (Europan Norway.).

There is a focus alongside this to improve connection between the main road and the harbor, as well as increase connectivity to nature throughout the town (Europan Norway.). Additionally the town specifies what areas it considers the town center and future development site, which informs the project moving forward. When creating these connections and developments, it is important to consider the role microclimate will play in helping the town achieve its goals.



Figures. 19-20 Maps of the Existing Town Center and Marked Development Site for Future Growth

CLIMATE TRENDS

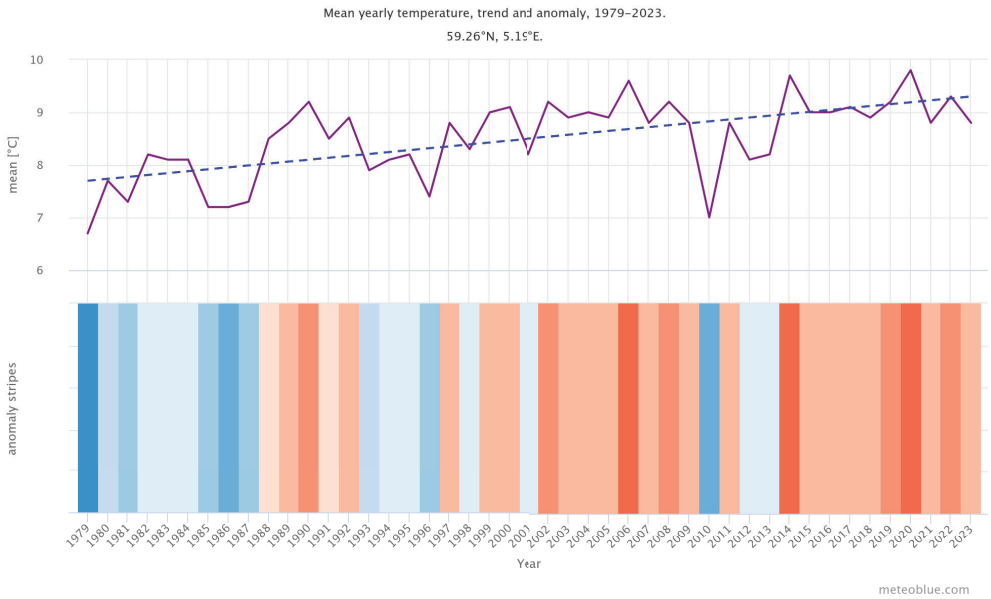


Figure. 21 Graph of Yearly Temperatures in Åkrehamn ("Climate Change Åkrehamn.")

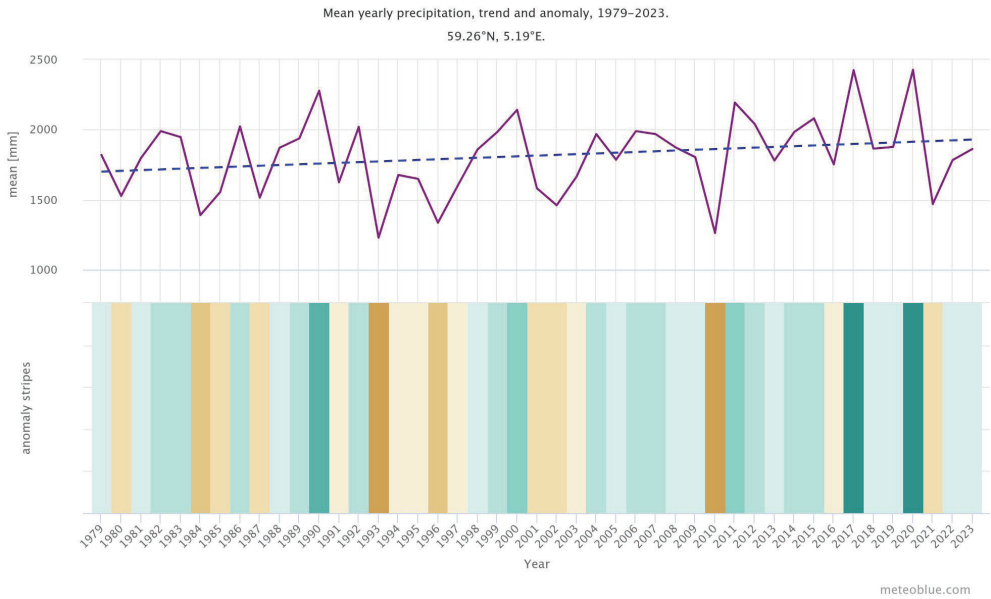


Figure. 22 Graph of Yearly Precipitation in Åkrehamn ("Climate Change Åkrehamn.")

In this data, we can see that the mean yearly temperature has been trending upwards since 1979, which reminds us that the climate we experience in the city is changing. It has increased by almost 2 degrees on average over this time, which suggests that overtime design strategies at the site will need to respond to warming temperatures.

Warmer temperatures are not the only change. The yearly precipitation amounts have also increased in this time frame, with the average precipitation value increasing by almost 250mm per year. This change suggests that more attention to drainage and rain shelter is important for the city moving forward.

SEASONAL MICROCLIMATE

Figure. 23 Collage of Seasonal Climate in Åkrehamn

When design responds to the micro-climate of a site it is important to consider how that climate changes throughout the year. In Åkrehamn the winters have a lot of snow and little sun, the spring has more sun, and strong winds, the summer has significant sun with cold coastal winds, and the fall has significant rain and cloud cover.

MICROCLIMATE

03

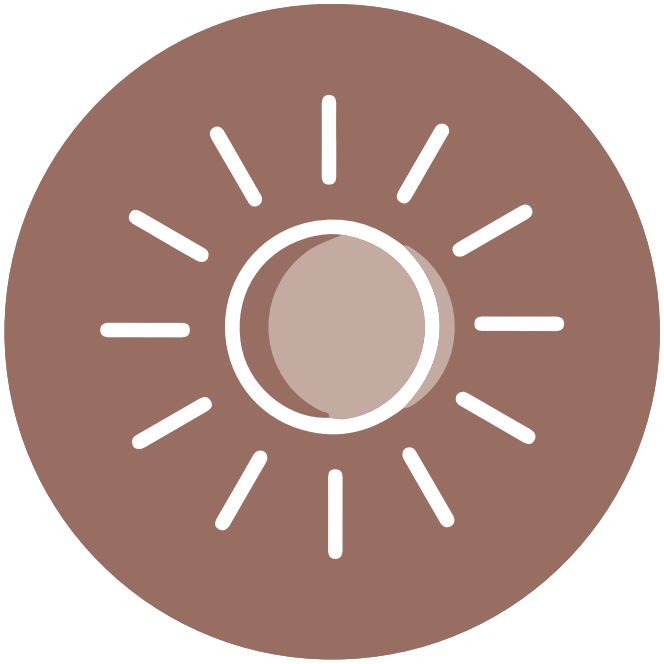
Humans are only comfortable within a small range of temperature, wind and humidity conditions. This is why we reach for different clothes or even choose to stay inside when we find the conditions outdoors to be outside of our comfort zone (Lenzholzer, Sanda). Thus, if we want to get more use out of outdoor public spaces, we need to be able to influence the microclimate to be closer to our comfort zone.

This section of the thesis explores the conditions that impact the local microclimate, including the three largest factors; the sun, which impacts thermal comfort, the wind, which impacts air movement, and precipitation, which impacts humidity levels ("Microclimate."). These factors together influence how people feel within a local space, so it is important to recognize which areas are working well, and which could be improved with climate strategies in order to help the town achieve its design goals.

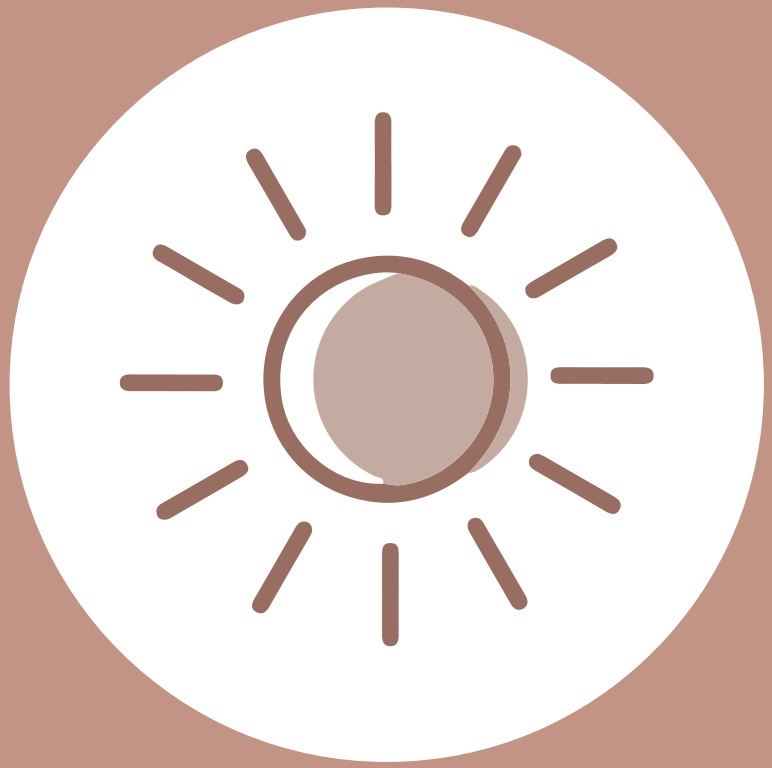
By analyzing conditions that impact microclimate factors and the seasonal microclimate conditions of Åkrehamn, we can identify vulnerable areas within the site that might benefit from climate responsive design strategies. Rather than exploring new spaces that might increase local sprawl, the microclimate analysis is instead framed around the previous stage of site analysis by being incorporated into the future development of the town center. Throughout, the social and community impacts of the site's microclimate are also considered, so the analysis is able to support Åkrehamn's growth as a valuable local center for the region.

How can microclimate analysis help identify vulnerable areas in local centers?

MICROCLIMATE FACTORS



SUN



The sun has a very strong influence on the temperature around us. The rays from the sun play a key role in warming local climates. In warmer areas this is something to be avoided, but in colder climates like Åkrehamn, the sun is a valuable resource for improving the town's microclimate.

The sun impacts light and temperature in public spaces, which causes it to have a strong impact on the microclimate. At the human scale, it is also heavily influenced by urban design, because the positioning of buildings and smaller scale items like trees and awnings around the site causes them to cast shadows across public spaces. Because of this, it is beneficial to study solar access when designing, so that these shadows are not cast in areas where having access to the sun would be beneficial. Likewise, in some seasons having additional shading can be beneficial, so considering the placement of temporary or seasonal shading opportunities like awnings or trees can also improve the local microclimate of a public space.

SOLAR PATHS

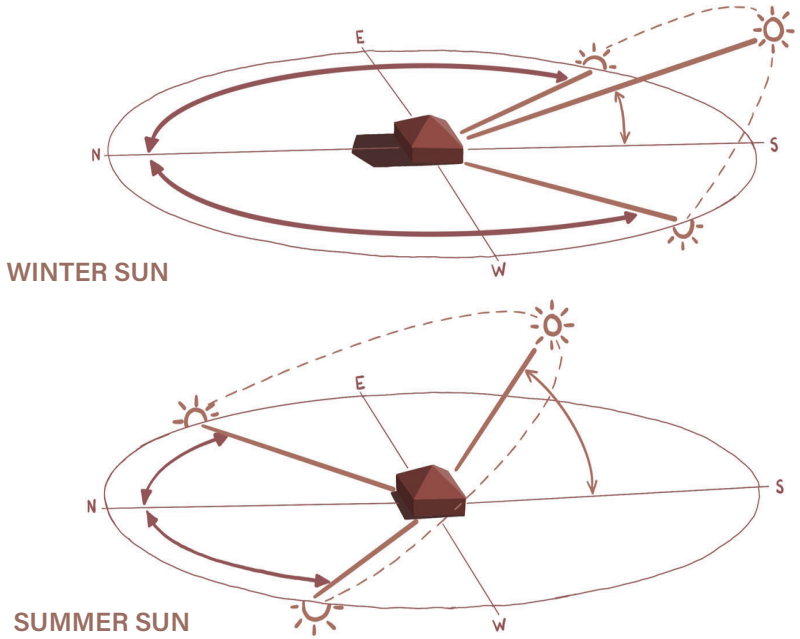


Figure. 24 Diagram of How the Sun's Position Changes Seasonally in the Nothern Hemisphere. Information gathered from (Lenzholzer, Sanda)

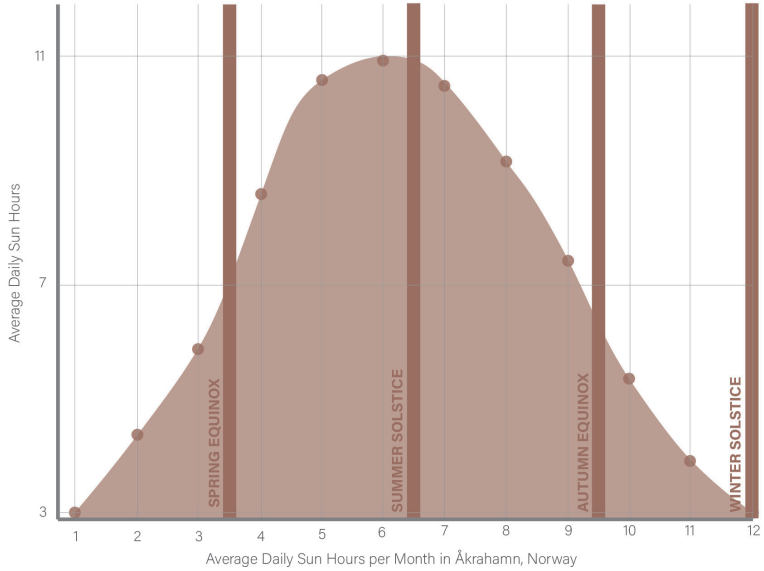


Figure. 25 Monthy Sun Hours that Account for Cloudiness. Data collected from ("Åkrehamn Climate.")

Figures 26-29 Pictured Above are Several Examples of the Seasonal Solar Conditions in Åkrehamn.

The amount of sun can vary throughout the year, especially in the northern hemisphere where the angle of the sun is quite low in the winter, but high in the summer (Lenzholzer, Sanda). Figure 25 shows the difference in solar access throughout the year in Åkrehamn, with the winter only having about 3 hours of sunlight, the equinox having about 7 hours, and the summer having an average of 11 hours of full sunlight each day.

SUN

SUMMER SUN ANALYSIS

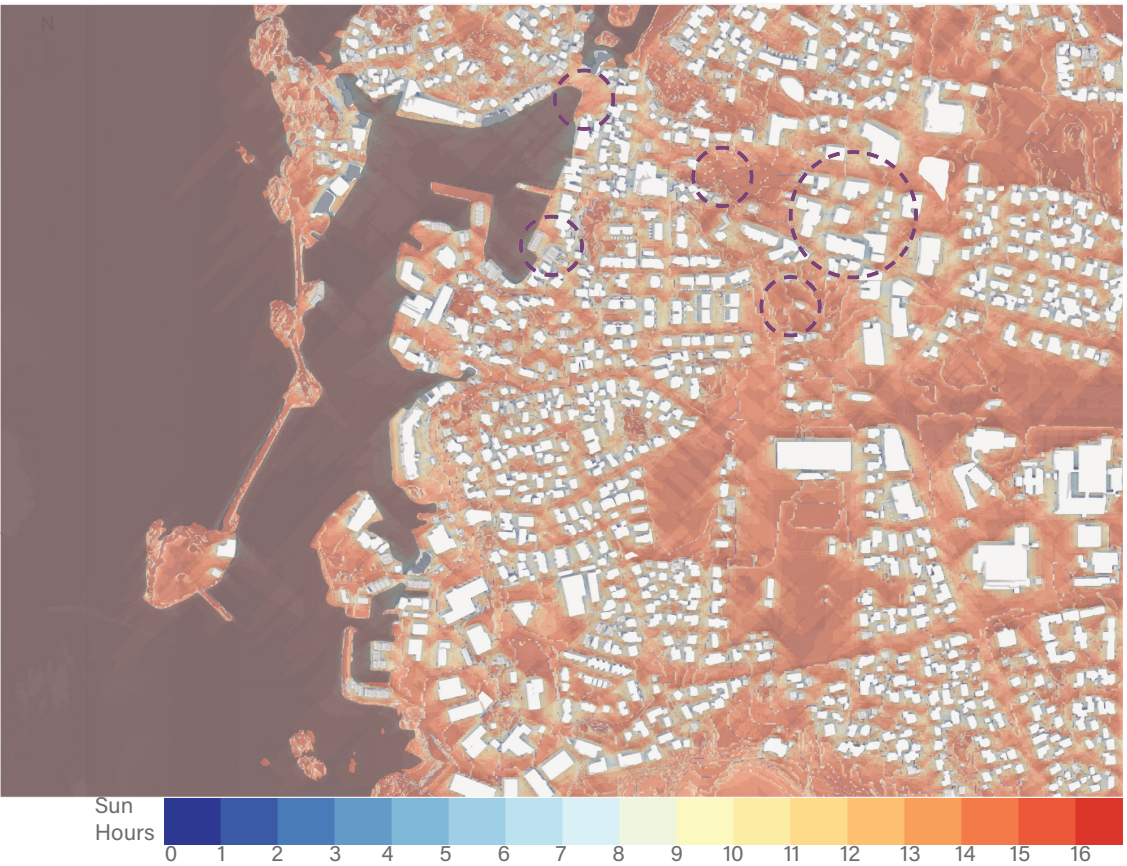


Figure. 30 In this Solar Analysis the Areas of the Development Site with Significant Solar Access in the Summer Have Been Circled. These Areas Could Benefit From Some Access to Shading in this Season.

WINTER SUN ANALYSIS

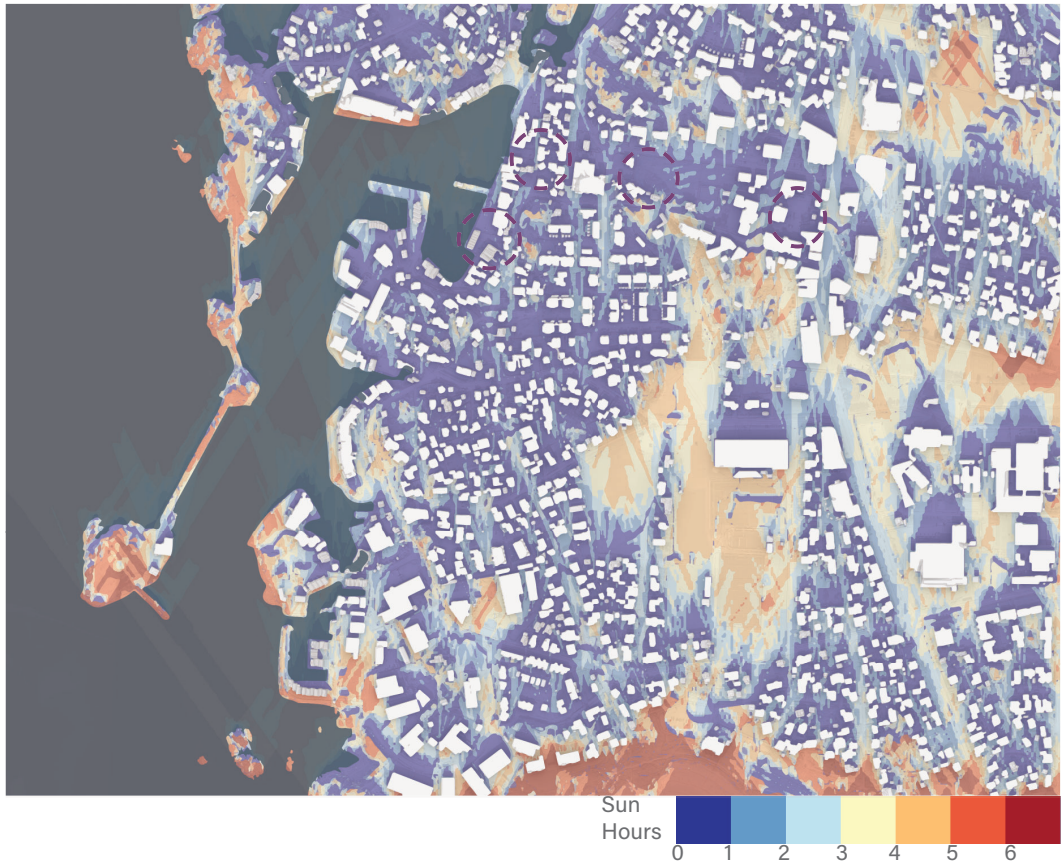


Figure. 31 In this Solar Analysis the Areas of the Development Site with a Lack of Solar Access in the Winter Have Been Circled. While There is No Way to Add Sun, Strategies Such as Added Lighting and Thermal Radiation can be Used to Make Them More Pleasant Seasonally.

SUN

THERMAL ENVIRONMENT

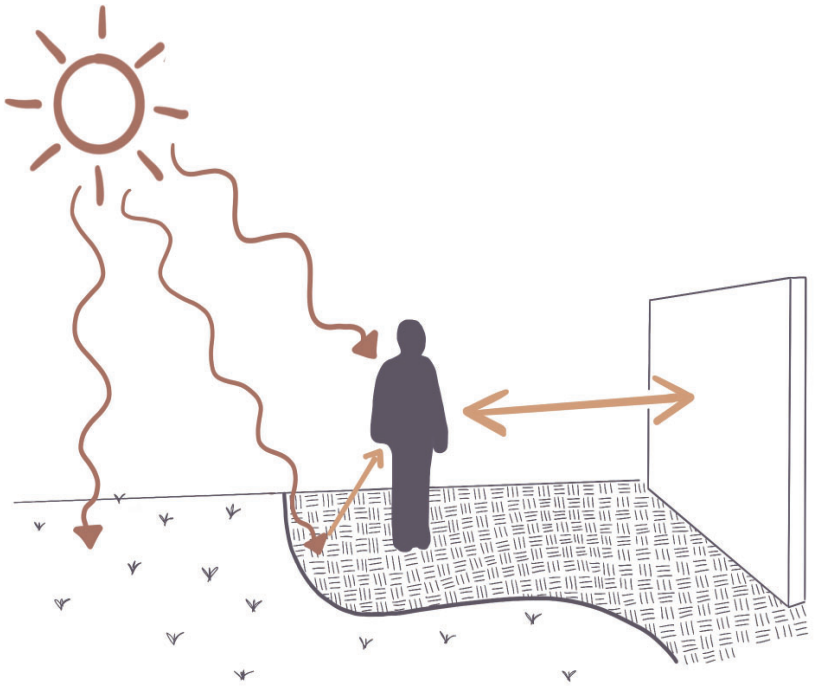


Figure.32 Diagram of How Materials Impact the Thermal Environment. Information gathered from (Lenzholzer, Sanda)

ENVIRONMENTAL RADIATON

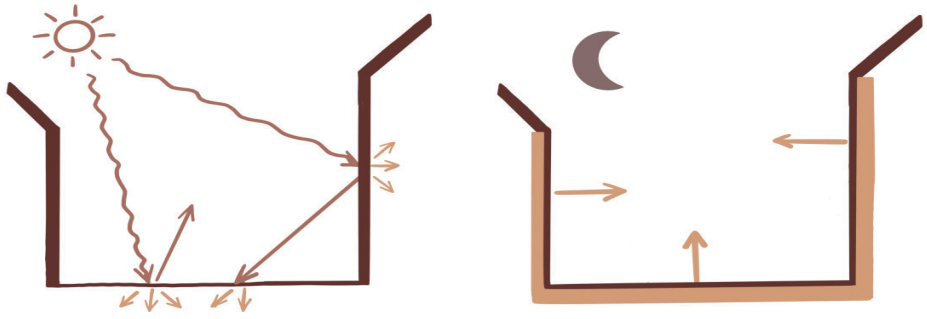


Figure. 33 Diagram of How Materials Absorb and Radiate Heat. Information gathered from (Lenzholzer, Sanda)

Figure.34 An Aerial View of the Current Town Center, Which is Largely Paved Space (Europan 17).

The materials around a site have a strong impact on its thermal environment, which can cause the microclimate to be warmer or cooler. For example, lightly colored surface areas reflect more sunlight, while darker surfaces tend to absorb more of the solar radiation. This can make paved areas have a warmer microclimate than unpaved spaces, as seen in figure 32.

RAIN

The rain is representative of all precipitation types, which impact the humidity levels around us. The presence of precipitation can be controlled on a site by providing drainage opportunities and shelter during rainy seasons, and incorporating vegetation to provide more consistent evaporation for the town's year round microclimate.

Like the sun, precipitation also has a strong influence on the microclimate and can be addressed with urban design. While it is important to incorporate shelter to provide spaces for people to get out of the rain, it is also important to consider where the rain and other forms of precipitation go on the site. As a harbor town most of the water is either being absorbed into the groundwater or being directed towards the sea. However improving ground cover and vegetation opportunities in public spaces can help them maintain a more pleasant microclimate. Considering where the water goes when it leaves the square also provided opportunities for expanding green connections within the town center of Åkrehamn towards the harbor.

PRECIPITATION TYPES

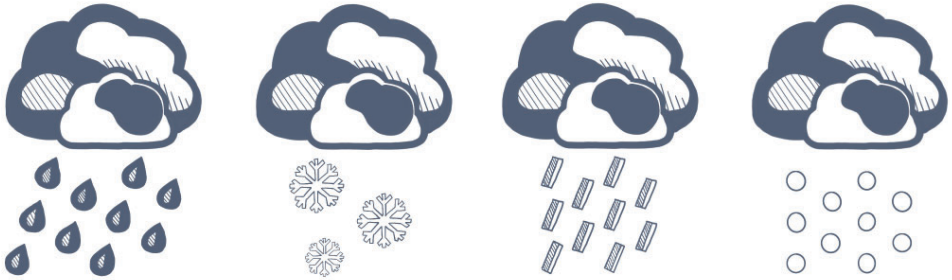


Figure. 35 Diagram of Precipitation Types

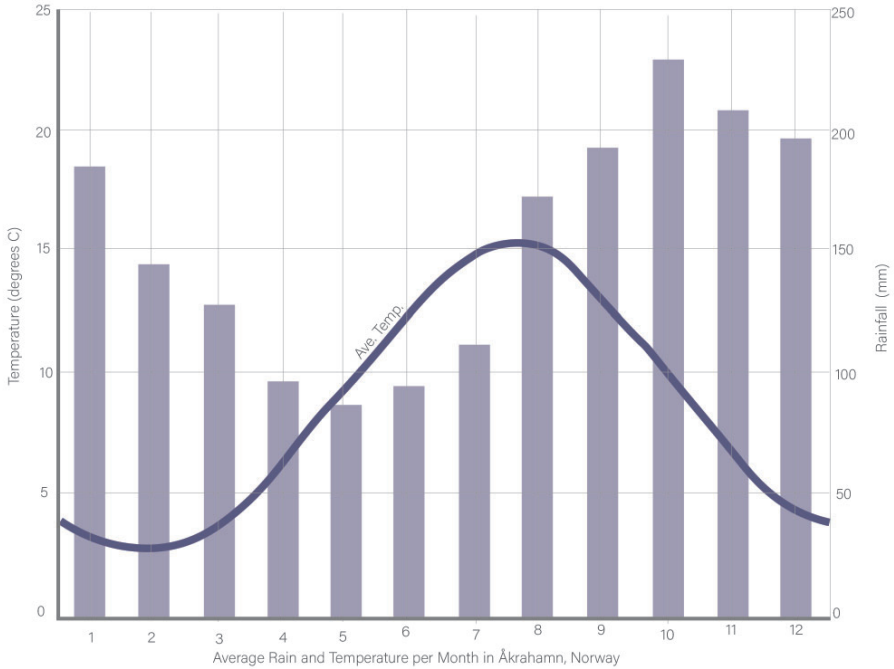


Figure. 36 Graph of Rainwater Amounts in Åkrehamn
Data collected from ("Åkrehamn Climate.")

RAIN

Figure. 37 Pictured Above is One of the Few Undeveloped or Paved Areas Available for Drainage within Åkrehamn's Development Site. There is Potential to Connect this Area with Other Nearby Green Spaces to Improve Drainage on the Site.

Precipitation on a site includes all forms of water, including rain, sleet, snow, and hail. In Åkrehamn most of the precipitation occurs in the fall and winter months, as seen in figure 36. These precipitation amounts are lowest in the late spring to early summer months from April to July, and highest in the fall months from September to November.

GROUND COVER ANALYSIS

Figure. 37 In this Ground Cover Analysis the Areas of the Development Site with Significant Paved Surfaces That are in Need of Better Drainage Opportunities Have Been Circled.

Figures. 38 - 41 Pictured Above are the Current Ground Cover Conditions for the Areas Circled in the Ground Cover Analysis.

PSYCHOMETRIC CHART

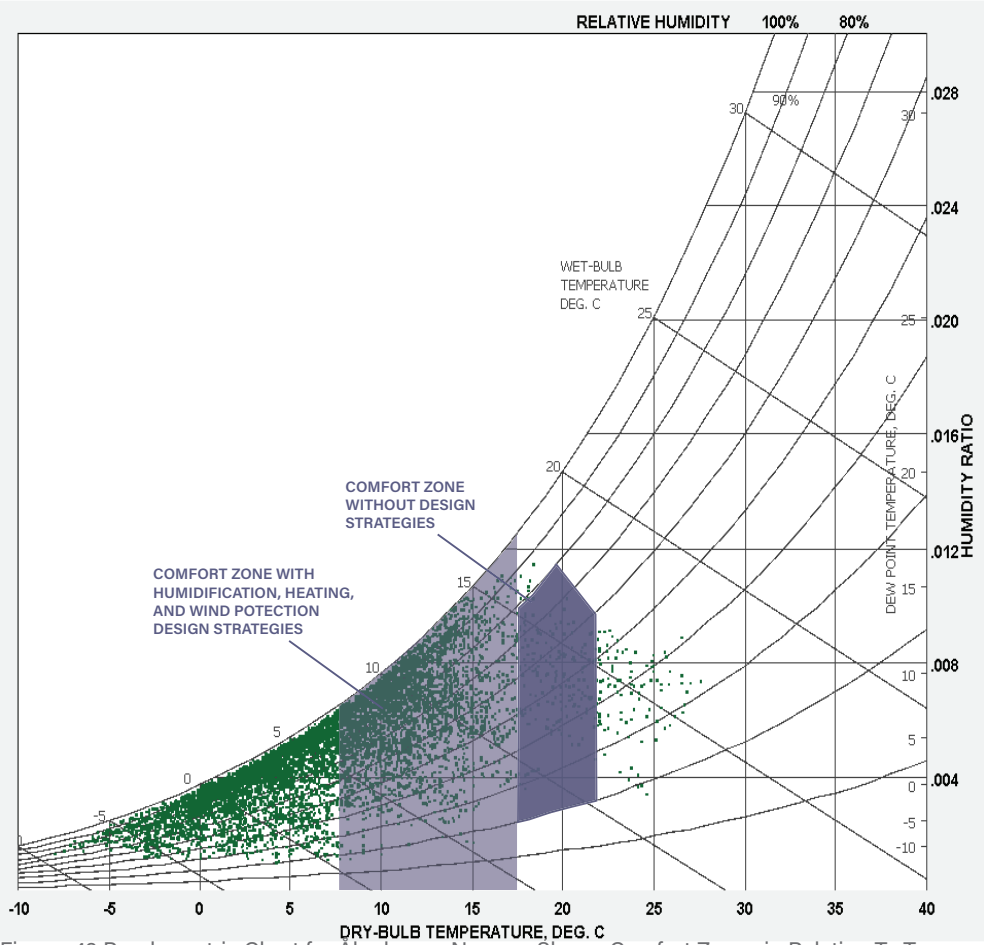


Figure. 42 Psychometric Chart for Åkrehamn, Norway. Shows Comfort Zones in Relation To Temperature and Humidity ("Climate Consultant.")

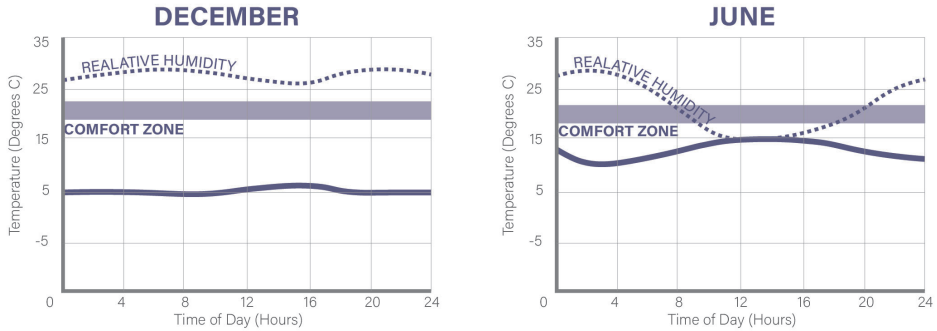


Figure. 43 Graphs of Seasonal Realative Humidity and Temperature in Relation to Comfort Zone. Data Collected from ("Climate Consultant.")

RAIN

EVAPOTRANSPIRATION AND HUMIDITY

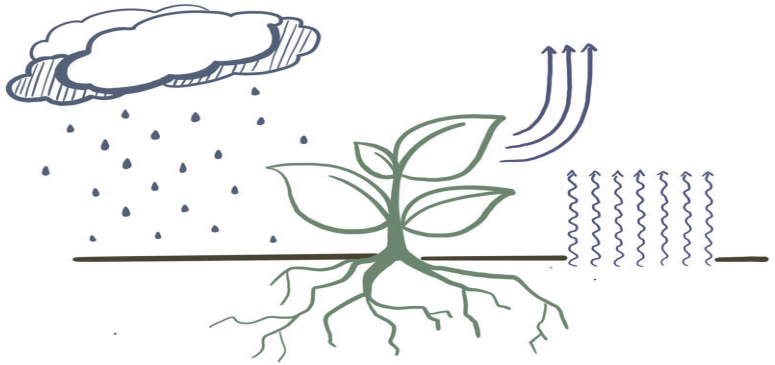


Figure. 44 A Diagram of the Evapotranspiration Process. Information gathered from (Lenzholzer, Sanda)

Psychrometric charts are used to understand the humidity levels and temperatures that people feel comfortable in. In figure 42 we can see the marked comfort areas with and without microclimate interventions on the psychrometric chart for Åkrehamn, which suggests strategies will be neccessary to improve the comfort of outdoor spaces. By looking at the seasonal relative humidity levels in figures 43, we can see that while the realative humidity overlaps with the comfort levels in June, they remain above the comfort level for all of December. This suggests that in the winter months more shelter is needed, whereas in the summer months techniques can be used to help the humidity remain more constant throughout the day. We can aslo see that throughout the temperature is under the comfort zone, so more solar access is helpful. One technique is evapotranspiration, which is diagrammed in figure 44. Through this process, water is able to be stored in vegetation like trees or other plants on the site. This water evaporates from the plant slowly (Lenzholzer, Sanda), which allows the humidity levels directly surrounding the plant to remain more constant throughout the day.

WIND

The wind influences the way air moves around us. Gentle air movements can feel nice, while strong movements can make us feel pushed around and uncomfortable. In windy areas like Åkrehamn, finding ways to help distribute or redirect strong winds becomes important for the town's microclimate.

Urban design has a strong impact on wind patterns. All wind has to change direction when it hits an obstacle, which includes buildings in towns and cities (Lenzholzer, Sanda). Because of this, areas behind buildings in the direction of the windflow are often sheltered from strong winds, whereas narrow spaces between buildings cause wind to speed up. At the ground level of public squares and streets, trees and other vegetation are also valuable tools for slowing the speed of winds, and can thus be used to create a more pleasant microclimate (Lenzholzer, Sanda). Studying wind patterns on the site can help us to understand what areas might be more prone to strong winds, which can help us place wind mitigation strategies in more effective ways.

SEASONAL WIND ROSE

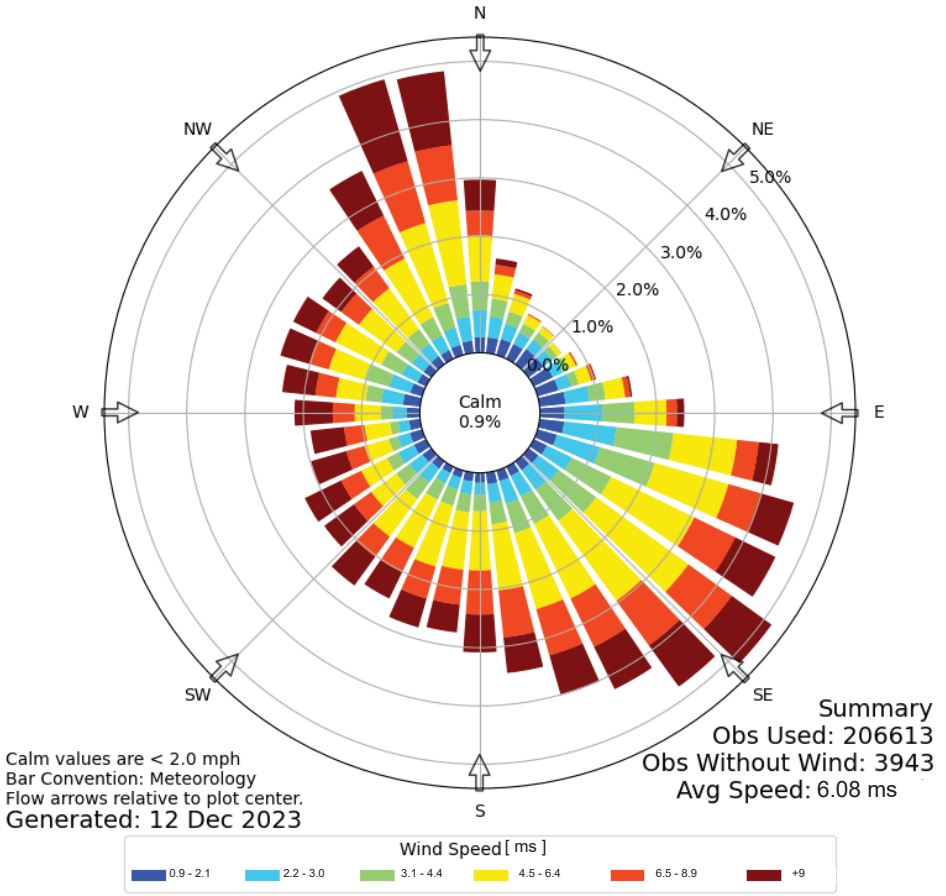
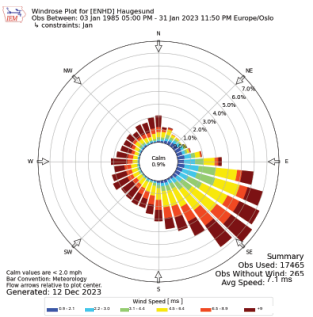
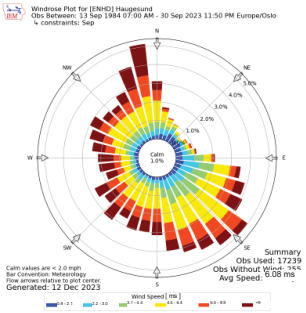


Figure. 45 Annual Wind Rose for Åkrehamn, Norway (“IEM :: Site Wind Roses.”)

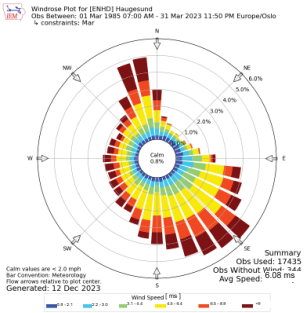
WINTER WIND



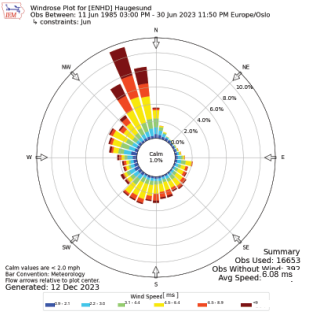
AUTUMN WIND



SPRING WIND



SUMMER WIND



Figures. 46-49 Seasonal Wind Roses for Åkrehamn, Norway (“IEM :: Site Wind Roses.”)

Wind roses tell us the direction the winds are coming from. As seen here, they can be viewed as a summary of the entire year, (figure 1) or broken down into different months or seasons (figures 2-5). By looking at the seasonal wind conditions we can see that the wind is strongest in the winter and summer months. It is also coming from different directions; the Northwest in the summer and south-east in the winter. This lets us know that seasonal wind mitigations techniques and studies will be necessary in the design phase, to account for the difference in wind flow.

SEASONAL WIND ANALYSIS

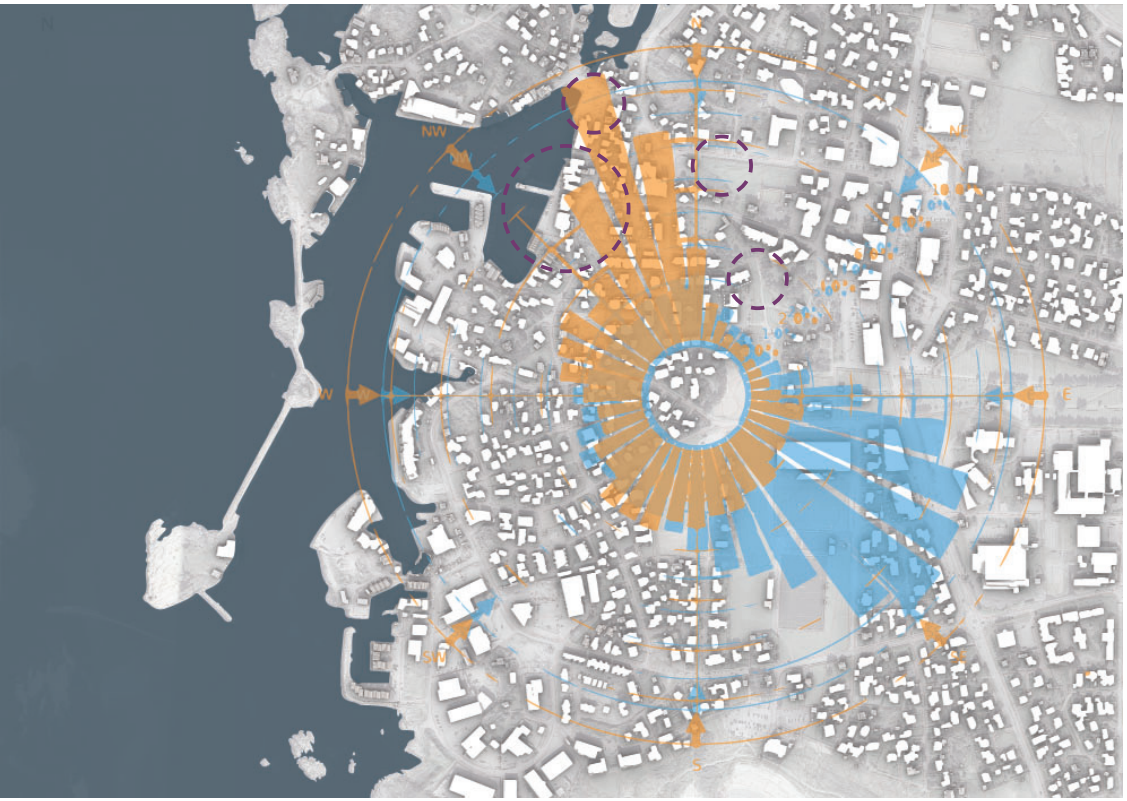


Figure. 50 In This Wind Analysis the Areas of the Site that are Most Vulnerable to the Summer and Winter Wind Flows Have Been Circled.

Figure. 51 Seating Along the Harbor is Currently Unsheltered From the Strong Winds.

WIND FLOW DIAGRAMS

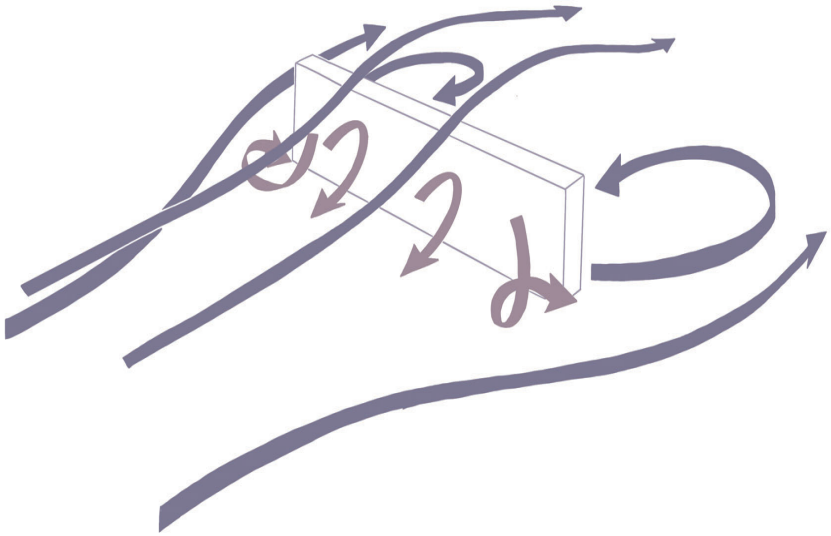


Figure. 52 An Axonometric Diagram Showing the Way the Wind Flows Around a Large Flat Surface of a Building. Information gathered from (Lenzholzer, Sanda)

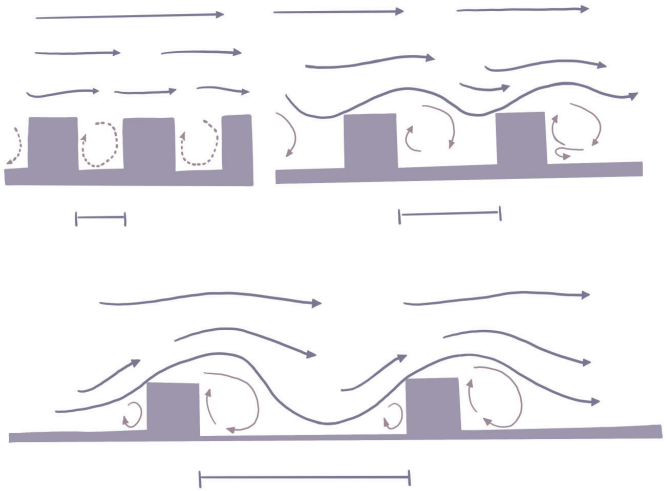


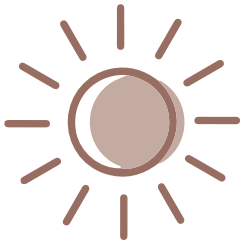
Figure. 53 A Series of Sections Diagraming How Wind Flows Around Buildings with Different Spacing Between Them. Information gathered from (Lenzholzer, Sanda)

Figure. 54-57 Pictured above are several examples of windy areas in Åkrehamn that could benefit from additional wind mitigation techniques.

The position of buildings also has a strong influence on the wind patterns of an area. As seen in figure 52 and 53, the structure and shape of a building can change the way the wind flows around a space. When designing for outdoor areas, like public streets and squares this is important to consider, as the placement of new buildings can be used to influence the amount of wind in the local microclimate. Doing so allows more opportunities for wind blocking and sheltering across the site.

MICROCLIMATE GOALS

Figure. 58 Microclimate Factor Collage



The design should maximize solar access as much as possible. Darker materials like stone should also be used in select gathering areas and seating to absorb sun and warm the thermal environment

Precipitation levels are quite high, so the design should prioritize drainage with permeable materials and preserving natural connections to the sea. Shelters from the rain should also be provided in public squares.

The design should provide shelter from and block wind as much as possible. There should be a focus on wind sheltering from both the NorthWest and the SouthEast due to seasonal wind trends.

“MICE ON ADMIRAL SEREBRYAKOV EMBANKMENT” BY PROGRESS, MIRALLES TAGLIABUE EMBT, AND CUSHMAN & WAKEFIELD
LOCATION:NOVOROSSIYSK, RUSSIA
DATE: 2018


Figure. 59

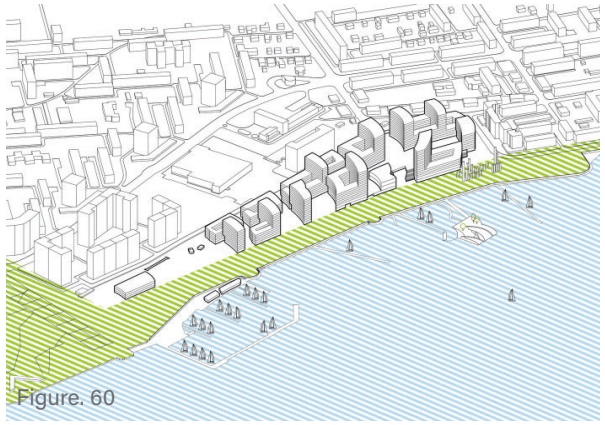


Figure. 60

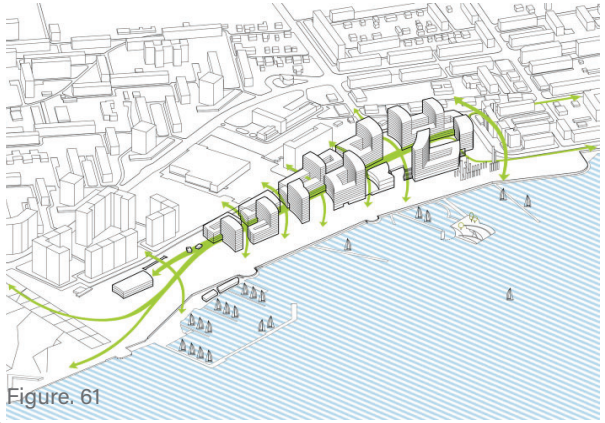


Figure. 61


Figure. 62

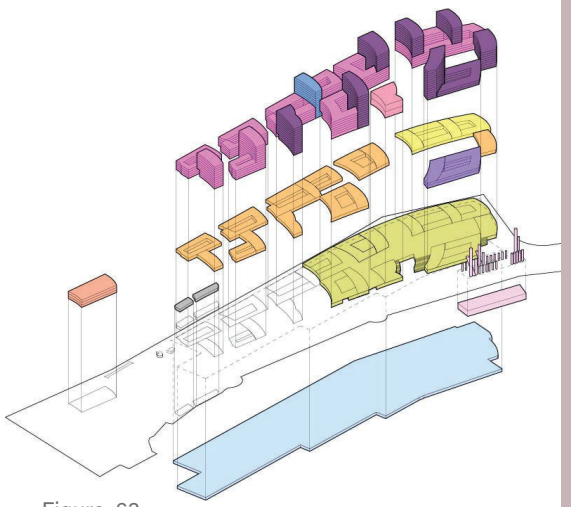


Figure. 63


Figure. 64


Figure. 65

“MICE on admiral Serebryakov embankment” proposes a new tourist hub along the port of Novorossiysk. Its goal is to help the city connect with and activate the area along the harbor by providing more public spaces and areas for pedestrians to walk (Abdallah, Collin). In this design, the site is split into two areas, the building area, which focuses on wind protection through the analyzed positioning of buildings, and the harbor front, which focuses on maximizing solar access. These wind and sun strategies can be similarly considered when working to achieve Åkrehamn’s microclimate goals. Unfortunately has a much larger scale of building and urban density than Åkrehamn, so most of the specific strategies used on the building forms are not applicable because they are for significantly taller buildings. However, it is still good to study because the zoning of the site allows focus on multiple microclimate factors and conditions. Additionally this project shows the use of climate analysis in the design stages of the project, which is helpful to look at when moving into the design phase.

‘A CITY FINDS ITS LAKE’
BY HOLSCHER ARKITEKTER
LOCATION: HOBRO, DENMARK
DATE: 2012-2013

Figure. 66

Figure. 67

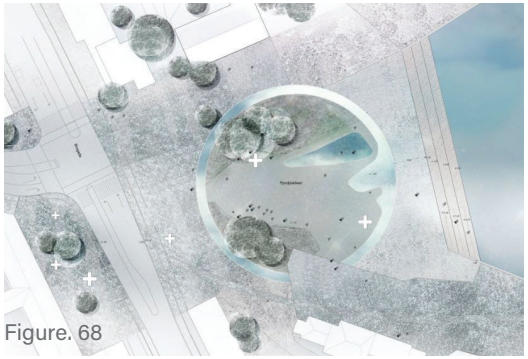


Figure. 68

Figure. 69

Figure. 70

Figure. 71

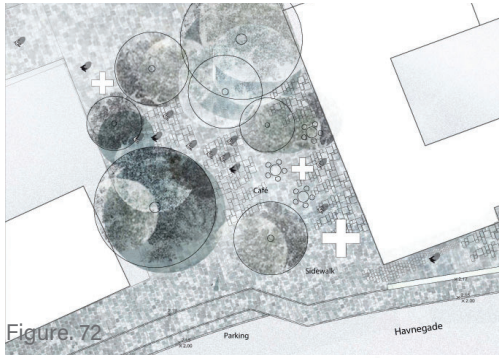


Figure. 72

Figure. 74

“A City Finds its Lake” works to connect the historical city center of Hobro with its developing harbor area. Holscher Arkitekter’s design does this by focusing on natural connections and designing a series of urban spaces, which are meant to have their own characters (Furuto, Alison). This is an important concept that can be related to Åkrehamn, as both projects are aiming to improve natural connections, create public spaces, and enforce connections between a town center and harbor area. Along its green connection, “A City Finds its Lake” uses greenery and permeable surfaces, which allows for better drainage and water control on the site. These rain strategies can also be applied in Åkrehamn. Additionally, this project uses tree clusters and variated building structures to help shelter from the wind. These ideas are similarly applicable in Åkrehamn. However, while this project considers wind, and incorporates drainage and water features to respond to rain, it does not focus much on the sun. Because of this, additional analysis could be included, to help better locate public spaces with prominent solar access.

SEASONAL SOCIAL SPACES

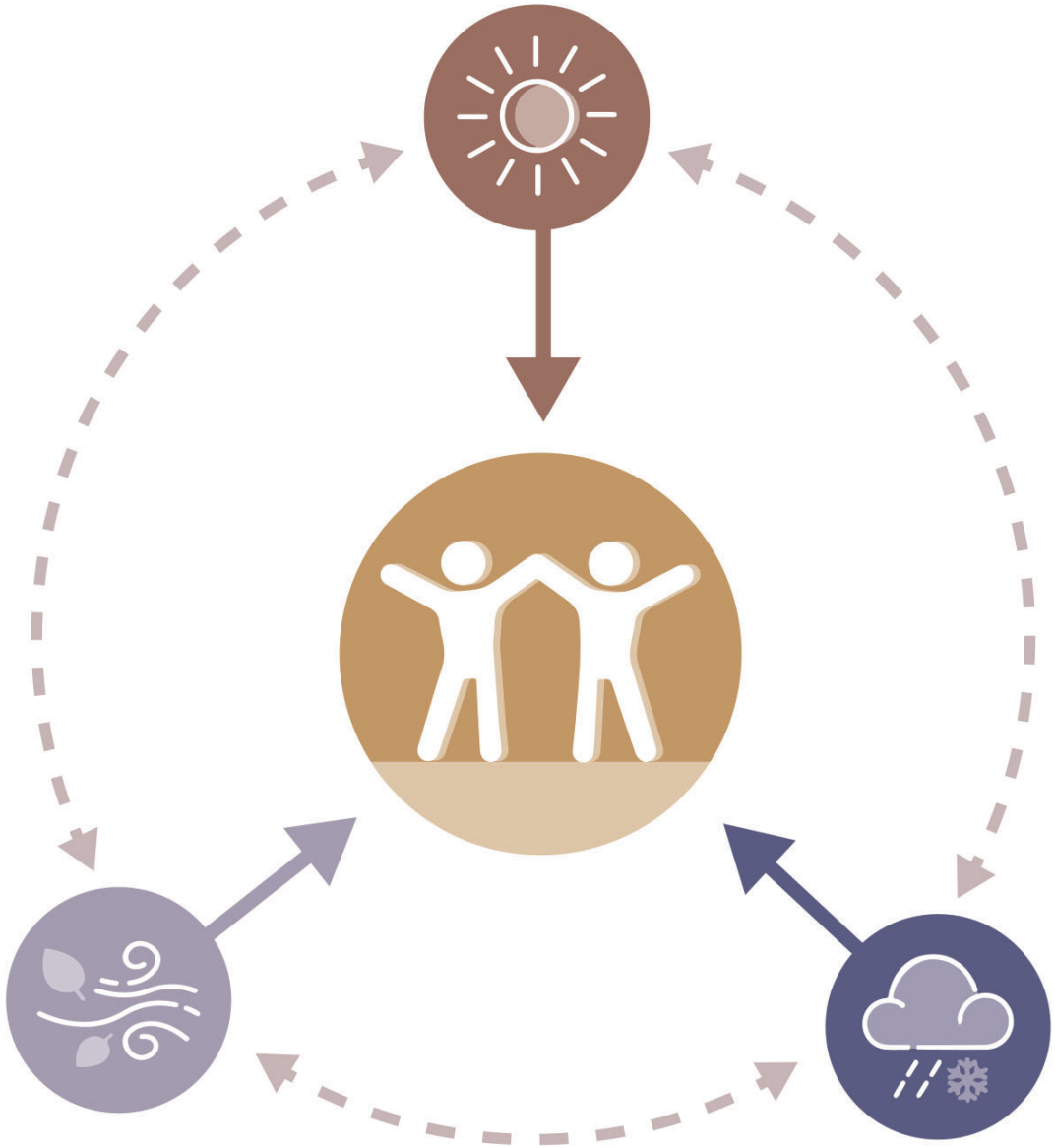


Figure. 75 Microclimate and Social Factor Relationship.

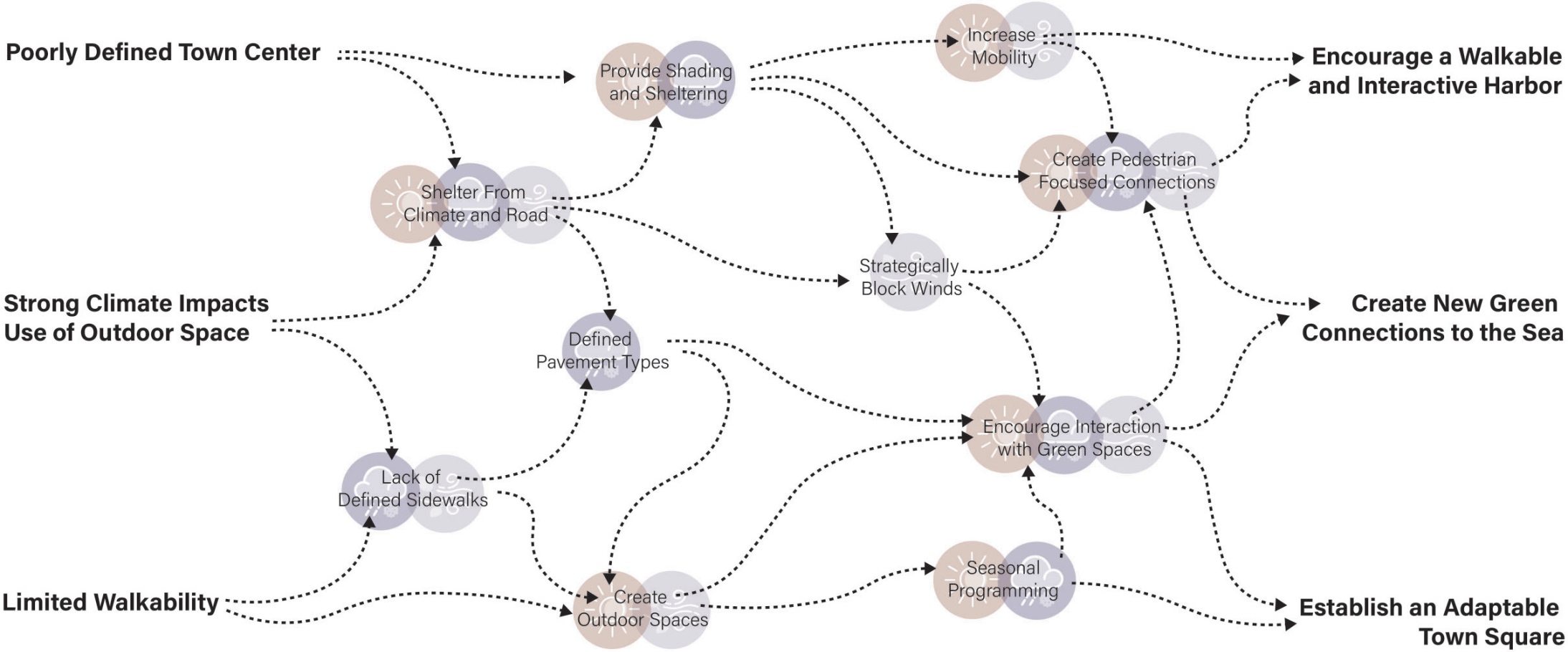
"All components of the urban microclimate... affect the physical well-being of people, whether separately or in conjunction... It is therefore vital that the urban microclimate is given considerable attention in the urban design process"

(Esch, Marjolein Van)

Attractive town centers and inclusive outdoor spaces are beneficial to the people in the town's community when they are pleasant to be in, as this allows them to want to be in the space more often and longer. As Marjolein Van Esch mentions, while each factor of the microclimate can contribute to creating a more pleasant place, it takes the synthesis of all the microclimate factors to create spaces that remain pleasant and lasting overtime. Thus, it is important to balance the microclimate factors and consider the needs of each season in Åkrehamn while moving forward into the design phase of the thesis.

THREATS

OPPORTUNITIES



DESIGN PROPOSAL

04

Nordic Microclimate Response studies the microclimate conditions of the site, and explores how to design with and around those conditions in order to create more pleasant and lasting public spaces. As Åkrehamn grows into a local center, these spaces will provide a framework and center for its future development.

Currently, Åkrehamn has a poorly defined town center, which limits the spaces people have available to gather in. Thus, a focus of the design is creating valuable public spaces for the residents of Åkrehamn to use throughout the year. It also has a strong climate, which currently limits the use of outdoor spaces. Applying microclimate strategies can directly help to address this issue, as the strategies can mitigate local climate impacts to help the spaces feel more pleasant.

Finally, Åkrehamn also struggles with limited walkability, because much of its development has been designed for driving, not walking. This has limited the feeling of connection between the town center and the sea, because many roads lack clear sidewalks for people, and there are not many people focused or accessible places especially along the harbor. Because of this, creating connections between public spaces that improve the natural connection between the site and its surroundings, as well as providing spaces for the residents of Åkrehamn to use as the town grows, is a priority in the design.

How can climate responsive design strengthen local centers and thier connections?

How can we apply climate strategies to create pleasant and lasting public spaces that respond to seasonal climate and movement?

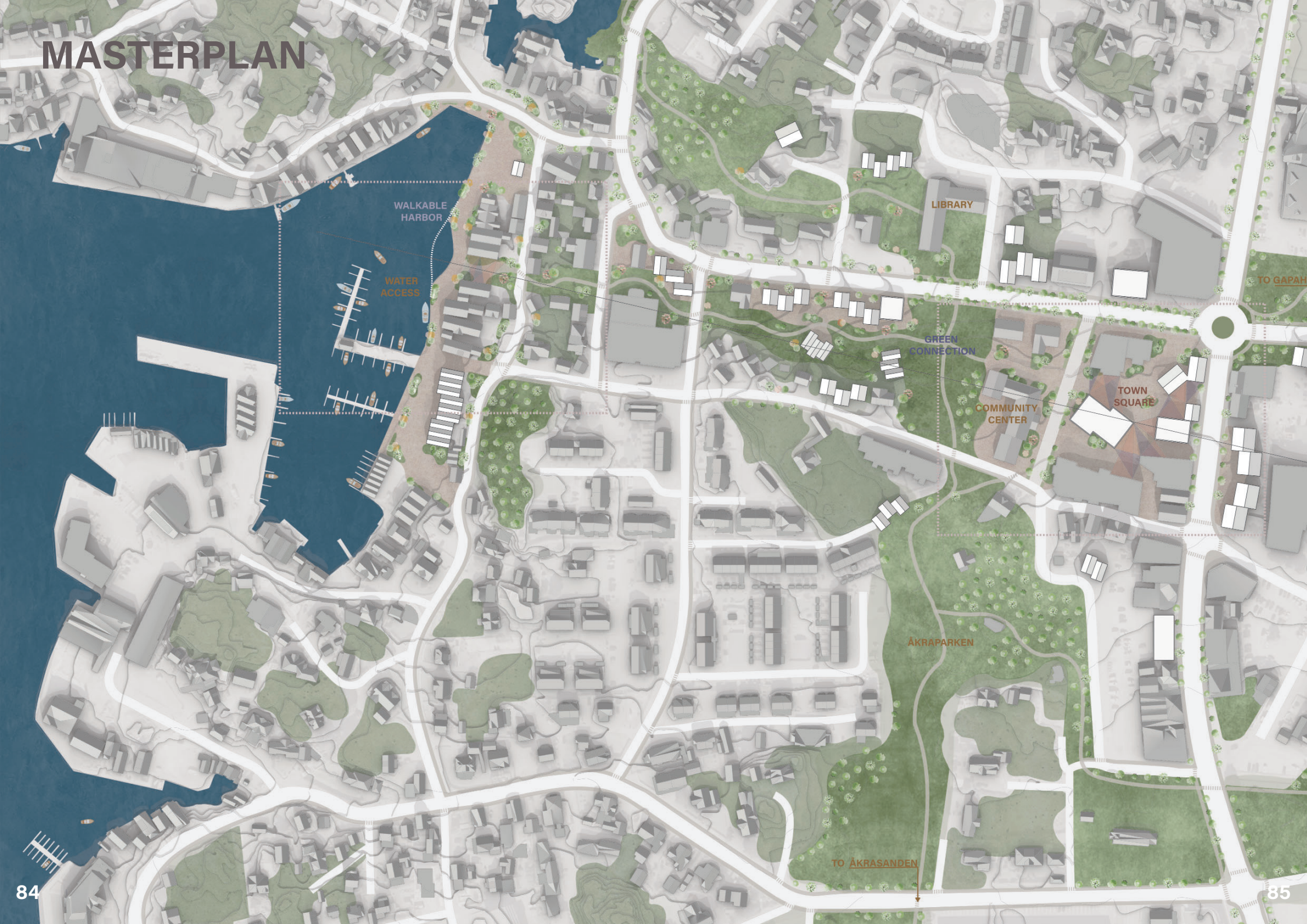
VISION DIAGRAM

Åkrehamn is growing into a local center in the Karmoy region of Norway, but it currently lacks a clear central gathering space or a clear connection between the town center and the sea. This lack of definition limits its ability to create strong public spaces, and has caused development to sprawl. Because of this Nordic Microclimate Response focuses development around the marked development site, and aims to provide a green network of public spaces for the town's growing residents.

Nordic Microclimate Response explores this vision through the lens of microclimate by focusing on how climate specific strategies can be used to establish seasonal public spaces that provide connection across the site. Namely, the project focuses on three opportunities for the site; establishing an adaptable town square, creating new green connections to the sea, and encouraging a walkable and interactive harbor. As the site develops, these opportunities will be located as public spaces that will serve to improve connection and access to outdoor areas across the site.

To do so, each of these spaces will target a microclimate response based on the way people move within and utilize them throughout the year. Specifically the town square will focus on the use of solar conditions in the winter, the green connections will focus on the use of precipitation strategies in the spring and autumn, and the harbor will focus on improving the wind conditions in the summer. This is not to say that the spaces won't be used on other seasons, or that they will only mitigate one microclimate factor, but rather that each space will focus their use of microclimate strategies on the seasons they are most impacted and used by residents. Applying these strategies will improve the microclimate throughout the year, but will have the most impact on the focus season and climate factor. In doing so, we can create a climate responsive design that seasonally strengthens Åkrehamn's public spaces and connections for its growing residents.

MASTERPLAN


WALKABLE HARBOR
WATER ACCESS
LIBRARY
TO GAPAH
GREEN CONNECTION
TOWN SQUARE
COMMUNITY CENTER
ÅKRAPARKEN
TO ÅKRASANDEN

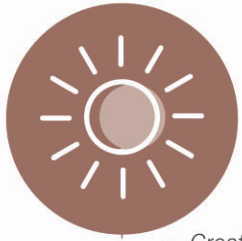
FOCUS AREAS

- *Interaction with the Sea*
- *Redirect Strong Sea Winds*
- *Encourage Mobility with Paths Along the Sea*

HARBOR

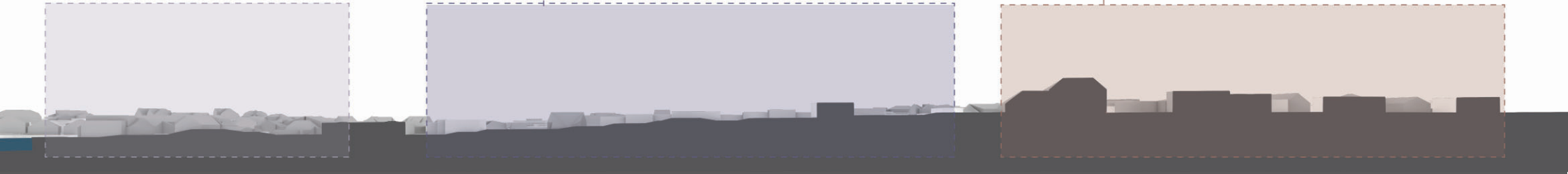
- *Direct Towards the Sea*
- *Provide Drainage*
- *Moderate Temperature and Shade with Greenery*

GREEN CONNECTION



- *Create a Central Gathering Point*
- *Consider Seasonal Uses*
- *Encourage Use by Providing Indoor and Outdoor Shelter*

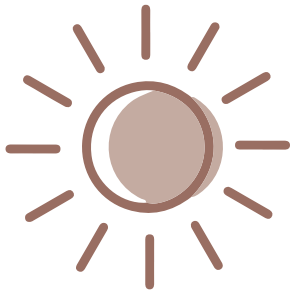
TOWN CENTER

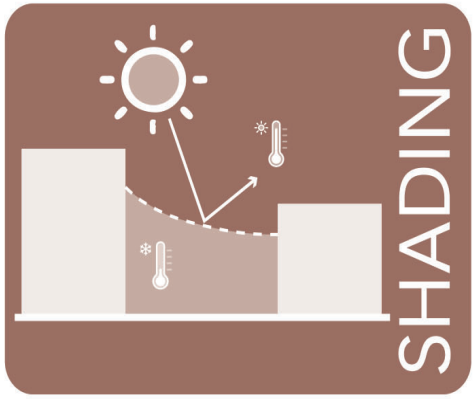


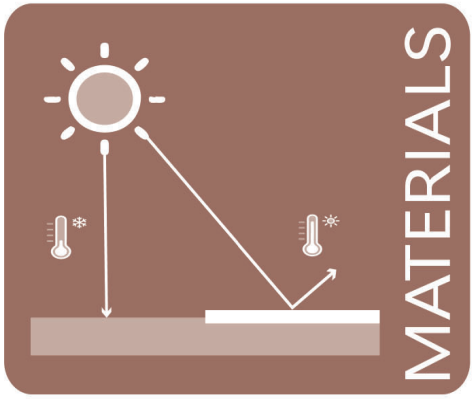
This design proposal focuses on three public spaces, the town square, the green connection, and the harbor. The Town Square is created near the main road, and focuses on providing both indoor and outdoor spaces for public shelter in order to create a valuable public gathering point for Åkrehamn. The green connection helps to overcome the town's car focused design by providing a walking path towards the sea. This path will provide drainage and access to greenery and the harbor from the town center. Finally the harbor focuses on increasing interaction with the sea, and thus looks to improve its microclimate by redirecting strong sea winds. In doing so it increases connections by developing a walkable public harbor, which improves access and mobility for this region of the site.

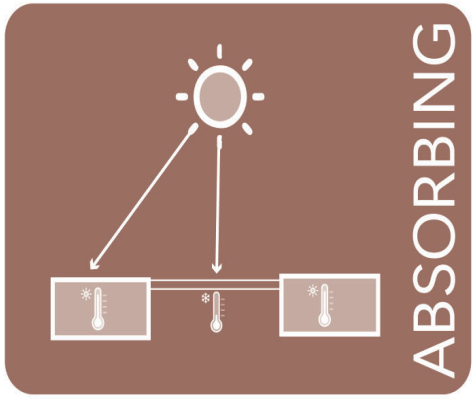
INTERVENTION:

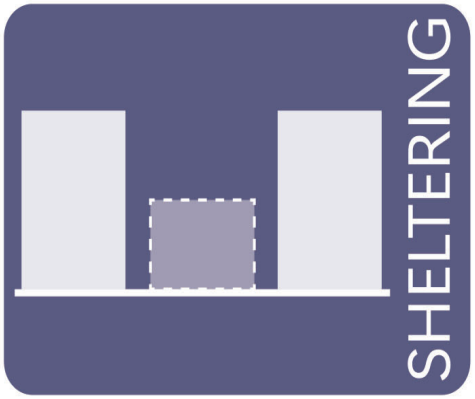
LARGE - SCALE ⟷ SMALL - SCALE

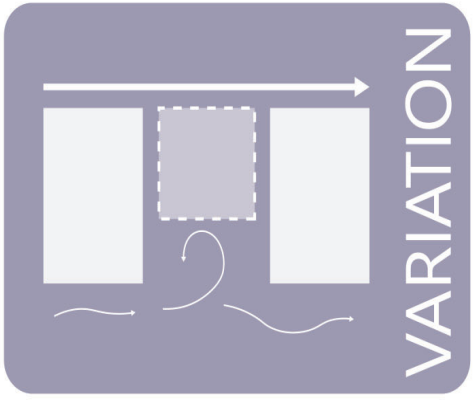


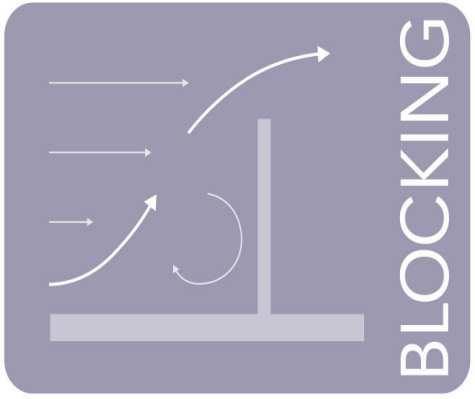




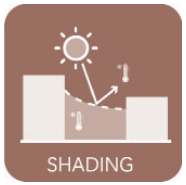




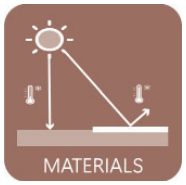




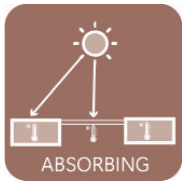
MICROCLIMATE TOOLBOX



The shading strategy refers to elements that block the sun, which can be helpful on long summer days in Åkrehamn. These elements could be public buildings, but can also be applied outdoors with sails and awnings.



The reflection of surface materials can impact the thermal environment. This strategy can be used in areas with little seasonal sun by redirecting solar radiation when it is out.

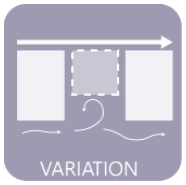


Absorbing refers to a material's ability to collect solar radiation. Seating and or other areas with public action can be made of dark materials with higher absorption properties to help increase the temperature experienced in the public space.

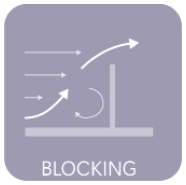
Sheltering addressed how the precipitation impacts the microclimate by incorporating more places for people to get out of the rain, such as access to public buildings alongside public spaces, rain covers and awnings.

Draining refers to how rain and other precipitation are able to infiltrate the ground, which relates to the concepts of connected green spaces, permeable pavement, and clear paths towards the sea.

Evaporation can occur from collected areas of rainwater or vegetation and it helps to keep humidity levels in the microclimate more consistent. this helps with the feeling of thermal comfort on the site.



Variation in building positions helps to slow down wind speeds. This strategy can be applied to new buildings as Åkrehamn develops to help reduce wind speeds.

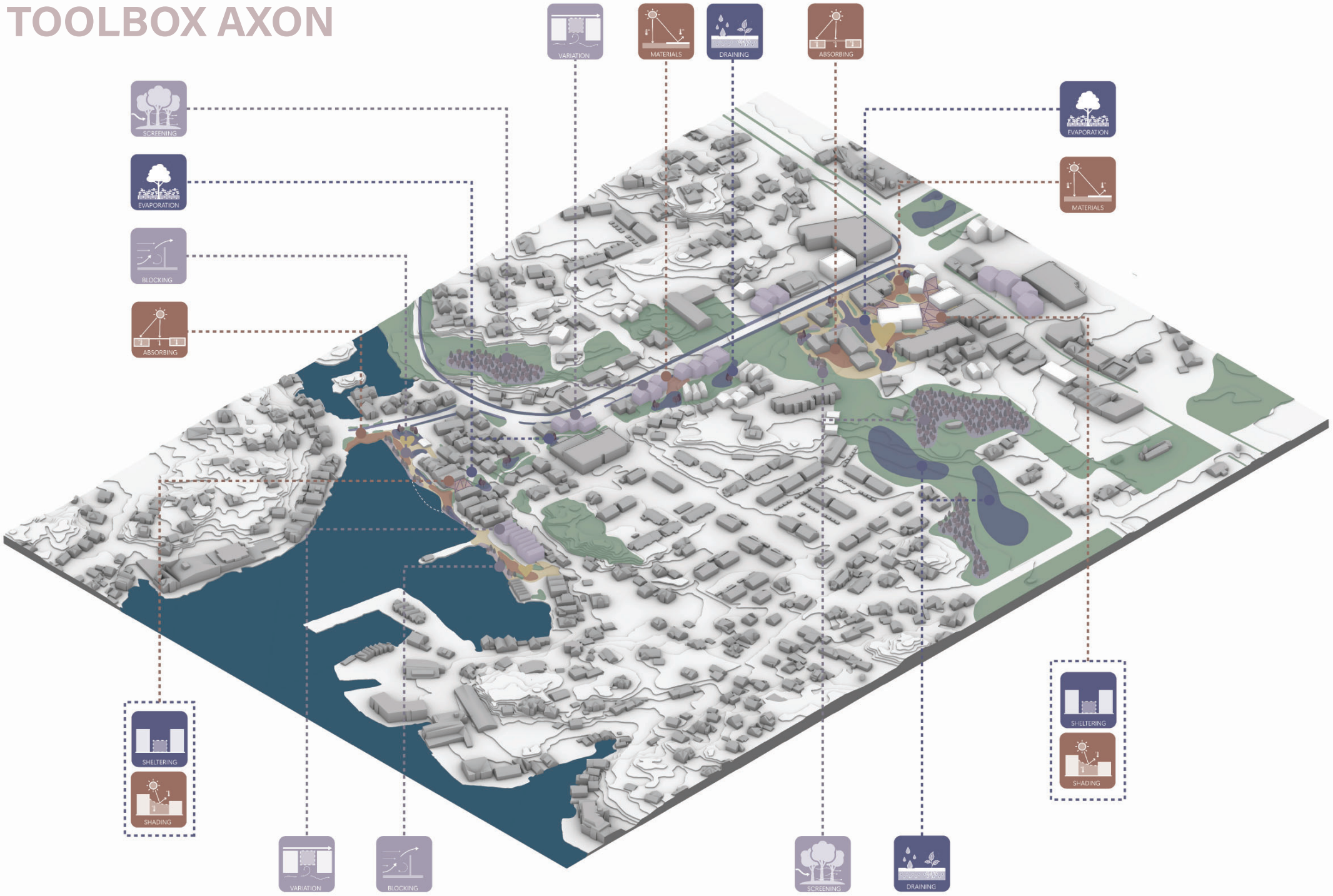


Blocking allows wind to be redirected around a specific area. These blocks can be installed seasonally and improve wind conditions at the human level of a public space.

Screening involves the filtration of wind flow, which helps to slow it down. Screening can be achieved with trees or other forms of vegetation.

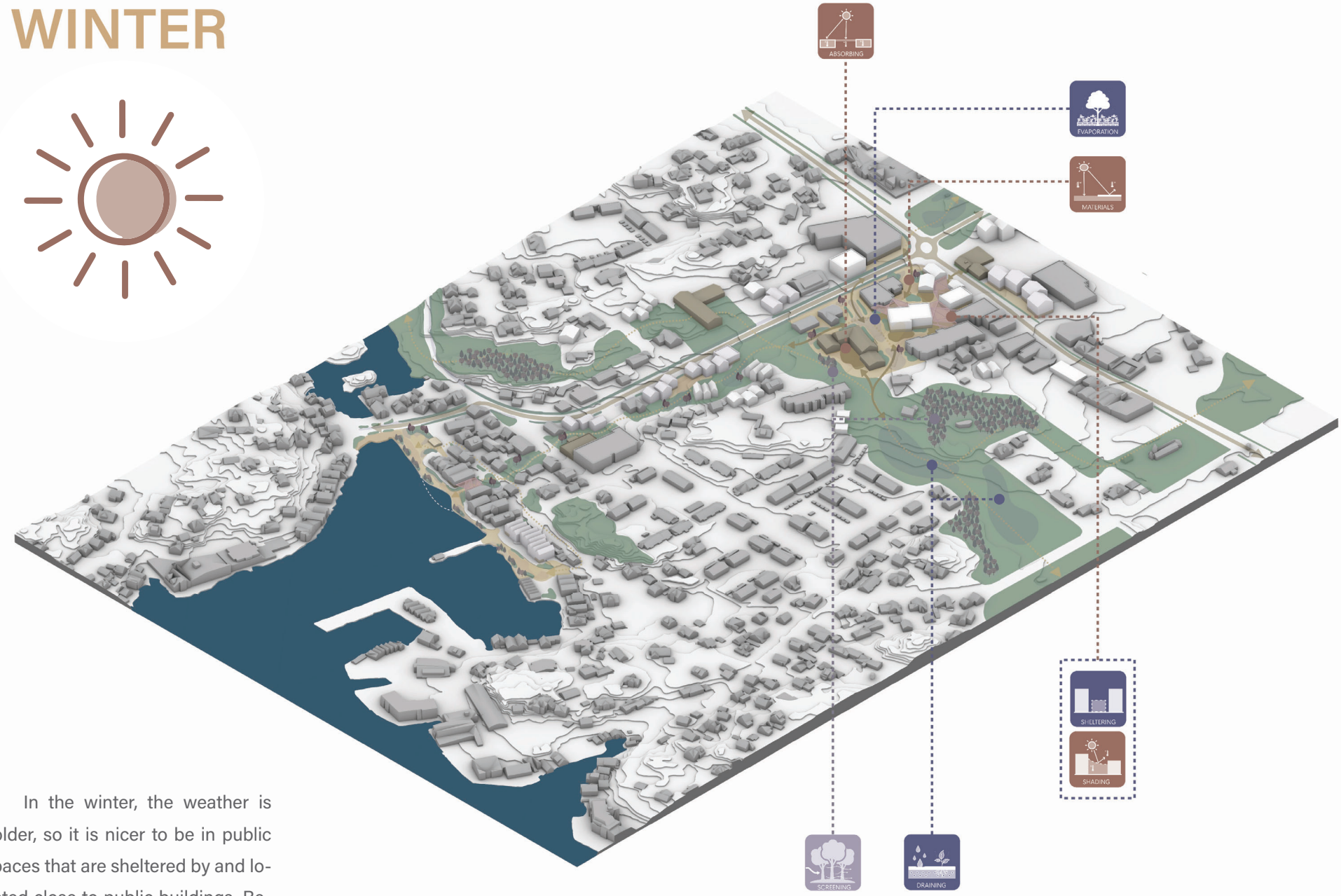
The toolbox on the previous pages has been developed to help apply microclimate strategies across the site. These strategies range from large scale interventions that are mostly focused on the scale of new building development, the medium scale interventions that are concerned with material impacts, and small scale interventions, which can be achieved by adding design elements like trees, vegetation and seating to both existing and developing regions within Åkrehamn.

TOOLBOX AXON



TOWN SQUARE

WINTER

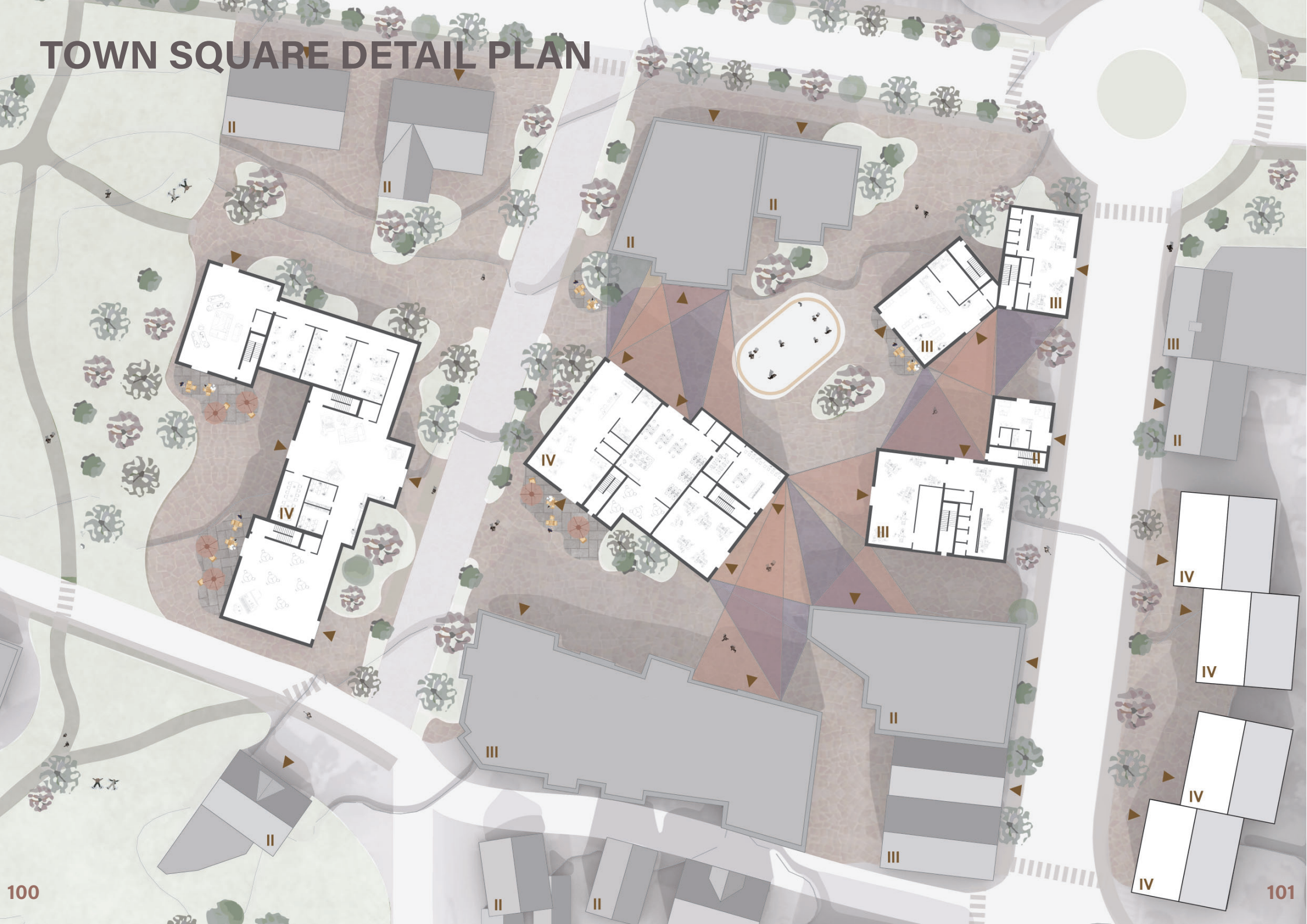


In the winter, the weather is colder, so it is nicer to be in public spaces that are sheltered by and located close to public buildings. Because of this, the town square becomes the focal point of seasonal social interaction.

The town square will have a mixed use programming with shops and restaurants along the ground floor, offices on the upper floors along the main road, and apartments on the upper floors of the interior buildings. In the detail plan on the following page the new buildings and their relationship with the town square at the ground floor have been included. This is done to show how the proposed design will increase the interactions between the buildings and the outdoor space. It will also feature space for Åkrehamn's food trucks and other mobile venders together, and will attract greater use with seasonal programming like markets, ice skating rinks, and town events.

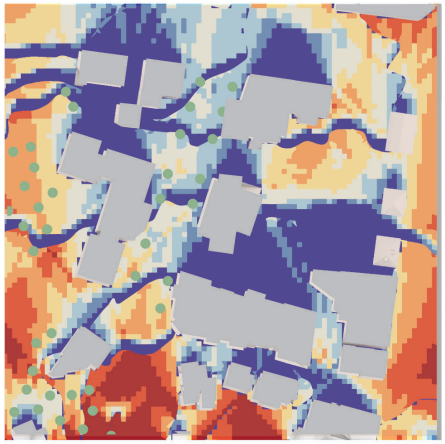
Between the buildings, shading and sheltering sails will be attached in the indicated areas. These will provide areas for lights and cover from the rain and snow in the winter, as well as provide some additional shading in the summer. From the solar studies on the previous page, these sails have been specifically located to not block solar access in the winter months, as these areas are valuable for outdoor gathering.

TOWN SQUARE DETAIL PLAN

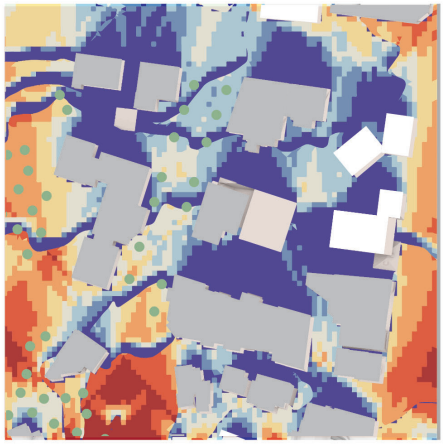


TOWN SQUARE SOLAR ACCESS

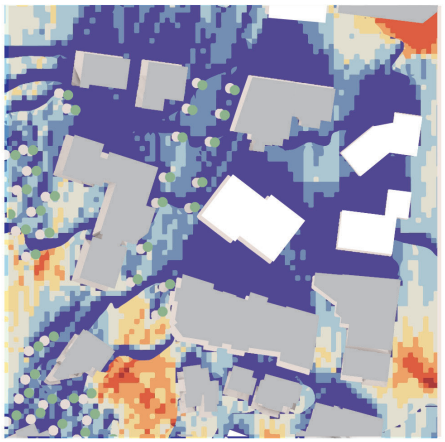
WINTER SUN



Existing Design

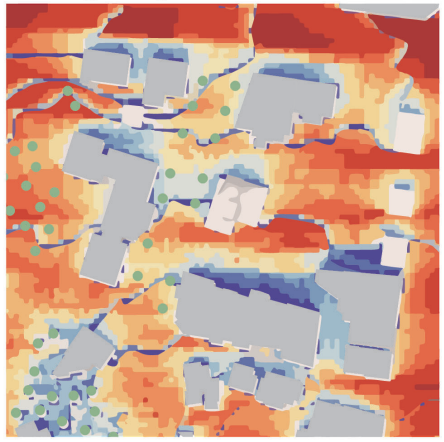


Design Iteration

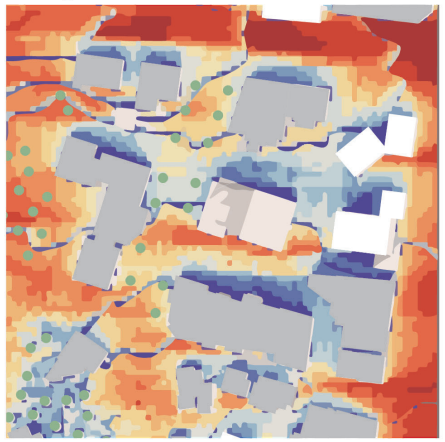


Proposed Design

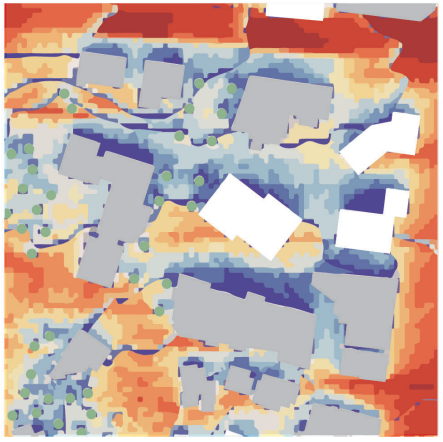
EQUINOX SUN



Existing Design

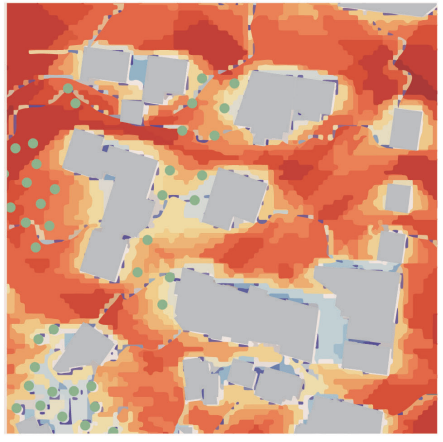


Design Iteration

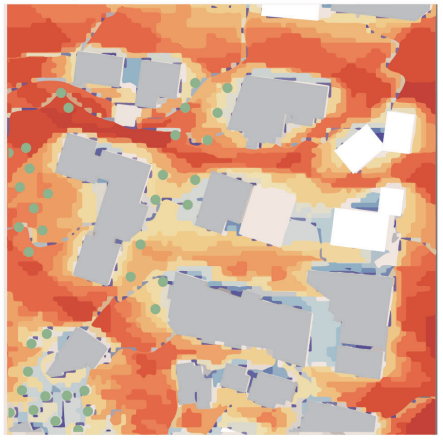


Proposed Design

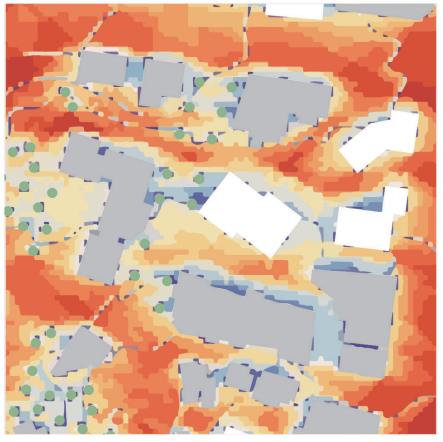
SUMMER SUN



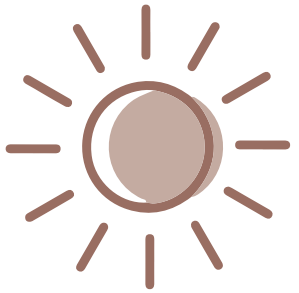
Existing Design



Design Iteration



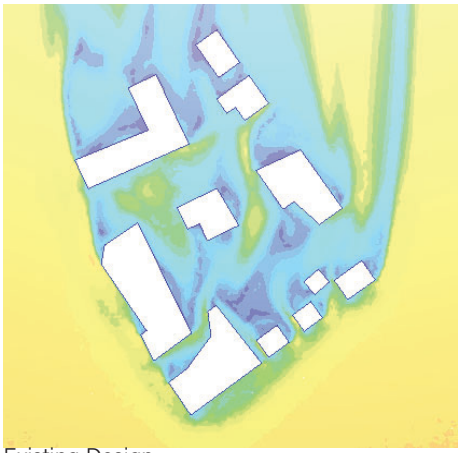
Proposed Design



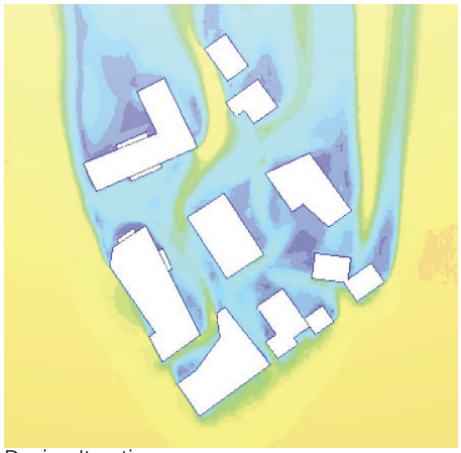
While the increase in building height does increase shading in this area, buildings in the town square are oriented through their iterations to promote greater solar access on select facades throughout the year. Doing so provides good areas for localized gathering points, like outdoor seating. Because there is little sun in the middle of winter, most of this study was conducted using the solar conditions at the equinox, as this is the time when the amount of sun shading is the most average, allowing the design to suit a greater number of days across the year.

TOWN SQUARE WIND ANALYSIS

Winter Wind: SE

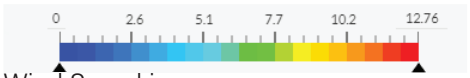


Existing Design



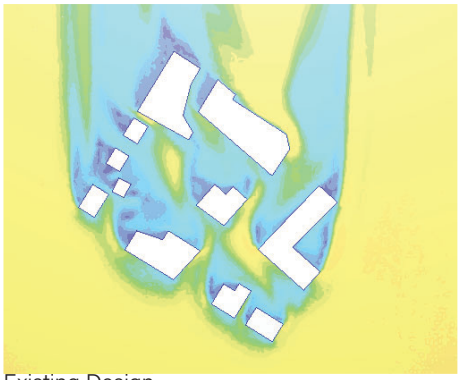
Design Iteration

Proposed Design

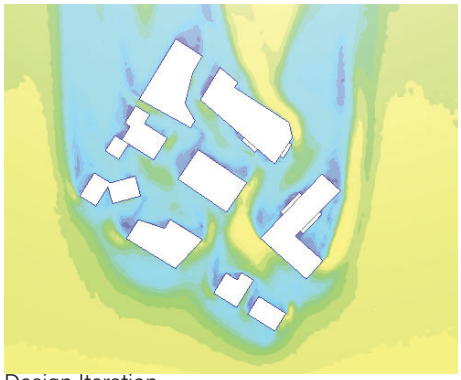


Wind Speed in ms

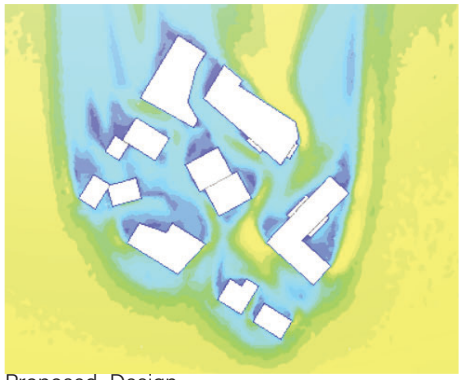
Summer Wind: NW



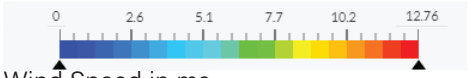
Existing Design



Design Iteration



Proposed Design



Wind Speed in ms

The town square is sheltered from wind by the buildings around it, especially in the winter, which will help to improve the microclimate of this public space. As seen in the design iterations, the positioning of new buildings plays an important role in this process, as it helps to create areas of greater shelter.

SHADING

SHELTERING

VARIATION

MATERIALS

EVAPORATION

BLOCKING

ABSORBING

DRAINING

SCREENING

Morning Sun 9:00

Mid-day Sun 12:00

Afternoon Sun 15:00

TOWN SQUARE EQUINOX SHADOW ANALYSIS

TOWN SQUARE VEGITATION SCREENING

Winter Wind: SE

Summer Wind: NW

Wind Speed in ms

SHADING

SHELTERING

VARIATION

MATERIALS

EVAPORATION

BLOCKING

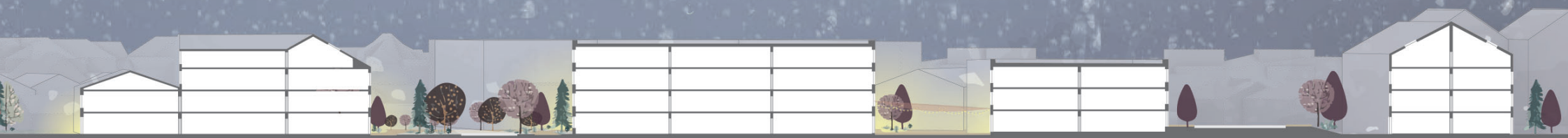
ABSORBING

DRAINING

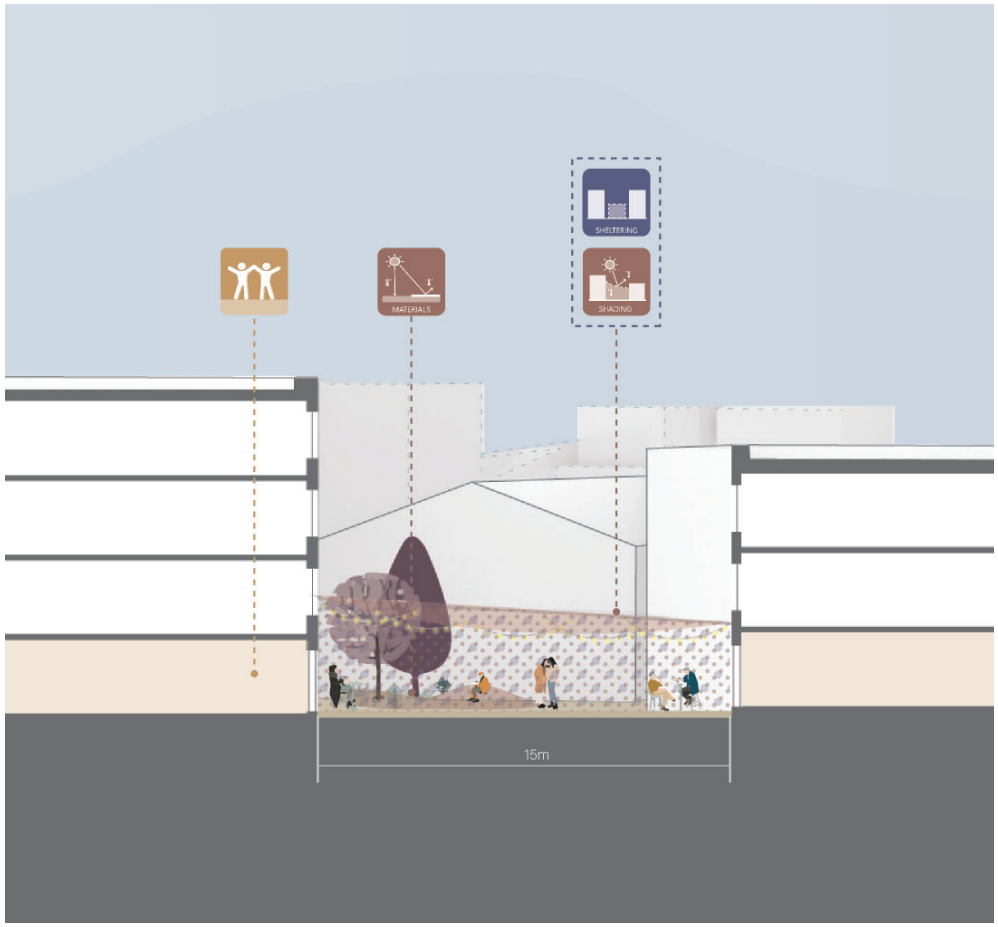
SCREENING

TOWN SQUARE SECTION

In the Town Square vegetation will be added to provide a greater sense of connection to the near-by green corridor. These spots of greenery have the additional benefit of adding wind sheltering and evap-oration strategies, and will be used in conjunction with the solar access and material strategies to create a warmer and drier microclimate for this public space in the winter. These strategies pair with the easy access to indoor public spaces, making the town square a valuable gathering space in each season, but especially adaptable to Åkrehamn's winter months.



TOWN SQUARE
DETAIL SECTIONS



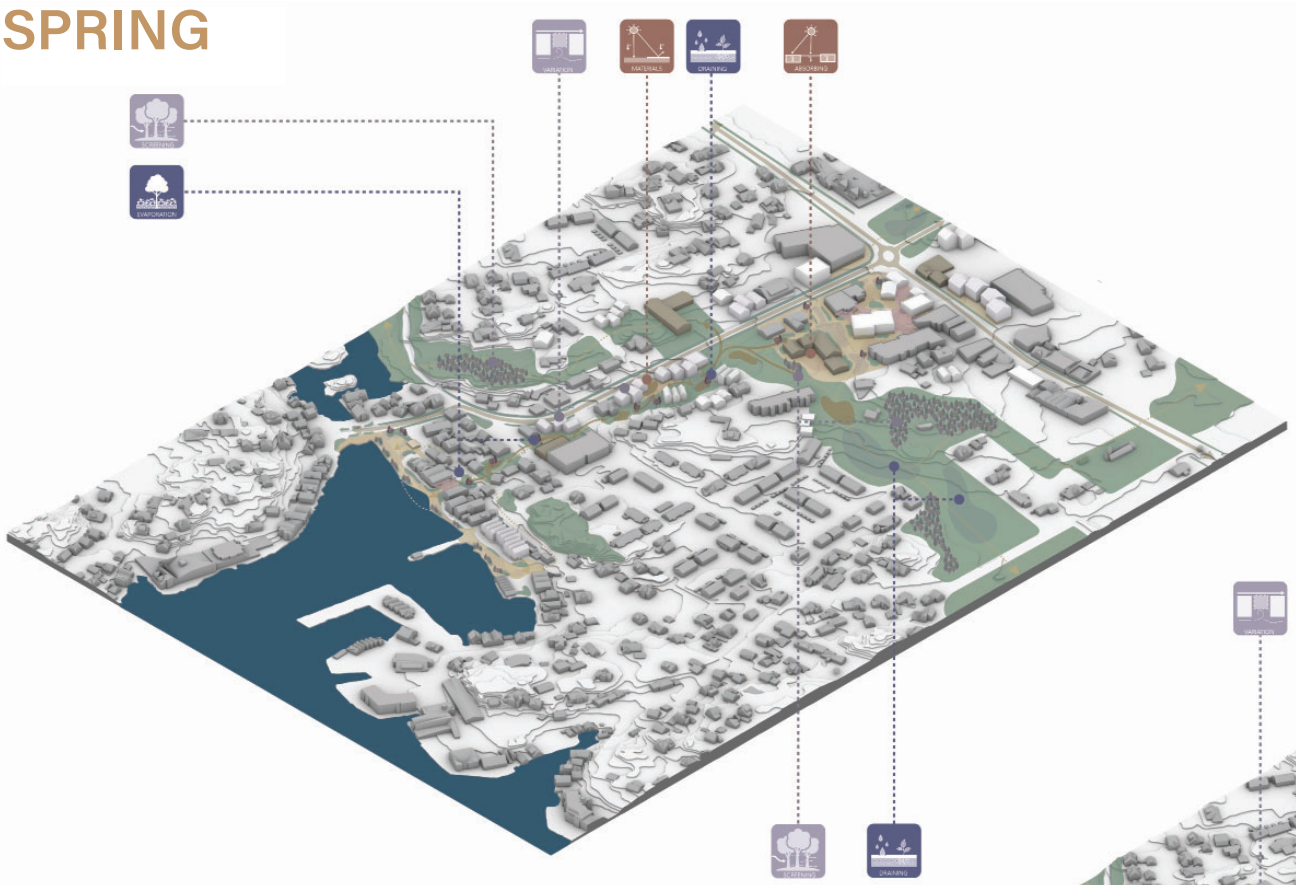
TOWN SQUARE
SECTION PERSPECTIVE

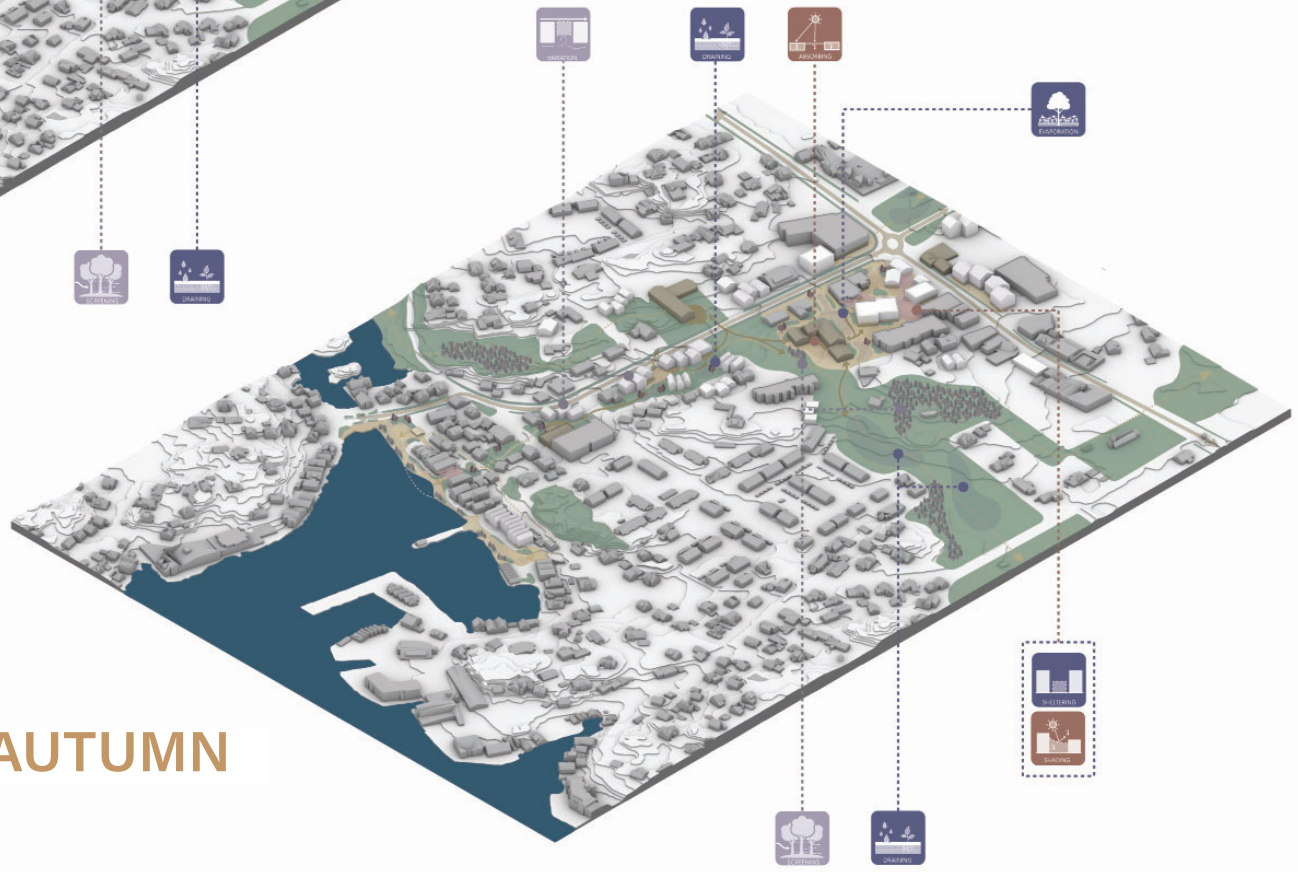
Existing Section

TOWN SQUARE WINTER PERSPECTIVE

GREEN CONNECTION

SPRING





AUTUMN

The spring and autumn equinox mark the midpoint of the year and have very similar solar and wind conditions. As snow melts in the spring and the rainiest season begins with the fall, the strategies of drainage and evaporation are also important for the use of the green connection for these seasons, but the greater rain in autumn places an added emphasis on access to public buildings and other rain shelters.

The green connection provides a specific place for people to connect to and access the harbor from the town center. It moves between the areas of the town square and harbor, and promotes residential development along the green corridor with occasional ground floor shops or offices. In doing so, the green connection provides a walkable path not only between the public spaces in the site, but also creates clearer access to the natural spaces surrounding the town.

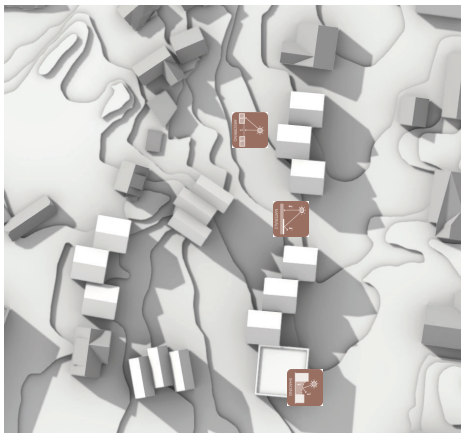
In addition to increasing connection, the green connection addresses the need for multifamily residential development in Åkrehamn. For example, it promotes a slightly more densified space for three to four story multi-family homes amongst Åkrehamn's mostly one to two story single family lots, and the areas of greenery maintain a good sense of outdoor space for these residents. This corridor also allows the residential areas to easily access other public spaces, which makes it easier for pedestrians and cyclists to get around in an otherwise car dominated community.

GREEN + BLUE ANALYSIS

"The residents of Åkrehamn feel a great deal of pride in the beautiful landscape surrounding the town"

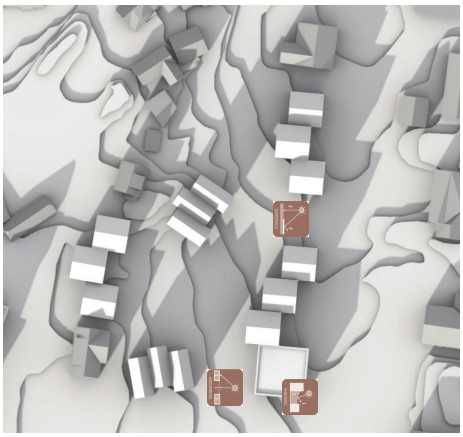
(Europan 17)

In connecting the developing town center to the sea, the green connections in Åkrehamn also aim to connect to a greater network of natural areas surrounding the site. Doing so will make these landscapes more accessible to residents, and densifying development within the site will make these green spaces less susceptible to the whims of sprawl.



Afternoon Sun 15:00

Mid-day Sun 12:00



Morning Sun 9:00

GREEN CONNECTION EQUINOX SHADOW ANALYSIS

DRAINAGE AND SHELTERING STRATEGIES

GREEN CONECTION
AUTUMN PERSPECTIVE

GREEN CONNECTION SECTION

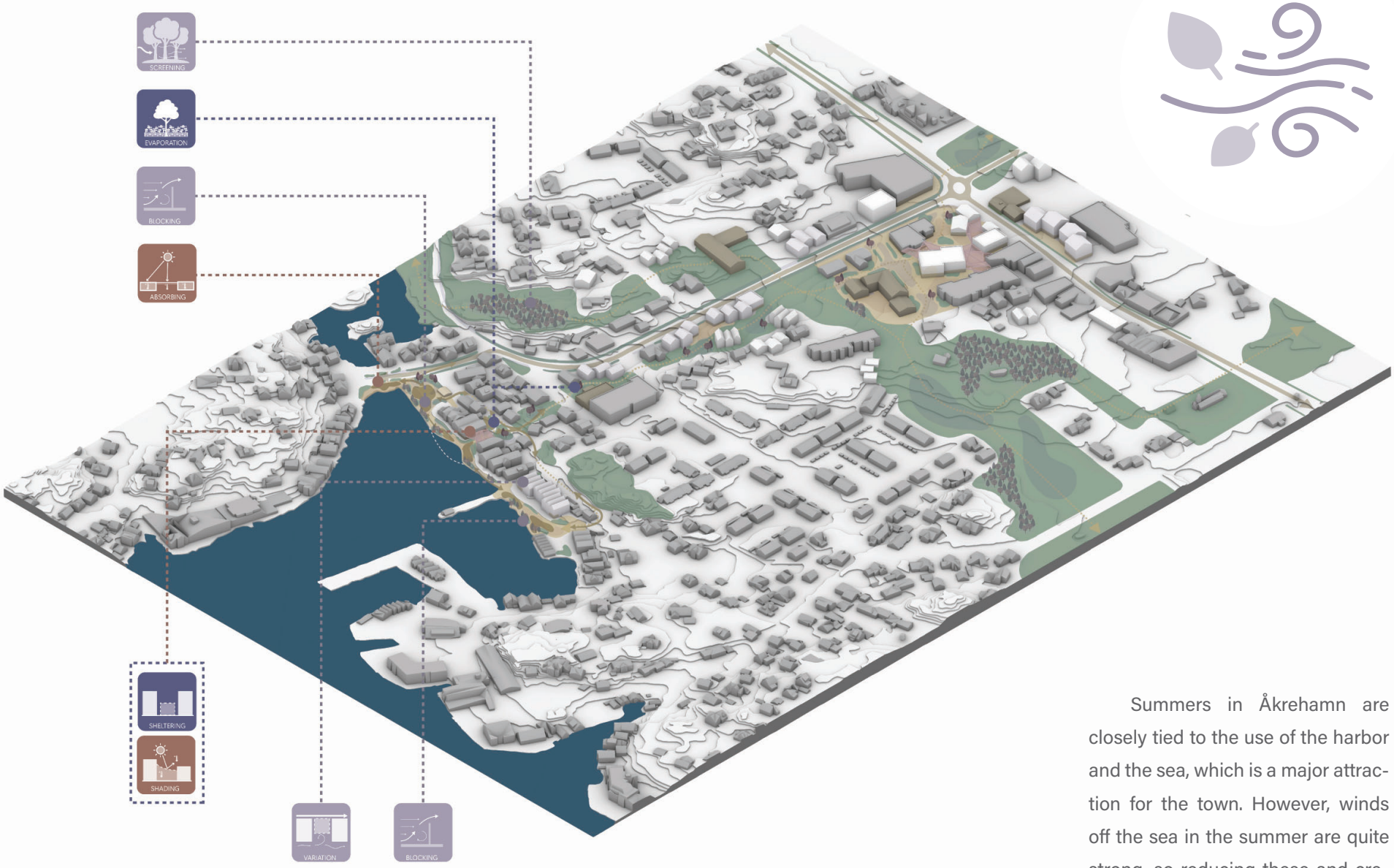
As movement through the green connection is encouraged this part of the site focus on addressing the rain impact of the microclimate. Trees and other vegetation planted throughout the area help control the humidity, and the presence of an lowly paved green connection to the sea helps aid with the drainage impacts of precipitation throughout the site.

GREEN CONECTION
DETAIL SECTIONS

GREEN CONNECTION
SPRING PERSPECTIVE

WALKABLE HARBOR

SUMMER

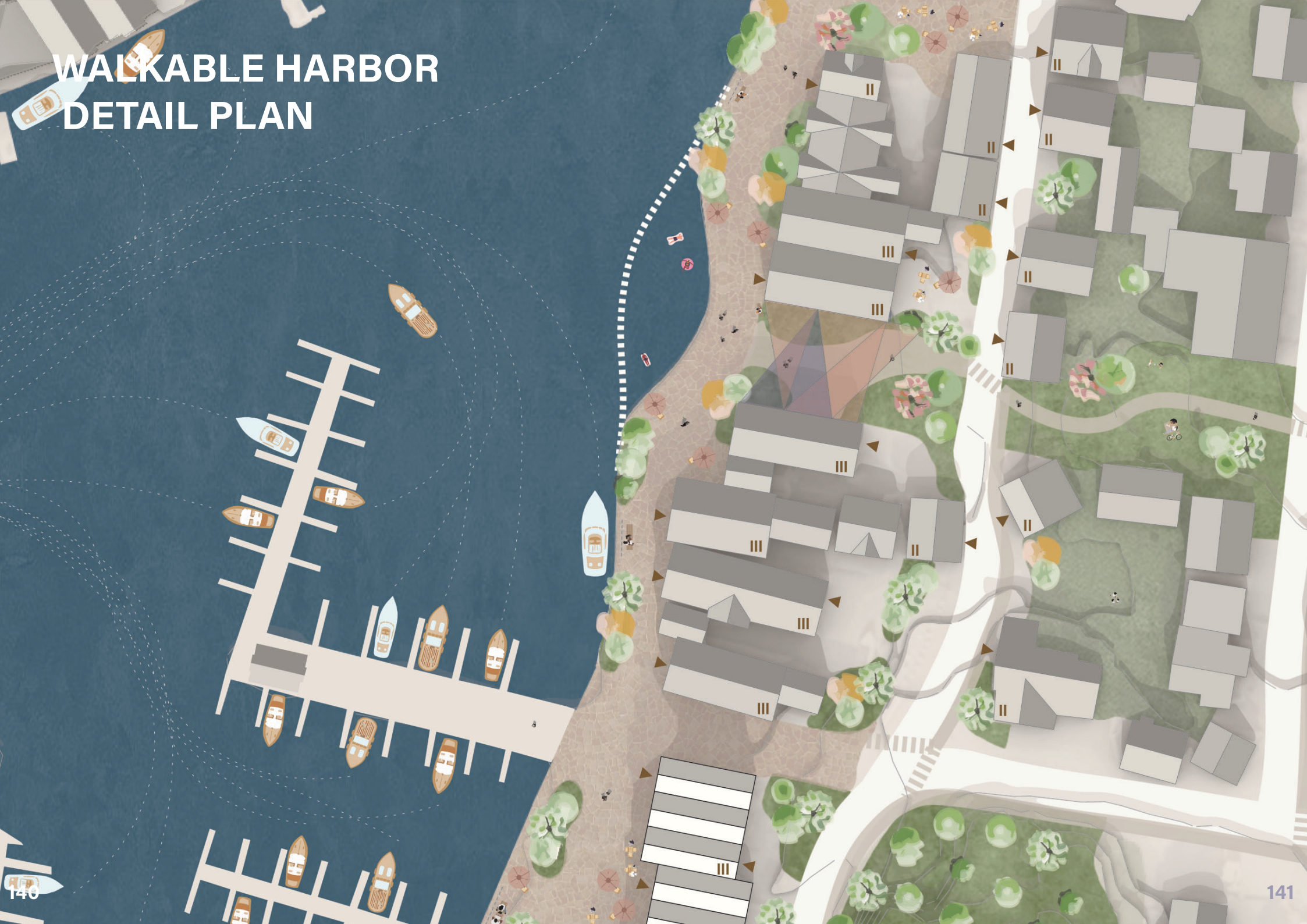


Summers in Åkrehamn are closely tied to the use of the harbor and the sea, which is a major attraction for the town. However, winds off the sea in the summer are quite strong, so reducing these and creating more connected areas of harbor access is beneficial for the use of the public space.

The walkable harbor aims to increase interaction between Åkrehamn and the sea. Currently the sea is not easily accessible from the town center, as there is no easily walkable path to it, and the harbor is mostly private lots, so there is no clear public access. The walkable harbor addresses this by culminating at the end of the green connection, which provides it with direct and pedestrian focused access to the town center. It also extends the walkway along the harborfront, allowing the space to feel more public.

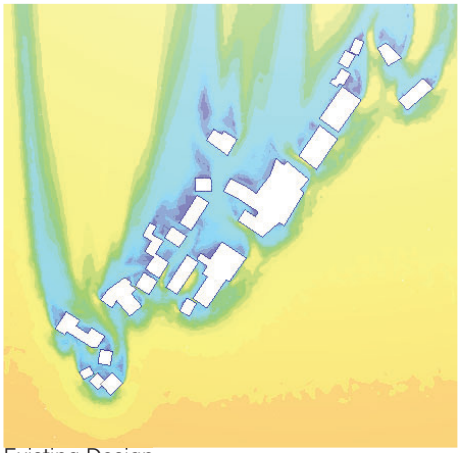
By creating a public walking space along the waterfront, the harbor is more accessible to those residing in and visiting the town. While most of the buildings in this region will remain residential, areas for mobile vendors like food trucks and market stalls will be provided in order to promote use in the summer months. Additionally, an area for swimming will be added, so that residents will not have to own waterfront property or travel outside of Åkrehamn to enjoy the water.

WALKABLE HARBOR DETAIL PLAN



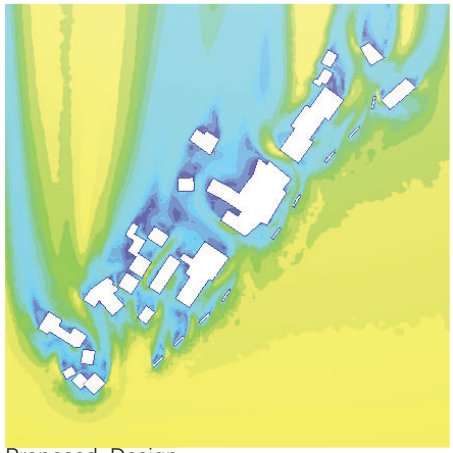
HARBOR WIND ANALYSIS

Summer Wind: NW

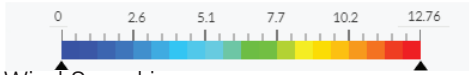


Existing Design

Design Iteration

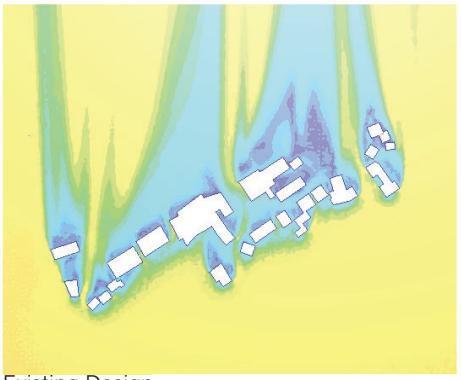


Proposed Design

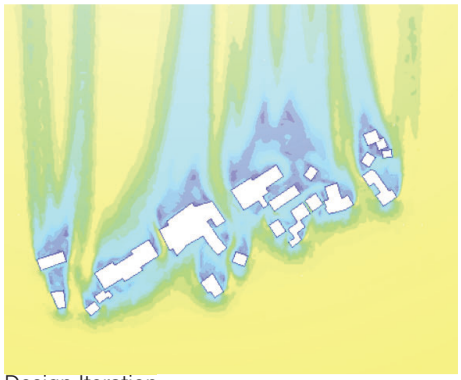


Wind Speed in ms

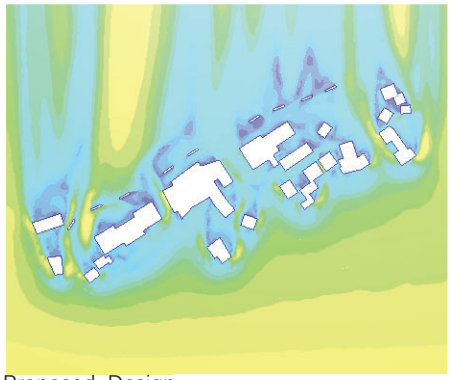
Winter Wind: SE



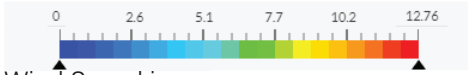
Existing Design



Design Iteration



Proposed Design

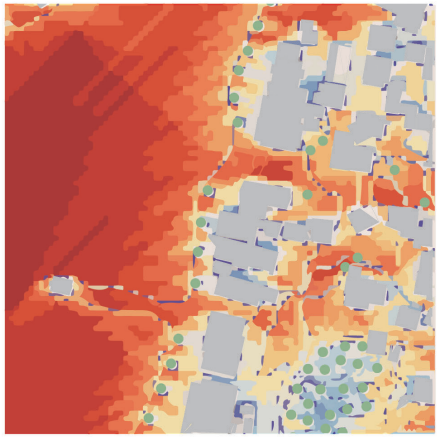


Wind Speed in ms

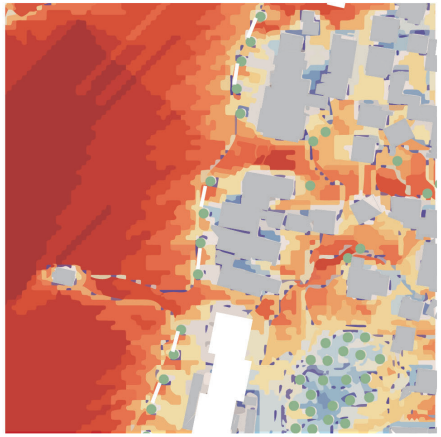
The wind coming off the sea is quite strong, especially in the harbor region of the site. Because of this, design iterations of this public space focus on the use of wind shelter from vegetation and seasonally placed wind blocks. These elements do not block access to the harbor the way a building would, but still allows for a more pleasant local microclimate.

HARBOR SOLAR ACCESS

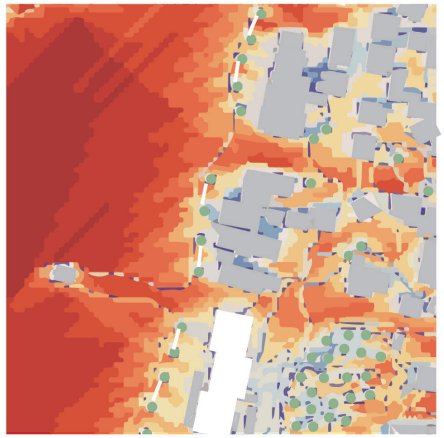
SUMMER SUN



Existing Design

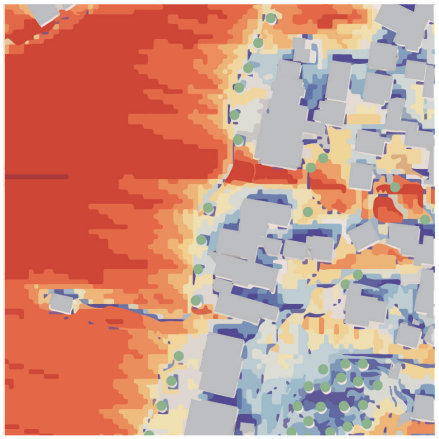


Design Iteration

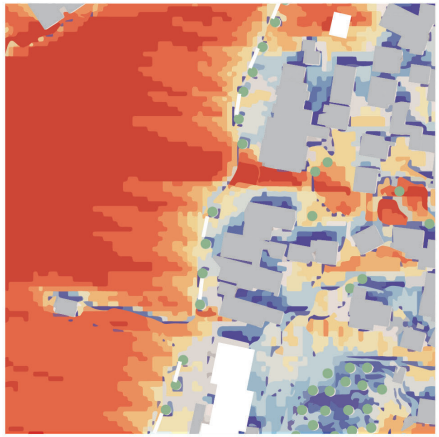


Proposed Design

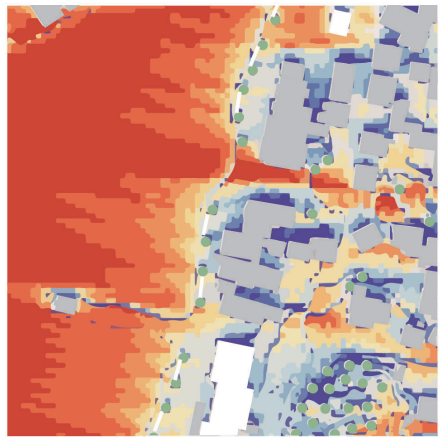
EQUINOX SUN



Existing Design

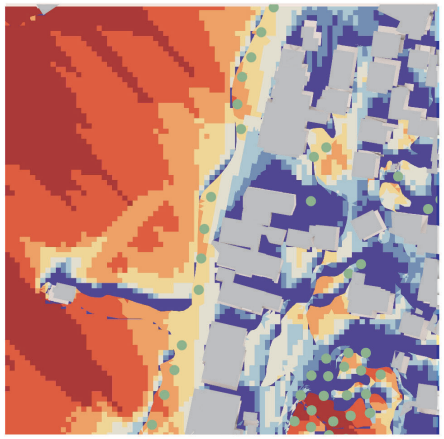


Design Iteration

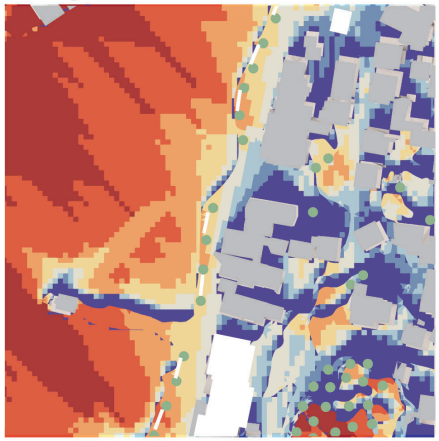


Proposed Design

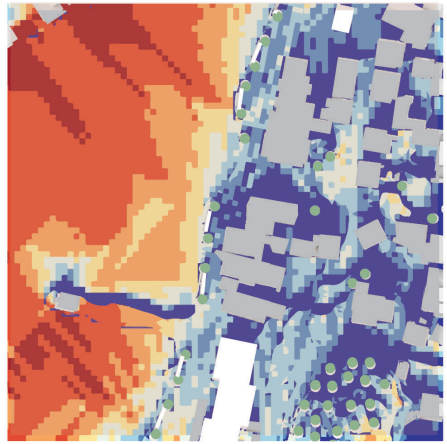
WINTER SUN



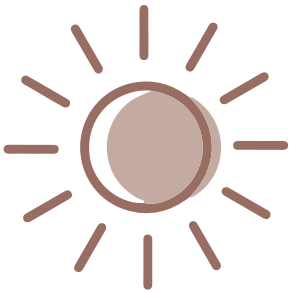
Existing Design



Design Iteration



Proposed Design



The harbor is mostly used in the summer, so it is helpful to add areas of shading. Currently the only shade is provided by the buildings. This is improved in the design iterations by adding vegetation along the harbor's edge. Like with the town square, this study focuses on the solar conditions at the equinox, as this is the time when the amount of shading from the sun is the most average, allowing the design to suit a greater number of days across the year.

Morning Sun 9:00

Mid-day Sun 12:00

Afternoon Sun 15:00

HARBOR EQUINOX SHADOW ANALYSIS

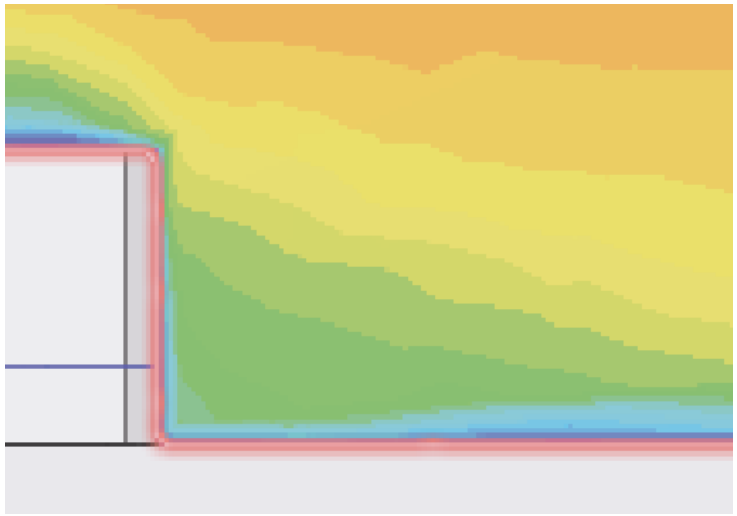
HARBOR VEGITATION SCREENING

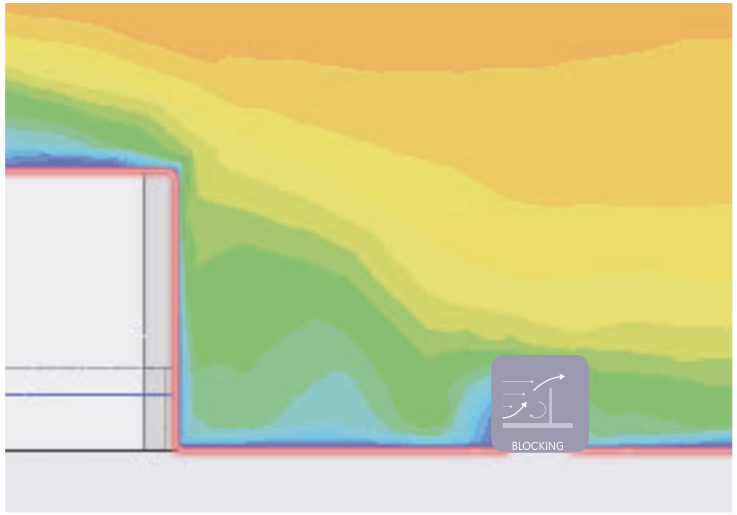
Winter Wind: SE

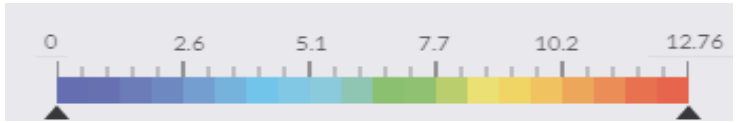
Summer Wind: NW

Wind Speed in ms

WIND BLOCKING SECTIONS







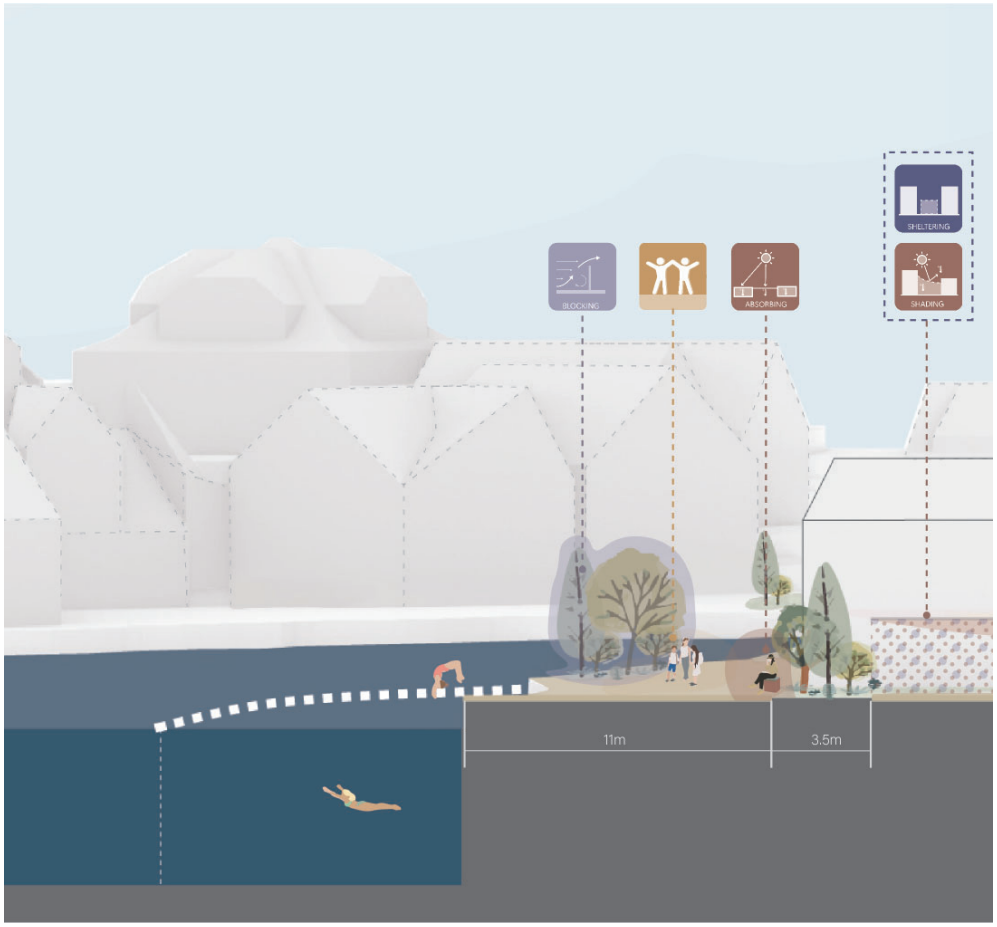
Wind Speed in ms

In addition to vegetation, wind blocks will be seasonally installed along the harbor's edge in the summer months. Like the sails used to add shelter and shading, these can be removed when not needed, and as seen here, are helpful in reducing winds at the human scale along the harbor's edge.

WALKABLE HARBOR SECTION

As well as social conditions, the walkable harbor also applies wind sheltering strategies to help reduce wind speeds in its microclimate and keep the walkway pleasant and active. Additionally, because this area is predominantly used in the summer months, shading sails will also be added to promote a lively public space where the walkable harbor and green connection meet.

WALKABLE HARBOR
DETAIL SECTIONS



WALKABLE HARBOR
SUMMER PERSPECTIVE

CONCLUSION

05

Throughout this thesis I have learned a lot about the process of including microclimate analysis in a design project. I learned the importance of considering microclimate impacts when selecting sites to work upon, and what strategies were most helpful when addressing the needs of the site. For Åkrehamn specifically the wind simulations became one of the most important tools in the design process, as the wind is quite strong in that coastal town, so developing and applying strategies to mitigate it became important. Running and learning these programs was sometimes quite challenging, but it was very valuable to see how climate simulation techniques can be used to influence design choices, and I will certainly take this knowledge with me in future projects.

However the project is not without limitations. While it is possible to gain an understanding of a town's microclimate through climate data and simulations, I have learned that it is not always a holistic view of the climate impact on the site. For example, in Åkrehamn, we know there is an average of 11 hours of sunlight a day and 85 mm of rainfall in June. However, while we know that this sunlight amount accounts for cloudiness, we do not know how the rain and sun are distributed throughout the month. It could be possible to have several rainy and sunny days, or it might be that it rains for almost 5 hours each day. Though they are similar in terms of microclimate, both of these scenarios impact the social use of the space quite differently. Thus, involving more community questions or personal accounts about the site's weather might have helped to address the microclimate at another level of detail.

Finally, because of the time and detail of incorporating microclimate analysis, a large portion of this project revolves around the diagrammed scale of applied strategies. An additional level of material detail has been included in the town square of the project, to better show how the microclimate might interact with the social life of Åkrehamn. In doing so, it aims to show how people use the spaces, and how the inclusion of microclimate strategies will influence seasonal life as the town develops.

REFERENCES

Reference List

1. Abdallah, Collin. "Proposed Tourist Hub by Progress, Miralles Tagliabue Embt, and Cushman & Wakefield Utilizes the Forces of Nature to Promote a 'Natural City.'" ArchDaily, ArchDaily, 8 Sept. 2018, www.archdaily.com/901024/proposed-tourist-hub-by-miralles-tagliabue-embt-utilizes-the-forces-of-nature-to-promote-a-natural-city?ad-source=search&ad-medium=projects-tab
2. Chauhan, Priya. "What Is Climate-Responsive Architecture? Significance & Examples." Planet Custodian, 11 July 2022, www.planetcustodian.com/climate-responsive-architecture/26421/.
3. "Climate Change Åkrehamn." Meteoblue, www.meteoblue.com/en/climate-change/%c3%85krehamn-norway-3163443. Accessed 23 May 2024.
4. "Climate of Norway." Encyclopædia Britannica, Encyclopædia Britannica, inc., www.britannica.com/place/Norway/Climate. Accessed 12 May 2024.
5. Douglas, Ian, and Philip James. Urban Ecology: An Introduction. Routledge, 2015.
6. Esch, Marjolein Van. "Designing the Urban Microclimate. A Framework for a ..." Researchgate, Delft University of Technology, 2015, www.researchgate.net/publication/307748592-Designing-the-Urban-Microclimate-A-framework-for-a-design-decision-support-tool-for-the-dissemination-of-knowledge-on-the-urban-microclimate-to-the-urban-design-process.
7. Europan Norway. "Åkrehamn Competition Breif." Europan 17, Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/6960ed894288b86cd-8921cbf508e33cf58f60ef0.pdf.
8. Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b-256c9aac95acf831fa39e8f42b-62f628b9.pdf.
9. Furuto, Alison. "Hobro – 'a City Finds Its Lake' Winning Proposal / Holscher Arkitekter." ArchDaily, ArchDaily, 26 Apr. 2013, www.archdaily.com/364837/hobro-nil-a-city-finds-its-lake-winning-proposal-holscher-arkitekter?ad-source=search&ad-medium=projects-tab.
10. Google Earth, Google, earth.google.com/web/. Accessed 23 May 2024.
11. Graham, James. Climates: Architecture and the Planetary Imaginary. Lars Müller, 2016. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4931266
12. Lenzholzer, Sanda. Weather in the City: How Design Shapes the Urban Climate. Nai010 Publishers, 2015. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4937906
13. "Microclimate." Encyclopædia Britannica, Encyclopædia Britannica, inc., www.britannica.com/science/microclimate. Accessed 12 May 2024.
14. "Microclimate." Microclimate - an Overview, ScienceDirect, www.sciencedirect.com/topics/earth-and-planetary-sciences/microclimate#:-:text=Microclimate%20is%20the%20suite%20of,selection%20and%20other%20ecological%20activities. Accessed 13 May 2024.
15. "Norway." Climate & Clean Air Coalition, www.ccacoalition.org/partners/norway#:-:text=Jonas%20Gahr%20St%C3%B8re%2C%20current%20Prime,together%20to%20reduce%20global%20warming. Accessed 12 May 2024.
16. Norway, Europan. "Åkrehamn." ArcGIS StoryMaps, Esri, 22 June 2023, storymaps.arcgis.com/stories/be-7b4e4289c3490b9823fe77532824f0.
17. Olgyay, Victor, et al. Design with Climate: Bioclimatic Approach to Architectural Regionalism. Princeton University Press, 2015. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=920312
18. Santamouris, Matheos, and Denia Kolokotsa. Urban Climate Mitigation Techniques. Routledge-Earthscan, 2016. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4753060
19. "Seasons and Climate in Norway." Weather and Temperatures, www.visitnorway.com/plan-your-trip/seasons-climate/. Accessed 12 May 2024.
20. Torgal, Fernando Pacheco, and Claes G. Granqvist. Adapting the Built Environment for Climate Change: Design Principles for Climate Emergencies. Woodhead Publishing, 2023. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=7494663
21. "Urban Microclimate." Urban Microclimate - an Overview, ScienceDirect, www.sciencedirect.com/topics/earth-and-planetary-sciences/urban-microclimate. Accessed 12 May 2024.
22. Yuan, Chao. Urban Wind Environment: Integrated Climate-Sensitive Planning and Design. Springer, 2018. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=5914130
23. "Åkrehamn." Europan Norway, europan.no/sites/akrehamn. Accessed 12 May 2024.
24. "Åkrehamn - Fjord Norway." Fjord Norway, www.fjordnorway.com/en/attractions/akrehamn. Accessed 13 May 2024.
25. "Åkrehamn (NO) - Site." Europan, www.europan-europe.eu/en/session/europan-17/site/akrehamn-no. Accessed 12 May 2024.

Climate Data References

26. "Butterfly." Ladybug Tools | Butterfly, Ladybug Tools LLC, www.ladybug.tools/butterfly.html. Accessed 13 May 2024.
27. "Climate Change Åkrehamn." Meteoblue, www.meteoblue.com/en/climate-change/%c3%85krehamn-norway-3163443?month=2. Accessed 13 May 2024.
28. "Climate Consultant." Climate Consultant | Society of Building Science Educators, www.sbse.org/resources/climate-consultant. Accessed 13 May 2024.
29. "IEM :: Site Wind Roses." Iowa Environmental Mesonet, Department of Agronomy, mesonet.agron.iastate.edu/sites/windrose.phtml?station=ENHD&network=NO--ASOS. Accessed 13 May 2024.
30. "Ladybug Tools." Ladybug, Ladybug Tools LLC, www.ladybug.tools/ladybug.html. Accessed 13 May 2024.
31. "SimScale Documentation: Online Simulation Software." SimScale, 29 Aug. 2022, www.simscale.com/docs/.
32. "Åkrehamn Climate." Åkrehamn Climate: Data and Graphs for Weather and Climate in Åkrehamn, Climate-data.org, en.climate-data.org/europe/norway/rogaland/akrehamn-9938/#google-vignette?utm-content=cmp-true. Accessed 13 May 2024.

FIGURE REFERENCES

All images and diagrams included in this booklet are my own, unless noted otherwise here. Some diagrams were made by referencing sources or data sets, which has also been noted below.

Figure 5: Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b256c9aac95acf831fa39e8f42b62f628b9.pdf.

Figures 6-10: Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b256c9aac95acf831fa39e8f42b62f628b9.pdf.

Figure 12: Google Earth, Google, earth.google.com/web/. Accessed 23 May 2024.

Figures 13-17: Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b256c9aac95acf831fa39e8f42b62f628b9.pdf.

Figures 21-22: "Climate Change Åkrehamn." Meteoblue, www.meteoblue.com/en/climate-change/%c3%85krehamn-norway-3163443. Accessed 23 May 2024.

Figure 24: Information collected from: Lenzholzer, Sanda. Weather in the City: How Design Shapes the Urban Climate. Nai010 Publishers, 2015. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4937906

Figure 25 Data collected from: "Åkrehamn Climate." Åkrehamn Climate: Data and Graphs for Weather and Climate in Åkrehamn, Climate-data.org, en.climate-data.org/europe/norway/rogaland/akrehamn-9938/#google-vignette?utm-content=cmp-true. Accessed 13 May 2024.

Figure 26: Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b256c9aac95acf831fa39e8f42b62f628b9.pdf.

Figure 32 -33 Information collected from Lenzholzer, Sanda. Weather in the City: How Design Shapes the Urban Climate. Nai010 Publishers, 2015. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4937906

Figure 34: Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b256c9aac95acf831fa39e8f42b62f628b9.pdf.

Figure 36: Data collected from: "Åkrehamn Climate." Åkrehamn Climate: Data and Graphs for Weather and Climate in Åkrehamn, Climate-data.org, en.climate-data.org/europe/norway/rogaland/akrehamn-9938/#google-vignette?utm-content=cmp-true. Accessed 13 May 2024.

Figure 42-43 Data Collected from: "Climate Consultant." Climate Consultant | Society of Building Science Educators, www.sbse.org/resources/climate-consultant. Accessed 13 May 2024.

Figure 44 Information collected from Lenzholzer, Sanda. Weather in the City: How Design Shapes the Urban Climate. Nai010 Publishers, 2015. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4937906

Figures 45-49: "IEM :: Site Wind Roses." Iowa Environmental Mesonet, Department of Agronomy, mesonet.agron.iastate.edu/sites/windrose.phtml?station=ENHD&network=NO--ASOS. Accessed 13 May 2024.

Figures 52-53: Information collected from Lenzholzer, Sanda. Weather in the City: How Design Shapes the Urban Climate. Nai010 Publishers, 2015. https://lubcat.lub.lu.se/cgi-bin/koha/opac-detail.pl?biblionumber=4937906

Figures 56-57: Europan 17. Åkrehamn (NO), Europan-Europe, 2023, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/www.europan-europe.eu/media/default/0001/27/47539b256c9aac95acf831fa39e8f42b62f628b9.pdf.

Figures 59-65 Case Study Images: Abdallah, Collin. "Proposed Tourist Hub by Progress, Miralles Tagliabue Embt, and Cushman & Wakefield Utilizes the Forces of Nature to Promote a 'Natural City.'" ArchDaily, ArchDaily, 8 Sept. 2018, www.archdaily.com/901024/proposed-tourist-hub-by-miralles-tagliabue-embt-utilizes-the-forces-of-nature-to-promote-a-natural-city?ad-source=search&ad-medium=projects-tab

Figures 66-74 Case Study Images: Furuto, Alison. "Hobro – 'a City Finds Its Lake' Winning Proposal / Holscher Arkitekter." ArchDaily, ArchDaily, 26 Apr. 2013, www.archdaily.com/364837/hobro-nil-a-city-finds-its-lake-winning-proposal-holscher-arkitekter?ad-source=search&ad-medium=projects-tab.