winter is coming

Investigating urban design in a Winter city

Degree Project in Sustainable Urban Design

by Erica Välimaa — May 2021

The title, 'Winter is coming', refers to the book- and TV series Game of Thrones by George R.R. Martin. The saying "Winter is coming" is the motto of House Stark, the lords of the North. The meaning behind it is to always remember to be prepared for the coming of winter. The same goes for cities: when prepared, we can still enjoy parks, squares, courtyards and playgrounds even if the ground is covered in a white blanket of snow.

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Master's Degree project in Sustainable Urban Design
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All visuals and images are mine unless stated otherwise.

Image by Joel Edin

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ABSTRACT

All around the world is the form of the built environment playing a significant role in either enabling or inhibiting outdoor activities. When it comes to winter and Winter cities, it is a challenge how to enable and encourage outdoor activities and soft mobility as the harsh conditions often make it uncomfortable to spend longer periods of time outdoors.

A major urban design challenge in Winter cities is the reduction of public space as large amounts of snow take a firm grip on open outdoor spaces. By gaining knowledge about how to design in Winter cities, urban designers can properly work towards achieving or improving outdoor comfort all year round.

The main findings this thesis focuses on are the three issues that are crucial to work with in Winter cities: maximizing solar access, mitigating wind and managing snow.

Using these issues as a stepping stone, a toolbox of Winter city design principles is introduced and explained. By using these principles, urban designers can adapt their projects to the often very harsh and challenging climate in Winter cities.

To work with locally adapted climate principles is not only a question of creating comfortable outdoor climates and attractive places for people. It is also about supporting and enabling people's rights to the city during all parts of the year. If failing to do so, there is a risk of people spending a large part of their lives indoors, which has an effect not only on people's overall wellbeing but also on the social and economical activity in our cities.

Kiruna is used as a testbed on which the Winter city design principles are applied. To propose a locally contextual project, the city of Kiruna and the project site is analyzed in detail. The thesis aims to present one version of what urban design in a Winter city could look like.

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Image by Marianne Välimaa

DRIVING FORCES

I have spent the majority of my life in Kiruna, a Winter city. Because of (or thanks to) this, winter has always been a big part of my life. It is my favorite season, mainly because it opens up the possibility to do a lot of the things and activities I enjoy doing: cross-country skiing, going on a hike with our snowmobiles, relaxing in a snow-pit with my face turned towards the sun, ice fishing, sledding with my niece Rut and nephew Artur and so much more.

Living in a Winter city is a different thing though. Winter in all its glory; it is not always with great joy I welcome the first snow of the season in late September or experience -3 °C on Midsummer eve. However difficult to accept, it is the price we pay to be able to go cross country skiing in October.

When I started studying and becoming more interested in urban design, I wanted to know more about designing places in a Winter city. How should urban designers think when designing in a Winter city? What are the differences compared to designing in a non-Winter city?

When looking into existing research about urban design in Winter cities I have learned a great deal. Along the way, I realized that ***how*** all this knowledge on urban design in Winter cities translates to actual urban design in a Swedish context is difficult to find. I, therefore, decided to fill parts of that knowledge gap with my master's thesis. My aim has been to learn more about how to create great living conditions in harsh weather conditions.

By taking part in my work I hope you too will learn something new!

—
Erica Välimaa
Malmö, May 2021

GUIDING QUESTIONS

The research questions that guide the work include:

- *What is a Winter city and what are its characteristics?*
- *What are the major challenges urban designers have to deal with in Winter cities?*
- *How can we, through architecture and urban design, achieve or improve outdoor comfort in Winter cities?*
- *How can gaining knowledge about urban design in Winter cities contribute to social, ecological and economical sustainability?*
- *How could a place designed with Winter city design principles organize?*

STRUCTURE, METHOD AND LIMITATIONS

Simply put, the thesis is divided into two parts: the research and the design, where the first outlines the theoretical framework upon which the design later is based upon.

The first part of this thesis introduces and explores the subject of urban design in Winter cities. An extra focus is put on a Swedish context as much of the literature found investigates Swedish Winter cities. The literature explored in this thesis is chosen based on relevance and applicability. Since much research exploring the subject focuses on the building itself, the aim was to broaden the scope and find research that also looks at a climate-sensitive design on a larger scale.

At the end of the research part is the collected knowledge and recommendations summarized and put together into the Winter city design principles. These principles can be used by anyone who is practicing urban design, spatial planning and architecture in Winter cities.

The second part of the thesis investigates how a site would look like if we base it largely on the Winter city design principles, although set in a local context.

The process starts with analyzing the city of Kiruna where the project site is located. This is done to get an overall view of the city-wide and regional conditions. After that, the site itself is analyzed and discussed. This is done to outline the prerequisites on which the design itself will be placed.

The design (masterplan, detailed plans, sections, perspectives etcetera) constitutes the last part of the second segment. Here, the finished design is explored and explained.

The design aims to not only answer the questions of what a Winter city could look like but also what such a place could include in Kiruna. By drawing upon local activities and generators, the design strives to create an area where such activities and generators can thrive. However, when exploring the design one should have in mind that this project tests the Winter city design principles and emphasis has been put on investigating how we can achieve or improve outdoor comfort in Winter cities. Exploring density, building typologies, building architecture, or landscape architecture has been secondary to exploring the Winter city design principles.

The thesis wraps up by looking back and reflecting upon the subject of urban design in Winter cities and what future research on the subject could explore to widen the scope of knowledge about Winter cities.

part 01

Introducing winter

A WINTER CITY?

A Winter city is defined by being an urban center where they experience long periods with temperatures below 0 °C, where the experienced precipitation is mainly snow and where the access to daylight and sunshine is limited during the winter months. These urban centers are almost exclusively located in the northern hemisphere and the term “northern cities” is almost synonymous with Winter cities (Stout, Collings, Stadler, Soans, Sanborn & Summers, 2018; Chapman, 2018).

LIFE IN WINTER CITIES

The climate and weather play a big role in the way we experience our cities and in the way we move around in them. As winter arrives, the world outside our windows changes. The days get shorter, the city is covered in a white blanket of snow and many animals hibernate or migrate to warmer climates as a way to escape the harsh conditions. Maybe without even realizing it, people change their behavior when the temperature drops.

The impact of the cold climate experienced in Winter cities can be noted in the patterns of outdoor use, recreational activities and mode of transportation: although it is estimated that people are not spending more than 10 % of their total time outdoors, they are even less likely to spend time outdoors during winter (Evans & McCoy, 1998). A Finnish population-based study estimated that people only spend around 4 % of their total time exposed to cold outdoor conditions (Mäkinen et al., 2005). If this number is correct, Winter cities have to work hard to encourage people to spend time outdoors.

When studying the attitude children and adults have towards winter, Masamichi, et. al., (2004), found out that young children go from having a positive attitude towards winter to having a more negative attitude as they grow older and become teenagers. Adults often have a more negative yet nuanced attitude towards winter (Masamichi, et. al., 2004). Our attitudes towards winter can be affected by how much time we have spent outdoors as children:

“The more time that schoolchildren outdoor play increases; the more they reply, “I like winter”. There is a relationship between the amount of time playing outdoors and the rates of positive adaptation replies to winter”

(Masamichi, et. al., 2004)

This shows one of several reasons why it is important to promote outdoor activities for children. If we spend more time outdoors as children, our attitudes towards winter can change and become more positive later in life.

Structures difficult to remove snow from are at risk of being left unmaintained during winter, resulting in a reduction of public space

CHALLENGES WITH WINTER

Despite the expansion of public space and the many opportunities brought by winter, people in Winter cities tend to spend less time outdoors and become less active during the cold and dark seasons that characterize winter. One major urban design challenge in Winter cities is therefore to create attractive spaces and built environments that encourage outdoor activities all year round. To do so, it is essential to understand the impact local weather conditions have on people's behaviors and attitudes towards visiting outdoor spaces.

What people like and dislike

Meteorological conditions have a large impact on people's emotions. A study carried out by Knez, Thorsson, Eliasson and Lindberg (2008) concerning psychological mechanisms in outdoor places showed that the participants felt most glad when the temperature was high and the sky was clear. The participants felt the least glad and active when the opposite conditions were studied: low temperatures and cloudy skies. The same study also highlighted that the participants thought the best weather for outdoor activities was when the temperature was high and the sky was clear (Knez, Thorsson, Eliasson & Lindberg, 2008). Research also shows that people are more likely to tolerate harsh conditions such as strong winds if the place is rich in natural characteristics, such as parks or waterfronts. In places that have a low amount of natural characteristics, such as squares or courtyards, strong winds as a result of poor building geometry or street orientation are disliked and contribute to a negative feeling of the place (Eliasson et al., 2007). Even though urban designers cannot affect the weather it is important that urban designers and other professionals involved in the design aim towards creating spaces within the city that are places that are comfortable for people to spend time in.

A reduction of soft mobility

Another major urban design challenge that faces Winter cities is the reduction of soft mobility amongst the inhabitants. This can have a large negative impact on people's overall health: a ground covered in snow and/or ice can pose as a threat to the mobility of people, especially senior citizens and people with mobility impairments. As the risk of slipping, falling and/or being exposed to barriers such as large piles of snow increases with winter there is a greater risk of a retraction from the public realm in the winter, leading to social isolation (Stout et al., 2018).

Barriers to soft mobility

In a study by Ebrahimabadi et al. (2011) it was reported that slipperiness, snow, rain and low temperatures were rated by the respondents as having the highest negative impact on the choice of transportation mode. Darkness was rated as neutral and did not have either a negative or a positive effect on the choice of transportation. Sun was rated as having a very positive impact on choosing whether to bike or walk (Ebrahimabadi et al., 2011).

In a similar study, this one carried out by Chapman, Nilsson, Rizzo and Larsson (2017), the results showed that the respondents were slightly more resistant to walk more than a kilometer during the winter months compared to what they were during the summer months. The respondents viewed rain, icy surfaces and

Snow takes up a lot of space, not uncommonly pedestrian space, which is a major urban design challenge in Winter cities

CHALLENGES WITH WINTER

darkness as the greatest barriers to soft mobility while snow and snow-covered surfaces were rated as the smallest barriers to winter walking (Chapman et al., 2017).

When analyzing how to enable soft mobility during all seasons, Chapman et al. (2019) highlighted that wide sidewalks in the summer become distinctly narrower in the winter due to large amounts of snow taking up pedestrian space. This resulted in pedestrians and cyclists having to walk and bike on the roadways, posing as a threat to both their safety and to the safety of drivers. The same study also noted that the white out-effect occurring when the landscape is covered in snow blurred the contours on the street, making it difficult to separate the different elements that make up the public realm. The result of the white out-effect is a public realm perceived as one single large undefined area (Chapman, Nilsson, Rizzo & Larsson, 2019). This can result in people having difficulties navigating the area. Especially difficult is it for people with visibility impairments. This could also result in elderly people not feeling safe enough to spend time outdoors, increasing the risk of social isolation.

Increased car use

As a result of the harsh conditions often experienced in Winter cities, transportation in such places can become dependent on motorized vehicles (Ebrahimabadi, 2015). This is the case in Kiruna, in which a study carried out by Ebrahimabadi, Johansson, Öberg and Nilsson (2011) shows. Compared to other Swedish municipalities with a similar number of inhabitants, Kiruna has a nearly 20 % larger share of private car transportation. Kiruna also reported a smaller share of public transport, biking or walking. The cold climate was seen as the largest barrier to walking or biking in Kiruna (Ebrahimabadi et al., 2011).

Use of public space

Strongly connected to the reluctance towards walking or biking, the use of the public realm decreases in Winter cities. While investigating the usage of public spaces, researchers Larsson and Chapman (2020) observed that people felt a greater resistance towards using public spaces during winter compared to using public spaces in summer. Furthermore, the respondents were also less likely to use a public space during rainfall or when the ground was icy or slushy. Poor lighting and darkness were also seen as barriers to public space use. On the other hand were snow, snow-covered surfaces and wind rated as lesser barriers to public space use (Larsson & Chapman, 2020).

The connection between the use of a place and micro-climatic conditions has been confirmed several times by, for example, Gehl (1971) and Nikolopoulou (2011). Access to sunlight and warmer temperatures increase the number of people present in an urban space. In Scandinavian countries, where access to sunlight is limited during the winter, people have an enormous urge to enjoy the sun if it is possible, even if it is only for a short period of time (Eliasson, Knez, Westerberg, Thorsson & Lindberg, 2007). In Winter cities located at high latitudes, the low sun elevation is a major concern when designing outdoor spaces. Especially difficult to get solar access

CHALLENGES WITH WINTER

is it on east-west oriented streets and/or open spaces during the late winter months March and April.

Enabling outdoor activities and soft mobility

With people spending more time indoors and less time outdoors, the use of the public realm decreases which affects on the social and economical activity in cities and the liveliness of such places (Stout et al., 2018). Therefore, actions to enable outdoor activities and the continuation of people's daily lives during winter could increase not only people's overall well-being but also the economical and social activity in cities. Being able to walk or bike within the built environment is also an essential part of sustainable urban development.

As a way to encourage people to walk and bike more during winter, Ebrahimabadi et al., (2011) suggest that urban planners should consider ensuring that sidewalks and other pedestrian routes have access to sunlight and that winter road maintenance for sidewalks and bicycle routes are prioritized (Ebrahimabadi et al., 2011). To enable people to use public spaces it is also recommended that the maintenance of the public realm is prioritized. To improve orientation and reduce the white out-effect it is important to use directional signage that is visible even when there is snow on the ground.

Another important action is to facilitate public spaces that have a clear purpose and function during winter. By doing this, it can be assured that public spaces are welcoming and used all year round (Chapman 2018). Skating rinks or loops, cross country skiing trails, ski parks, snow mounds and sledding hills all have a clear winter purpose. Some of the examples are also easily maintained or have the ability to be multi-functional. However, seating areas, public fire pits, pedestrian paths etcetera also have a clear winter purpose as long as they are being properly maintained when winter comes. Large amounts of snow also offer the possibility to carve out seating areas in the snow, providing not only outdoor furniture but also a maintenance-free structure within the city.

BARRIERS TO SOFT MOBILITY IN WINTER CITIES

PERKS OF SPENDING TIME OUTDOORS

People are spending less time outdoors and more time indoors during the cold and dark seasons which affects their overall well-being. As mentioned previously, a Finnish population-based study estimated that people only spend around 4 % of their total time exposed to cold outdoor conditions (Mäkinen et. al., 2005). If this result is correct it indicated that winter is a contributing factor to increased inactivity amongst people.

Physical activities such as walking and biking have a positive impact on people's health. So does being outdoors and spending time in nature. Research shows that being in outdoor environments can help lower blood pressure and reduce stress (Chapman, 2018).

Conditions within the built environments that encourage people to spend time outdoors could also lead to an increase in people's physical activity and should therefore be an aim with urban design. To achieve this, it is important to not only look at the quality of squares, parks or sports areas but also to analyze the layout of the urban form. Depending on where functions are located, they can either encourage or obstruct the choice of whether to walk, bike, ski or drive to those places. Spread out areas result in distances that can feel too long to go on foot or by bike. On the contrary, compact areas with good connectivity are enablers of physical activity in people's everyday lives and could also contribute to improved public health (Nilsson & Kostenius, 2016).

Besides the benefits we get by just being outdoors it is also a great way to see and interact with people. This creates connections and a feeling of belonging which can play a significant role in the reduction of social isolation.

Reference projects

Winter cities have a fantastic opportunity to use the snow and frozen areas to create unique and adventurous outdoor activities and experiences.

Many Winter cities around the world are doing just this. Every year in Östersund is the local lake Storsjön transformed into a winter park. The park aims to encourage public life and physical activity by offering different outdoor activities such as driving snowmobiles, taking a winter bath, going on a long-distance skate tour or participating in ice sculpting workshops. Almost every activity is free of charge, an important requisite for everyone to be able to participate.

Another project is Isbanan (the ice path), a popular place-making project located in Luleå. The ice path is constructed every year in Luleå when the sea freezes. The ice path connects the central parts of Luleå with surrounding districts, extending the general soft mobility network. There are several wind shelters with seating and barbecue possibilities located along the path. Isbanan is frequently used by residents and tourists.

Lastly, as winter arrives in Kiruna, the two local lakes Luossajärvi and Tuollajärvi freeze. The expansion of the public sphere opens up the possibility to go ice fishing, skiing and ice skating. Although no place-making projects happen on the lakes, they are still two very popular destinations for people in Kiruna.

part 02

Urban design in Winter cities

WHAT CAN URBAN DESIGN INFLUENCE?

A key urban design challenge in Winter cities is creating public outdoor spaces that are attractive and safe all year round (Chapman, Nilsson, Rizzo & Larsson, 2018). Norman Pressman, a prominent advocate for an urban design customized for Winter cities, argues that actively working to reduce discomfort in winter cities, by mitigating wind and increasing solar access, could extend comfortable outdoor days by up to 30 % annually (Pressman, 2004).

When it comes to what urban design can influence (micro)climate- and weather-wise the easiest thing to influence is the amount of solar access or solar exposure wanted in an area. The second easiest element to influence is wind - whether to shelter from it or welcome it.

Humidity and air temperature are the most difficult elements to influence with urban design.

ISSUES CRUCIAL TO WORK WITH IN WINTER CITIES TO ACHIEVE OR IMPROVE OUTDOOR COMFORT:

Maximizing solar access | Mitigating wind | Managing snow

URBAN DESIGN IN WINTER CITIES

That local meteorological conditions should have a great impact on a place's urban form is most likely something that many urban planners and architects can agree upon. Street orientation, building placement and typologies have a significant impact on the microclimate and how the city is perceived by its residents. Yet cities with substantial differences in local meteorological conditions have been constructed with similar street orientation, building placement and typologies. The "one size fits all"-solution can in the worst case result in very uncomfortable outdoor environments.

The modernist urban design doctrine has been singled out for criticism due to its advocacy for rational solutions and technological innovations that, on one hand, aimed to solve the challenges brought by winters by offering designs that completely erased the exposure to cold conditions (Stout et al., 2018). Enclosed pedestrian systems like Toronto's and shopping malls are two examples of the modernist way of dealing with winter conditions. On the other hand, many of these modernist solutions worsened microclimatic conditions: high-rise towers caused downdrafts, increased wind speed at the pedestrian level and contributed to shaded streets and a car favored streetscape made it possible for winds to accelerate as they went through the city (Stout et al., 2018). When looking at old city plans with an organic street layout, one can find many street layouts that have been arranged to create a more comfortable microclimate.

There is a significant public gain for every city that experiences snow (no matter the amount or for how long) to work with climate-conscious urban design and striving towards enabling safe and comfortable outdoor activities. The costs of injuries caused by slippery and icy surfaces in Sweden were estimated to 2,2 billion SEK yearly (Nilsson & Kostenius, 2016). On top of that, there is also a lot to gain ecologically, socially and economically if people in Winter cities feel encouraged to walk or bike rather than drive.

Three issues are crucial working with to achieve or improve outdoor comfort in Winter cities (Ebrahimabadi, 2015, Pressman 2004):

- maximizing solar access
- mitigating wind
- managing snow in outdoor environments

While positive aspects of winter: solar access, snow and snow-covered surfaces are viewed as positive enablers for outdoor activities and soft mobility, icy surfaces, wind and darkness are seen as barriers to outdoor activities and soft mobility. Simply put, solar access should therefore be maximized while the negative aspects of winter such as slush, ice and wind should be minimized (Chapman et al., 2017).

MAXIMIZING SOLAR ACCESS

Access to solar exposure is vital in any city due to its positive impact on people's overall health. By integrating solar access within the urban design in Winter cities, the sun can also be exploited to help clear snow, ice, water and slush from streets, squares and other places (Chapman et al., 2018). However, it can be challenging to get enough solar access since Winter cities usually are located at a higher latitude and therefore have a lower solar elevation.

Solar access on east-west oriented streets

Maximizing solar access in a place with low sun elevation requires a holistic approach regarding east-west oriented streets' height to width ratio (H/W ratio). For instance, in a city located at latitude 64°, a H/W ratio of 0.45 is required to ensure solar access in March on an east-west oriented street. It is important to remember that such a street will give only a little wind-shelter when winds blow normal to the street direction (Ebrahimabadi, 2015). Looking at Kiruna as an example, the city is located just above latitude 67°, and has a recommended H/W ratio of 2,5 to ensure solar access in March on the northern part of an east-west oriented street. This means that east-west oriented streets will have to be significantly wider than the height of the building framing the street. The use of angeled streets can also achieve better solar access than a straight street could.

Furthermore, having wider sidewalks on the sunny side of the street is an easy way of enabling people to enjoy the sun while walking or sitting. It also opens up to the possibility of cafés or other shops "spilling out" into the street. By doing that, streets that have a higher H/W ratio can still have the elements that make up an attractive and interesting street even if the street itself is wider than other streets.

Public spaces

Sunshine makes people feel more comfortable, especially in Winter cities. Maximizing solar access and mitigating wind can make an outdoor public space feel 10°C warmer (Edmonton Winter city). To create public spaces with solar access it is of great importance that urban designers look at the benefits of implementing several smaller public spaces that benefit from solar access over the course of the year rather than only implementing a single large public space (Chapman, 2018). By doing that, the goal is to always have one (or more) public place that has solar access while others are shaded.

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The next two pages show two diagrams comparing the difference in solar elevation and lengths of shadows. Diagram 2:1 shows a comparison in solar elevation in Kiruna (Winter city) and Malmö (Non-Winter city). The result shows that Kiruna has a lower solar elevation during all parts of the year.

Diagram 2:2 shows a result of the difference in solar elevation and what effect it has on the lengths of shadows. On the same day (Spring equinox) the same three-story building in Kiruna and Malmö casts two very different shadows. The building in Kiruna casts an almost 24 meters long shadow while the same building in Malmö only cast a 12 meters long shadow. This is something urban designers need to have in mind when designing in Winter cities.

Diagram 2:1

DIFFERENCES IN SOLAR ELEVATION: KIRUNA AND MALMÖ

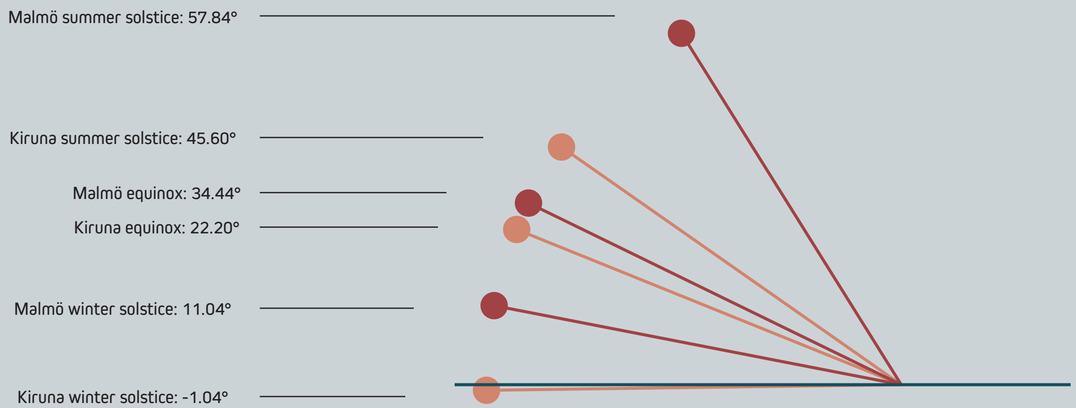


Diagram 2:2

DIFFERENCES IN SOLAR ELEVATION: IMPACT ON SHADOWS

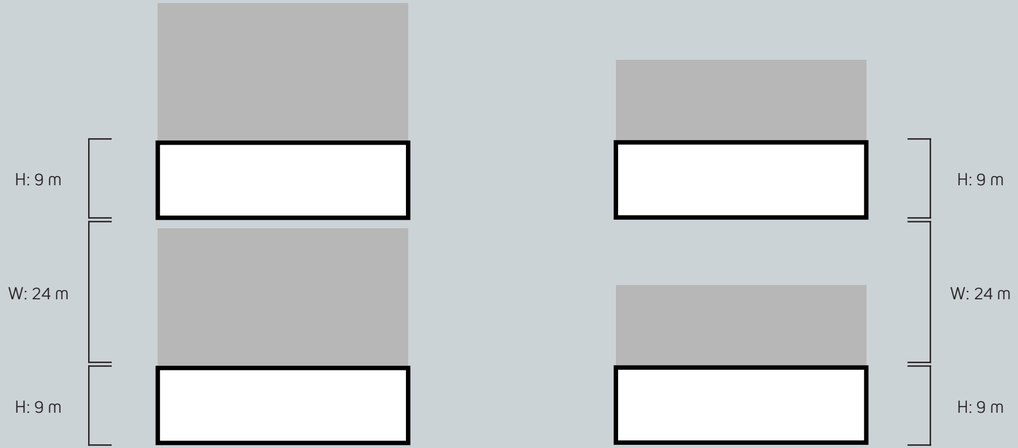
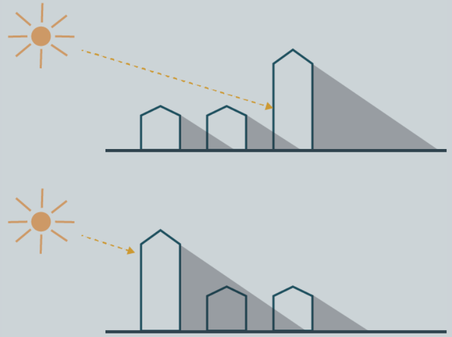


Diagram 2:3

AVOID "UNNECESSARY" SHADOWS BY LOCATING TALLER BUILDINGS IN THE NORTHERN PART



MAXIMIZING SOLAR ACCESS

Besides the layout of the street grid, H/W ratio on east-west oriented streets and the importance of offering several public places for people to go to depending on time and season, some actions can be taken to create a brighter and more sun-exposed area.

Typologies

Partly because of the advantages a closed block typology has on other building typologies in creating a comfortable microclimate on the blocks' inside, the (semi-)closed block is used in many new development projects. Although being highly effective in mitigating wind, the closed block typology has some disadvantages. One is the risk of ending up with shaded courtyards as the buildings' do not let any sun into the courtyard. In Winter cities, where the solar elevation is significantly lower than in other cities, this can become a big challenge for urban designers and architects. One way to get around this challenge and allow solar access on the courtyard and into people's homes is to have lower buildings in the south part of the block and taller buildings in the north part of the block. Another intervention is to keep parts of the block completely free from buildings. By using vegetation, snow storages, the topography etcetera, urban designers can still mitigate winds and create a boundary between public and private if needed.

The same organization of building heights can of course be used in projects where the closed block typology is not being used. As tall buildings in urban environments tend to shade the entire area behind and around it, it is recommended that taller buildings are located in the site's back edge (Diagram 2:3).

The building

When it comes to the building it is recommended to use darker colors over lighter ones for the building to absorb and radiate heat for a longer period (Edmonton Winter city).

The pedestrian experience can be enhanced by designing suitable setbacks and other variations in building frontages. More so, setbacks create spaces where the sun is "trapped" and the wind is mitigated. If combined with darker materials these sun traps can be available and free of snow for long periods every year (Edmonton Winter city).

Vegetation

Deciduous trees are good for maximizing solar access during winter. When the deciduous trees lose their leaves, sunlight can filter through the branches. This is not the case with coniferous trees which is why the planting of deciduous trees close to public places or other spaces where it would be good to get solar access is preferred.

All in all, these interventions to maximize solar access might seem simple and obvious. The challenging part is, however, not to implement these in a project but to combine them with other interventions combating other challenges. If maximizing solar access includes creating spaces that are large enough for the sun to reach and locating taller buildings in the back; interventions to mitigate wind are often about the opposite as you will learn in the next chapter.

MITIGATING WIND

Due to the large negative impact strong winds have on people's overall experience, especially in a place that has a low amount of natural characteristics, the notion of wind-sheltering needs to be taken into account early on in an urban design project.

Street layout
A major factor influencing wind speeds is the layout of the street grid. Using an irregular or broken street grid layout and curved streets could reduce wind and improve pedestrian comfort. Another contributing factor is the density of an area. A more compact area has the advantage of being able to reduce wind speeds drastically (Ebrahimabadi, 2015). More on how different street grids influence wind speeds on page 38.

Natural snow clearing
However, winds do not only have to be mitigated within the urban environment. As the snow gathers where wind speeds are low, streets and roads oriented in the prevailing wind direction can benefit from natural snow clearing (Chapman et al., 2018). Exactly how a natural snow clearing could function is not thoroughly investigated in the research. It could be assumed that, if making it work properly, the need for snow removing actions would reduce resulting in a "win-win" situation for the ecological and economical sustainability of cities.

Building heights
To minimize the turbulence on the pedestrian level, reduce wind speed and steer the wind over the buildings it is preferable to have low buildings with similar heights (Chapman et al., 2018). Tall buildings (about twice the average height in an area) will have the opposite effect on the wind as mentioned before: downdrafts and increased wind speed at the pedestrian level. If tall buildings are needed in a project urban designers should look into the possibility of using features such as a podium as a way to prevent the wind from going straight to the ground level.

In a study carried out by the city of Toronto, it was proven that building height plays a significant role in either reducing or increasing wind speeds. On a 20 meters wide street framed by mainly four-story buildings, the wind speed was 23 - 52 % lower compared to the wind speed outside the built environment. A street with several highrises framing it, the wind speed was 94 - 150 % faster, no matter the wind direction. High rises that are taller than 44 meters and standing on a 40 meter wide street push the wind down to the closest sidewalk, according to the performed studies. The more varied building heights between surrounding neighborhoods and a highrise, the faster wind speed (Bosselmann, 1995. in Thoren, 2013).

The building itself
To create good micro-climatic environments for people living in windy places there are a couple of recommendations that could guide architects and urban designers. When it comes to the building, the use of setbacks, canopies, arcades and/or colonnades can help reduce wind speeds and create areas where people can shelter themselves from the wind. The use of inset balconies is also recommended in windy places as such balconies offer shelter from the wind (Edmonton Winter city).

Buildings with rounded or chamfered corners can help reduce wind turbulence. Pictured are the Ortdrivaren buildings (1961) by architect Ralph Erskine. Located in Kiruna, the buildings were designed with several interventions adapted to the harsh climate.

MITIGATING WIND

Trees and snow to mitigate wind
Trees can work as natural windbreakers and it is suggested that coniferous trees are used in Winter cities as they both buffer wind and add color in an otherwise colorless environment. A three meter high planting can reduce strong winds to moderate breezes from the windshield up to 60 meters and at the same time increase temperatures by 1-5 °C (Steinsvik, 2004).

To achieve the best result of the vegetation, it should be planted in a strategic way. By planting compact shrubs along with compact coniferous trees, the wind will not be able to go under the taller trees and will therefore be reduced.

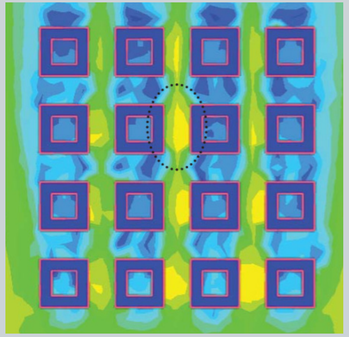
Shelters and structures
To offer wind sheltering possibilities within the public realm is important to encourage people to spend time outdoors. Many Winter cities have over the years used different types of structures such as small huts. The use of huts can offer shelter from the elements while at the same time offering seating areas for people. Such huts may also be designed as a piece of art in the landscape, To maximize the connection between inside the huts and outdoors it is important to remember using see-through materials.

Diagram 2:4
TREES TO MITIGATE WIND

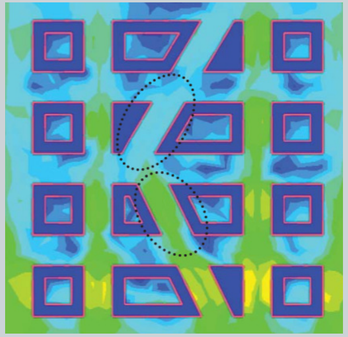
Diagram 2:5

DIFFERENT STREET GRIDS' IMPACT ON WIND SPEED

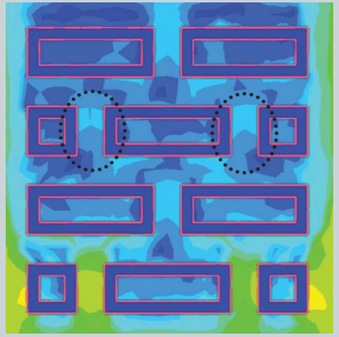
Ebrahimabadi & Johansson (2014)



Wind speed increases when streets are parallel to wind direction



Wind speed reduces on streets that turn in a north-east direction



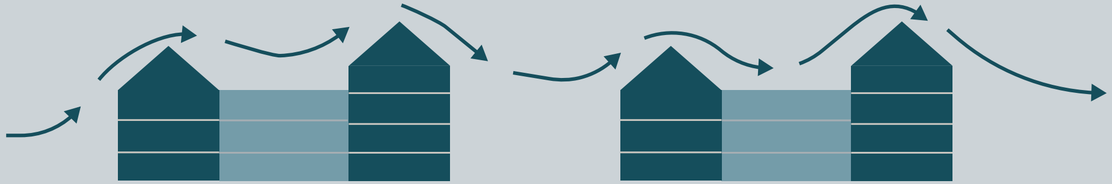
Wind speed reduces on several points when streets break in the shape of a brick pattern

The layout of the street grid has a significant impact on wind speed. As shown in diagram 2:4 by Ebrahimabadi and Johansson (2014), a street grid with streets parallel to each other can increase the wind speed. If possible, it is recommended to not design long streets aligned with the prevailing wind direction as such streets will increase the wind speed.

When looking at streets that turn in a direction away from the prevailing wind direction, it is clear that the angeled street has a reduced wind speed. Lastly, a street grid with a "broken" network in the shape of a brick pattern or a T-type grid has the possibility of reducing wind speeds on several points (Ebrahimabadi & Johansson, 2014).

Diagram 2:6

THE BUILDING'S EFFECT ON WIND



Low buildings with similar heights and closed courtyards create good micro-climatic conditions

The building itself has an impact on the wind speed and direction. Buildings with pitched roofs can help to steer the wind over the buildings and/or the neighborhood. Lower buildings with similar building heights also help to reduce the wind turbulence as tall buildings "catch" the wind and push it down to the street level.

If a neighborhood or a district needs taller buildings there are a few tools that can be used to achieve a comfortable microclimate on the street level. Locating taller buildings at the edges of the site can help in steering the wind over the site. Having a gradual increase to building height could also help. The most important thing to remember is to reject having a single tall building without a base as such a building will increase the turbulence in the area.

The closed courtyard typology is recommended in windy areas as it keeps the wind from entering the courtyard.

MANAGING SNOW

Although making it possible to go skiing, sledding, snowboarding and snowmobiling, there is also the more mechanical part to snow which contains the parts inevitable in a Winter city: plowing, removing, storing and sanding.

Removing snow

The removal of the snow is a set of different actions that take place during the entire winter season. It is done to clear the city from snow and by that enabling people to move around and their lives to continue as usual.

There are no general guidelines for how Swedish cities and municipalities should handle their snow management (Reinosdotter, 2007). The notion of removing snow from the city and its roads is usually a service that municipalities buy from private entrepreneurs combined with having in-house snow removal service(s) (Josefsson & Johansson, 2014).

Different parts of the city have different ways of removing the snow. In less dense areas, such as single-family residential areas, is it common for the snow to be "pushed" towards the edges of the street which results in a more narrow street every time more snow falls. When the street is too narrow to maintain its intended safety, the snow is transported to a local or central snow storage (Josefsson & Johansson, 2014).

In city centers or on larger roads are both trucks with snow-blowers and snowplow cars used. First, the snowplow car collects the snow before the snow-blower comes and blows the snow onto a truck that later transports the snow away from the area. It is not always necessary to immediately transport the snow and in such cases is the snow stored in a local snow storage, such as a lawn or parking lot (Josefsson & Johansson, 2014).

On highly trafficked or prioritized roads is the snow removed completely and the width of the road is preserved. The snow mounds aligning the road are transported away to a central snow storage when they get so large that they might make up a safety risk (Josefsson & Johansson, 2014).

Equal snow removal

For a long time have the car roads have been prioritized in the snow removal order. The car roads were cleared of the snow before sidewalks, pedestrian paths and bicycle paths were plowed. This priority favored men's availability over women's as more men use the car as their main mode of transportation. Women, on the other hand, are more inclined to walk, bike, use public transport or ride a car as a passenger.

During the last couple of years, there has been a shift. In 2011, the Swedish municipality Karlskoga decided that they were going to practice a more equal snow removal (Dahlqvist, 2021). After interviewing people in Karlskoga the municipality found out that people who were out early in the morning were on their way to preschools. With this in mind, the municipality decided to change its order of priority. The car roads were removed from the top of the list. Instead, the routes that lead to different preschools were the first to be removed of the snow. After that are the routes to larger workplaces cleared of the snow together with pedestrian- and bicycle routes

MANAGING SNOW

leading to schools in the municipality. By doing this the municipality hopes that more people will decide to walk, bike or use public transportation (Dahlqvist, 2021). Since 2011, several other Swedish municipalities such as Umeå, Boden, Huddinge and Stockholm have also adopted a more equal removal of snow.

Several actions can be taken to speed up and simplify the snow removal process. One action that plays a big role in doing this is choosing structures with few or no poles fixed in the ground. By choosing hanging street lights over fixed street poles, wayfinding signage on walls instead of poles and so on can significantly reduce the time and money spent on removing snow (Björling Francki & Johansson, 2014).

Storing snow

Another major urban design task in Winter cities is how to handle the storage of snow. Research has shown that from an economical and environmentally sustainable point of view it is preferable to store snow in multiple smaller locations (local snow storage) rather than in a single location (central snow storage). By enabling multiple smaller locations such as empty green areas, parking spots and leftover spaces within the area being cleared of snow, the need for longer transportations to larger snow dumps are reduced (Reinosdotter et al., 2007). In Helsinki and Jyväskylä studies have shown that storing around 30 % of the total amount of snow locally reduces the financial costs up to 19 % and the CO2-emissions by 12 % (Reinosdotter et al., 2007).

Since the snow will eventually melt and become water within our stormwater systems it is, however, important to analyze the snow quality before deciding where to store it. The largest reason to polluted snow is the car and the choice of where to store snow should be done according to the amount of traffic in the area. Reinosdotter et. al., (2007) proposed a recommendation of how to decide where to store snow depending on the number of cars there are in the area per day (Reinosdotter et. al., 2007 in Josefsson & Johansson, 2014). For more information: Diagram 2:6 Where to store snow (page 49).

If possible, snow storing locations should seek to be located in places where there is solar access to speed up the melting process (Chapman et al., 2018).

If the local snow storages are large enough to handle a great amount of snow and are located in places where they are not posing as a threat to the safety of pedestrians, bicyclists and drivers it is possible to let the snow mounds be there for a longer time, possibly the entire season. When located strategically, the snow storages can be a nice recreational addition to a neighborhood or district (Björling Francki & Johansson, 2014).

2 ha

Central snow storage located in Kiruna

3 ha

Central snow storage located in Porsön, Luleå

4,5 ha

Central snow storage located in Umeå

Diagram 2:7 References of central snow storages

2500 m²

Local snow storage on a grass lawn in a residential neighborhood in Kiruna

400 + 640 m²

Local snow storages on both sides of a neighborhood street in Kiruna

240 + 140 + 420 + 240 m²

Several local snow storages on grass patches along a street in Kiruna

Diagram 2:8 References of local snow storages

CENTRAL SNOW STORAGES

A central snow storage is a large area often located on the outskirts of the city where large volumes of snow can be stored (Reinosdotter et al., 2007).

The snow that is stored in the central snow storages is usually too polluted to be stored in a local snow storage. It is, however, not only the polluted snow that is being stored in the central snow storage. When (or in the occasion of) a local snow storages run out of space the snow is usually transported to the central snow storage. The same goes for the highly compact snow that is removed when the streets are being completely emptied of snow during spring to prevent the streets from becoming too slushy.

The snow stored in a central snow storage does not always melt entirely because of the cool summers in Winter cities. It is therefore important to located central snow storages in places where they are not too close to the city's residential areas as such large amounts of snow and water can be a bit smelly, full of dirt and waste and attract mosquitoes.

The advantages of storing snow in a central snow storage include easy control of the contaminated melting water and that it liberates space in the city (Reinosdotter et al., 2007).

LOCAL SNOW STORAGES

A local snow storage is a smaller area located close to the area that is being plowed. There are often several local snow storages within the same neighborhood and they can all have a high recreational value (Reinosdotter et al., 2007).

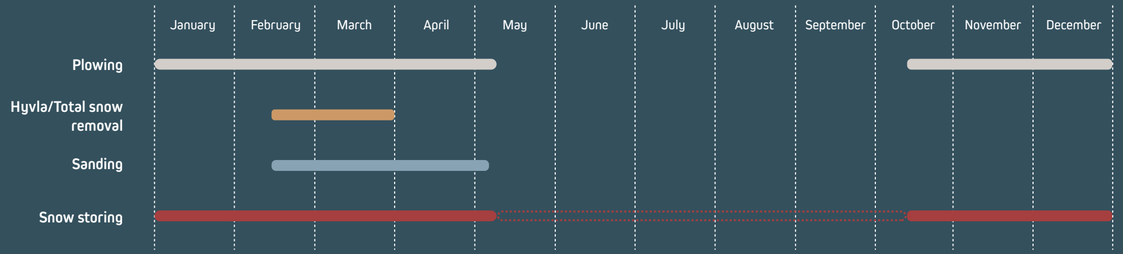
Local snow storages often appear where there is room within the city. This can be a contributing factor to why sidewalks, public spaces and other places often used by people are taken up by snow storages when the snow falls and the large-scale removal of snow begins.

The advantages of having several local snow storages include shorter transportations, reduced emissions from transportations and that there is money to be saved. The disadvantages include that it can be hard to control the contaminated melting water and that it is space-demanding (Reinosdotter et al., 2007).

Because of the amount of snow and the advantages of storing snow locally, urban planners in Winter cities should always try to implement local storages within the project site. By doing this, places that are traditionally not aimed for storing snow, such as sidewalks and public spaces, will continue to serve their purpose even during the months with snow.

Diagram 2:9

A YEAR OF SNOW: AN EXAMPLE FROM KIRUNA



In Kiruna, snow removal activities (plowing, "hyvla" and transportation) are being done according to the municipality's declaration of snow clearing quality (Kiruna municipality, 2012). Snow removal does not start immediately when the snow falls. Instead, there are a few criterias that need to be checked before the plowing can start:

on primary streets, pedestrian paths and bicycle paths is the snow removal expected to be done within five hours on the occasion of five centimeters of snow.

On secondary streets, pedestrian paths and bicycle paths is the snow removal is expected to be done within 15 hours on the occasion of eight centimeters of snow.

The declaration also states that the total removal of the compressed snow ground, to "hyvla" the streets, is expected to be done before March 31st (Kiruna municipality, 2012). This is done to prevent the thick and extremely compressed snow cover on the streets from melting and becoming slush, making it difficult to drive and walk.

Storing snow often takes place during the entire year as not even the summers in Winter cities are warm enough to melt the large amounts of snow being stored in the central snow storages.

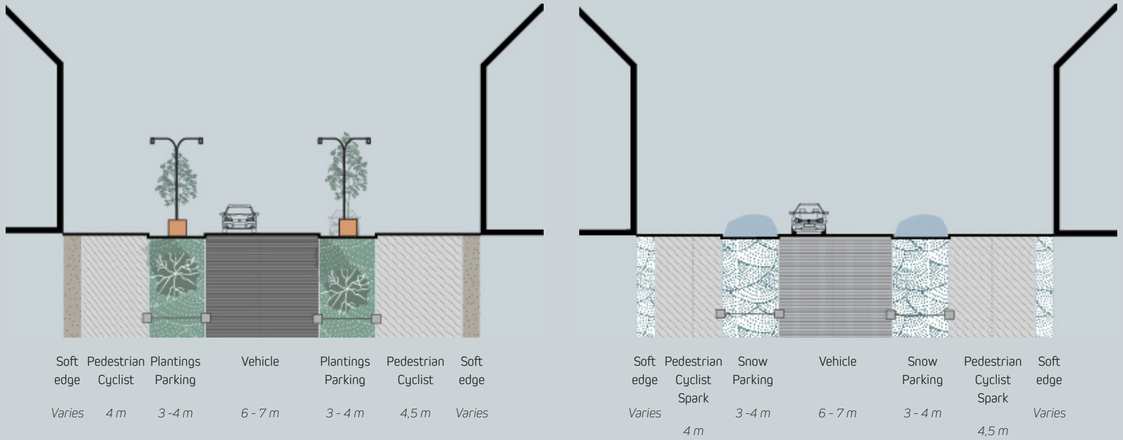
Diagram 2:10

WHERE TO STORE SNOW

(Based on Reinosdotter et al., 2007)

Cars/day	< 5000	5000 - 10000	10000 - 20000	> 20000
Snow storing recommendation	**Local storage.** *If not enough space - dumping in water could be an option*	**Local or central storage.** *Shall be stored on land*	**Central storage.** *Melting water should be analysed and controlled before being released*	**Central storage.** *Melting water should be controlled and treated*

A STREETSCAPE THAT VARIES WITH SEASON



SNOW WITHIN THE STREETSCAPE

Storing snow can also be integrated into the streetscape to minimize the negative effects of snow. A slightly raised or graded sidewalk will help to eliminate the accumulation of snowmelt or ice formation. Snowmelt should be directed towards the roadways and away from the building. By designing larger pedestrian areas within the public realm, both soft mobility, public life and snow storage can be accommodated (Chapman et al., 2018).

To store snow within the streetscape, the area where the snow is supposed to go needs to be at least three meters wide for the snow not to fall. The height of the stored snow should not exceed 0,8 meters as it will affect the visibility of drivers and pedestrians negatively (Björling Francki & Johansson, 2014).

Heated sidewalks

In a study initiated by Trafikverket and carried out by Carlsson, Sawaya, Kovaceva and Andersson (2016), the researchers investigated the effect heated streets and sidewalks have on reducing the number of injuries. When analyzing the accidents the result shows that the share of accidents on heated streets is 100 % lower in Helsingborg, 68 % in Stockholm and 83 % in Umeå compared to the non-heated surface during fall, winter and spring months (Carlsson et al., 2016). This means that 67 % - 100 % of the accidents caused by people slipping on icy surfaces could have been avoided if the street and/or sidewalk had been heated (Carlsson et al., 2016).

Street trees

Due to the exposure to heavy machines used to remove snow, street trees in Winter cities can have difficulties thriving. It is recommended not to plant trees or other vegetation too close to streets or roads that are objects to large-scale snow removal. Besides the risk of being hit or damages by cars or trucks, street trees are also facing threats of breaking as large amounts of snow leans on the trees. Using movable and flexible “vegetation boxes” is therefore recommended in Winter cities (Björling Francki & Johansson, 2014).

If there are trees or other vegetation within the built environment, it can be wise to also place bicycle stands, bus stops, signage, street lights etcetera close to the trees to assemble permanent and delicate structures close to each other.

part 03

Winter city design principles

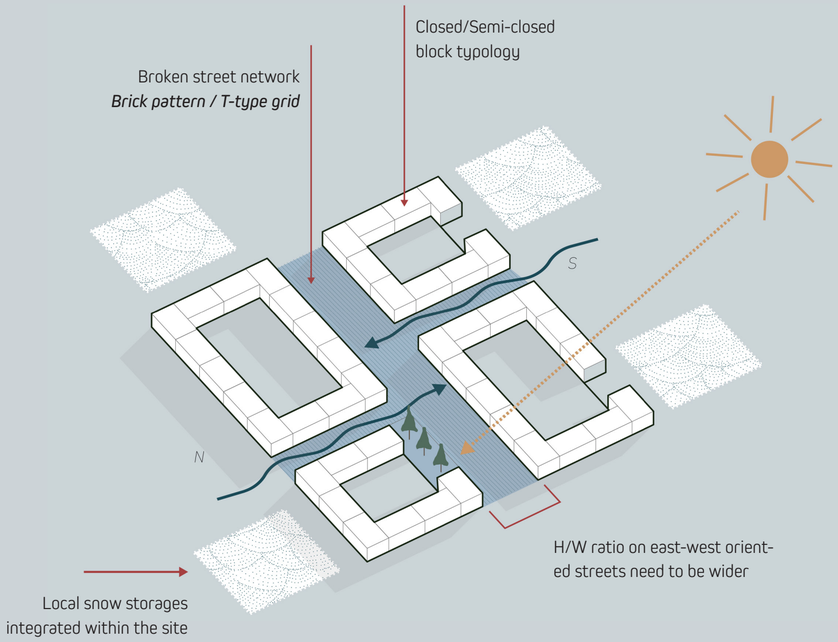
DESIGN PRINCIPLES

To summarize the research and translate it into urban design and architecture several Winter city design principles have been composed. The design principles all aim to answer to the previously stated issues that are crucial working with to achieve or improve outdoor comfort in Winter cities:

- *maximizing solar access*
- *mitigating wind*
- *managing snow*

The Winter city design principles also strive to contribute to creating attractive and safe environments for people living in and/or visiting Winter cities.

The Winter city design principles are divided into three scales: the neighborhood scale, the block scale and the street scale.



THE NEIGHBORHOOD

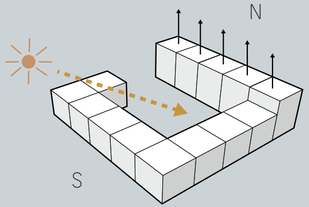
Many major design decisions taken on a larger and more zoomed-out scale are essential to creating comfortable outdoor environments. It is on this scale the microclimatic base is formed. If failing to take the locally appropriate design decisions on the neighborhood scale, it can be difficult to later transform and adjust the microclimatic conditions in the area.

Broken street grid and a closed block typology
On the neighborhood scale, there are a couple of vital design principles. The most fundamental one is the layout of the street grid. As stated previously in the thesis, having a broken street network in the shape of a brick pattern or a T-type grid is preferable as such a grid will help reduce wind speeds. Another design principle that will help create comfortable outdoor conditions is using a closed block typology. By using it, the courtyard can become a place sheltered from the wind in a way that almost no other building typology can achieve. However, using a closed block typology in a Winter city needs to be weighed against the risk of ending up with completely shaded courtyards due to the, on average, low solar elevation. How to get around this issue is discussed in the next scale.

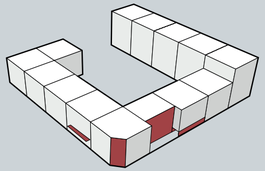
Snow and vegetation to mitigate wind
Winter cities can take advantage of large snow mounds as a way to steer the wind over the buildings. The same result can be achieved with the use of vegetation. Evergreens are excellent wind sheltering structures as they are compact and thick, thus not letting much wind filter through.

Wider east-west oriented streets
East-west oriented streets located at a high latitude quickly become shaded. It is therefore important to think about the width to height ratio on those streets. By doing that the urban designers can make sure that parts of the street are exposed to the sun at times.

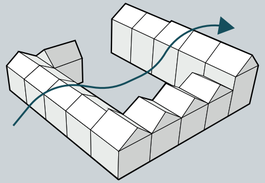
Integrate local snow storages
Lastly, it is of high importance to plan for and implement local snow storages within the neighborhood/project site when designing in Winter cities. Failing to do this could result in large amounts of snow taking up pedestrian space as sidewalks, playgrounds, squares etcetera become covered in snow as the city runs out of space to store the snow in. It is therefore not only a question of logistics but also about people's right to public spaces and feeling safe while walking in the city.



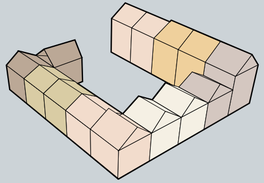
Taller buildings in north
and lower in south



Chamfered corners, set
backs, canopies etcetera



Pitched roofs



Add colors to an
otherwise white area

THE BLOCK

After implementing the principles on the neighborhood scale, several interventions can be done on a more zoomed-in scale to create a comfortable microclimate. These interventions could be applied to entire blocks or single buildings depending on the area.

Lower in the south, taller in the north
As stated previously, it is preferable to use a closed block typology as a way to mitigate the wind. Such a feature could lead to shaded courtyards as the solar elevation on places at a higher latitude is lower. A way to get around this problem is to have lower buildings in the south part of the block and taller buildings in the north part. By keeping the south free from buildings can also improve the access to solar exposure.

Pitched roofs
Moving on to the roofs, it is preferable to have pitched roofs over flat roofs as pitched roofs help steer the wind over the buildings. Furthermore, a flat roof needs a thorough evaluation as to where the melting water is supposed to go. Failing to think about this could lead to damages to the building as the snow melts.

Chamfered or rounded corners
Another wind mitigating principle that should be implemented in windy places is the use of chamfered or rounded corners. Such a feature will reduce wind turbulence and result in a more comfortable outdoor environment.

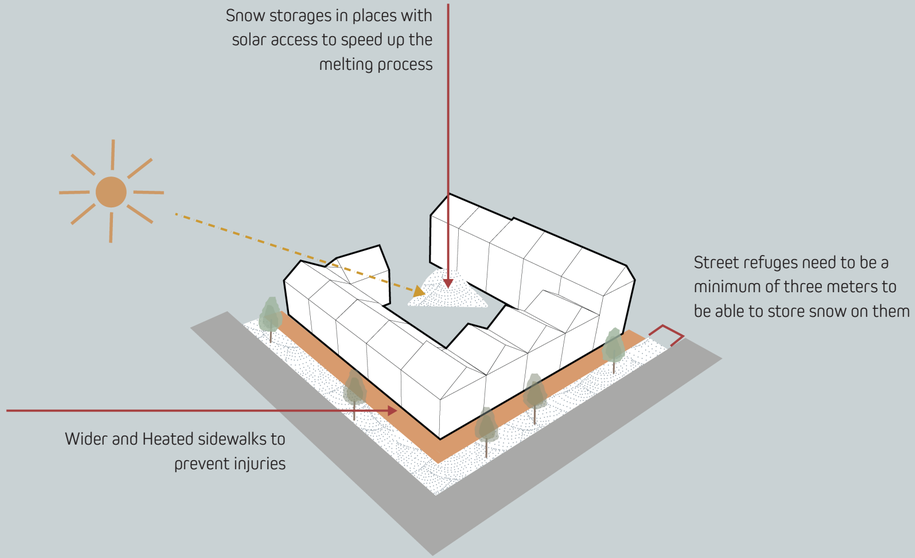
Adding colors
Thirdly, although the snow is highly reflective and adds light during a dark period of the year, it could also cause the so-called white out-effect. This effect makes every part of the image look similar and it can be difficult to separate one element from another and can lead to difficulties orientating yourself when outdoors. By thinking about which colors buildings will have, architects and urban designers could help to minimize the white out-effect. This will not only result in easier navigation but also contribute to beautifying an otherwise white area caused by the snow.

Setbacks, canopies and arcades
As nice as the snow may be it is always a good idea to integrate structures within the building or the block that will offer people the possibility to shelter from the weather. A couple of such structures include setbacks, canopies and arcades.

Setbacks will help in mitigating the wind and create places where the sun is “trapped”, resulting in outdoor places where people feel comfortable.

Canopies and arcades will help people shelter from the precipitation, offering them a chance to pause, brush the snow off of their jackets etcetera. Canopies also shelter people on the streets from wind that is forced downwards after hitting a taller building.

At the same time, these structures will also offer shelter from the sun if that is wanted.



THE STREET AND THE COURTYARD

Going into a more detailed scale, there are a number of actions that can be done to achieve a Winter city-proofed street and courtyard.

Wider sidewalks and bicycle lanes
Since snow takes up a lot of space, not uncommonly pedestrian space, it is important to take the measures needed to make sure that pedestrians and bicyclists have sufficient space to walk, run or bike on during all parts of the year. One way of doing this is to implement wider sidewalks and bicycle lanes. A one meter wide sidewalk quickly becomes half its size when piles of snow get plowed to the side of the road. Having a minimum

Heated sidewalks
To create safe and ice-free sidewalks and squares, the use of heated sidewalks is recommended. Since heated sidewalks may not be possible on every sidewalk in an area, it is recommended to analyze where many people will move around or gather and focusing to implement heated sidewalks and areas in those places. This would enable people to move around outdoors during all parts of the year.

Storing snow within the streetscape
To be able to store snow within the streetscape it is recommended that the street refuges are at least three meters wide or wider. A more narrow street refuge will result in the snow falling into the areas where people walk, bike or drive. However, some municipalities have local provisions. Umeå municipality has a minimum width of two meters before it is acceptable to store snow on that street refuge or sidewalk (Umeå municipality, 2020).

To keep everyone safe it is recommended that snow stored on street refuges should not be higher than 0,8 meters.

Besides storing snow, the street refuges also have the possibility to change with the seasons. As permanent structures such as trees, signage, street lamps etcetera can obstruct the snow removal process it is recommended to use movable objects during the parts of the year when there is no snow on the ground. This could include movable planting arrangements, outdoor furniture and bicycle stands. By doing this, cities can assure smooth snow removal while at the same time having a green street with several seating possibilities.

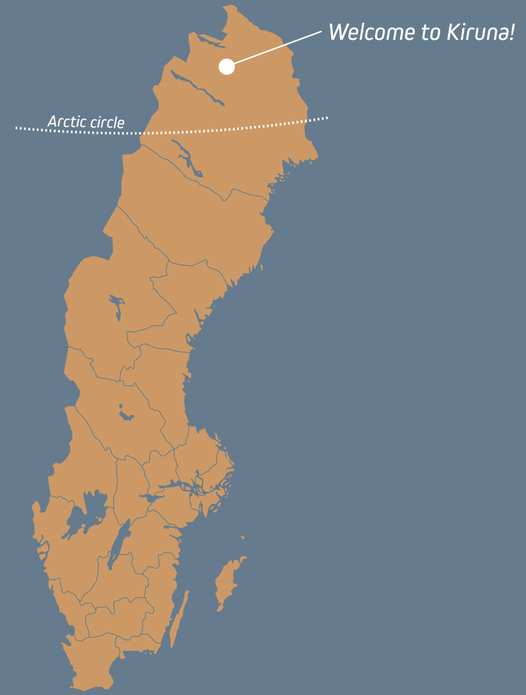
Storing snow on places with solar access
On courtyards, there is a possibility to use the snow mound(s) as a recreational and playful element during the winter months. As it gets warmer the snow mound will start to melt. In order not to have snow mounds in late July it is recommended to store snow in places where there is solar access. The ground should preferably be permeable and prepared to hold large amounts of melting water.

part 04

Implementing the Winter city design principles: Kiruna

The site where the Winter city design principles will be implemented is located in Kiruna, Sweden.

Kiruna is located approximately 140 kilometers north of the Arctic circle and is one of northern Sweden's largest Winter cities.



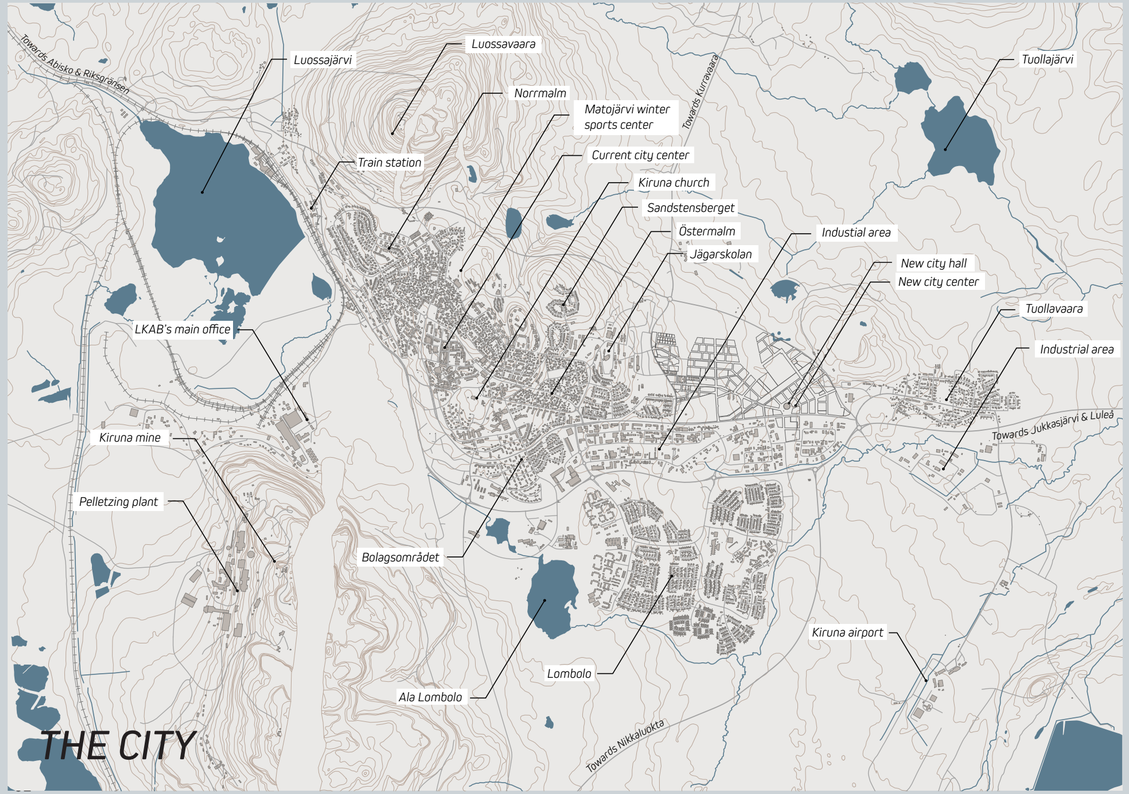
KIRUNA, SWEDEN

Located in Norrbotten county, 140 kilometers above the Arctic circle, Kiruna is probably most known to be the base to the state-owned mining company Luossavaara-Kiirunavaara AB (LKAB) who operates the world's largest and most modern underground iron ore mine: Kirunagruvan (the Kiruna mine). Established in 1890, LKAB was the driving force behind the founding of the city and is still today strongly connected to the identity of the city.

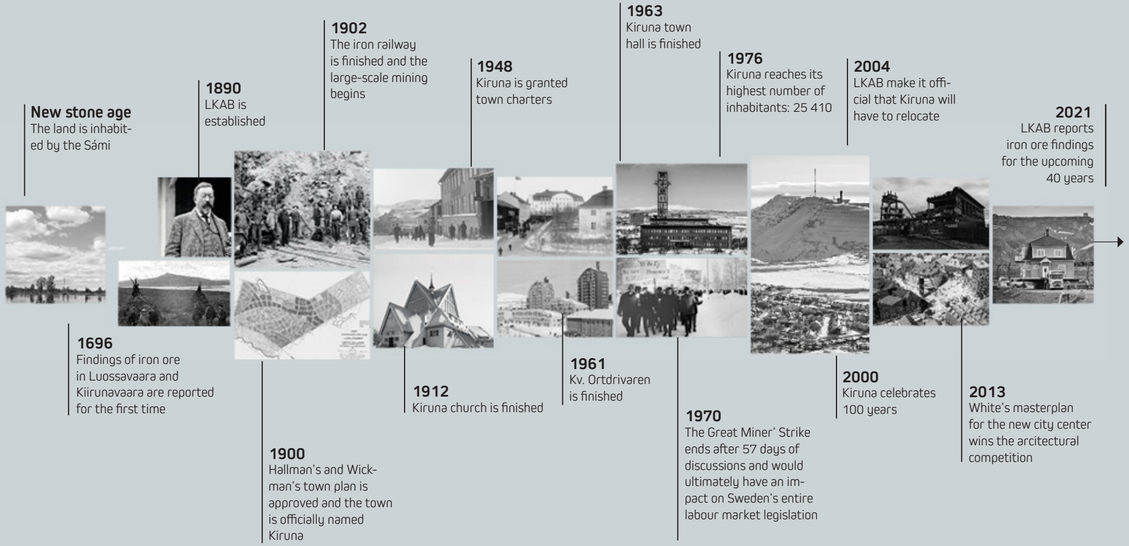
Besides the mine, Kiruna municipality is also the home to 22 867 inhabitants of which around 17 000 of them live in the City of Kiruna itself. The nearest larger locality is Gällivare, 115 kilometers south of Kiruna C. On the Norwegian coast, about 170 kilometers northwest of Kiruna C, is the LKAB-connected harbor city Narvik located.

Norrbotten county is rich in great natural resources which are vitally important to Sweden's economy and energy supply. The most important natural assets are forests, iron ores, rivers and mountain areas. Large amount of uninhabited land is also an important asset; Esrange, Europe's largest civilian space center, has operated in Kiruna since 1966 when it was located there because of the large land areas.

Kiruna is facing a large urban transformation as the ground that the city is standing on is starting to sink due to the mining taking place underneath the city. People are being forced to move and a new city center is being built two kilometers east of the existing city center.


Towards Abisko & Riksgränsen
Luossajärvi
Luossavaara
Norrmalm
Mätojärvi winter sports center
Towards Kurravaara
Train station
Current city center
Kiruna church
Sandstensberget
Östermalm
Jägarskolan
Industial area
New city hall
New city center
Tuollajärvi
Tuollavaara
Industrial area
LKAB's main office
Towards Jukkasjärvi & Luleå
Kiruna mine
Pelletzing plant
Bolagsområdet
Kiruna airport
Lombolo
Ala Lombolo
Towards Nikkaluokta
THE CITY


1 km
2 km
3 km
DISTANCES



A BRIEF HISTORY OF KIRUNA

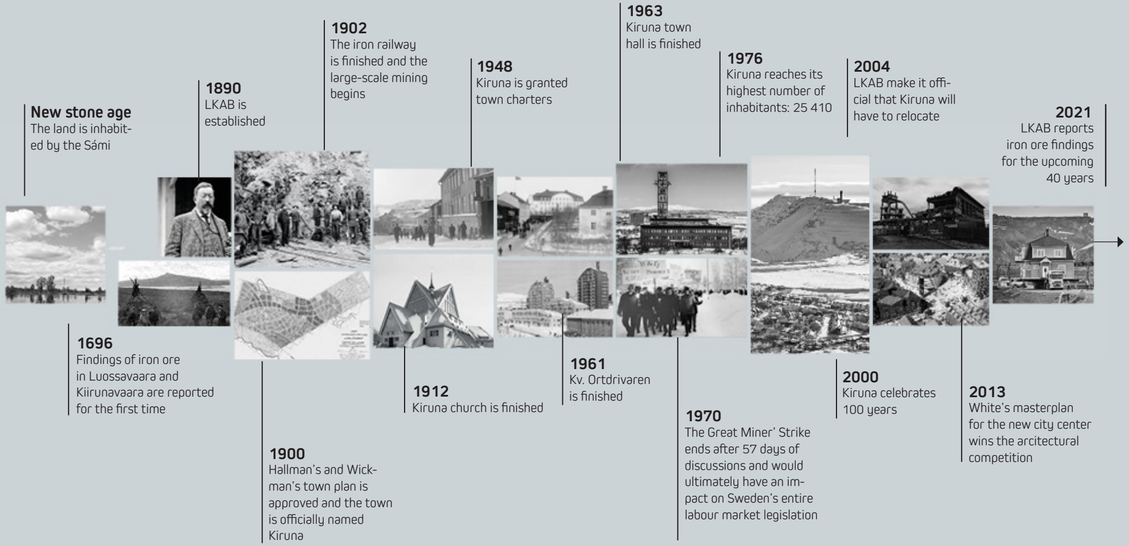
The mining community Kiruna was established in 1900, but ancient findings show that the first people known to have lived in the Arctic region date back 6000 years. As far as historians know, the Sami and Finnish-speaking cultures have roamed the lands of what today is known as Kiruna municipality a long time before any "Swedish" pioneers arrived (Kiruna municipality, 2020). Before discovering the region's rich natural assets, little governmental interest was shown towards the region. When the natural assets were brought to light it attracted the attention of the Swedish Crown which initiated industrial expeditions and settlements in areas where minerals had been found.

The first evidence of the Arctic's rich natural assets was discovered in 1642 in Masugnsbyn, a small village located around 100 kilometers southeast of Kiruna. As the story goes, a local hunter discovered that his iron-made arrowhead got stuck on a magnetic iron boulder. A few years later, in 1647, an iron ore mine was established in Masugnsbyn. At this time there was no knowledge of the iron ore located deep within the mountain Kiirunavaara at which foot the city of Kiruna would later be established. A short time later, in the 1700s, Amund Amundsen Mangi discovered some heavy black stones by the foot of the mountain Luossavaara. The discovery was kept a secret as a way to keep the Crown and pioneers from exploiting the land. The discovery was not kept a secret very long and soon Mangi was called to show the findings to Landshövdingen. However, it was not until the 1880s when trial drilling and geological quality analyses started in Kirunavaara that the establishment of the city of Kiruna properly began (Tjärnlund & Henningsson, 2017).

Before any large-scale mining could start, decisions about a railway connecting Luleå in southern Norrbotten with Narvik in northern Norway via Gällivare, Malmberget and Kiruna had to be made. The railway's purpose was to freight iron, magnetite and other minerals from the mines in Norrbotten to ports in Narvik and Luleå. In 1890, Luossavaara-Kiirunavaara AB [LKAB] was established and in 1902, the railway route Luleå - Narvik was finished which became the stepping stone for large-scale mining in the Kiruna mine (Kiruna municipality, 2020).

At this time around 2000 people were living in Kiruna under very primitive conditions. As a way to attract the workforce, Lundbohm wanted Kiruna to become the "world's best community" (Tjärnlund & Henningsson, 2017). In the late 1890s, more people moved to the north to work in the mine and shantytowns arose. People built simple sheds out of waste wood, empty dynamite boxes and everything else they would get a hold of. To be able to control the housing situation Lundbohm hired architect and master planner Per Olof Hallman and architect Gustaf Wickman in 1898 to design a town plan. In 1900, the royal majesty approved the plan.

The town plan was unique in the sense that it was done with the topography and climatic conditions in mind. Hallman was strongly inspired by Austrian architect and urbanist Camillo Sitte who advocated for a more medieval and organic city fabric in comparison to the strict grid network which had become the prevailing ideal at that



A BRIEF HISTORY OF KIRUNA (CONTINUED)

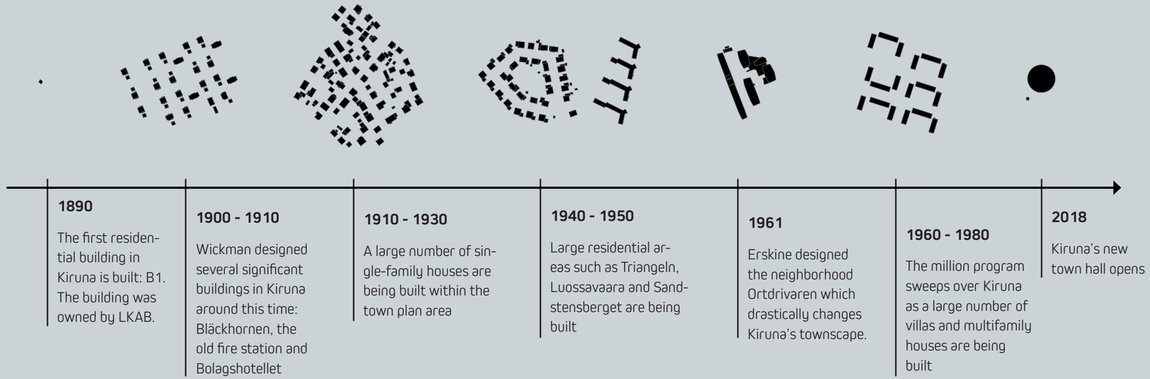
time. In Kiruna, Hallman and Wickman came up with a city fabric where the street network followed the southwestern slope of the city to protect from the cold climate. By proposing a street network with broken and angeled streets, the town plan managed to prevent the wind from becoming too strong within the city. The streets were designed to softly follow the topography and allow for vistas towards the surrounding landscape (Tjärnlund & Henningsson, 2017). Another central idea was the vision of a decentralized city. There should not be one main square with important and/or monumental buildings framing it, nor should there be a central park. Instead, important and/or monumental buildings and different types of open spaces should be spread out within the city.

The years after the second world war ended were characterized by optimism and LKAB expanded their business heavily, much due to a great global demand on iron ore products as a result of the second world war. Kiruna experienced a heavy influx of people and new districts were constructed beyond the regulated areas. In 1948, Kiruna was granted town charter and was now officially a town both legally and officially. The three areas Bolagsområdet, Stadsplanen and SJ-området merged and became one single administrative unit. To celebrate the town charter the town hall "Igloo" by Arthur von Schmalensee was built.
In 1971, Kiruna municipality was established after merging Kiruna town with the Karesuando district. The city of Kiruna became the regional center within the municipality (Norrbottens museum).

By 1976, the Swedish state acquired 100 % of LKAB's shares and was now the only owner. There were now around 25 000 people living in Kiruna around this time. At this time, LKAB was experiencing stagnation which influenced the entire city. Around 5000 people left Kiruna and several multi-family dwellings were vacant and later torn down. Asia's growth in the early 2000s had a direct influence on the price on iron which has a positive effect on LKAB and Kiruna.

The entire city of Kiruna was designated a heritage site in 1900 by the Swedish National Heritage Board. The board based their decision because it represented ***"an early 20th-century town setting and industrial landscape, where a vision of a model society was realized in an unprecedented manner in previously unexploited mountain scenery"*** (Sjölund, 2019).

The future of Kiruna
In 2020, LKAB launched a new investment that aims to reduce the company's carbon dioxide emissions to zero by shifting production from iron ore pellets to carbon dioxide-free sponge iron. The investment of SEK 400 billion is said to be the most comprehensive transformation in the company's history and could be the largest industrial investment ever performed in Sweden. Thousands of new job opportunities will be created in Malmfälten during 20 years, creating a vast need for more housing in Kiruna. In an interview with SVT, municipal commissioner Gunnar Selberg explained that when it comes to infrastructure and housing, the supply is far from sufficient (Johansson, 2020).



KIRUNA DEVELOPS

1890 -1900
In the late 1890s, more people moved to the north to work in the mine. The large and fast influx of people caused the rising of several shantytowns. People built simple sheds out of waste wood, empty dynamite boxes and everything else they would get a hold of. To be able to control the housing situation, Lundbohm hired Per Olof Hallman and Gustaf Wickman in 1898 to design a master plan which was approved in 1900.

The master plan was divided into three parts: Bolagsområdet ("The company's area"), Stadsplanområdet ("The town plan area") and SJ-området ("The railway area").

Bolagsområdet was under direct control by LKAB and intended to serve the employees of LKAB with housing and other amenities. Bolagsområdet is strongly connected to Wickman who was the architect behind several significant buildings; the church, Bolagshotellet, the old fire station, four schools and the residential buildings Bläckhornen of which around 60 were built.
The second area, Stadsplanområdet aimed to serve as a complement to the area(s) owned by LKAB. Stadsplanområdet had plots for sale on the free market which resulted in different typologies when people built their own houses compared to the area(s) owned by LKAB. In the division between these two areas, many of Kiruna's institutional buildings are located; the church, the old fire station (now offices), the bathhouse and later the town hall are all located here.

Lastly, SJ-området was also included in the master plan. Alongside the railway were a train station, a hotel, housing and engine sheds constructed. SJ-området was the largest of its kind in Sweden, marking the important role the railway had, and still has, in the success of the mining industry in Kiruna.

1900 - 1920
Few buildings are as strongly associated with Kiruna as Wickman's creations. Hired by Lundbohm in the early 1900s, Wickman became LKAB's architect in the upcoming years and is the architect behind significant buildings like Kiruna church, Bläckhornen and the old fire station. Wickman's architectural legacy is characterized by highly detailed wooden facades, large high-pitched roofs with soft roofing slopes. This style is especially visible in the residential buildings called Bläckhornen. Bläckhornen's color palette was dominated by red, yellow and green.

1920 - 1930
As the mining industry expanded in Kiruna, the area experienced a large influx of people which called for more housing. A large number of single-family houses were built within Stadsplanområdet. During this time, LKAB built several multi-family properties (Nyström, 2020). The architecture is characterized by softly colored wooden facades with a high level of detailing and distinctly marked stoops (Sjöholm, n.d.). Stylistic features from the 1920s also influenced large parts of the properties being built in Kiruna during the 1930s (Nyström, 2020). Today, properties built during this time is a common view in Kiruna's townscape.

KIRUNA DEVELOPS

1940 - 1950
The second world war resulted in the physical establishment of the Swedish Armed Forces in Kiruna. The buildings built to serve the military were built in the same style as other buildings during the same time as a way not to draw any attention to the operation (Nyström, 2020). During the 1940s initiated LKAB a comprehensive modernization of their properties on Bolagsområdet. Doors and windows were replaced, bathrooms were renovated and expanded and detailed stuccoes were replaced by sleek and easy-to-clean sockets and cases (LKAB, 2018). The years after the second world war ended were characterized by optimism and LKAB expanded its business heavily. Kiruna experienced a heavy influx of people and new districts were constructed beyond the regulated areas.

During this time were city centers all around Sweden experiencing large-scale demolishing and urban renewal projects. In Kiruna, large parts of the central developments were demolished to free up space for a more urban development. During 1958 - 1961, the most intense demolishing of older developments took place in Kiruna

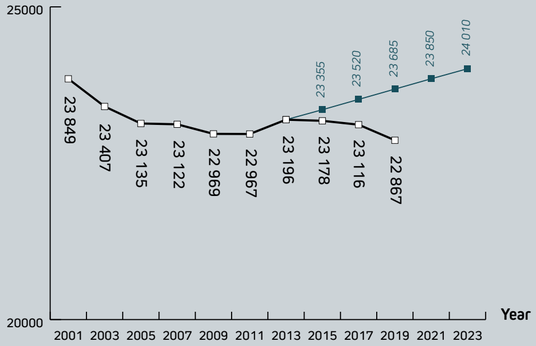
1960 -1980
The number of people moving to Kiruna continued to increase at a high level as LKAB expanded even more. In the mid-1960s, the total population in Kiruna doubled. To be able to provide housing for its employees, LKAB had architect Ralph Erskine design an entirely new neighborhood on a centrally located site that had previously housed a low-scale wooden development that was demolished a few years prior. The neighborhood drastically changed Kiruna's townscape but became with time a significant part of Kiruna's architectural identity. The neighborhood is characterized by two tall brown painted concrete buildings and three lower yellow-painted concrete buildings. The building's shapes are inspired by the mine and the mountains and the balconies aim to look like the elevators used in the mine. Erskine wanted to design climate-adapted buildings with stream-lined corners to prevent turbulence caused by strong winds and pockets on the roofs to prevent snow from falling on the sidewalk (Nyström, 2020).

In 1963 was the town hall Igloo by architect Arthur von Schmalensee inaugurated.

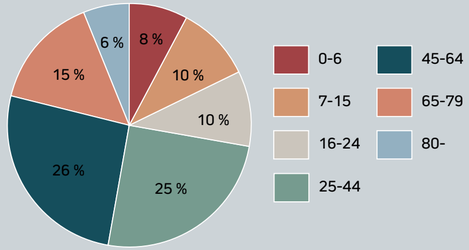
Parallel with new developments being built were many also being demolished. In 1972, the centrally located school Centralskolan was demolished to make room for a more modern educational facility, something the inhabitants of Kiruna did not approve of. This event is said to be the beginning of the end of the large-scale demolition of buildings in Kiruna.

Suburban residential areas are being built as the million program sweeps over Kiruna. A high number of single-family dwellings are being built intensely. The residential area Lombolo continues to grow and is characterized by single-family dwellings and a few multi-family dwellings.

POPULATION: PREDICTED AND ACTUAL



AGE GROUPS (2018)



DEMOGRAPHICS

Kiruna municipality had 22 867 inhabitants in 2019. The population declined by 125 inhabitants from the year before (2018). In 2013, Kiruna municipality (2013) estimated that there would be 23 685 inhabitants living in Kiruna in 2019, 818 inhabitants more than the actual number. Furthermore, Kiruna municipality predicted a continuous increase of inhabitants with 23 850 inhabitants in 2021 and 24 010 inhabitants in 2023 (Kiruna municipality, 2013). The estimation has so far shown to be incorrect as the number of inhabitants continues to decline. During the period 2000 - 2019, the population in Kiruna declined by 1447 individuals (SCB, 2019).

Kiruna has an aging population with an average age of 42 years which is higher than the country average. Nearly 20 % of the total population is 65 years or older. At the same time, the younger age groups are shrinking, creating a gap between a larger group of people retiring and a smaller group of younger people entering the labor market. An aging population has an impact on the needs of urban development and should be taken into consideration when designing and implementing new areas. For example, an aging population could lead to an increased need for smaller apartments without the same maintenance needs as a villa. Aging eyes and slower reflexes could also lead to a decreasing ability to drive cars and the placing of services and the design of streets are therefore of high importance.

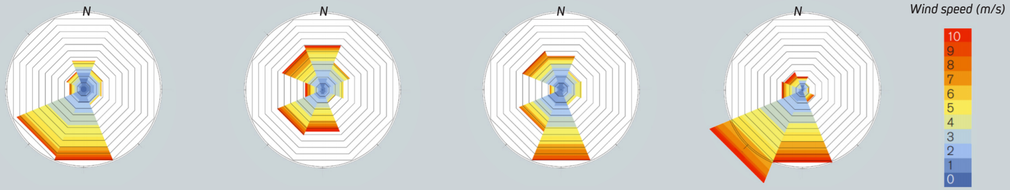
47,9 % of the total population in Kiruna municipality in 2019 were women (52,1 % men). The gender imbalance is one of the largest in Sweden. Kiruna municipality (2013) believes that a reason for the imbalance is the significant male-dominated business sector, such as the mining industry and its subcontractors (Kiruna municipality, 2013). The male-dominated business sector could also be a contributing factor as to why more women (36 %) than men (21 %) have a university degree.

The number of inhabitants in Kiruna is strongly linked to the productivity of the mining company LKAB. Looking at the historic number of inhabitants, there have always been more people living in Kiruna when LKAB is in an economic boom and fewer people living in Kiruna when LKAB is experiencing an economic recession. Depending on how LKAB performs, it has spin-off effects on other industries in Kiruna. It is not only subcontractors who experience boosts when LKAB does, but also other industries such as commercial services, financial services and administration.

For around the past 10 years, Kiruna experienced an extensive housing shortage. Several businesses and companies have had a difficult time hiring employees who do not already have a residence in Kiruna (Kiruna municipality, 2015:68). As a result of large industrial investments, such as fossil-free sponge iron in LKAB's mines and fossil-free steel in HYBRIT's effort to change the iron and steel industry fundamentally, in the northern regions Norrbotten and Västerbotten it is estimated that there is a need for 25 000 new employees.

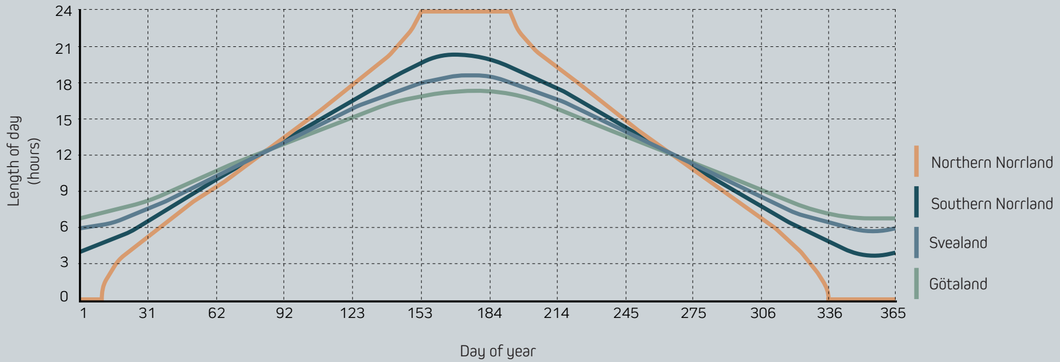
SEASONAL WIND DIRECTIONS AND SPEED

Pacheco Diéguez et al., (2017)



January - March | April - June | July - September | October - December

LENGTH OF DAY



KIRUNA'S CLIMATE

Kiruna has a subarctic climate (also called subpolar climate, or boreal climate) with long, often very cold winters and short, cool summers.

The climate in Kiruna would have been much colder if it was not for the proximity to the Atlantic and the Gulf stream. Because of its location above the Arctic circle, Kiruna has three weeks of Polar nights during the winter where the sun does not rise above the horizon. The opposite phenomenon, Polar days (also known as Midnight sun), lasts for 50 days during the summer and means that the sun does not set beyond the horizon.

The yearly temperatures vary from an average of -14.5 °C in January to +12 °C in June. The annual average temperature is - 2,2 °C. Kiruna is usually covered in snow from October to May, but the average amount of precipitation is fairly low; around 500 milliliters per year and around half of it falls as snow (Kiruna municipality, 2014).

The prevailing wind direction during summer (June through August) is from the north. The average wind speed is 3,4 m/s but can in extreme cases reach 8,5 m/s. During fall, winter and spring (September through May) are the prevailing wind directions from south and southwest with an average wind speed of 3,5 m/s but can in extreme cases reach 10,5 m/s.

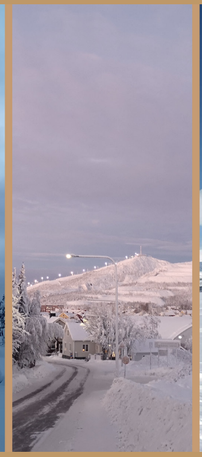
TEMPERATURES AND PRECIPITATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest average temp (°C)	-10	-8	-4	1	7	14	17	14	8	2	-5	-8
Lowest average temp (°C)	-19	-18	-14	-8	-1	5	7	6	1	-5	-12	-17
Average temp (°C)	-14,5	-13	-9	-3,5	4	9,5	12	10	4,5	-1,5	-8,5	-12,5
Precipitation (mm)	30	25	26	27	34	49	86	74	49	47	42	34

A YEAR IN KIRUNA

JANUARY

Bye Polar night! Welcome back, sun! After being absent for around three weeks, the sun is finally reaching above the horizon again. January is the coldest month with an average temperature of -14,3 °C. Snöfestivalen (The Snow festival) takes place.



FEBRUARY

The days keep on getting brighter and brighter. The weather in February is similar to January's. The ski resorts Björkliden and Riksgränsen open which attract many locals and tourists to go skiing. Vintermarknaden (The Winter market) takes place.

MARCH

Vårvintern (The spring-winter) is here! The season is many locals' favorite as it is characterized by snowmobile driving, ice fishing and skiing. Villages all around the municipality are being inhabited during the weekends as locals temporarily move to their cabins.

APRIL

Vårvintern continues. The Ice Hotel melts. Outdoor activities continue to dominate the locals' leisure time as long as there is snow on the ground. The city is emptied as almost everyone spends their weekends in villages around the municipality. Ice fishing contests are a common sight.

MAY

Welcome, Midnight sun! There is still plenty of snow in the mountains which enables skiing and driving snowmobiles, even during the night if you want. May is usually not the prettiest month as the melting snow displays dirt that has been concealed in the snow the past months.

JUNE

Hello, summer! June marks the beginning of the hiking season. The sun does not set at all in June but the mosquitoes do not seem to ever disappear either. Kirunafestivalen takes place. Forget the usual music festival attire: here, down jackets and Lovikka-gloves are not an uncommon sight.

JULY

This is the season of climbing to the top of Sweden: Kebnekaise. The midnight sun ends in mid-July but the days and nights are still bright. Many locals leave Kiruna in search of warmer temperatures further south and the city can feel somewhat empty.

AUGUST

The hiking season is still active as the trees start changing colors. The days are still long with an average of 16 hours of sunshine. One might be able to spot the northern lights again. The berry picking season really kicks off.

SEPTEMBER

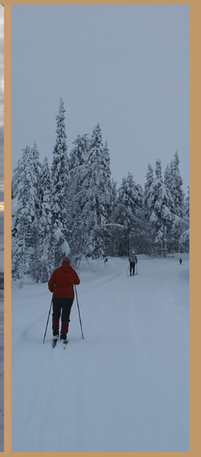
The days become shorter as fall makes an entrance. The mosquitoes finally disappear which makes September a great month to spend time outdoors. The elk hunting season normally starts in September which calls for many locals' to inhabit their cabins once again.

OCTOBER

The days are now only lasting around 7 - 10 hours which makes October a great month for northern lights watching. The first batch of snow usually arrives in October, but it is not until the end of the month that it really stays.

NOVEMBER

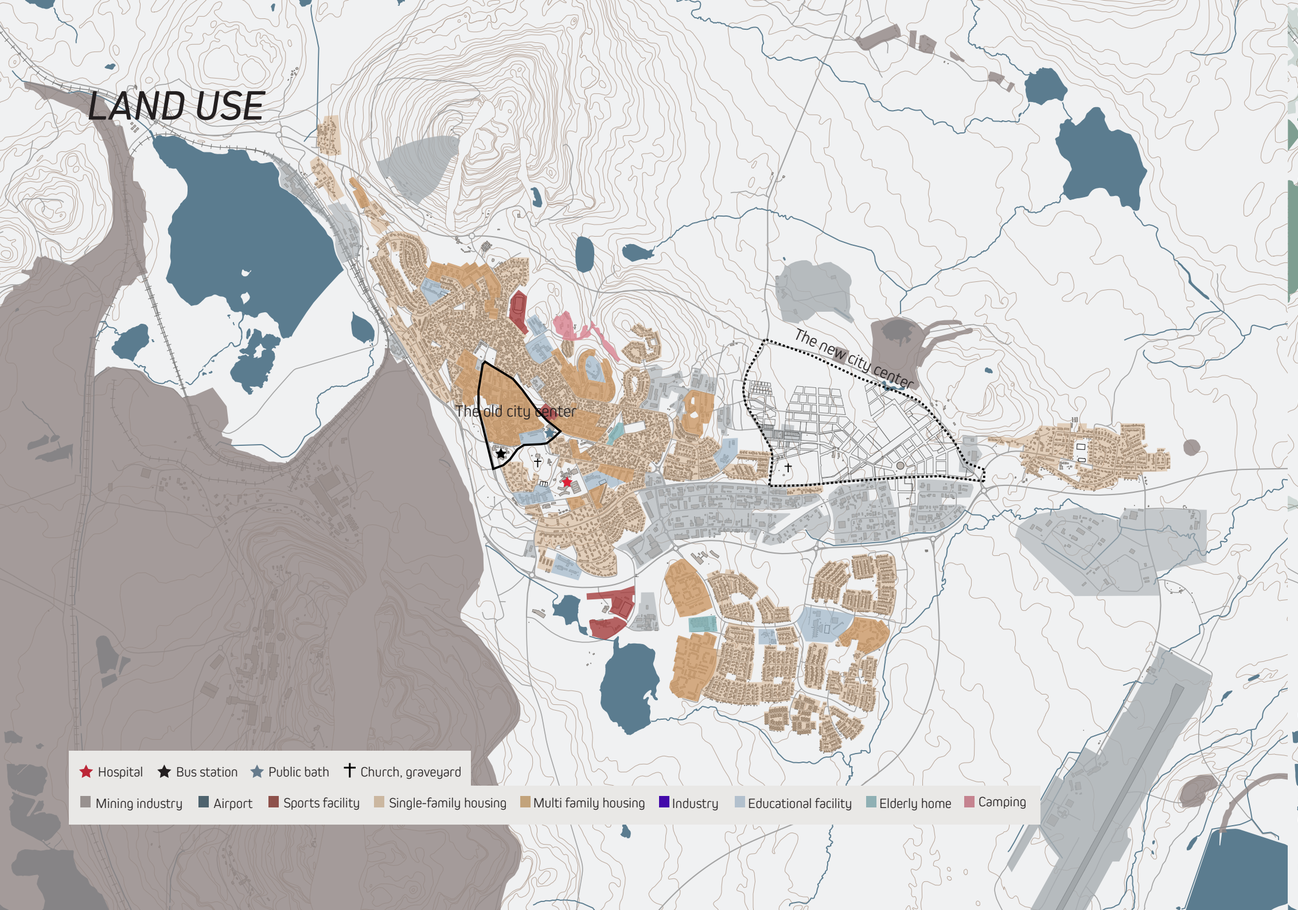
The snow is here to stay and the local hill Luossavaara opens up for downhill skiing. Other winter activities such as cross country skiing and dog sledding are available once again. The average temperature is -8,6 °C and it is not more than 7 hours of daylight.



DECEMBER

Merry Christmas! December is characterized by dark and cold days and nights as the Polar nights start. Ice Hotel opens up for visitors which attracts many tourists. The average temperature is -12,5 °C but it is often much colder than that.

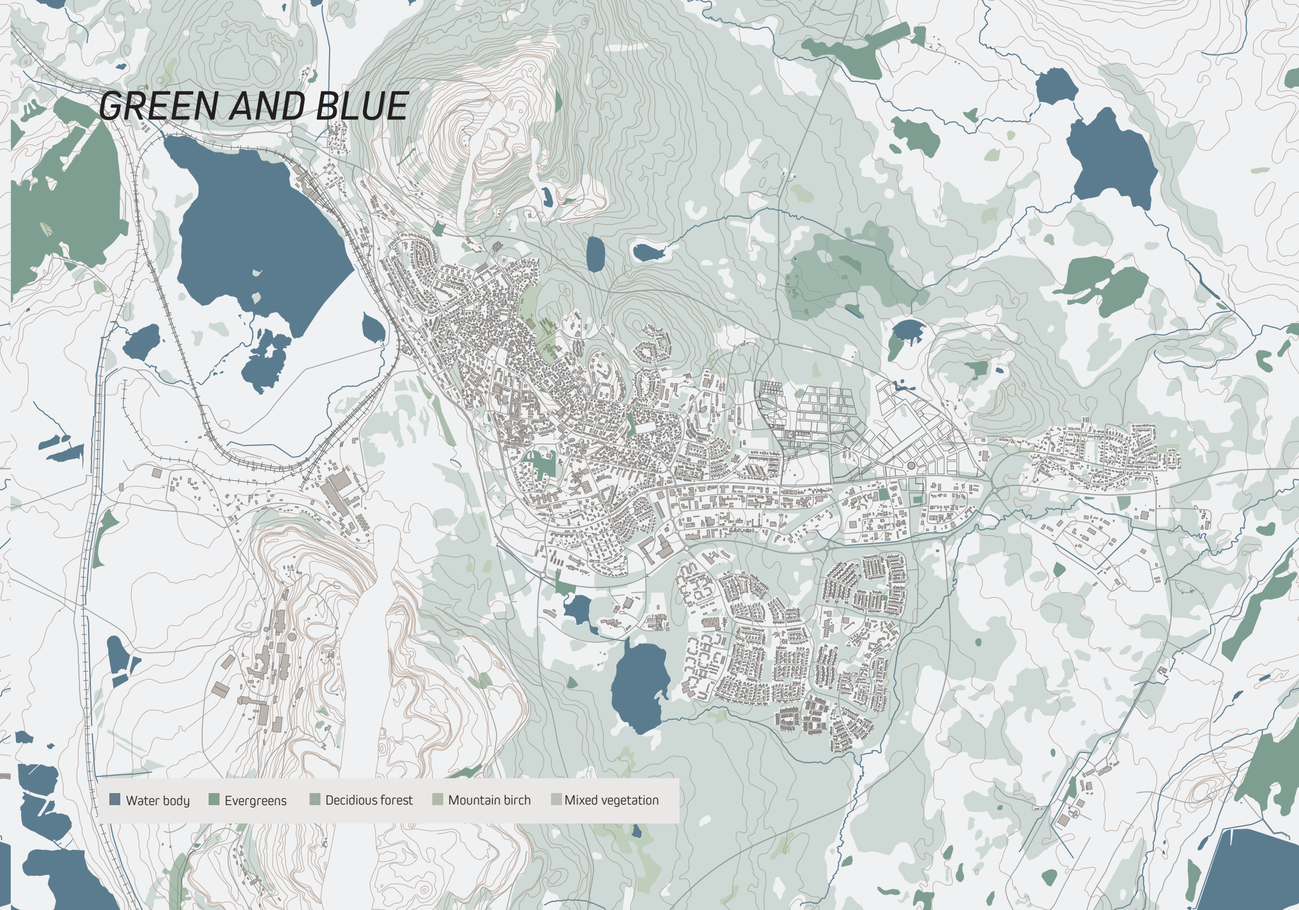
LAND USE



Hospital · Bus station · Public bath · Church, graveyard

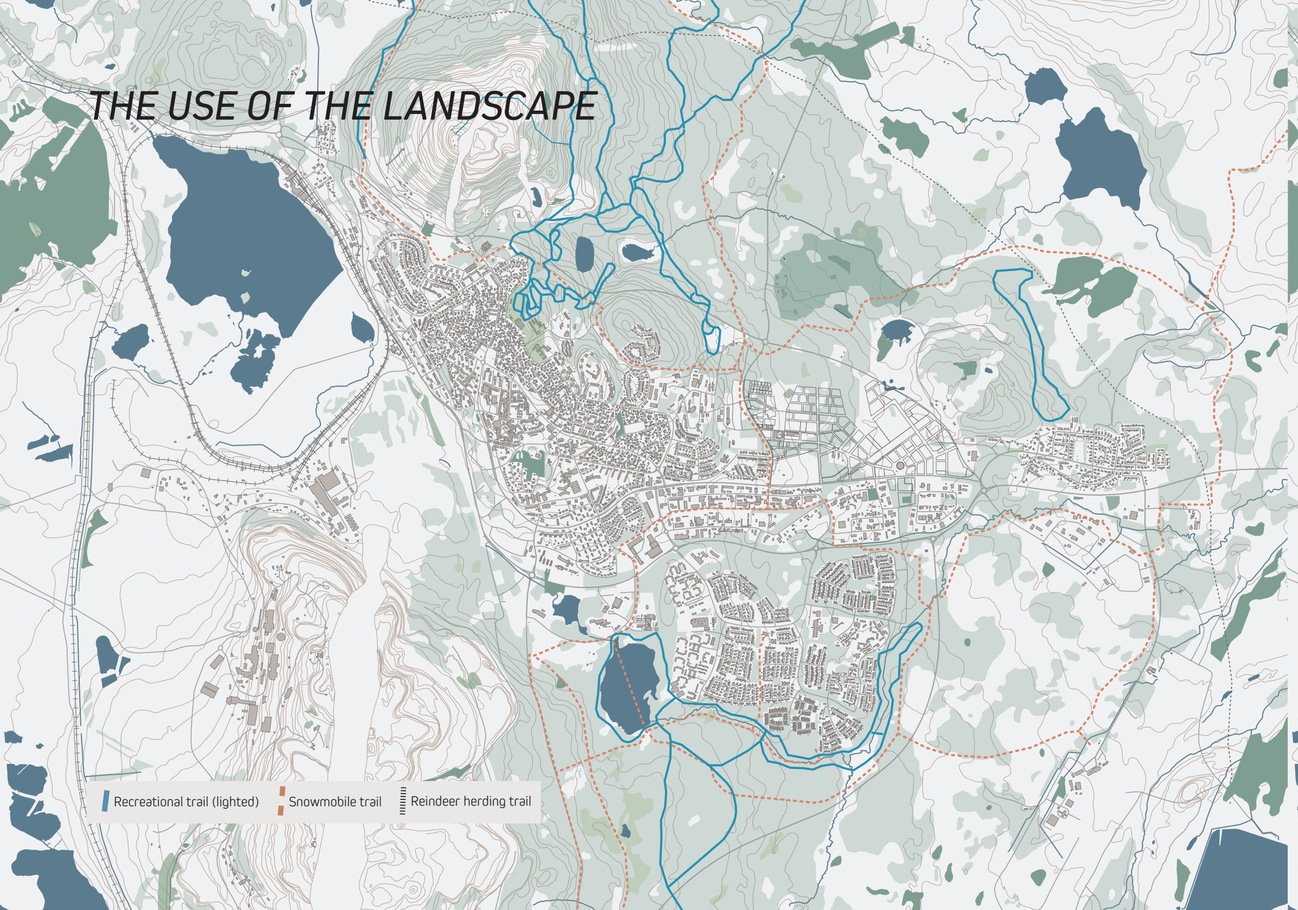
Mining industry · Airport · Sports facility · Single-family housing · Multi family housing · Industry · Educational facility · Elderly home · Camping

GREEN AND BLUE

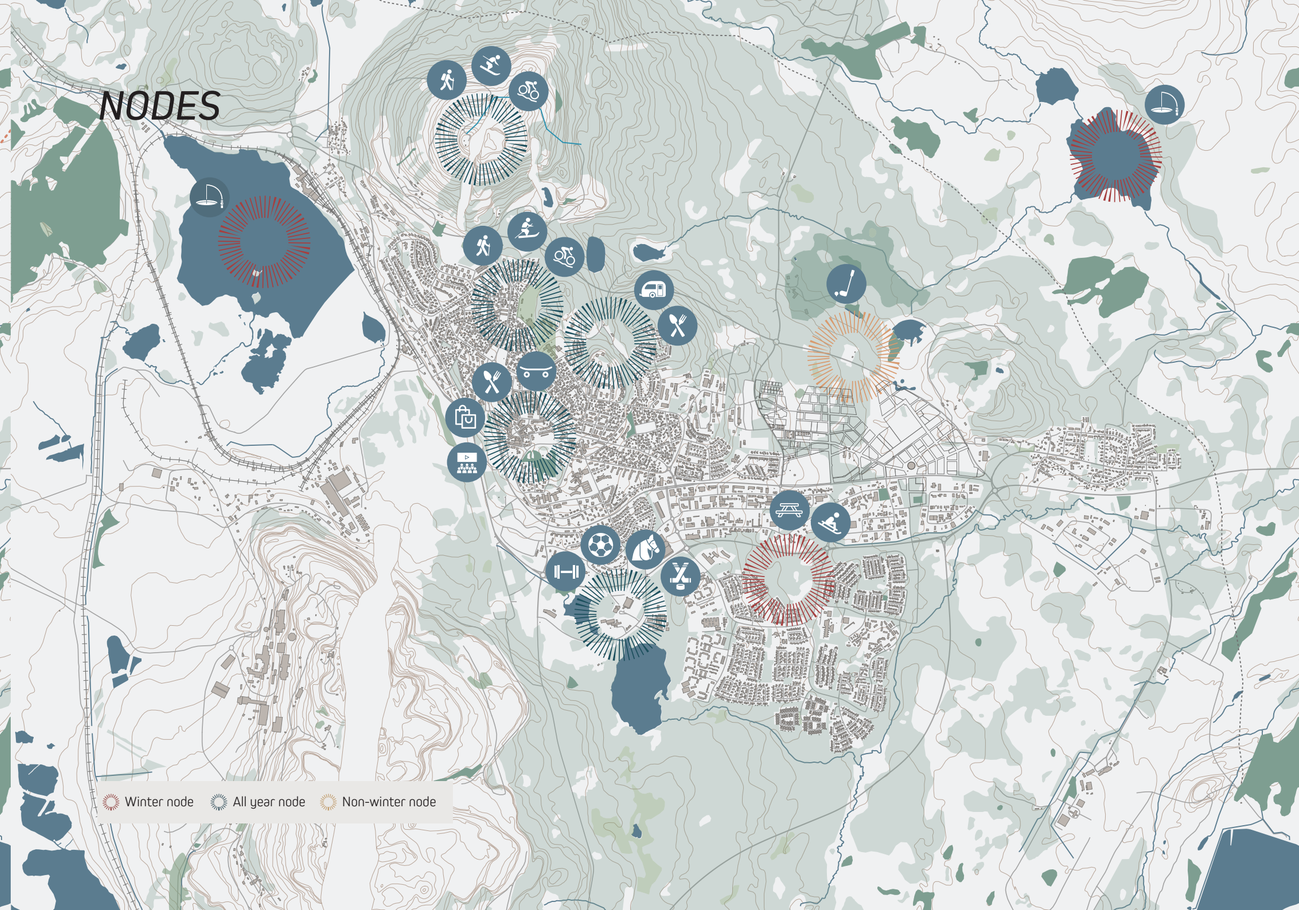


Water body · Evergreens · Decidious forest · Mountain birch · Mixed vegetation

THE USE OF THE LANDSCAPE



NODES



Hermelinsgatan

Views towards Luossavaara

Erskine's Ortdrivaren

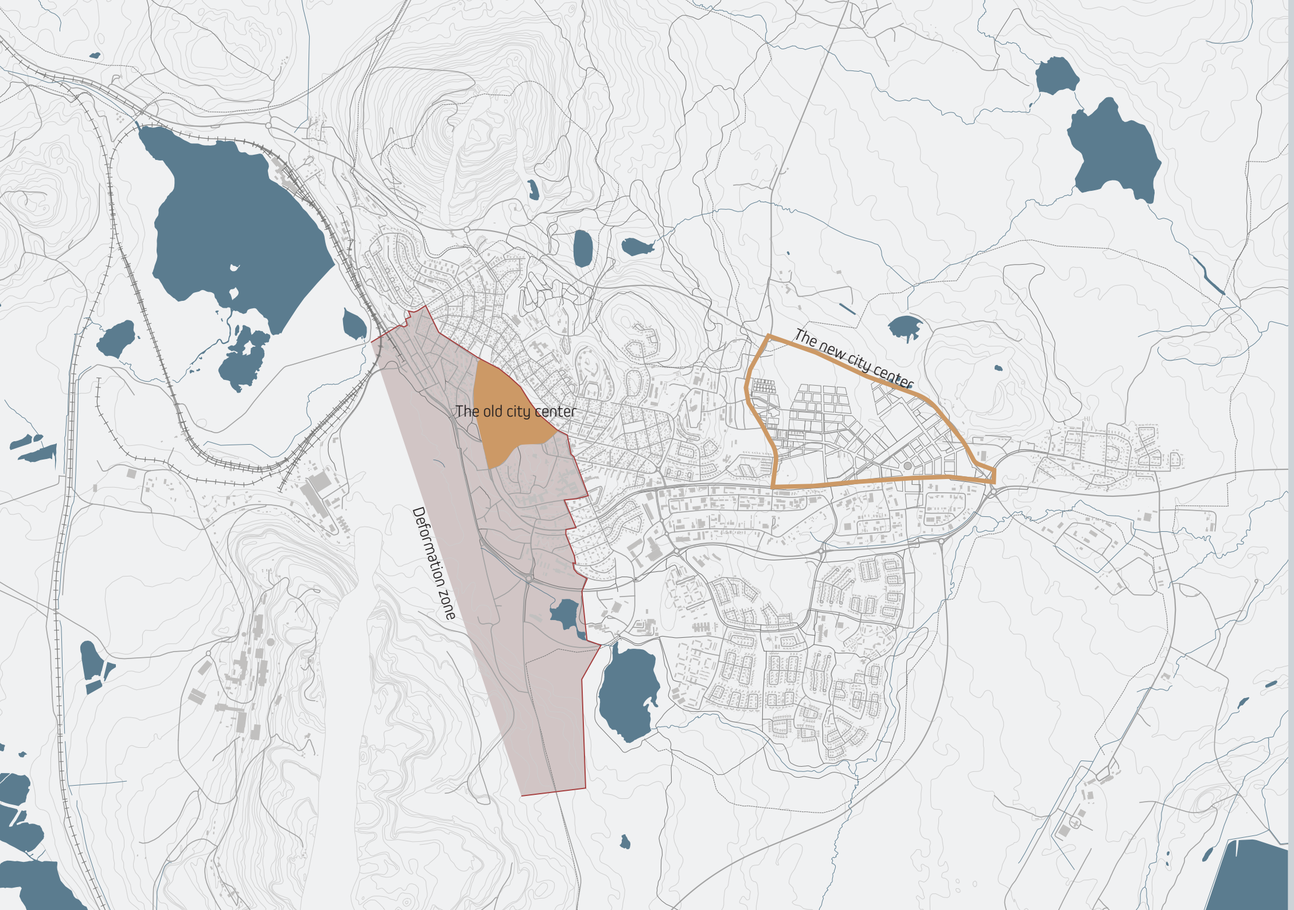
An empty lawn becomes a large playground as winter comes

Hermelinsgatan

The current city center with the mine in the background

Wickman's fire station, now offices

Views towards the current city center with the mine in the background



URBAN TRANSFORMATION

The Kiruna mine, owned and operated by LKAB, is the world's largest and most modern underground iron ore mine.

The ore body in LKAB's mine is leaning towards the city center which is causing the ground that the city is standing on to sink. In November 2003, LKAB met with representatives from Kiruna municipality's planning department to inform them about the mine's future expansion and needs (Kiruna municipality, 2019). In March 2004, LKAB officially notified Kiruna municipality that the mining process will affect the city within a few years. LKAB emphasized their need to be able to continue mining and encouraged the municipality to develop an updated comprehensive plan that introduced an alternative site for the city center of Kiruna (Kiruna municipality, 2019). Responding to LKAB's quest, Kiruna municipality said they were "[...] prepared to relocate parts of the city since the mining operation is an important industry" (Kiruna municipality, 2019, my translation).

In 2004, Kiruna municipality sent out a press release with the title "We're moving a town" (Kiruna municipality, 2019) and the work of coming up with a new deepened comprehensive plan for Kiruna started.

In 2010, the municipality's executive committee decided that the new city center was going to be located three kilometers east of the existing city center (Nyberg, 2010). In September 2011, the deepened comprehensive plan supporting the eastern option was approved (Kiruna municipality, 2011). Around the same time, the executive committee also decided that an architecture competition concerning the design of the new city center should be initiated.

In June 2012, the competition concerning the design of the new city center started. Ten teams were invited to compete and were asked to come up with a vision for the future Kiruna, strategies on how to reach the vision and lastly a proposed design. The teams were invited to Kiruna where they had a start-up meeting. This meeting was also an opportunity for the citizens to be informed about the competition and give their perspective of the transformation. In 2013, the proposal "Kiruna 4-ever" by White architects was announced as the winning proposal (Arkitekt.se, 2013).

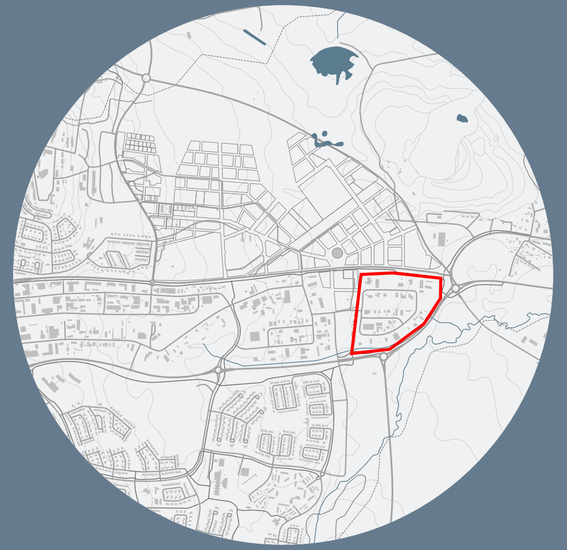
As a result of the sinking ground, 6000 people will be directly affected. However, it is safe to say that everyone living in the municipality will be affected in one way or another. The areas that are being relocated contain several public facilities: the hospital, the city hall, the library, several clinics, schools and sports facilities. The non-public facilities connected to the city center like clothing stores, florists, hairdressers, the cinema, cafes and restaurants will also have to relocate to the new city center. It is, however, important to note that the city center is not actually moving. It is, besides approximately 40 buildings, being demolished and erased while completely new structures are built up at the new site.

part 05

Introducing the site

PROJECT SITE

The site is located around three kilometers east of the current city center and just south of the future city center. The 23 ha large site is currently working as an area for small-scale industries and companies. The business on-site includes a bus firm, carpentries, snowmobile shop and several industries connected to LKAB's operations. The majority of the industries located within the site all have large plots used as employee and customer parking, parking for larger vehicles and storage of goods, vehicles etcetera.



SITE ANALYSIS: LAND USE

The area within the site boundary is characterized by several plots of small-scale industrial companies. Parking and storing take up a lot of space within the area.

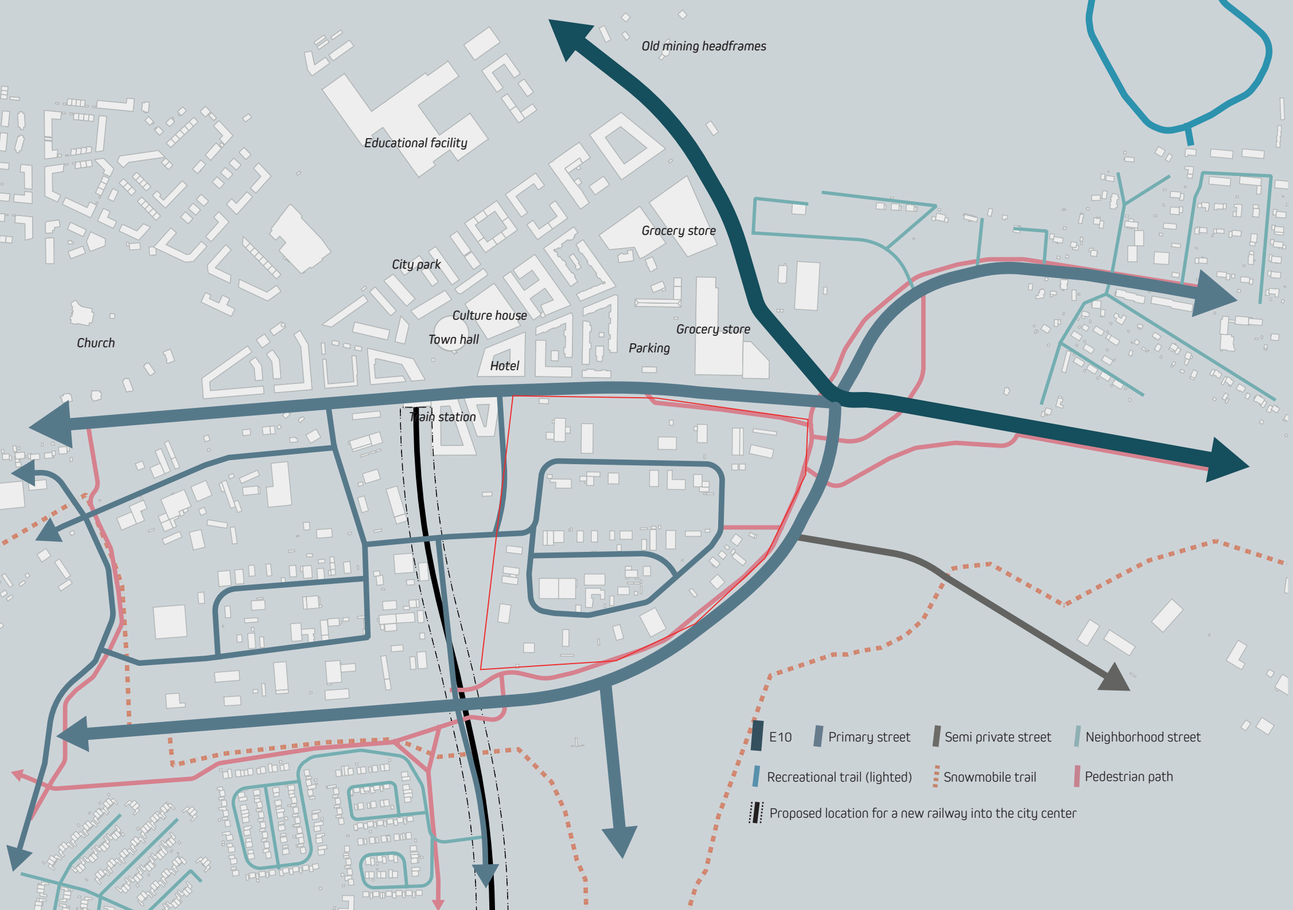
Surrounding the site are two large residential areas: Lombolo and Toullavaara. Lombolo consist mainly of single-family villas built during the million program. Toullavaara is also characterized by single-family villas but has a more differentiated architecture as the area has been built and expanded over a longer time.

Also located close to the site are two small-scale industrial areas. The area to the right is a newly developed industrial area.

North of the site is the new city center located. The masterplan is the result of a architectural competition where the winning proposal “Kiruna 4-ever” by White Architects was announced the winner in 2013. The site specific aim with the masterplan is to develop the site in harmony with the surrounding arctic landscape, so that people are never more than three blocks away from the landscape.

While analyzing White’s masterplan it is easy to see that the landscape is omnipresent, even after several alterations have been made to the initial proposal. Looking at it from a microclimatic perspective, some things could be improved. For example, the city park is located in a south-west-northeast direction which also is the prevailing wind direction. Considering this, the park could be object to strong, cold winds.

Today, only the town hall is completed. Several other buildings are being developed at the moment and in just a short time will a hotel and a cultural center along with other residential buildings be completed.



SITE ANALYSIS: TRANSPORTATION

The transportation infrastructure in the area is characterized by many streets and roads for cars and few paths for pedestrians and bicyclists. In the future and when the new city center is finished it will, of course, look a lot different.

The largest road, E10, is where you enter, pass or exit Kiruna. Framing the site are two medium-sized streets where Malmvägen is the main street into the new city center.

Since the site is highly car-dependent there is only one pedestrian path existing within the site. These paths are mainly used by people living in Toullavaara and working in the (old) city center.

There is a major snowmobile track running south of the site. In the northeastern corner is a recreational trail located.

SITE ANALYSIS: GREEN, BLUE, WHITE

The site is located circa 100 m lower than the existing city center and is therefore rather protected from the wind by the surrounding terrain. However, the lower altitude impacts the temperatures and the site can at times be colder than other parts of Kiruna. Kiruna Airport, located 2 500 m southeast of the site, often has around 10°C colder temperatures in winter than the existing city center (Kiruna municipality, 2016).

The site lies within vegetation zone 8 and there are a few clusters of large pine trees in the site's outer parts. Within the site is the vegetation mainly characterized by shrubs and small deciduous and coniferous trees. The greatest landscape feature is the linear green area located in the center of the site. The green area varies in width and is at the east side of the site around 50 m wide, while only being around 15 meters at parts where the plot owners use more land than their plot boundaries allow.

In the northern part of the site, just south of Malmvägen, runs a smaller stormwater ditch which has its inflow from two northern located streets in the city center. In the center of the site is a 10 meters wide man-made ditch located in the west-east direction. The ditch is connected to a beautiful open stormwater management system in the site's northwest corner. The ditch aims to serve the future city center's stormwater management needs by infiltrating and delaying the stormwater. Both ditches have their outflow to a stormwater pond located east of the site boundary. The pond infiltrates the entire city center's stormwater before releasing it to the stream Luossajoki.

SITE ANALYSIS: SOFT VALUES

The site is today a place that few people besides those who work within the area have a connection to. It is a space that separates the new city center from the surrounding residential and recreational areas. The site does not feel walk- and bikeable due to the lack of sidewalks and the large amounts of larger vehicles and goods being stored in the area results in a highly car-dependent area and private feeling surrounding it. The site is not a place where people go if they do not have to work or run an errand.

There are several great sightlines towards both the city center and the old mining towers north of the site. At ground level, there are views towards the forests and open lands on the site's southern and eastern parts, but there is an increased possibility of having views towards Aptasvaara when living on the second or third floor.
The open stormwater solution offers a nice and welcome landscape feature where people can sit and enjoy the stream of water passing by.

The main node of the area is the city center where the town hall, main shopping street, hotel with a sky bar and the culture house are located. The hotel is around ten stories tall and will be a new landmark in the new city center. Another landmark are the old mining headframes located north of the site. The headframes are a leftover structure from the old Toullavaara mine.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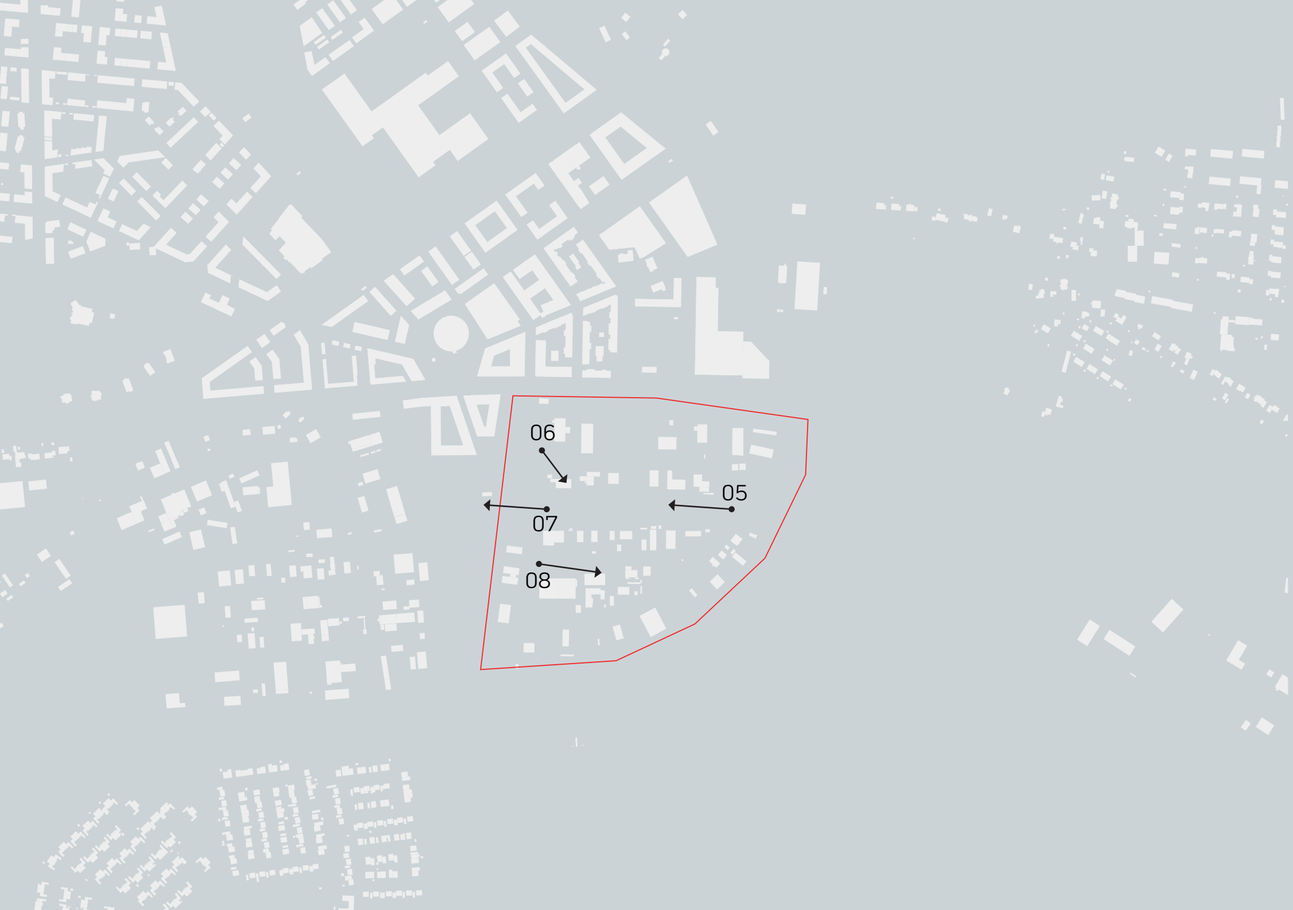
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part 06

The design

VISION

The design concept has been for the site to be the bridge between the new city center and the recreational forests that are located just around the corner.

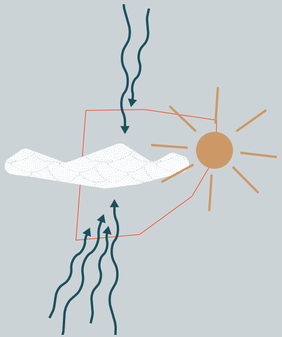
The vision is to create an urban district that feels enjoyable and lively during all parts of the year. The site is integrated with the new city center as well as with nature. It is a new and modern place where you will still get the qualities from living in a small town: short distances, familiar faces and nature within a fem meters. In the new city district, you will live with the city center on one side and nature on the other. The goal is to create a mixed urban district where everyone feels at home. This is done by offering different typologies, architecture and public spaces. From the color of the facade to the recreational trails to the layout of the street grid: everything is done with Kiruna in mind.

By letting existing buildings located within the site be the starting point, the project aims to connect people to the site and creating multi-use facilities such as workshops, studios and a community building that will generate urban life and movements throughout the day and create the basis for local associations, activities and communities to flourish.

The project is glued together by the community park that runs through the site. Here you can find snow caves and slides, ice skating and hockey rinks, wind-sheltered sun pits and recreational trails intending to weave the entire city together. By welcoming existing recreational trails into the built environment, a network of spaces that encourages people to move around in Kiruna during all parts of the year is created.

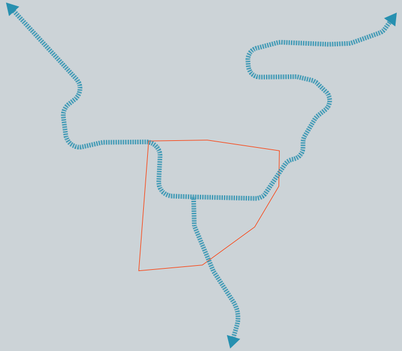
It is a new place in Kiruna that embraces winter. A place where large amounts of snow are not seen as a barrier for public life but rather as an enabler for it. To achieve this, the Winter city design principles are applied to Winter city-proof the site and create public places that are comfortable and attractive for people in Kiruna to spend time in.

DESIGN STRATEGIES



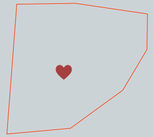
Winter city-proof

The first strategy, **Winter city-proofing**, uses the Winter city design principles to create an area that is designed to achieve or improve comfortable outdoor spaces. The principles include maximizing solar access, mitigating wind and managing snow. The project aims to apply the principles on different parts and test what the principles would look like in a project.



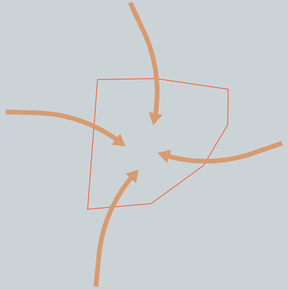
Introduce winter purposes

The second strategy, **Introduce winter purposes**, aims to create and embrace activities that have a clear winter purpose. By doing this, the strategy aims to create a site in Kiruna where public spaces are open and accessible during all parts of the year, not only during snow-free months. The backbone of this strategy is the existing and proposed recreational trails that will create a loop around Kiruna.



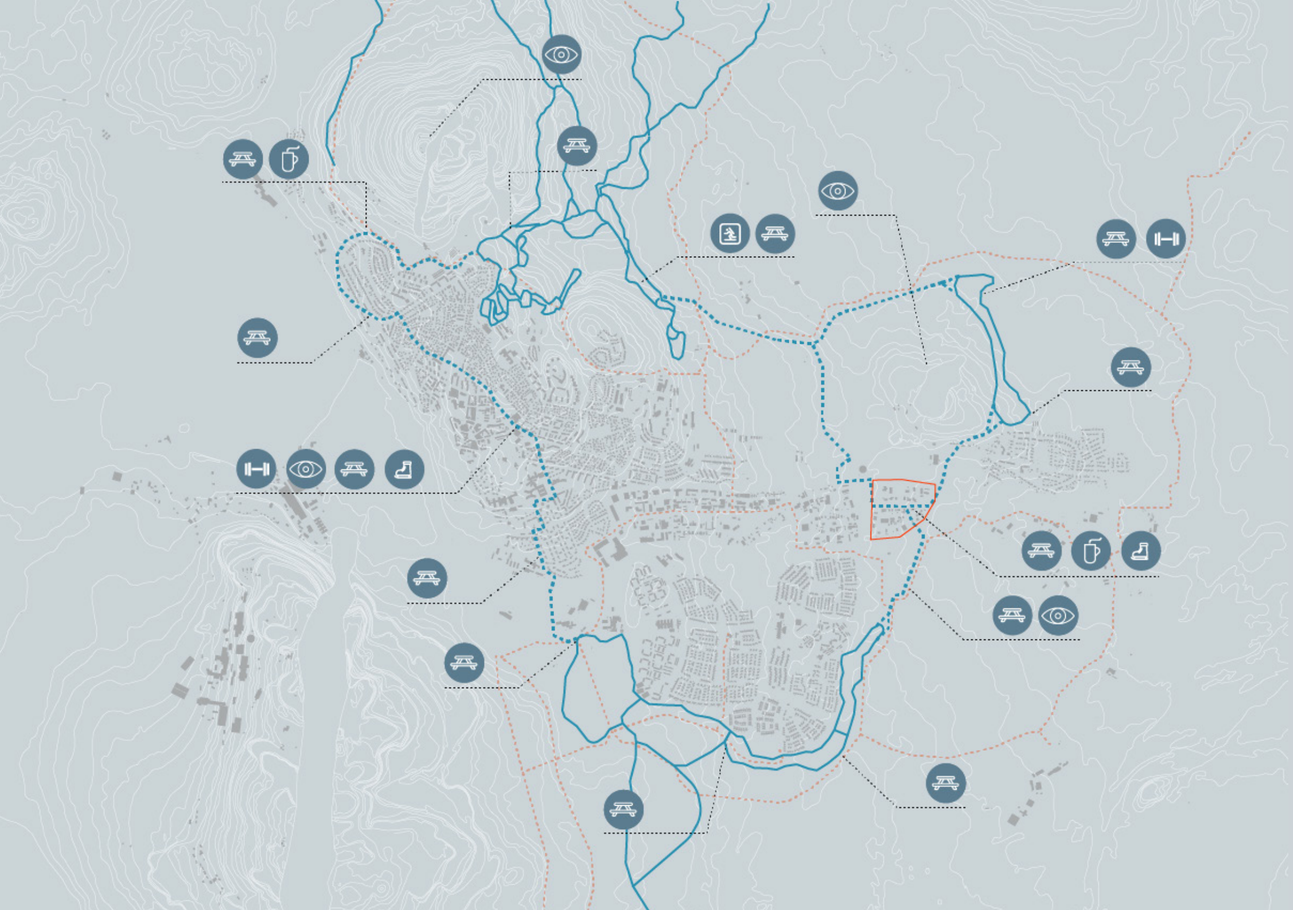
Support local activities

The third strategy, **Support local activities**, is about caring for the local activities and associations that will be forced to move when the demolishing of buildings starts. By recycling six existing buildings on the site the strategy aims not only to support the continuation of such activities but also to create new generators on-site by using activities and associations that are well functioning in Kiruna today.



Create connections

Create connections is about connecting the city with nature, old with new and people with the site. By connecting the city with the (recreational) nature the area will draw upon existing local activities to create public places that are well-used and appreciated. By connecting the old city center with the new city center the perceived mental barrier will be reduced. The strategy is also about introducing a site that has been mentally distanced from the rest of the city.

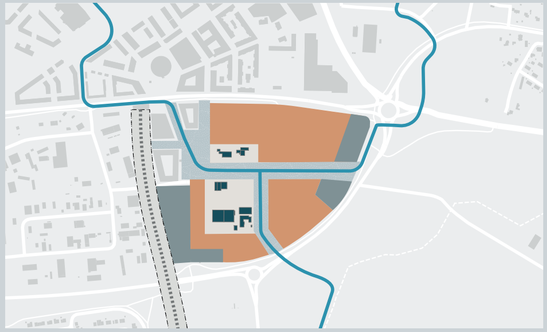


THE RECREATIONAL TRAILS

The existing recreational trails in Kiruna are highly used during all parts of the year. They take people in Kiruna straight out to the forests and mountain landscape surrounding the city. The existing trails can connect to each other (the dotted blue line) and by doing that creating a approximately 17 km long loop around the entire city of Kiruna. The trails can connect the new city center with the old, people of Kiruna with their wonderful backyard and tie the entire city of Kiruna together.

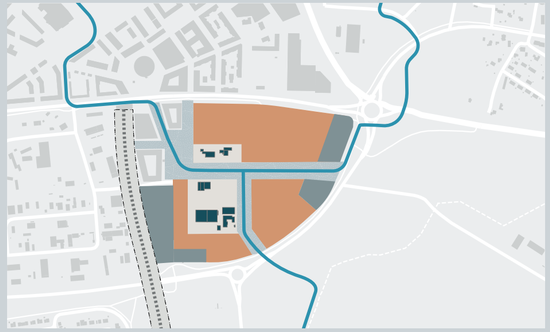
In the future, existing and new activities and events can take place within the recreational trails. The activities can include viewpoints, outdoor furniture, skating rinks, outdoor gyms, cafés etcetera. All in all, creating a recreational addition in Kiruna where you can go hiking, skiing, biking or just stroll around.

THE MASTERPLAN COMPONENTS



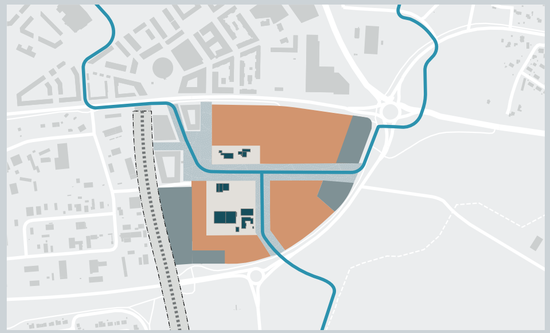
01 The trail runs through the site

The first part of the build-up to the finished masterplan consists of the recreational trail running through the site's park. The recreational trail is the spine of the project; connecting the site to the new city center. It also opens up the possibility of having different activities happening along or tied to the trails, such as ice skating, seating areas, open fire-places etcetera. Thus turning it into a public place with a clear winter purpose.



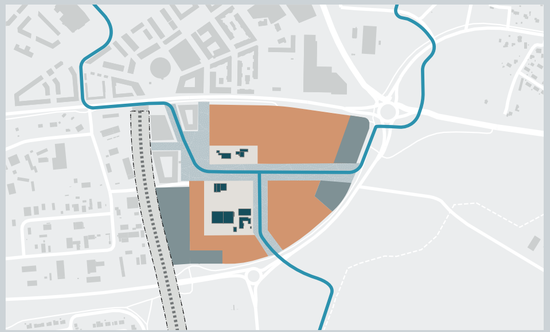
02 The recycled buildings

Framing the park and the recreational trail are six recycled buildings that also make up the second part of the build-up. These buildings aim to serve the need for new locations and buildings for existing activities when the demolishing starts within the deformation zone. By doing this, the project aims to support local activities and associations in Kiruna by not only offering them a new space to practice their hobbies or passions in but to also developing the site around them.



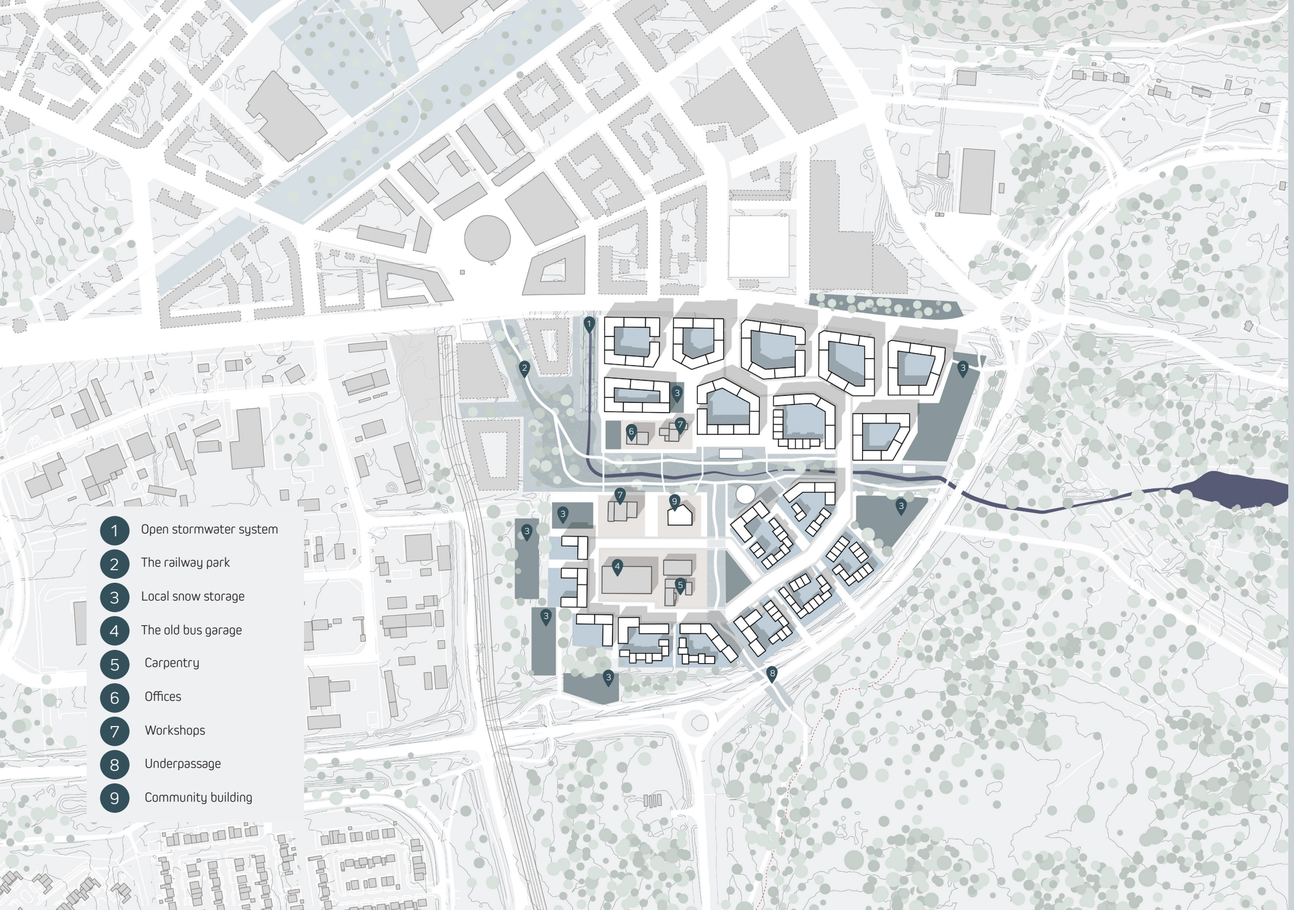
03 Snow storages on strategic locations

The third part shows the location of the local snow storages. These are located strategically to not only serve the site's snow storage but also to shield from strong winds coming from the prevailing wind direction south and southwest. The snow storages also aim to shield from the noise pollution caused by larger infrastructure systems such as the proposed railway and the roundabout in the site's northeast corner. During snow-free months, the snow storages are used to take care of stormwater coming from the city center.



04 Three neighborhoods and the recycled area

Lastly, the fourth part shows the division of areas within the site: the recycled area which contains the six recycled buildings and aims to be a new node in Kiruna where activities such as arts and crafts, bands, skateboarding and so on can take place. Lastly, three different resi-dential areas with mixed typologies are located within the site.



THE MASTERPLAN

The layout of the masterplan is largely based on the research investigated in this project.

The northern area has more of an urban and dense characteristic that aim to "mirror" the new city center. The south-eastern area has a more low-scale neighborhood with row houses being the main typology. The third residential area (framing the recycled area) is characterized by two to three-story buildings to frame the recycled public area. The glue that will hold all of these areas together is the park. The park will work as the main public place where people from all around Kiruna can come to enjoy snow art, outdoor fireplaces, seating and barbecue possibilities etcetera.

Maximizing solar access
On east-west oriented streets, a larger height to width ratio has been applied to achieve solar access on parts of the streets.

South facing facades on places with low wind speeds are used as plazas where people can sit down, get some sun and relax. One example of this is the south part of the recycled bus garage (4).

Buildings that are on the south side of the block are lower compared to buildings on the north side. This is especially visible in the blocks containing row houses.

Mitigating wind
The grid on the northern part of the masterplan is in the shape of a brick pattern to reduce the wind speeds coming from both south, southwest and north. The buildings in the northern part of the site facing the new city center are intentionally not parallel to the opposing buildings. This is done to block the winds coming from the north and to break long sightlines.

To create comfortable micro-climates on public spaces, courtyards and streets have a closed block structure been applied to the majority of the plan. Besides mitigating wind, the closed block structure also adds a clear boundary between public and private and between city and nature.

Managing snow
On several parts of the site are local snow storages located. The biggest ones are located on the edges of the site to not only store snow but also to block winds and reduce noise coming from the railway and street. Additional to the larger snow storages there are a couple of smaller local snow storages located completely within the built environment. These have the possibility of being highly recreational snow storages to store snow in, but also to enable and encourage outdoor play and activities.

Landscape features
The new Railway park (2), a tribute to the same concept previously existing in Kiruna, works as the natural entrance to the area before the park transforms into a landscape with high natural characteristics and exciting activities taking place; a place within the city that is constantly changing as time goes by and alters the landscape. During snow-free months, the park is used for pick nicks, sunbathing and relaxing.

MASTERPLAN: LAYER BY LAYER

Winter city design principles

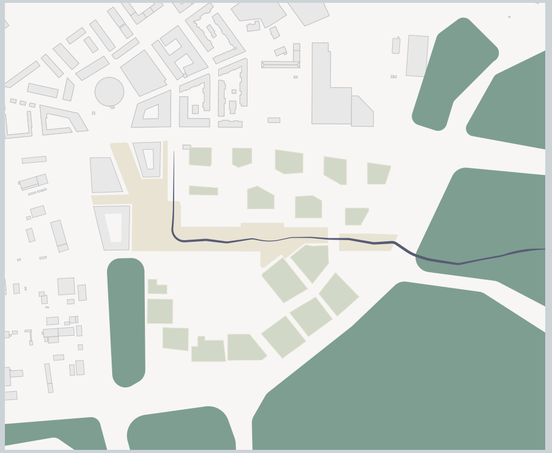
Taller building
Lower building
Broken street network
Heated sidewalk
Snow storage
Vegetation to mitigate wind
Natural snow clearing
Wider east - west oriented street

Paths, trails, streets and roads

Larger road
Main street
Secondary street
Pedestrian path
Recreational trail
Entrance street

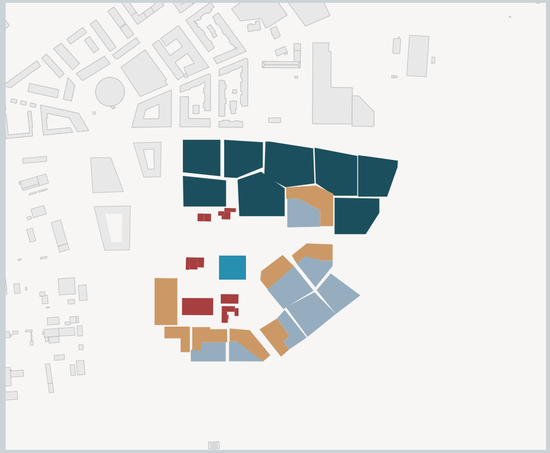
MASTERPLAN: LAYER BY LAYER

Green, blue and white fabric



Courtyard
Forest
Park
Stormwater creek

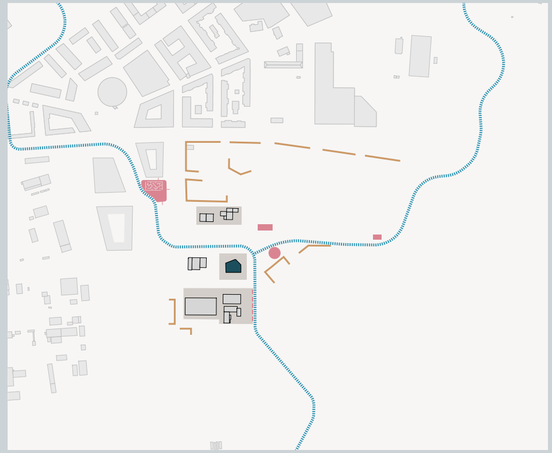
Neighborhood characteristics



Dense block
Edge buildings
Row houses
Recycled buildings
Public building

MASTERPLAN: LAYER BY LAYER

Social meeting points and areas



Active facade | Recreational trail | Plaza | Community center | Park activity

Storm- and melting water solutions

Direction | Ditch | Snow storage/ Water retention area | Creek | Permeable surface

MASTERPLAN: LAYER BY LAYER

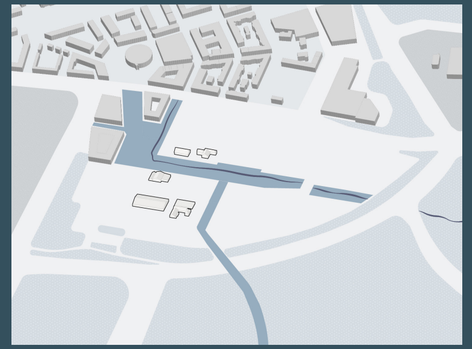
Recycled and proposed buildings

Recycled | Proposed

Functions

Mixed use | Mainly residential | Community building | Public building | Sports facility

PHASING



Phase 01: Landscaping and placemaking

The first phase of the project includes landscaping and place-making as a way to connect people to the site and supporting the local activities taking place in Kiruna today. The site has previously been a minor industry area containing several large garages that will be recycled into skateboarding halls, workshops etcetera. By doing this, the local activities that are forced to move will have a new centrally located spot in Kiruna.

Phase 02: Activating the recycled area

After connecting people into the site and turning the site to a natural part of the city, the second phase aims to build housing surrounding the park and the recycled area. The development starts in this location because of its proximity to the railway and the most central parts of the new city center.

Phase 03: Framing Malmvägen

The third phase is about the continued work of building more housing. Malmvägen, the street north of the site, is one of the main entrance streets into the new city center. By framing it, the entire area will receive a more urban and dense feeling.

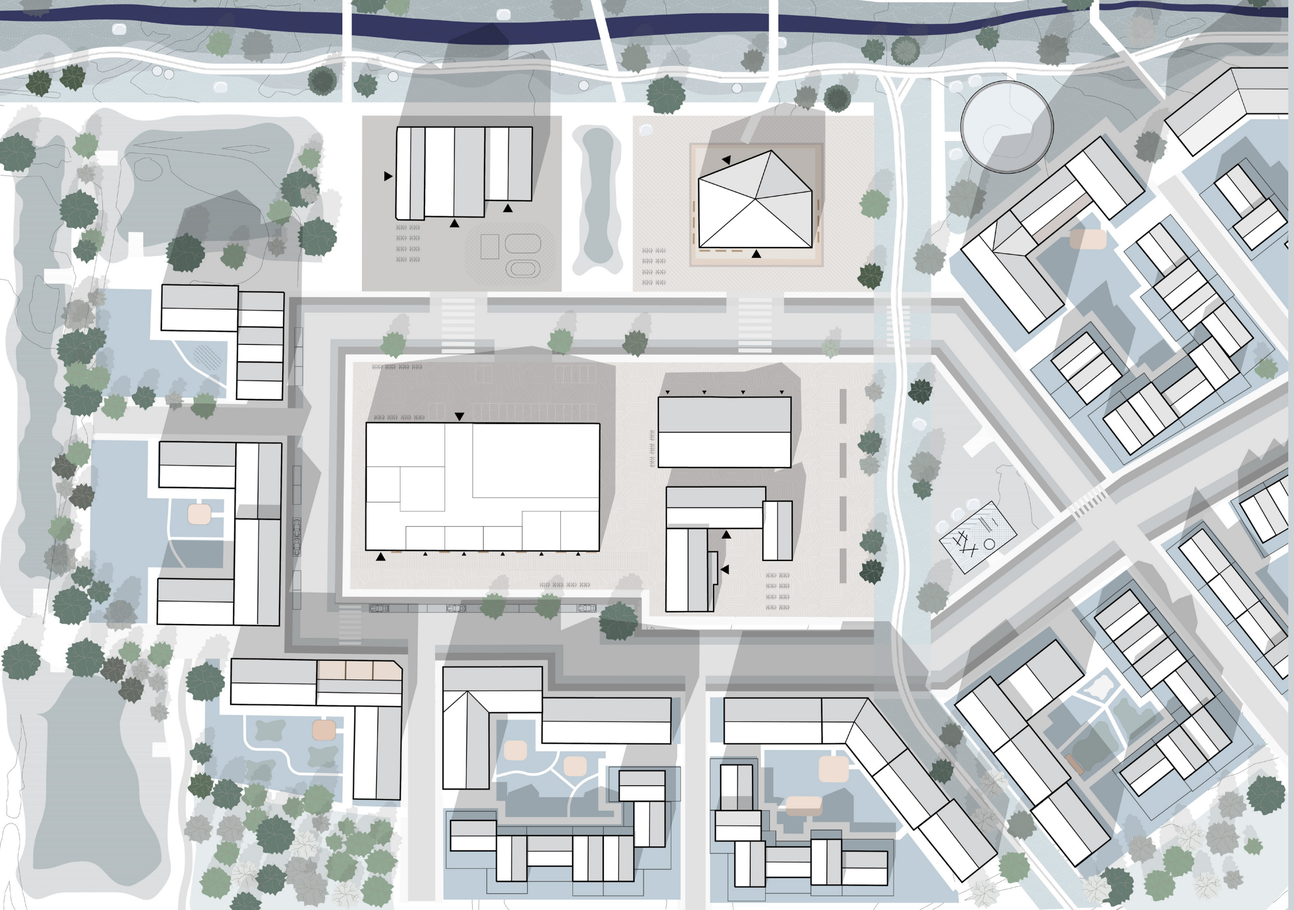
Phase 04: The third neighborhood

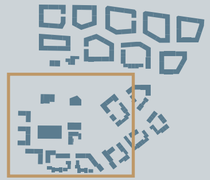
Lastly, the forth phase is about gluing the entire area togeth-er. This is done by developing the third residential area where several row houses are located. This phase will also continue the work of framing the park.

Detailed plan 1:500

The northern area which has a more urban and dense character compared to the rest of the site

Standing next to the community building looking towards the park





Detailed plan 1:500

The recycled buildings and surroundings

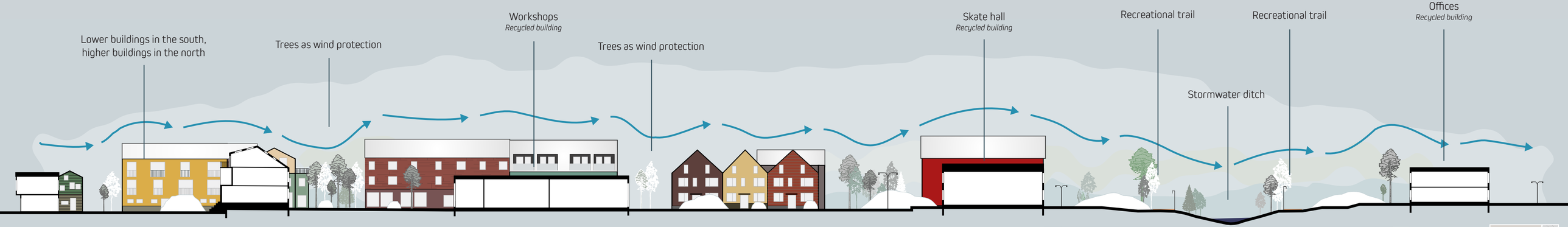
The decision to keep and recycle these four buildings (plus two additional buildings located north of this detailed plan) depends on two things.

First, these five buildings have very different characteristics which enable different activities to happen within them. Several other existing buildings that were not recycled are quite similar, making it more difficult to facilitate different types of activities.

Second, these six buildings are clustered nicely which opens up to the possibility to create a clear node within the site.

Section a-a

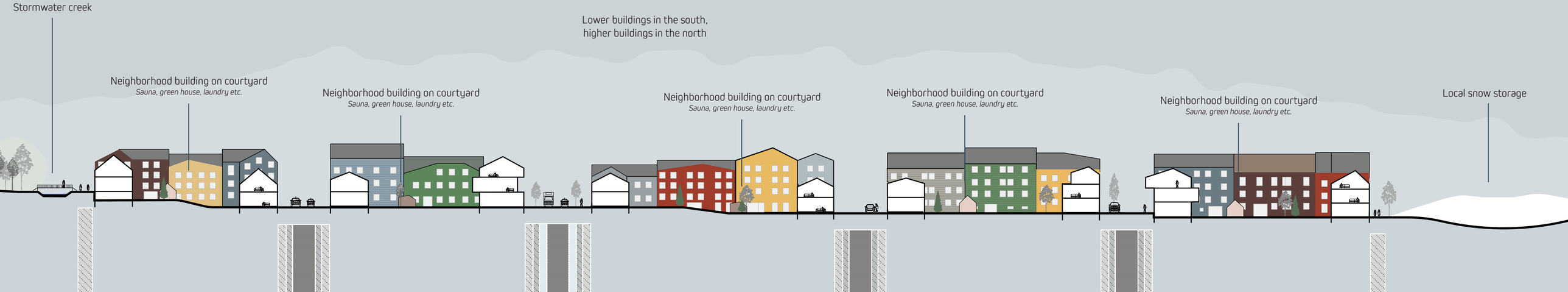
The recycled area and the park



Overlooking the square in front of the old bus garage

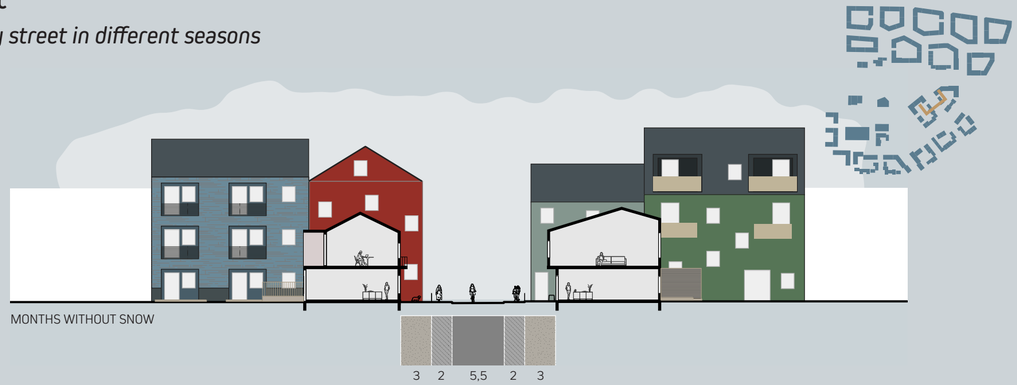
Section b-b

The northern blocks



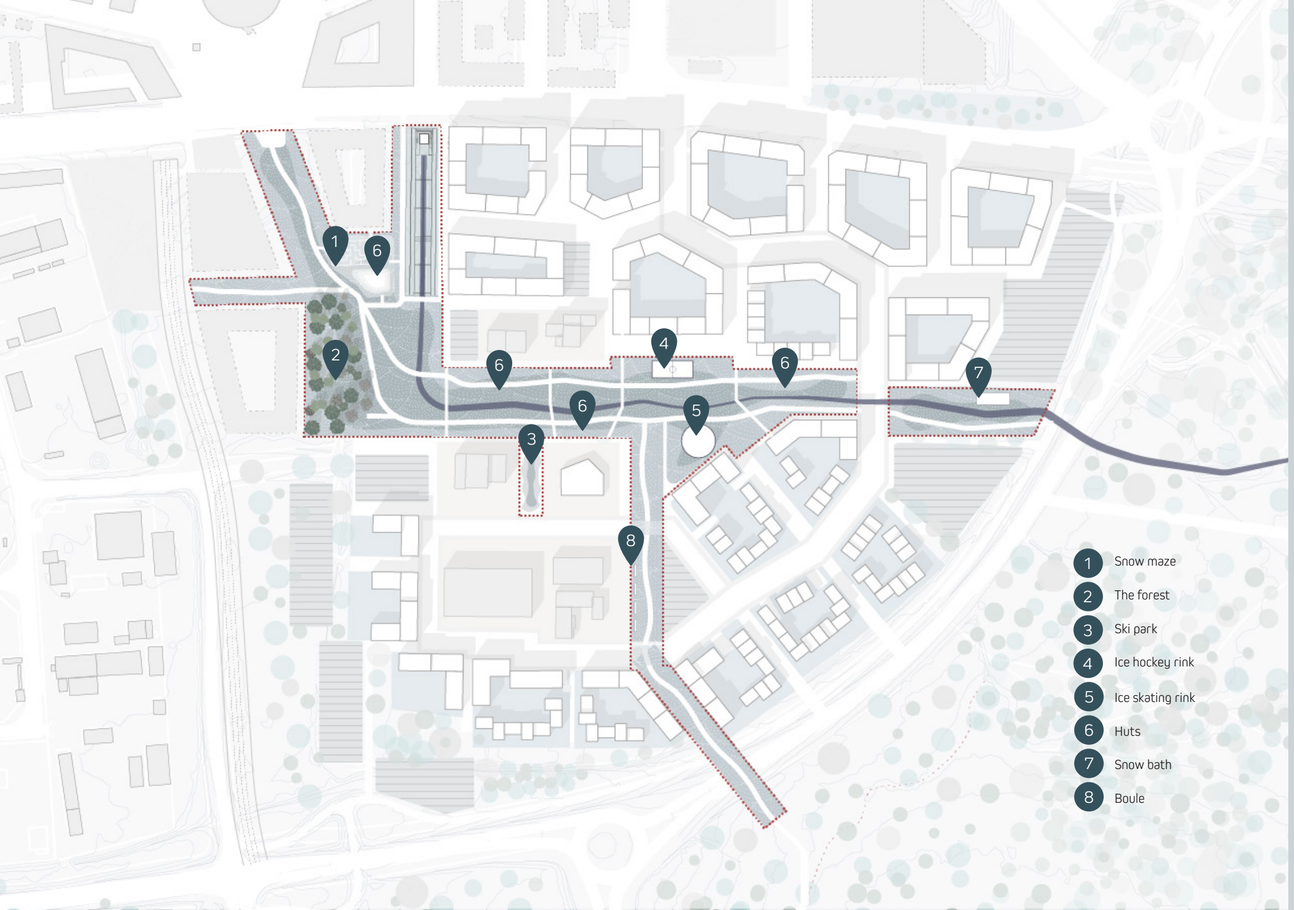
Section c-c

Secondary street in different seasons



Section d-d

Main street in different seasons

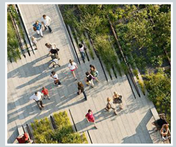


Winter characteristics





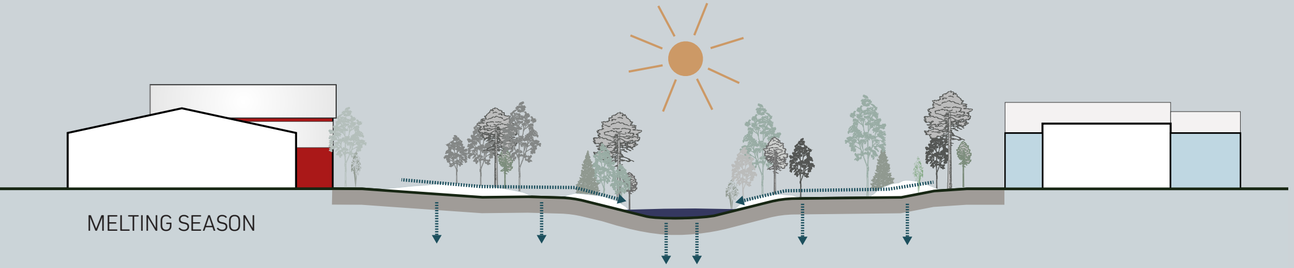

Summer characteristics



Park programming

The park includes a sequence of areas with different activities taking place over the course of the year. During snow-free months, the park becomes a place with several temporary interventions and activities



Section e-e

Investigating the stormwater creek's function during different seasons

Section f-f

The recreational trail going through the residential area during winter. During snow-free months, the recreational trail is used for biking and hiking around Kiruna

Skiing out into the forest on a nice spring-winter day!

Isometric view
The entire area with its surrounding environment.

Spring equinox

Summer solstice

Fall equinox

SHADOW RANGES

The sun and/or shadow study looks at the relationship between the sun elevation and shadows during three different moments of the day: 09.00, 12.00 and 15.00.

As showing in the study, the park has solar access during the entire year. When analyzing the squares it is noticeable that they are shaded during different parts of the day. This means that when one square (for example the one in front of the old bus garage) is shaded, you can go to the one in front of the community building and get solar access.

The study on the Winter solstice is missing. This is because Kiruna experiences Polar nights during the same time as the Winter solstice. This means that the sun does not rise above the horizon and there are therefore no shadows to study.

REFLECTIONS

Working with this master's thesis has been one of the most challenging yet inspiring projects I have ever been involved in. I have gained a great deal of new knowledge about urban design and myself. Being from Kiruna has been a huge motivation in going further into research about urban design in Winter cities. I have experienced, and been a part of, the mindset that spring and summer are the times of the year when cities become alive and active. While this is naturally somewhat true, winter is the suit Kiruna is dressed in during the majority of the year. Accepting and embracing that has opened me towards new ideas and ideals and challenged me in the way I present my projects.

The main reflection while looking back at the thesis is that I have come to realize that it is challenging to both mitigate wind and maximize solar access in Winter cities (and probably in all Scandinavian cities).

Furthermore, the existing research on storing snow has turned out to be limited. It has not been possible to find recommendations of measurements or preferred sizes of local snow storages. It is therefore difficult to estimate how much space is needed for a local snow storage. The area needed if of course connected to the amount of precipitation in the shape of snow but there is an opportunity for municipalities, researchers or others involved in this topic to investigate if there could be recommended dimensions of snow storages. Such recommendations could support urban designers in Winter cities to integrate snow storages which could free up pedestrian space.

There is more to be investigated, tried and learned about urban design in Winter cities. How do we deal with the not-so-nice snow-melting process? How well does a Winter city-proofed city stand in the future?

At last, my vision for my project has been to simplify and gather knowledge about urban design in Winter cities. Such knowledge and urban design is not only good during winter, but during all seasons. People want to be able to enjoy the sun without being subject to strong winds during all parts of the year. By designing with the Winter city design principles in mind, we can achieve places that are attractive and comfortable at all times of the year. I hope that urban designers such as myself can use the Winter city design principles in strive towards creating places where people go outdoors as winter comes.

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Images

Pages 62, 64:
Hjalmar Lundbohm, mine workers, town plan, town & Centralskolan: Kiruna municipality's archive
Old town hall, Kiruna church, kv Ortdrivaren: Kiruna municipality
"Vi är ej maskiner": Pressens bild/TT. Published in Arbetet
Sami huts: SGU archive
Rendering new city center: White architects
House on the move: LKAB

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