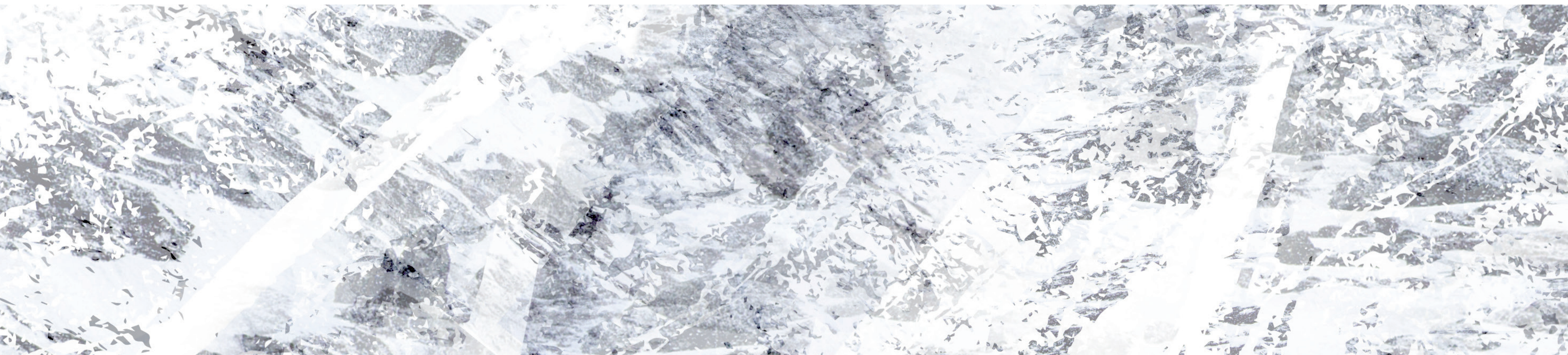
HIGH LATITUDE **HOUSING**

A HOUSING PROJECT IN NUUK

MSC4-ARK34
JUNE 2014



Aalborg University

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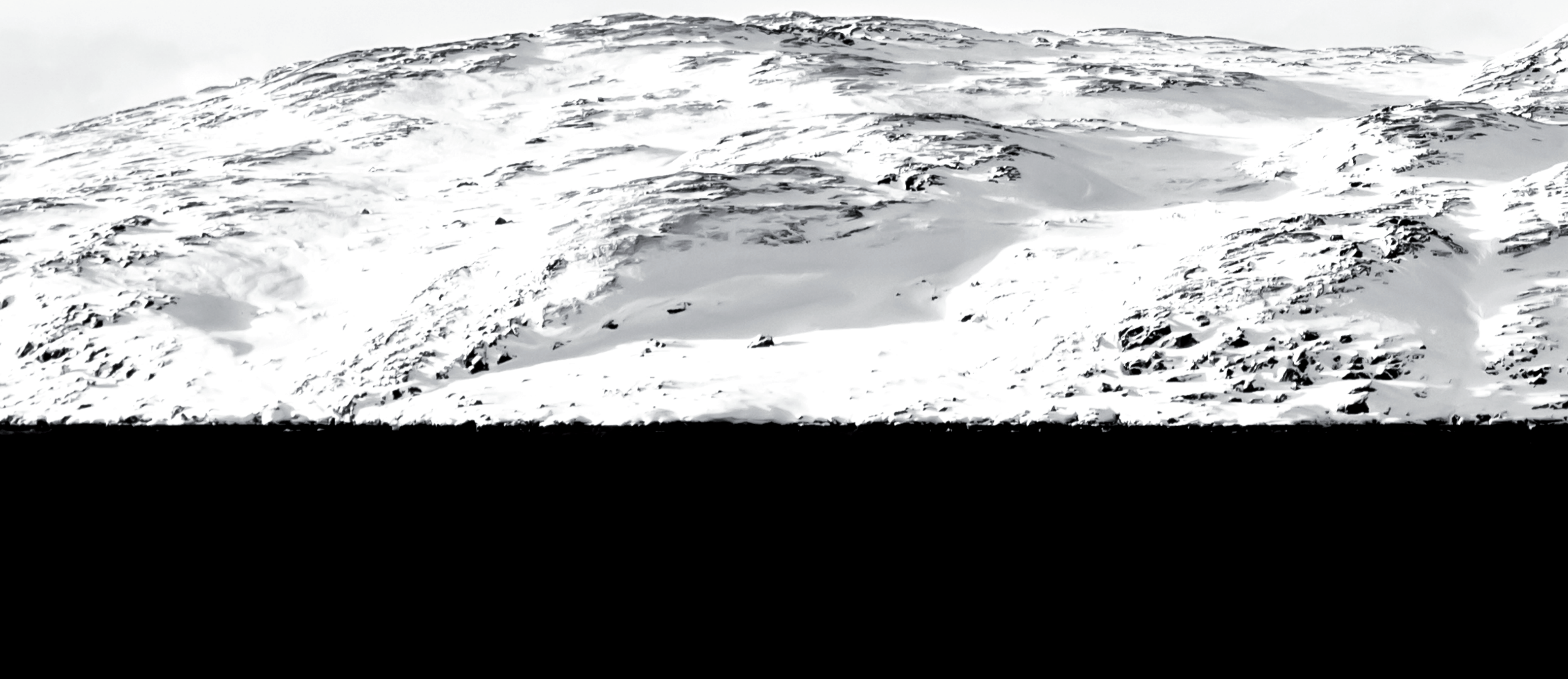

SYNOPSIS

This project deals with the design and development of a housing community in Nuuk - the capital of Greenland. It is a place where landscapes, climate and solar conditions are important aspects in achieving an environmentally and socially sustainable design. With our homes likely being the place where most of our time is spent - the quality of the physical environment, the indoor climate and daylight have an influence on our daily lives and well-being.

The design focuses on creating a home for Greenlandic people that allows the Greenlanders to continue and develop their cultural identity and lifestyle. The design acknowledges the fact that many people who live on Greenland enjoy fishing and hunting and have many tools and much clothing to cope with the climate, which has to be dealt with in a functional and environmentally efficient envelope.

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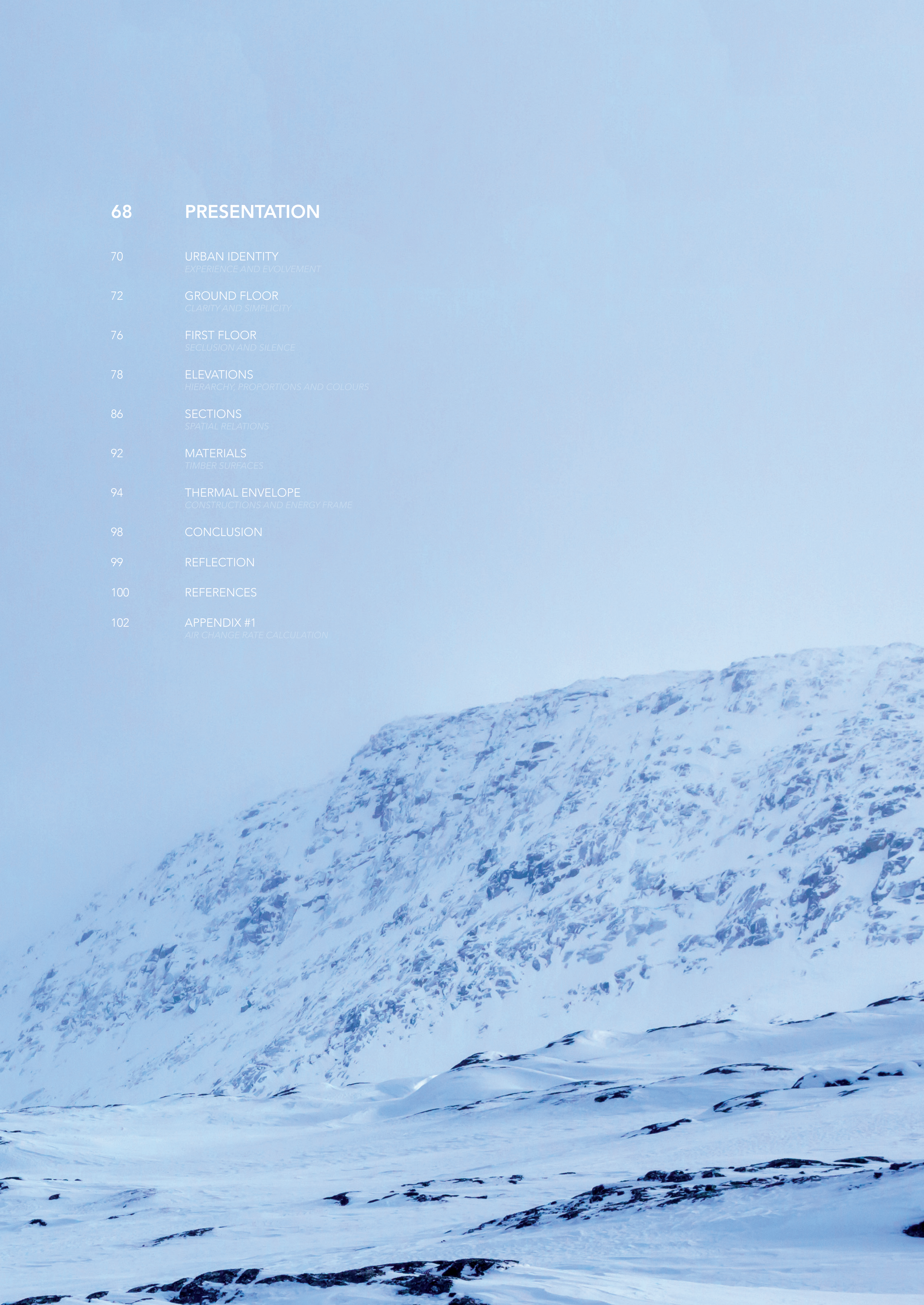


INTRODUCTION
FUTURE OF GREENLAND

In recent years, Greenland has received significant global attention as it is going through dramatic changes due to globalization, politics and climate change. The temperature change in the Arctic is greater than ever causing the sea ice to diminish and opening new shipping routes to Asia, Europe and America. As the ice melts, more and more of Greenland's minerals and natural resources are exposed.

Nuuk is by international standards a quite small capital with its approximately 16.000 inhabitants. The housing situation in Nuuk echoes the larger metropolises around the world, where prices are rising along with the demand. The situation is particularly bad in Nuuk where there has been a shortage of housing and it has been difficult to meet demand because the development of housing is complicated by the landscape and the climate. There is an immediate need for 620 dwellings in Nuuk resulting in an average waiting time of 7.5 years for a dwelling. If the current growth in population continues it is estimated that the demand for housing will be met within 12 years assuming that the current pace of building 150 dwellings a year continues.

This project will address the challenges of developing a dense housing community in the Arctic region, where landscapes, climate and solar conditions are important aspects for achieving an environmentally and socially sustainable design. With our homes likely being the place where most of our time is spent - the quality of the physical environment, the indoor climate and daylight have an influence on our daily life and well-being. The design will be derived from the traditional building culture and a sense of place to have an immediate relation to the Greenlandic people.

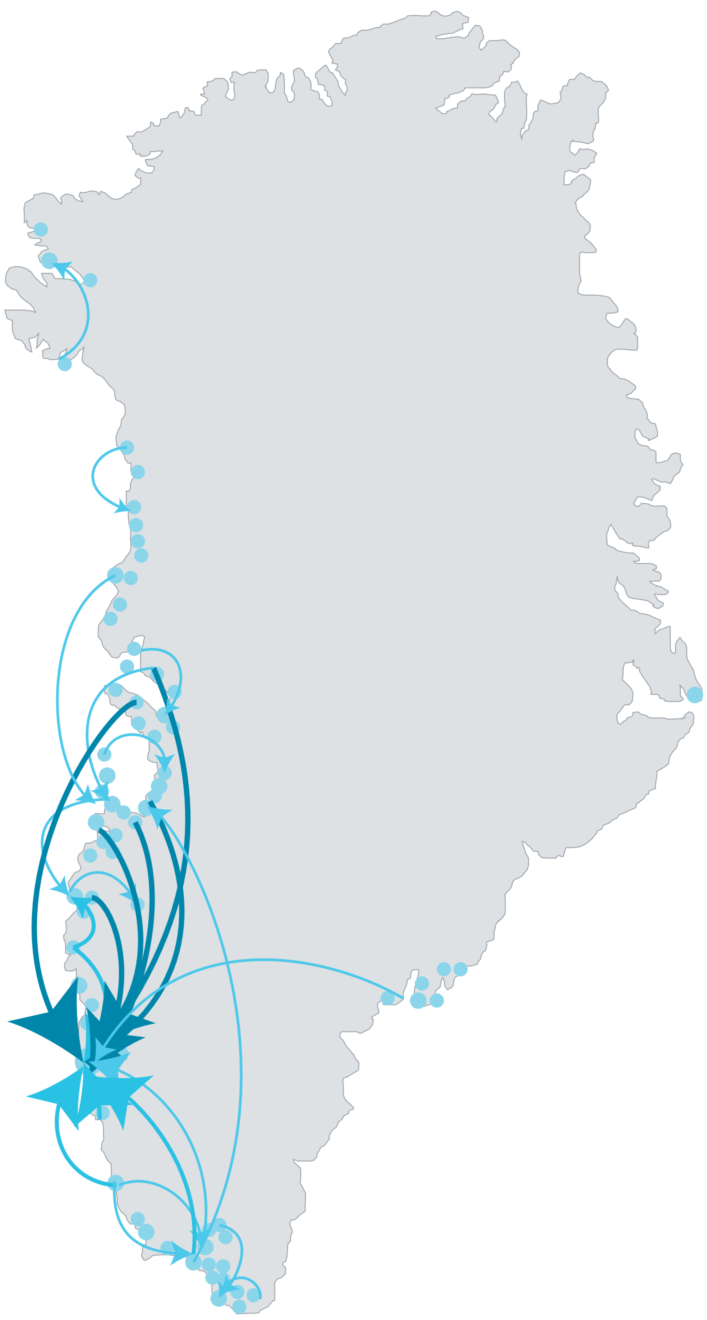


Fig. 1 *Main migration of people (Source: Mobilitet i Grønland, NordRegio, 2010)*

> *The average waiting time in Nuuk for an ordinary house is about 7,5 years.*
> **sermersooq2024.gl (Translated from Danish)**

METHOD
INTEGRATED DESIGN PROCESS

Architecture is an interdisciplinary field, involving several kinds of engineers and, of course, architects. Designing a building is not only a matter of solving aesthetics and functionality, but also a matter of solving technical, environmental and social aspects in harmony with the design. These are all important for achieving a holistic building design.

This design will be developed as an integrated design process, which will work with aesthetical, environmental and technical aspects in parallel to achieve a strong architectural design. Every aspect of the project will be considered and reconsidered during its various phases and iterations. Different methods including physical models, drawings and computational tools will be used simultaneously to develop the concept further.

The integrated design process is divided into the five major phases of a design project: problem, analysis, sketching, synthesis and presentation. It is important to stress that the design process will develop through iterations between phases.

Problem. The point of departure for the design project is derived from the problem. This encompasses the challenges and themes that are to be further explored in the next phase.

Analysis. This phase serves as the basis for the design phase – the site and context are studied and analysed along with the important aspects and themes of the project. At the end of this phase there will be a set of guidelines and boundaries, which should be echoed in the final design.

Sketching. The sketching phase is the creative development of architectural concepts in correlation with technical demands. Each design is by now a specific shape with different strength and weaknesses that are evaluated and optimized in relation to the aspects studied during the analysis.

Synthesis. The architectural design has reached its final shape and detail. All aspects of the analysis have come together in a project that incorporates the design criteria and technical demands in one coherent architectural solution.

Presentation. The final project is visualized in this phase though accurate drawings, calculations and models. With a persuasive clarity the final material must express the intentions that have been created mainly during the analysis but also in the subsequent phases. This means, of course, that the architectural, technical, functional and environmental results are presented with equal importance (Knudstrup 2004).

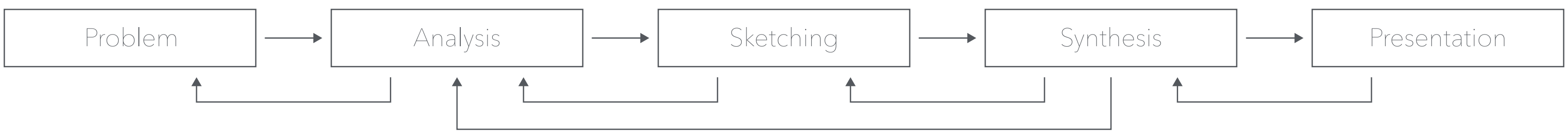


Fig. 2 *Integrated design process*

Fig. 3 *Sneak Peak*

PROGRAM

Inhabiting the Arctic

"In Ilulissat, West Greenland, 69 degrees north latitude, at noon every January 13, townspeople walk up the ridge overlooking the southern horizon to celebrate the reappearance of the sun."

Strub, 1996: 41

INHABITING THE ARCTIC

APPRECIATING THE ARCTIC ENVIRONMENT

To approach the design of dwellings within the Arctic requires profound compassion for its particular context. The harsh, cold and empty environment could to outsiders be seen as uninhabitable and inimical to human comfort. However, the design should embody an understanding of the Arctic climate, responding and accepting these conditions and celebrating the unique qualities offered by the climate and landscape. The indigenous people of the Arctic possess the quality to integrate their living habits with nature. The following will exploit the same potentials in a modern Arctic.

For the past 4.500 years the indigenous people have inhabited the pristine landscapes of the northern circumpolar regions, which are mostly characterized by the cold, emptiness and the hostile environment. However, these people understood how to live in this climate. Furthermore they not only managed to survive but also to thrive and adapt to the ever-changing Arctic. The native northerners saw the opportunities and possibilities in a landscape that humankind otherwise turned its back against and deemed too brutal. Their lifestyle was finely tuned to cope with the weather and climate and throughout the millennia they developed a spiritual and physical connection with the landscape.

Of course, one of the key aspects of surviving is to build structures that offer shelter from the elements. These were constructed from only the natural materials that were at their disposal and they provided the necessary shelter from the rain, wind, snow and predatory animals. The people of each region across the Arctic devised their own kind of shelter based on their needs and available materials such as wood, snow, ice, sod, whale bones and skin from animals. These shelters, whether they were temporary or permanent, were crafted with a thorough knowledge of the problems of living in a cold climate, such as drifting snow and the force of the wind. Depending on the season and its activities it was a necessity to switch between different types of shelter that each responded accordingly to the needs for mobility and comfort. One of the most well known of arctic structures is the igloo, which is built only from snow. Structurally the dome shape of the igloo is very rigid and heat loss is kept at a minimum due to the limited surface area exposed to the climate. A fresh layer will give a thicker layer of insulation and less heat loss, which in combination with the rather small size of the igloo causes them to warm quickly. The excess warmth of the interior can cause the inside ice to melt and the water to run along the sides of the dome where it would refreeze again on reaching the bottom, thus improving the rigidity. Igloos are simply abandoned as the temperature rises and the domes slowly melt away leaving no debris whatsoever (Axelsson 2010, pp. 20-29; Decker 2010, pp. 8-11).

Historically, settlers and adventurers have always been drawn to seek new inhabitable places and undiscovered areas of the earth. About a thousand years ago Eric the Red headed from Iceland into unknown seas to discover

> *"There is no one answer to how best to build in such extremes. Solutions are found at each site and pay homage to a variety of traditions, from indigenous houses of the Arctic to the sophisticated building industry of more urban places."*
> **Decker 2010: 7**

foreign lands where the Norsemen could settle. What he found was the distant and savage lands of what became known as Greenland – lands characterized by their beauty and mystery. Later he would return to Iceland telling about his discovery of Greenland and enticed more Norsemen to join his colonies in Greenland. He was successful in bringing more people to his colony but there was one major weakness in his plan. Unlike the indigenous people, the Norsemen did not adapt to the foreign lands and did not know how to inhabit such a vast and empty landscape. In the colonies people continued their usual living habits and maintained a connection to Iceland as they were dependent on supplies of wood, iron and corn to survive. The last trace of the Norsemen in Greenland dates back to 1500, about 500 years after the first settlers established colonies. While the is no evidence of what suddenly caused them to disappear it is believed that they never managed to adapt to the harsh context of Greenland and that their vital supplies from Iceland terminated. However, the indigenous people were unaffected by the colonies and continued their way of inhabiting the Arctic and even today they are still found in the remote areas of the northern circumpolar region (Augustesen & Hansen 2011, p. 8-15).

In more recent and modern years the desire to inhabit Arctic region has increasingly grown – both because of its immense and pristine landscapes and the possibilities of extracting oil and natural minerals. Some of the first contemporary buildings within the Arctic Circle were constructed by settlers and based upon a building tradition that was native to them – not native to the specific site. These buildings were often conceived as graceless objects that responded to neither the topography nor the climate. That, of course, gave rise to challenges as the buildings failed to address the issues of snow drifting, thawing and freezing. The indigenous people had over several thousands of years developed and perfected shelters and building techniques for the specific environment, which the new breed of permanent construction ignored. Ideas and techniques were directly imported from more southern and warmer environments and then plopped down in the Arctic regions without any tailoring besides a thicker layer of insulation. Though this standardized design was not a flawless solution it was basically the only feasible solution at the given time.

A building in the Arctic should be more just a building within the Arctic latitudes. It should become Arctic in how it interprets and responds to the environment and climate. It should utilize the topography and landscape to enhance its architectural appearance. The cold low-angle light of the sun creates a visually vibrant and dramatic landscape that makes the warmth of dwellings even more welcoming. Architecture should provide an inherent shelter from the environment and instead of isolating inhabitants from their surroundings it should strengthen the relationship between them (Decker 2010, p. 8-11).

HIGH LATITUDE DESIGN

PRECAUTIONS AND CONSIDERATIONS

When heading north, the climate changes gradually with lower temperatures and longer winters with increasingly less daylight and a summer with virtually continuous daylight. There is a pronounced climatic difference between the seasons in high latitudes in terms of temperature and the length of a day. The following define the essence of the climate within the Arctic Circle. It is not site specific, but serves as a general guideline for Arctic building design.

DAYLIGHT IN ARCTIC REGIONS

In high latitude regions the sun is seen as a desirable light and heating source, but also presents some design challenges. Characterized by its low angle and periods of darkness the sunlight suggests alternative ways of utilizing the light and solar gain when the sun is above the horizon. North of latitude 66,5 °N, defined as the Arctic Circle, the midnight sun occurs for a part of or the entire summer while sunlight is absent for a part of the winter. Although the building physically has to respond to the dark winters and bright summers the design also has to acknowledge and maintain the physiological well-being of the inhabitants during times of little sunlight. The building envelope should maximize exposure to the south and take advantage of all the available daylight and at the same time not cast shadows on nearby buildings. To cope with the month where there are only a few hours of daylight, which is accompanied by feelings of isolation and boredom, the layout of a house should maximize contact between the inhabitants and provide diverse interior spaces with a connection to the outside elements. The use of a vibrant colour palette is also a common architectural feature in high latitudes and serves as a colourful contrast to the endless shades of grey in the landscape.

The characteristics and distribution of the sun vary considerably as the latitude changes due to the spherical shape of the earth. Summertime in a mid latitude location will experience a sun that is high enough above the horizon to affect horizontal surfaces. However, this is not true for high latitude locations where the majority of sunlight reaches the earth from a low angle, meaning that the effects of the sun are mainly on the vertical surfaces. The intensity of the sun is reduced quite a bit, as the sunlight has to travel a longer distance through the atmosphere that absorbs some of the solar energy.

Solar shading strategies are different from one another depending on latitudinal location. In low latitude regions the path taken by sunlight through the atmosphere is the shortest, which results in the least loss of solar energy and therefore reaching an intensity that requires shading all year round. In mid latitude regions, the direction of solar radiation varies over the course of a year and ideally solar shading should block the sun when its radiation and intensity are at a maximum, while at the same time allowing heat gain in buildings for cooler periods. In high latitude locations the goal is to capture and store the heat from sunlight throughout the year.

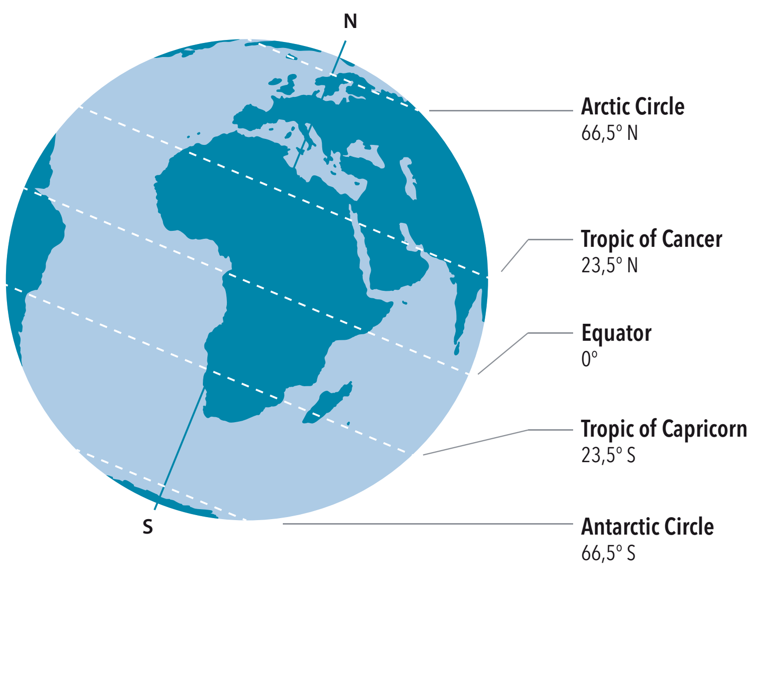


Fig. 4 *Circles of latitude*

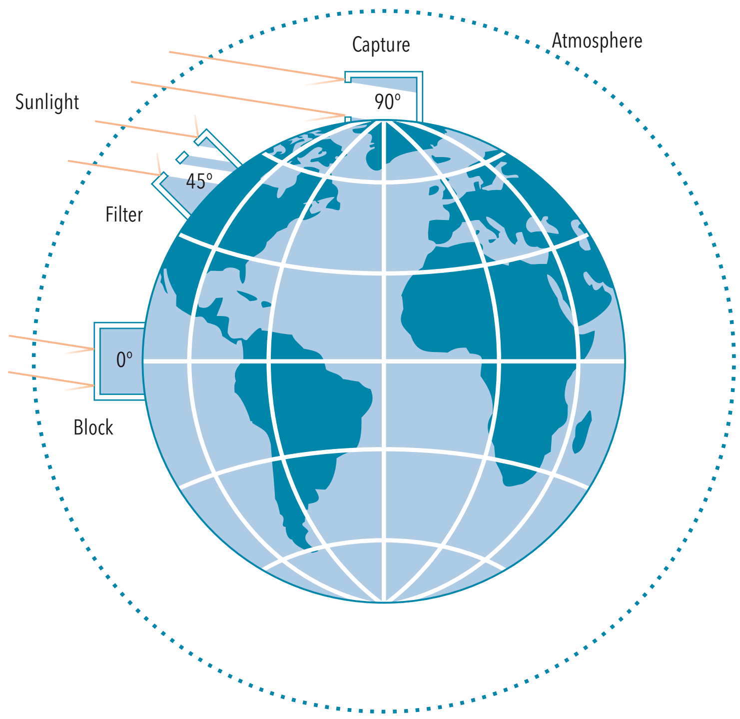


Fig. 5 *Shading strategies according to latitude*

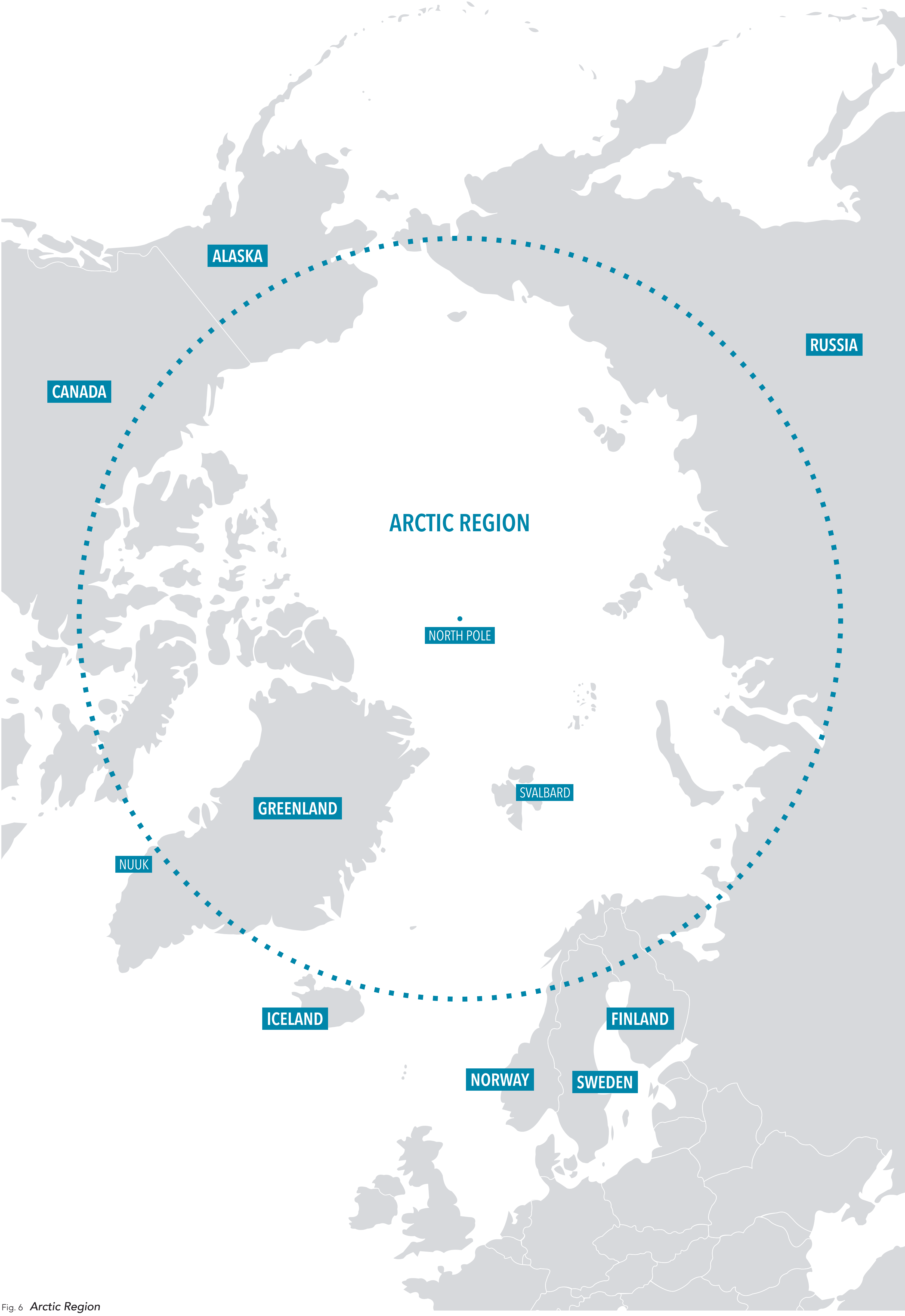


Fig. 6 *Arctic Region*

TEMPERATURE

When designing a building envelope for Arctic conditions the same guidelines apply as for mid latitude buildings regarding airtightness and thermal resistance. However, consequences of thermal bridges and infiltration will have a greater impact on heat loss due to the higher temperature difference between the inside and outside, which increases the rate of loss.

The exterior materials of a building that are exposed to sunlight can in winter time go as low as -40 °C and reach up to 60 °C during the summer. These temperature variations cause the materials to expand and contract and when this happens the building materials may crack or buckle under the stresses. Air temperature differences can also cause ice to form in concealed spaces, such as exterior walls, from water vapour. This will result in a lower thermal resistance when the ice forms within the insulated layer.

WIND

In the northern circumpolar regions, movement of the cold and dry air can have a vigorous impact on both humans and buildings. It will cause snow to drift uncontrollably and hamper crucial external shipments in remote locations. The wind will always be part of the environment whether it is desirably or not, but with an intimate understanding of wind behaviour the negative consequences of the wind forces can be brought to a minimum. One of the key things to know for any given site is the prevailing wind direction. This will determine the faces of the building to orient against the wind direction and which faces should be on the leeward side. The wind will accelerate heat loss on the exposed facade and it will cause snowdrifts in the least turbulent spots. Snow can accumulate on both the windward and the leeward sides of the building and it can reach the same height as the adjacent building. The distance between buildings is also critical as snow drifting from one building can disrupt buildings close to it. The effects of drifting snow can be considerably reduced by raising the building on pillars above the ground and allowing the air to flow beneath it. The building's entrances should preferably be positioned perpendicular to the windward side to eliminate snowdrifts in front of the entrance (Strub 1996, pp. 41-53; Decker 2010, pp. 17-26).

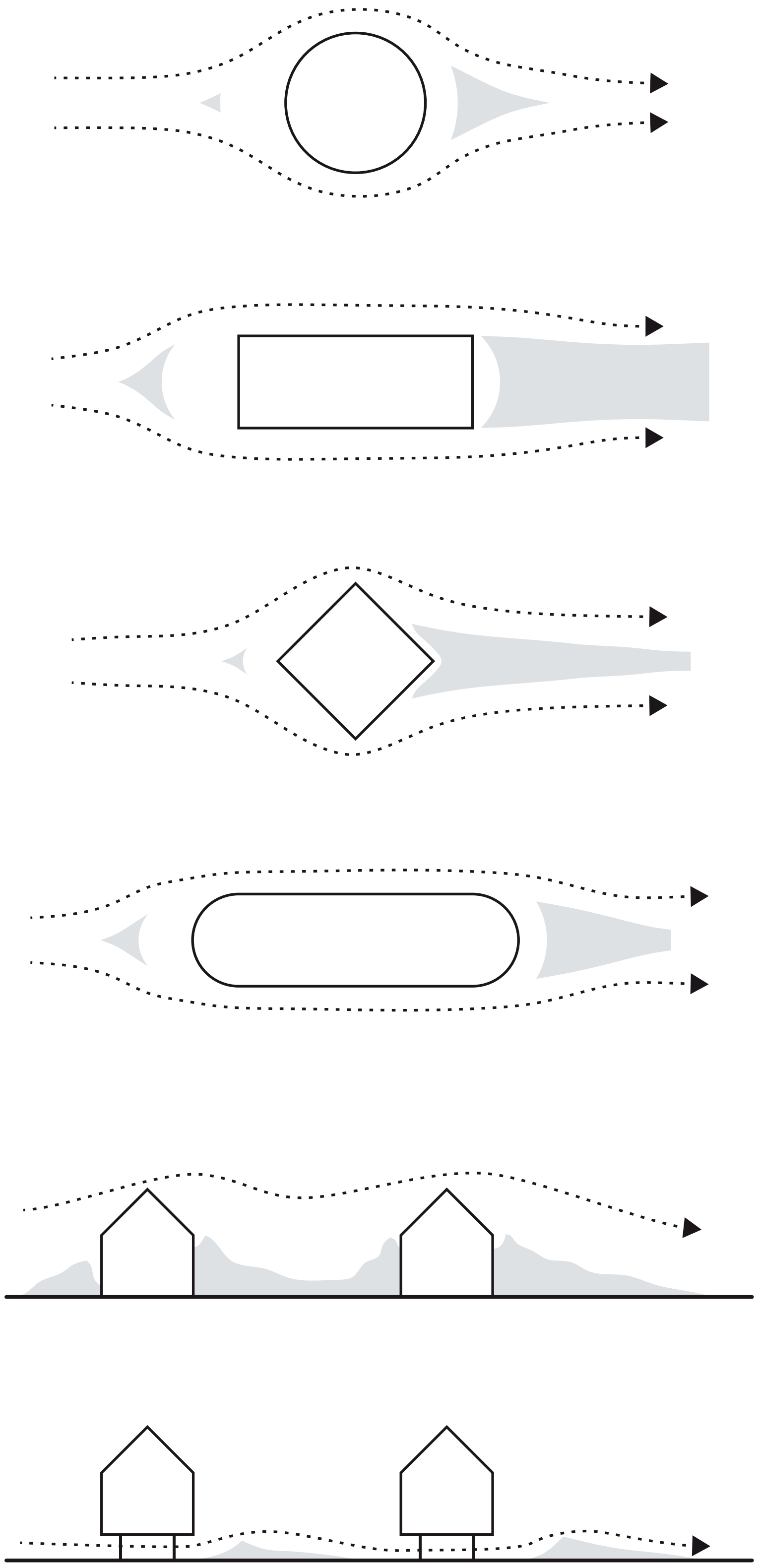
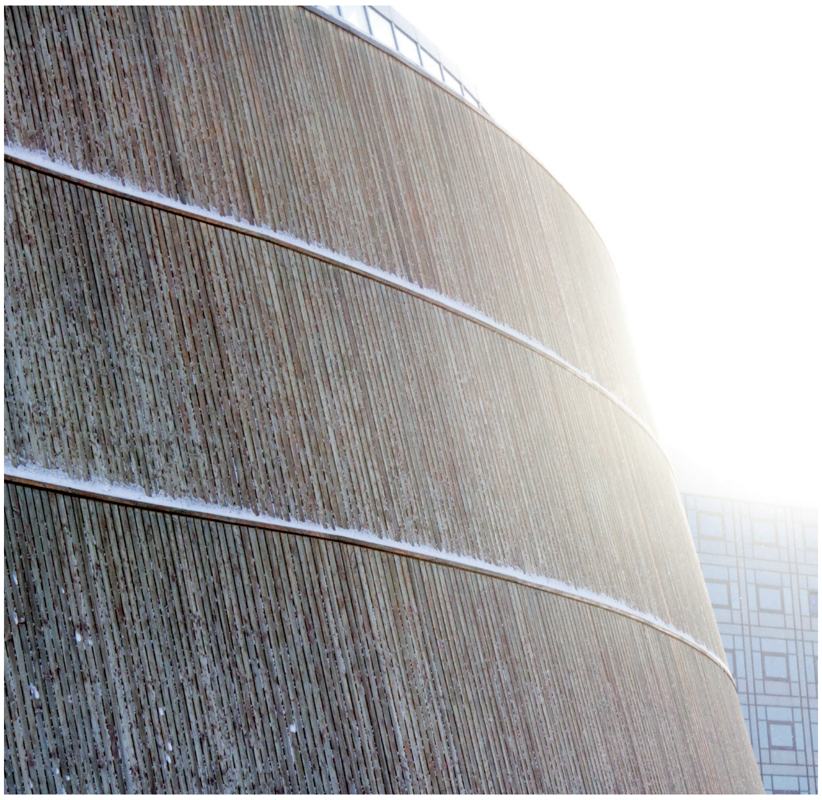


Fig. 7 *Snow drifting around buildings*




L.P
1983
L.P
K.P

GREENLAND
LIVING ON THE EDGE OF AN ICE CAP

Greenland is the largest island in the world – it is known for its hostile landscapes and inhospitable climate and yet is so astonishing and attractive. With its incomprehensible scale, its remote location and its few inhabitants situated on the edge of the ice cap, the Arctic nature of Greenland dominates everything.

The Inuit have, despite the Arctic climate, lived and thrived in Greenland for thousands of years. Their culture developed from the idea that each individual is a part of the community and the community is a part of each individual. Survival was ensured by having a healthy environment, a healthy community and healthy individuals. Conflicts and disharmonies were solved collectively for the benefit of the community rather than an individual. The Inuit way of living has over the past generation changed from being a hunting society to a Western-designed community. Permanent housing and industry have been built in a European tradition and societies have been recreated accordingly. Lifestyles are broadly similar to those in Europe, with increasing globalization and a more prevalent political agenda (Thorup, 2012).

POPULATION
Only **56.543** people live in this large country.

AREA
The area of Greenland is **2.166.086 m²**. It is 50 times larger than Denmark.

POPULATION DENSITY
With **0,14 people/km²** (ice-free area) Greenland is one of the least dense places.

ICE CAP
The ice cap makes up approximately **80 %** of the total area.

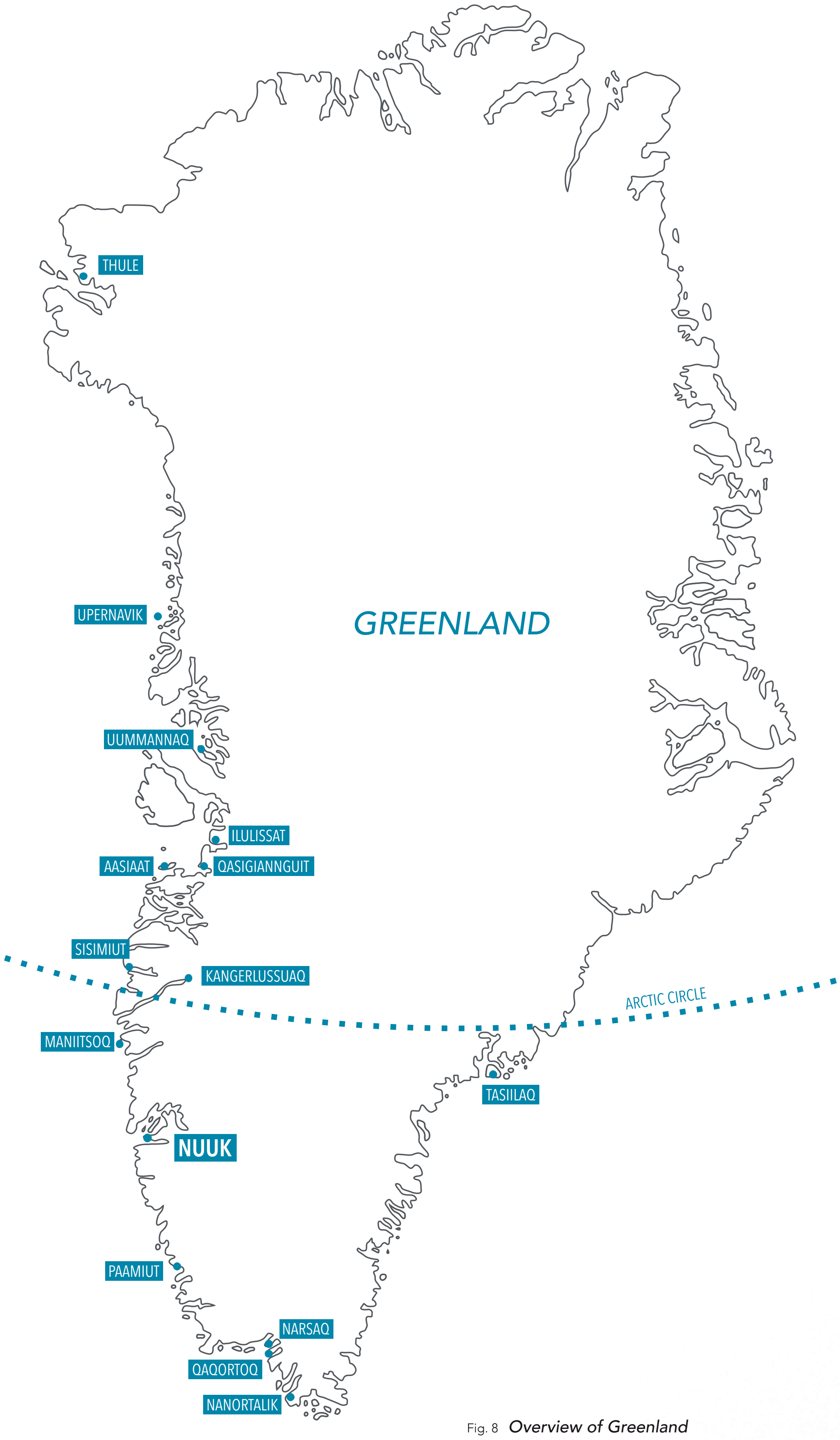
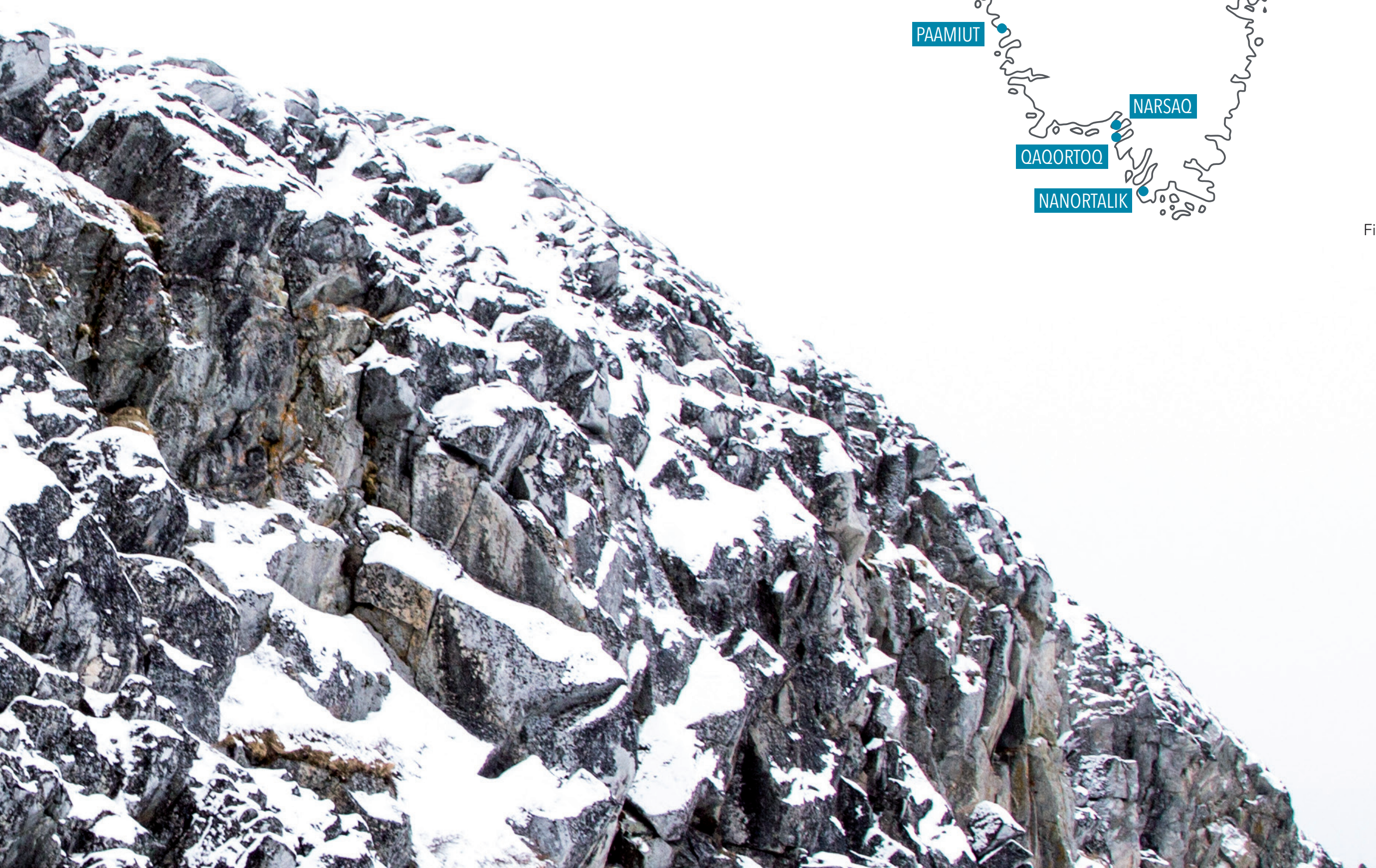


Fig. 8 *Overview of Greenland*



GREENLANDIC IDENTITY

RELATION TO THE LANDSCAPE

During the rapid development of the 1960's most buildings were standardized and were in fact designed by Danish people who were not aware of the particular Greenlandic requirements for housing. Most of the indigenous people were at that time, living in settlements built by themselves and accommodating their own specific demands. These people were in a short period of time transferred from living in settlements without rent and still hunting for their food to being housed in modern dwellings with unfamiliar technical equipment. For some people this modern way of living was in conflict with the traditional fish and hunting communities and they did not wish to live in standardized concrete flats with no outdoor space allocated for tools and clothing. Some of these characteristic buildings are now seen as slums and they are being demolished.

That does not mean that the Greenlandic people will forever remain hunters and fishers who build their own detached settlements. This was a development that went too fast with a transition from one extremity to another (Steenfos & Taagholt 2012, pp. 159-161).

While the housing blocks in Greenland solved many of the intentions of that time, they proved to be lacking social values and urban qualities. Over the years, this was manifested as vandalism, violence, and neighbourhood disputes. In summary, there was a lack of comprehension of the families who were to live there and their living habits – at least in the context of multi-storey housing. The scheme that formed the foundation for the housing was very much inspired by the Danish building industry. The flats were significantly smaller compared those in Denmark although the average Greenlandic family was larger. In later years the buildings were wherever possible tailored to suit the ingrained manners of the Greenlanders. However, there was still one issue, which couldn't be addressed – the size of the flats. The partition walls were loadbearing and cast in concrete, which meant that the footprint for each apartment was fixed. Corridors and doorways also proved to be too narrow for Greenlandic winter clothing (Steenfos & Taagholt 2012, pp. 328-330).

Contemporary Greenlanders live in a modern society with all the ensuing drawbacks and opportunities. The contemporary Greenlander stills values the kayaks and dogsleds for sports as well as going hunting or fishing. Not because they have to, like their ancestors, but because these are part of their cultural identity and a way to exploit the landscape and climate rather than being isolated from it. The intimate relation with the landscape is what identifies the Greenlander and is what should identify the architecture (Rosing 2012).

"*Modern Greenlanders still values kayak for sports and dogsled for sports as well as hunting and fishing. However, warming over the past decade has almost rendered dogsledding obsolete, because the sea ice rarely forms anymore.*"

Minik Rosing: CONDITIONS #11/12, p.70

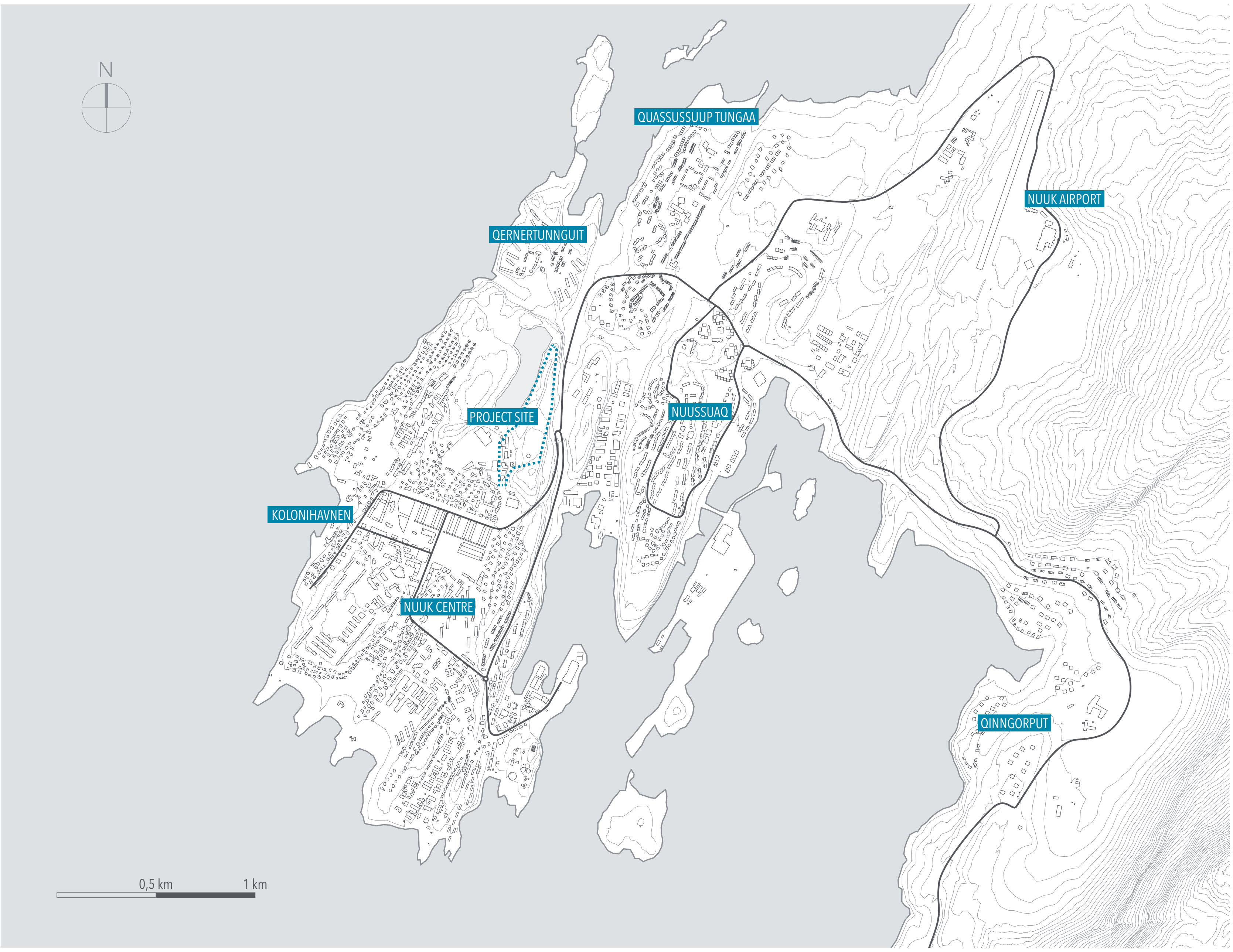


Fig. 9 *Overview of Nuuk*

NUUK

ARCTIC METROPOLIS

Nuuk, the capital of Greenland, is ever expanding and is currently the home for approximately 15.000 people. The city is one of the most desirable cities in which to live in Greenland where the need for housing seems to be endless – it is estimated that three-quarters of the population of the whole of Greenland would live in Nuuk, if there was an adequate amount of housing. More than a fourth of Greenland's population live in Nuuk.

In the 1930's only a quarter of Greenland's population was housed in cities and the rest in settlements. Nowadays it is the other way around, where three-quarters of Greenland's population live in cities. According to an experienced Greenlandic journalist, Jørgen Fleischer, the currently 60 settlements and 18 cities, will in the future be reduced to only four "major" cities; Qaqortoq in the south, Sisimiut and Nuuk in middle-Greenland and finally Ilulissat in the north.

Nuuk is a fairly new city and has during the past years grown into what can only be described as a hybrid of Greenland and Denmark. The city is trying to pursue the Danish and the European way of being a capital though it is located on this remote island.

Nuuk is a city of hybrids – a diffusion of Greenlandic architecture, culture and nationalities. In the 1960's the controversial G-60 policy was introduced to centralize the population of the island. Some of the settlements that were too costly to maintain were closed. The idea behind the centralization was to give the people of Greenland equal opportunities for employment and education as Danish people. The result of this was a massive need for housing in Nuuk, which rapidly spawned ten concrete housing blocks among them the well-known Block P, which before it was demolished was home to one percent of Greenland's population. While Block P and the other concrete blocks were able to solve the immediate need for inexpensive housing they also caused social problems in the society and now – only about 40 years after it was build – it has been demolished. (Andersen 2008, pp. 37-57)






PLANNING
A COMMON FUTURE

As the Greenlandic centre for education, trade and industry, Nuuk is undergoing rapid growth with newcomers from all over the country. This has resulted in an infrastructure that cannot cope with the number of people and vehicles and long waiting lists for housing.

A couple of years ago a new strategy to develop Greenland's second largest municipality by area - Kommuneqarfik Sermersooq - was conceived. It was based on three core values: sustainability, quality of life and democracy. The aim was to make the municipality stand out as a modern and sustainable society for not only Greenland but for the entire Arctic region. More specifically the architecture of Greenland and in particular Nuuk, must reach a high quality functionally and aesthetically to set the standard for Arctic architecture in the future.

Greenland is aiming for a high standard for housing and living, aspiring to reduce the shortage and immediate need for housing - without rushing into development and risking building urban areas like the old housing blocks, which would increase the possibility of ghettoization once again. New neighbourhoods should be vibrant and diverse and offer housing for elderly, young, families and disabled people. These are the conditions for creating a society with synergy and coherence (Planstrategi Vores Fælles Fremtid 2011).

> *"And modern Greenlanders now live in modern houses built to Danish tradition."*
>
> Minik Rosing: CONDITIONS #11/12, p.190

SITE
A CENTRAL RESIDENTIAL AREA

Nuuk is an expanding city and finding ground for buildings is becoming increasingly more difficulty. For the moment, there are two parallel strategies of continuing the development: building at sites that were previously deemed too difficult to construct on because of their topography and expanding the city along the shores and thereby creating new satellite cities. The chosen site for this project falls into the first category and is situated close to the centre of Nuuk. It is largely characterized by challenging topographic conditions and a large adjacent water reservoir, which serves as Nuuk's main drinking water supply.

According to the development plans, the site will comprise approximately 150 dwellings. The large majority will be for families with children, but there will be housing for students and elderly as well. This project will address the development of housing units for families. The site measures 81.000 m^2 and stretches to a length of 500 m with a height difference of 38 m.

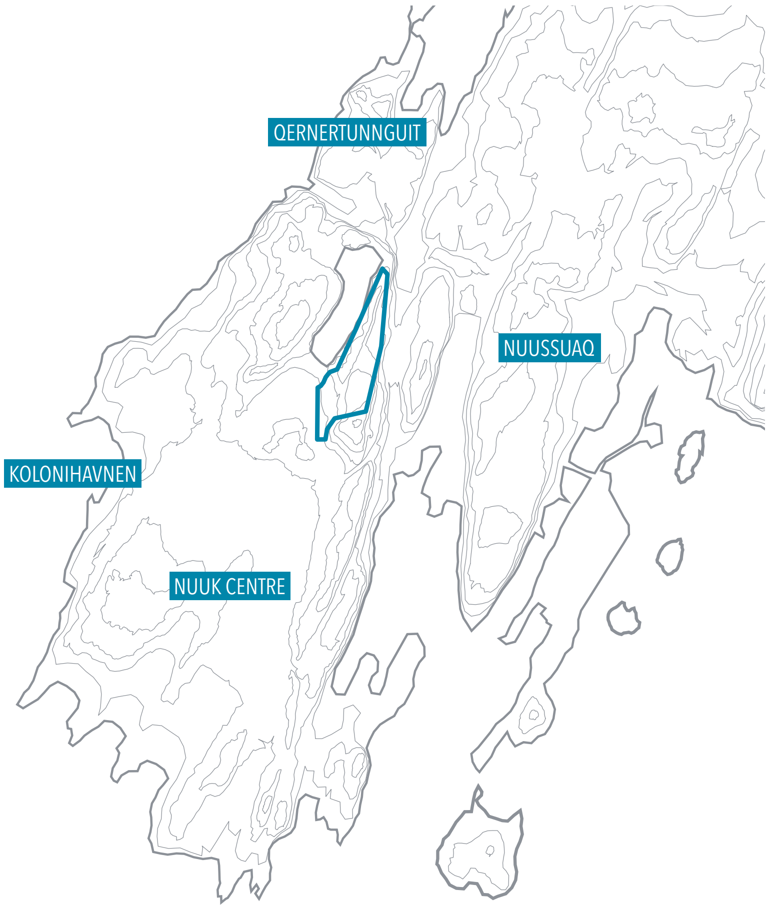


Fig. 10 *Project site in Nuuk*

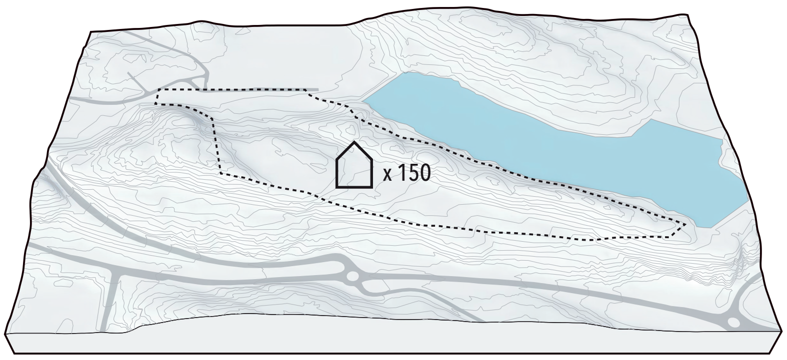


Fig. 11 *Number of housing units*

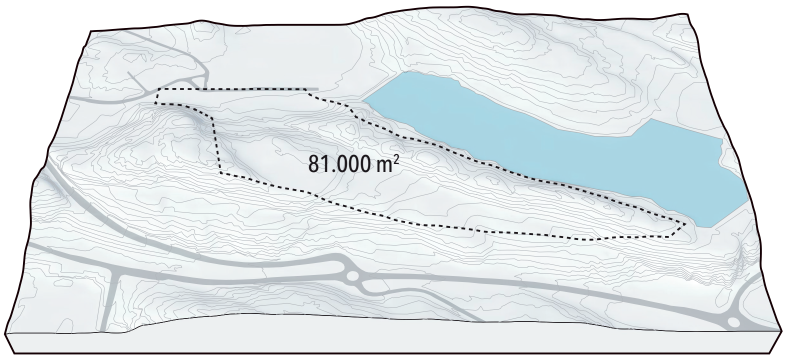


Fig. 12 *Size of site*

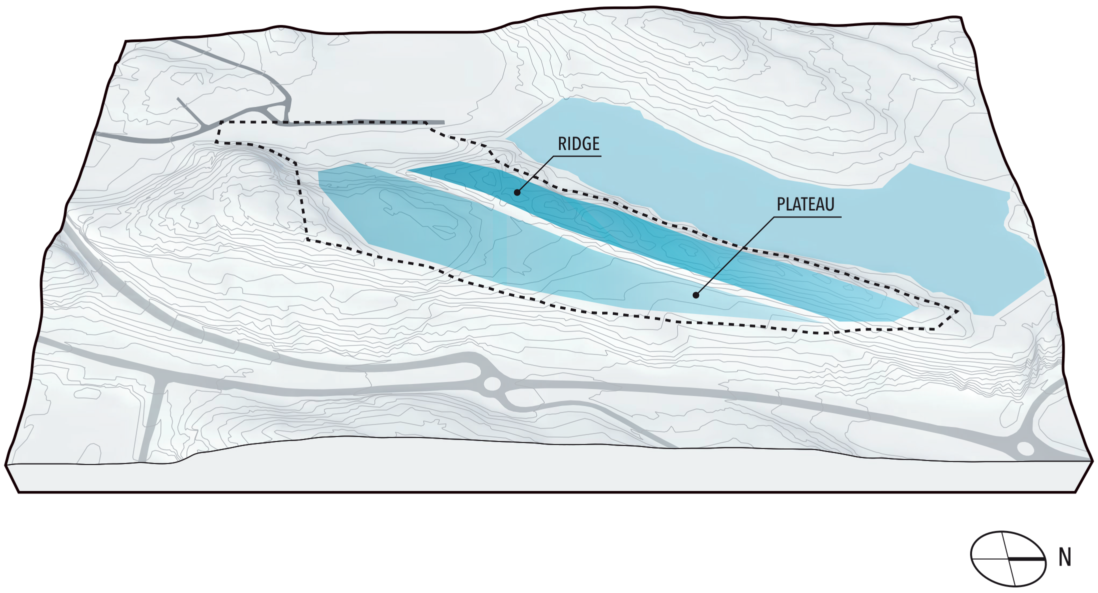
Fig. 13 *Satellite image of site (Source: Google Maps)*

MAPPINGS

LANDSCAPE, TRAFFIC, VIEWS AND TOPOGRAPHY

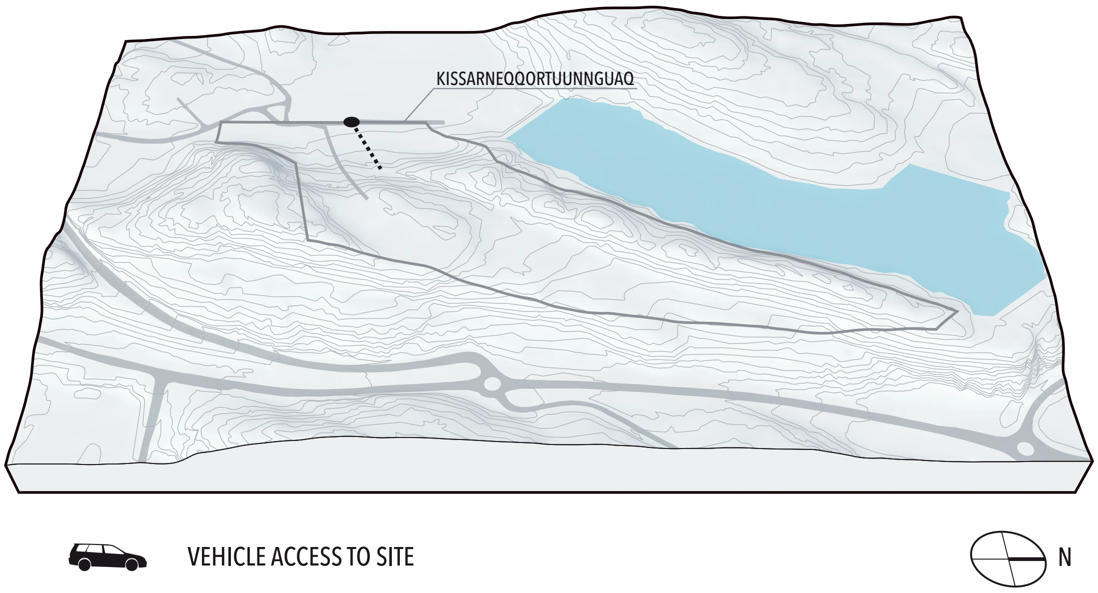
LANDSCAPE

The landscape of the site is largely characterized by a north-east sloping plateau and a ridge located next to the water reservoir. The ridge has an almost straight outline that visually separates it from the plateau.



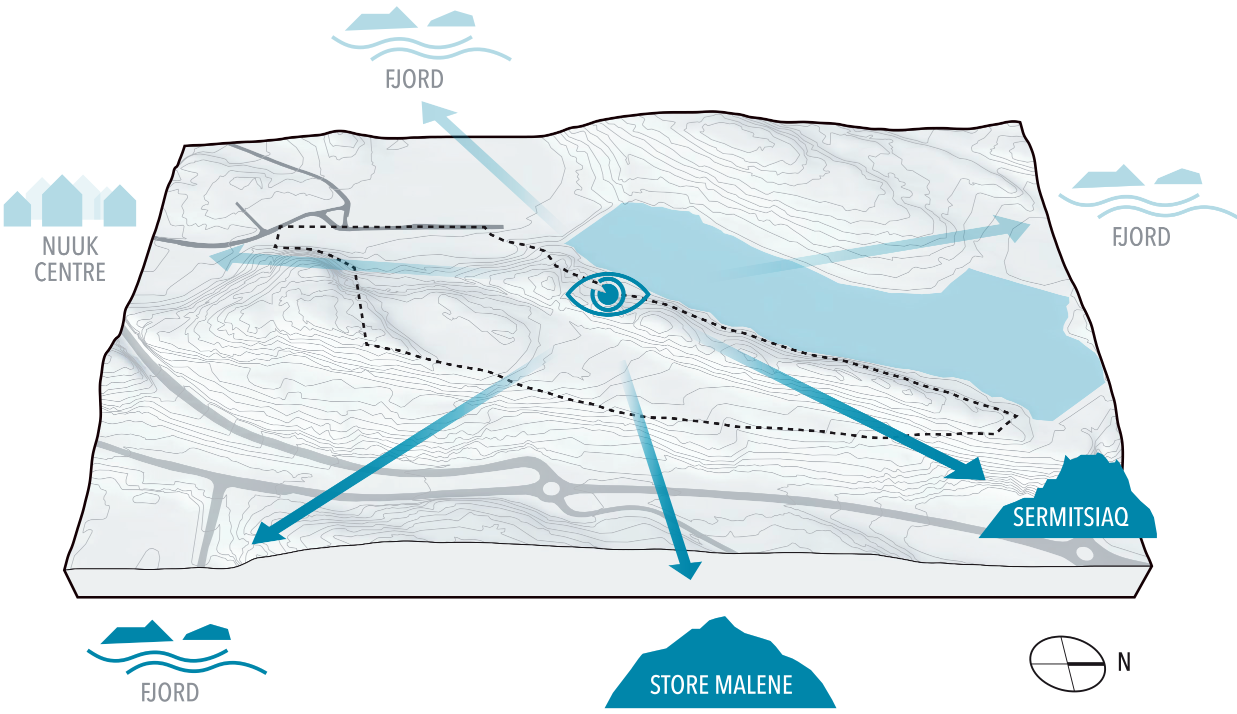
TRAFFIC

According to the local development plan the main traffic access to the site has to connect to Kissarneqqortuunnguaq in the south-western part of the site.



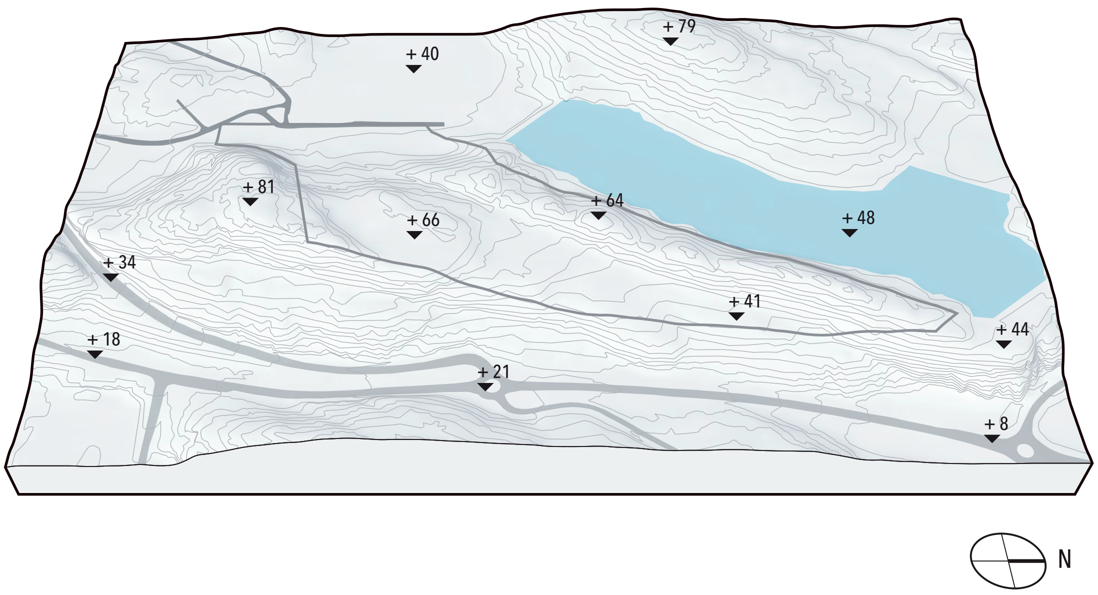
VIEWS FROM SITE

As the plateau and ridge are raised above the adjacent landscapes the site offers a series of views. From the plateau there is an immediate and clear view to the mountain named Sermitsiaq – the landmark of Nuuk – as well as a view to the fjord and the mountain Store Malene. Walking to the top of the ridge gives a new series of views to the fjord and the city that are only slightly obscured by the ridge west of the water reservoir.



TOPOGRAPHY

The topography of the site has considerable quality and potential but also some challenges. The diagram shows the specific elevations at some significant points that give an idea of the scale of the topography at the site.



SITE PHOTOS
CONTEXT AND VIEWS

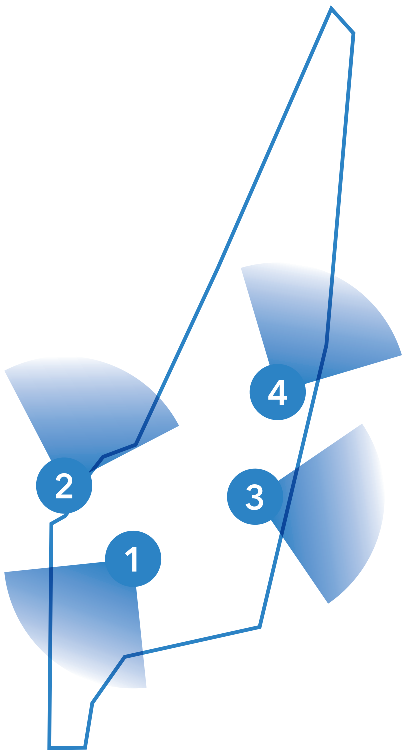


PHOTO 1: *VIEW TO THE SOUTH FACING THE CENTRAL AREA OF NUUK*

PHOTO 4: *NORTH FACING VIEW WITH SERMITSIAQ IN THE BACKGROUND*

PHOTO 2: *WEST FACING SIDE OF THE RIDGE, ADJACENT TO VANDSØEN*

PHOTO 3: *VIEW TOWARDS NUUSSUAQ AND LILLE MALENE*

CLIMATE

CONDITIONS IN NUUK

When designing for an unfamiliar place on earth and in particular a place as distant as Greenland it is crucial to understand the local climate and it can be a good idea to compare it with familiar conditions to truly comprehend the differences.

SUN

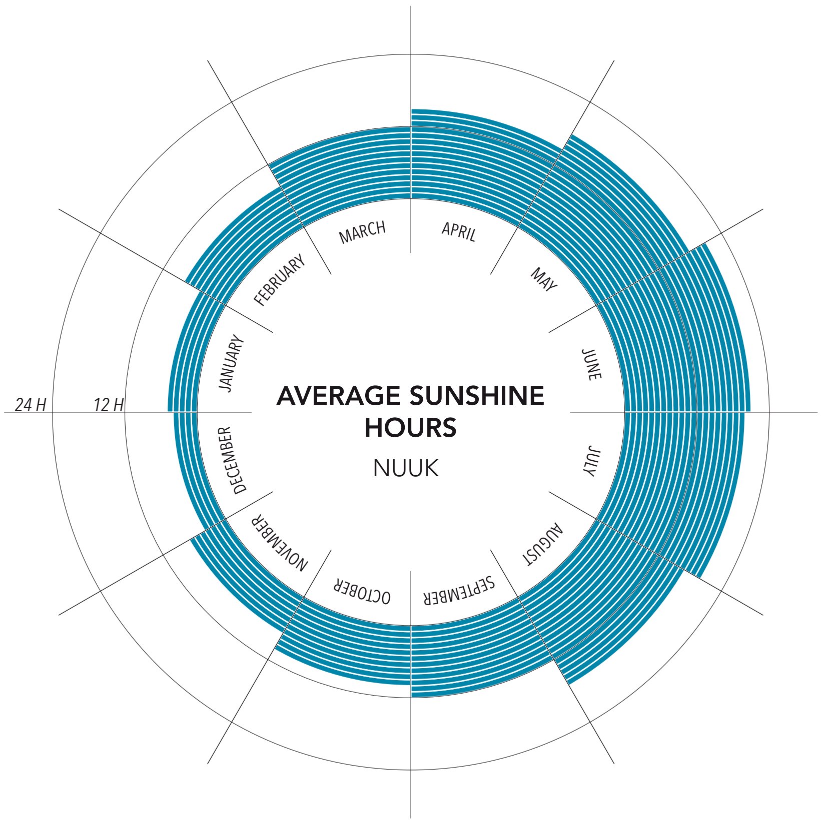
Nuuk is a city located in the far north of the world yet not beyond the Arctic Circle. The climate is considered and treated as Arctic climate but Nuuk does not comprehend extreme cold temperatures and the 24-hour day and nights. The sun path diagram shows that the sun at winter solstice only reaches an altitude of 4° at maximum and is only above the horizon for a few hours whereas the sun in Copenhagen has a maximum altitude of 12°. While the Arctic climate consists of short days in the winter the days in summer are equally longer and from April to September Nuuk has an equal number or more hours of sunshine than Copenhagen.

TEMPERATURE

Temperatures in Nuuk or the Arctic are of course significantly lower compared to temperatures in Denmark. The highest average outside air temperature in Nuuk is 6,7 °C from which it can be assumed that the heating season lasts the entire year. According to the Danish definition, the outside air temperature must exceeded 12 °C for three consecutive days for the heating season to end. This also means that the ventilation will require a strategy, which includes heat exchange in the system to avoid discomfort from drafts and a high rate of heat loss that can be a result of low outside air temperatures. (Kragh & Svendsen 2002, p. 5)

WIND

Understanding the site-specific wind conditions can dramatically improve not just the building performance and controlling snowdrifts but also create shelter and comfort for humans when conditions are tough. The wind is for the vast majority of the time from either the south or the north-east, which poses some challenges as the site slopes towards the north-east. However, my own first-hand experience of the actual site on a day with winds from the north tells me that the ridges to the south and west shelter the plateau. On the plateau, the wind speeds could be moderate, but when ascending to the top of the ridges the speeds increased considerably.



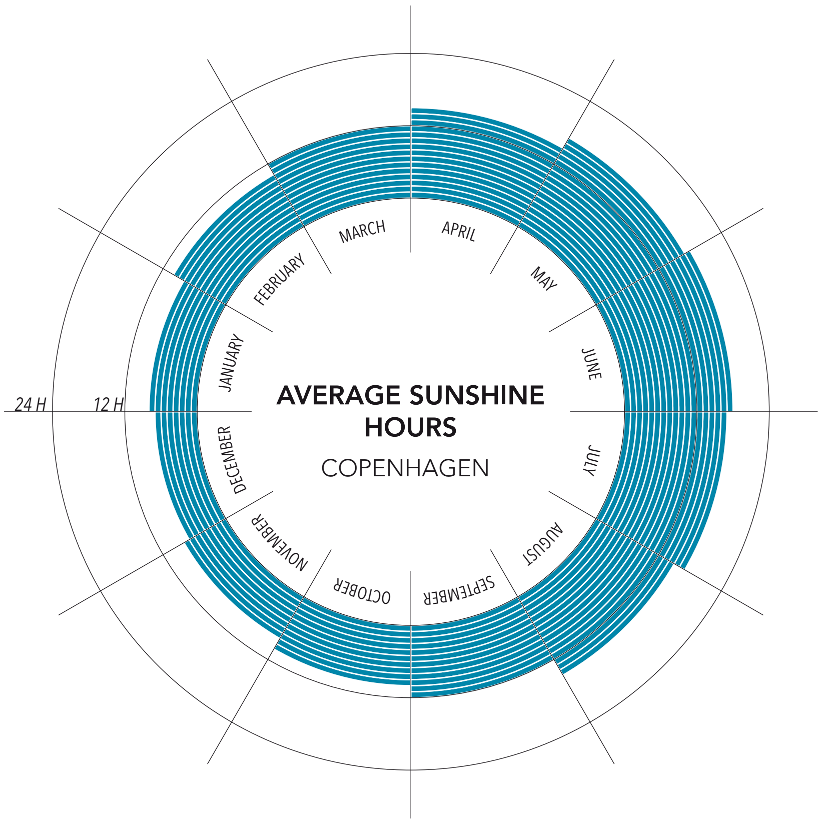
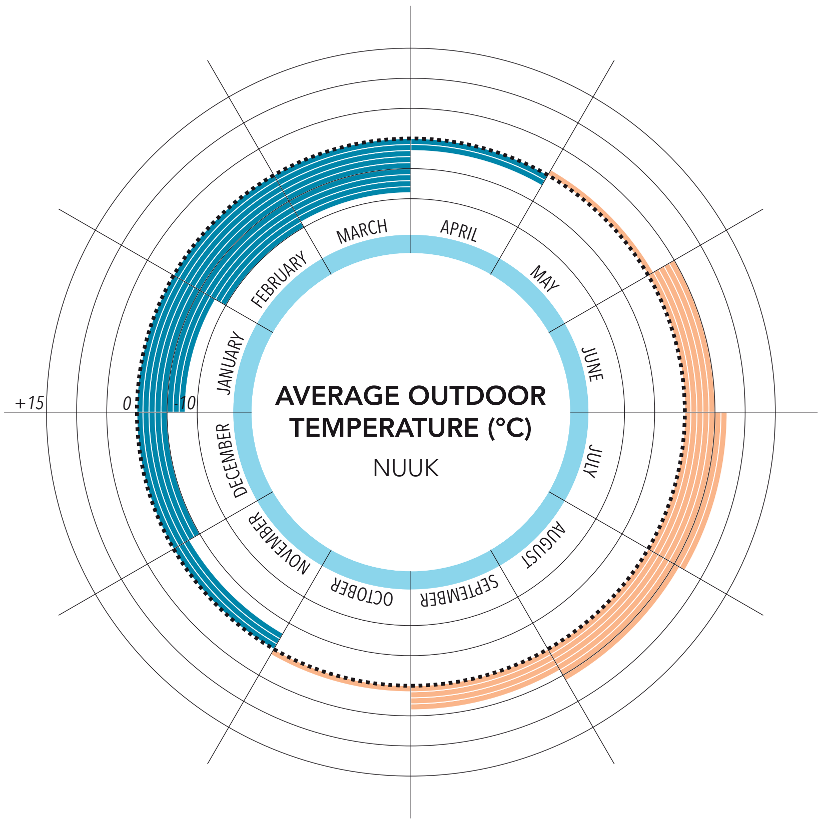


Fig. 14 *Hours of sunshine per day per month (Source: dmi.dk)*

"From my amateur knowledge of architecture and what I see being built in these extreme northern climates, architecture is ever more dedicated to it's fashions and less to fitting the climate."
Laurence C. Smith: CONDITIONS #11/12, p.17



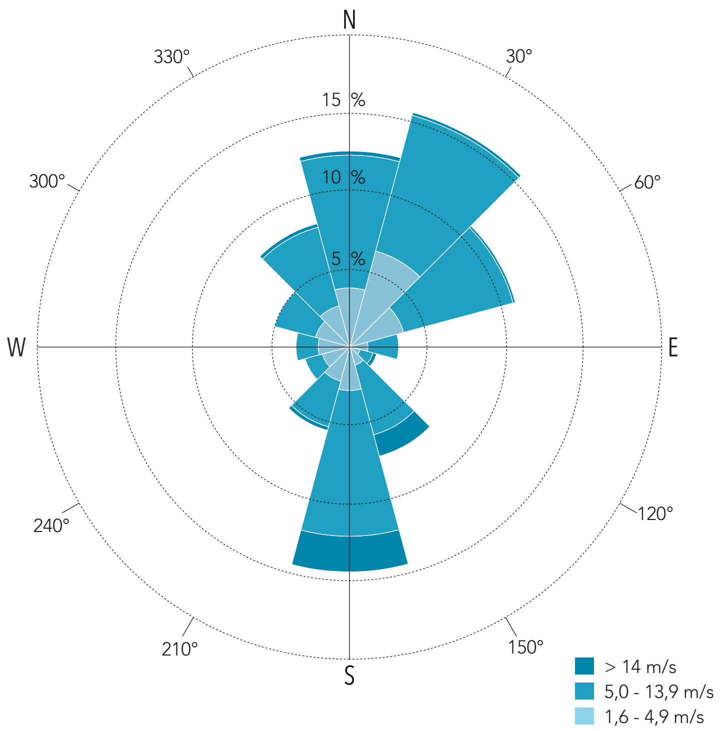
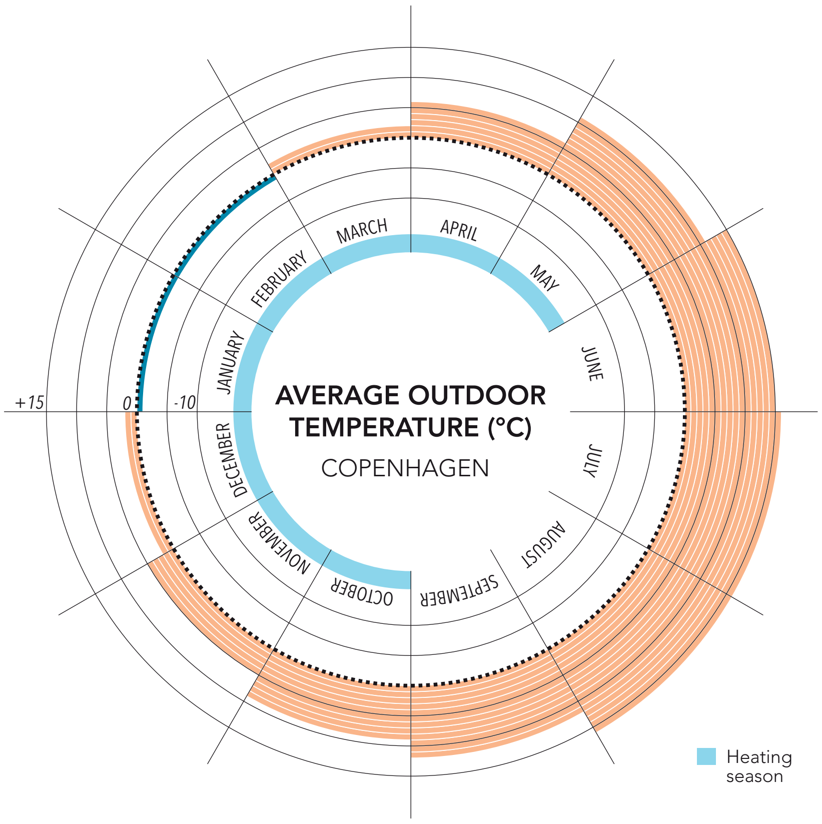


Fig. 16 *Wind rose - Nuuk*



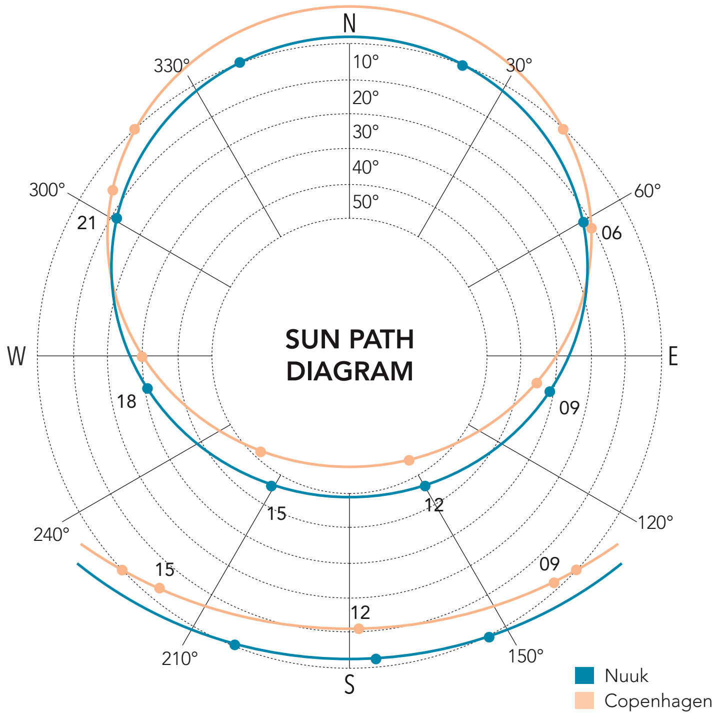


Fig. 15 *Average monthly outdoor temperature (Nuuk: 1993-2001, Copenhagen: DRY)*

Fig. 17 *Sun path diagram*

ENVIRONMENTAL STRATEGY

LOW ENERGY IN THE ARCTIC

Sustainability or being environmentally friendly are commonly used words nowadays and can imply so many meanings on so many levels that they actually say nothing about a building's performance or its qualities. The environmental principles used for this project are the low-tech/passive initiatives developed and refined by indigenous cultures throughout the world. These are solutions that exploit potentials and qualities given by the particular landscape and local conditions. This project strives to achieve modern standards for energy efficiency solely by utilizing the passive initiatives in a way that supports and strengthens the main architectural concept.

ENERGY FRAME

The intention to reduce the impact of a building on the environment is ever more noticeable. The demands from building regulations increase as building technology develops, but they also force designers to address energy strategies in the development of architectural concepts. Of course, building in an Arctic environment calls for even more attention to the planning and development as the impacts of bad design choices multiplies for the worse in the cold environment.

In Danish terms there are several classes of energy frames that a building can reach, but all buildings must at minimum comply with the requirements from the building regulations. The energy frame calculation is a measure of the maximum energy a building might use. The energy frame includes the building's total demand for energy for heating, ventilation, cooling and domestic hot water.

The specific building regulation for Greenland has the same overall structure as the Danish regulations, but of course with adjustments to suit the Greenlandic environment. One thing to note though is that the latest regulations from Greenland are from 2006 and that the requirements for meeting the energy frame is quite low by today's standards. In Denmark, the requirements have been updated and tightened several times since 2006.

Just meeting the requirements of the Greenlandic building regulation would probably not be much of a challenge and even less ambitious for this project. This project strives for an energy-efficient housing community in Nuuk by the standards of today. However, assuming that the project can achieve Danish standards would likely be too ambitious. Somehow, a realistic goal for this project had to be made. Hence, an incremental tightening of the Danish regulations was translated into a fictitious Greenlandic regulation as a guideline for the project (calculations were based on a one-storey detached house of 100 m^2). The project has a target value of 45 kWh/m^2 per year as this seems comparable to the 2020 regulations in Denmark and without further knowledge the value seems a plausible starting point for Arctic conditions (Statens Byggeforskningsinstitut 2009 & Direktoratet for Boliger og Infrastruktur 2006).

ENERGY FRAME FOR HOUSING

	Denmark (kWh/m^2 per year)	Greenland* (kWh/m^2 per year)
2006	70 + 2200/A	116 + 78/e
2010	52,5 + 1650/A	-
2015	30 + 1000/A	-
2020	20	-

** south of the Arctic Circle*

A = heated floor space
e = heated floor space/footprint

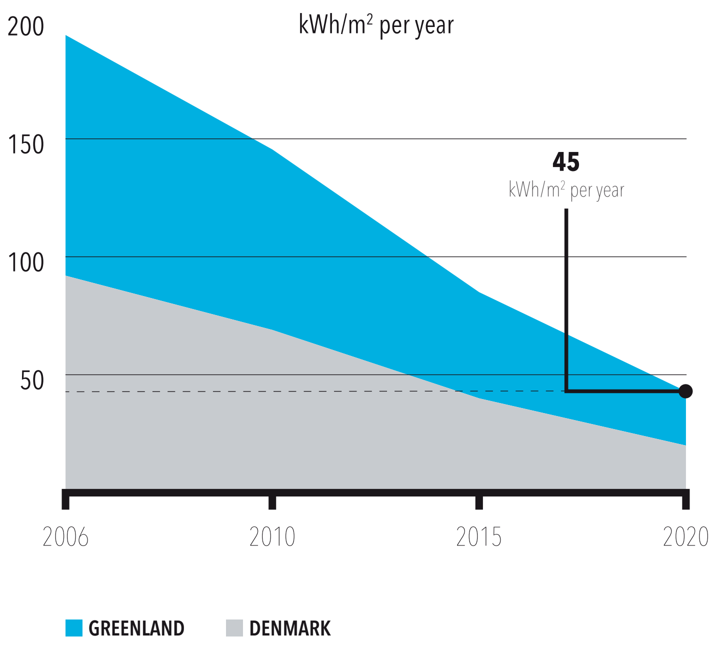


Fig. 18 *Calculated energy frame for Greenland*

INDOOR ENVIRONMENT

A HEALTHY AND COMFORTABLE INDOOR ENVIRONMENT

Any kind of building requires ventilation to maintain a satisfactory indoor environment for the people staying in the building. The indoor environment is inextricably linked to energy consumption, as natural ventilation might increase heat loss and mechanical ventilation requires energy to transport and preheat the air. In general the indoor climate can be divided into the thermal environment and indoor air quality.

THERMAL ENVIRONMENT

The thermal environment is used to describe whether the occupants perceive the thermal conditions of a space as comfortable. However, the term comfortable differs between people and therefore it cannot be strictly defined. The most essential elements of the thermal environment are the mean radiation temperature, air temperature, mean air velocity and air humidity in relation the occupants' clothing and activity level. To determine the optimal operating temperature of a room one has to consider the amount of clothing and the activity level of the occupants. During the heating season it is assumed that the occupants are wearing clothes with a thermal resistance of 1,0 clo and have an activity level of 1,0 met, which gives an operative temperature of 20 - 24 °C (DS 474).

INDOOR AIR QUALITY

The perceived air quality depends on the internal emissions and the rate of ventilation. Emissions may come from people and their activities, building materials, furniture and from the ventilation system. The required ventilation rate for a house can be calculated based on its size or number of occupants and ensures a healthy and comfortable indoor air quality. The indoor air quality is mainly achieved by expelling air from wet rooms such as the kitchen and bathroom, and having general ventilation for all rooms in the house and a fresh air supply for the bedrooms and living room. This can be achieved by having air inlets in the bedrooms and the living room and air outlets in the kitchen and bathroom, which allows air to travel from the main rooms to the kitchen and bathroom. The required air change for a dwelling according to the Greenlandic building regulations is 0,5 h^{-1}, but it is also necessary to calculate the air change rate based on pollution from the occupants and the size and geometry of the rooms. The highest air change rate is the design value for the ventilation system (DS/EN 15251).

HEATING SEASON

Giving the climate of Nuuk the heating season continues throughout the entire year. Natural ventilation is therefore undesirable, as it would cause significant heat loss as well as discomfort from cold air drafts. Consequently, using heat recovery systems is essential to reduce heat loss and thereby energy consumption for heating. To achieve a satisfying thermal environment without discomforts from drafts the inlet air should reach a temperature between 16 °C and 20 °C before entering any rooms. Given the climate of it is an energy-intensive task to preheat the air when the temperature difference can be 40 °C. Exchanging heat from the outlet air to the inlet air is important to reduce the energy demand for preheating the air

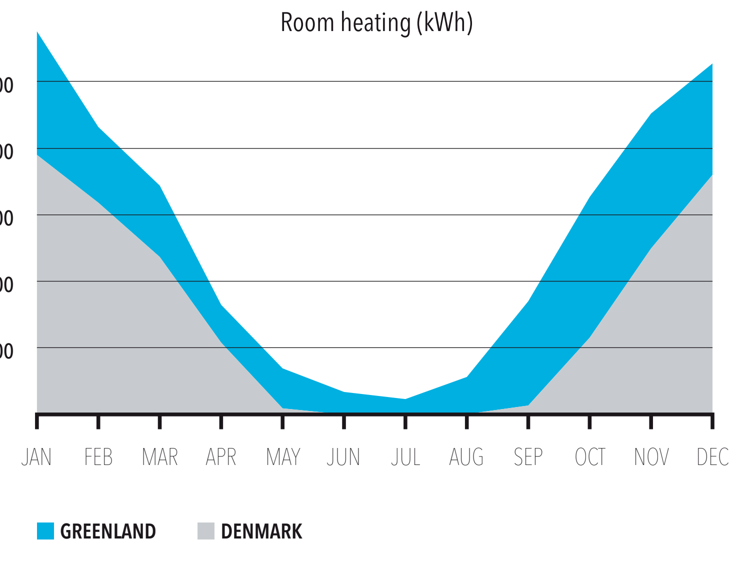


Fig. 19 *Energy consumption for room heating*

> *They are not all equally harmonious, well-proportioned, or at the best structural condition, but as a whole they present a coherent and clear building mass. Especially the colors bring life and excitement.*
>
> **Kristoffersen 2008: 15 (Translated from Danish)**

INSPIRATION

THE GREENLANDIC HOUSE

One of the few, yet very strong architectural traditions in Greenland is the colourful settlements that are generally consist of a series of separate houses scattered throughout the landscape. This creates a small urban development with a strong identity and an urban picture that can be read, no matter where one might be standing.

The individual housing units and the landscape establish the entire expression of a settlement. The picture is not being disturbed or decorated by trees or other things that would cover up the architectural expression of the houses. This holistic picture of a settlement and its interrelation with the landscape is so simple and clear that it appears as a coherent development – even with disharmonious houses.

The colours in Greenlandic settlements were introduced to distinguish the different functions of the buildings: trading houses were red, hospitals yellow, police stations black, fish factories blue etc. Nowadays, the colours are not associated with specific functions and there is a 'free' choice of colour, which is widely seen in Greenlandic housing projects. These vibrant colours of the housing are a distinctive characteristic of the cities in Greenland and contribute to a vivid atmosphere and diversity in the urban environment (Kristoffersen 2008, pp. 15-17).

VISION

My vision for this project is to design a residential area in the city of Nuuk that embraces and integrates with the unique northern aesthetic. Architecture that in its conception is site specific and responds to the cold environments, the natural light and hostile landscapes.

The approach embodies an understanding for the qualities of the particular landscapes and explores the potential of a northern aesthetic that is as purposeful as indigenous shelters while making use of contemporary technology to reach an architectural envelope that goes beyond satisfying the inherent need for shelter.

VALUES

LANDSCAPE

A significant value in the Greenlandic culture is its immediate connection to the vast and empty landscape.

IDENTITY

Creating architecture that stresses the individuality and identity of both the place and the people.

NATURAL LIGHT

Daylight is a fundamental need for human well-being and in northern places with extreme conditions, it demands even further attention.

ENERGY EFFICIENCY

Passive initiatives in building design and planning are the first key steps of reducing the demand for energy.

DESIGN PROCESS
Approaching the Greenlandic design

ORGANIZING THE LANDSCAPE

HOLOCAUST MEMORIAL AND PARC DE LA VILLETTE

Despite the scale and size of Greenland, there is a shortage of places to build in the larger and ever expanding towns. As a result, Nuuk, despite its rather small size, has been subdivided into several satellite cities wherever the landscape allowed for an urban development. However, this project takes its point of departure in one of the severe landscapes within the central areas of Nuuk that has been left unbuilt in the first place – a landscape that has contextual complexity and an appearance that echoes the Greenlandic identity.

The approach to organize and structure the landscape is explored in the following cases, where the introduction of a grid system is exploited to strengthen the characteristics of their particular place and context.

HOLOCAUST MEMORIAL BY PETER EISENMAN

Located in the centre of Berlin, the memorial is dedicated to the fallen Jews of World War II. It is generally referred to as the "field of stelae" and consists of 2.711 concrete stelae that are organized in an evenly spaced grid throughout the entire site. The pattern of stelae dissolves as they approach the boundaries of the site, giving the impression of kindness and clarity as well as making the entire perimeter serve as a unified entrance and exit to the memorial site.

Conceptually, the memorial consists of two undulating grids from between which the pillars extend. This results in a plan of the site that is yet so simple and straightforward. However, in the special experience of the memorial a layer of complexity and drama is obtained though the instability of the undulating ground and the ever-changing heights of the pillars that accentuate the spatial experience in the organized layout. It is an experience that decomposes the initial perception of the orderly layout of concrete pillars into an uncertain field of stelae (Davidson 2006, p. 290).

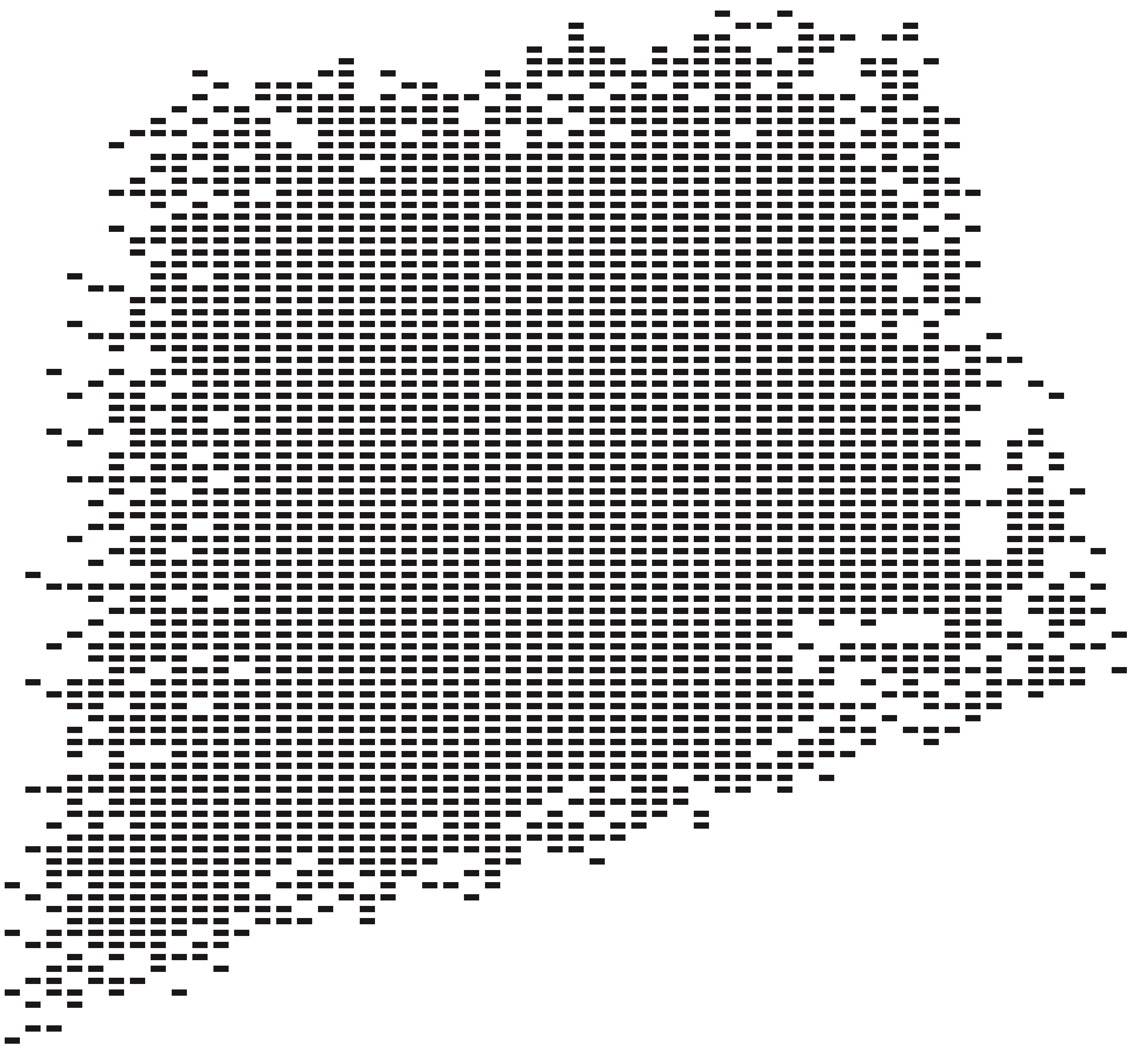


Fig. 20 *Plan of Holocaust Memorial*

Fig. 21 *Spatial variation and contrast created through pillars extending between two undulating grids*

PARC DE LA VILLETTE BY BERNARD TSCHUMI

The nineteenth-century notion of the park as a place to retreat from the city, with an abundance of landscape and nature, was contradicted in Bernard Tschumi's Parc de la Villette in Paris where natural and artificial elements are interwoven in an urban park.

The large park is spatially organized through a point-grid with a red cube folie placed at each intersection in the grid. Each and every folie is unique in its appearance and function but they are all unified by having the same distinctive red colour and overall scale and dimension. The recognisability along with the repetitive placement throughout the park make them serve as reference points and allow visitors to keep a sense of place within the large park.

Whereas the layer of complexity and spatiality in the Holocaust Memorial was given by the site conditions and emphasized through the use of concrete pillars and their varying height, Parc de la Villette is designed of a superimposition of points (red folies), lines (promenades and canals) and surfaces (playing fields and gardens), where the points serve as a common denominator to structure the site and the lines and surfaces provide contextual complexity to structure (Tschumi & Rutten 2009, pp. 60–85).

By organizing the site in a regular grid the vastness and potential of the landscape is accentuated through the repetition and simplicity in the architectural layout. Likewise, the architectural experience is solely caused by the uniqueness and diversity in the landscape that promotes a coherent yet varied spatial perception of the site.

Fig. 22 *Plan of Parc de la Villette*

> *" … a point grid of red folies serves as a common denominator to mark and structure a 125-acre site. "*
>
> **Tschumi & Rutten 2008: 85**

Fig. 23 *One of the unique red follies placed throughout the park*

DEVELOPMENT OF THE GRID
THE DISPLACED GRID

The previous cases of the Holocaust Memorial and the Parc de la Villette display the organizing power of a grid where the regularity and continuity are used to create a common structure in the schemes. With the rigid structure of a grid the objects placed within it can be dissimilar in function, form or size while still presenting a coherent structure.

GRID SYSTEM

The strength of the grid is its way of structuring the complexity of the landscape. But that structure also causes some straight lines to be accentuated in the landscape and the building mass. A rectangular grid stresses the length of the already oblong site, by creating long views through the entire building mass. However, by displacing every second row of the grid the long view through the site is being interrupted and thereby dissolving the orderly grid pattern. Something else obtained through this displacement is a visually significant larger gap between the houses, which effectively extends the views from the interior spaces and stresses the sense of intimacy and privacy within these spaces.

To determine the spacing between the points in the grid, multiple factors are taken into consideration. The overall aim is of course to reach about 150 housing units, which was specified in the site's development plan, while allowing the infrastructure to be handled in-between the grid points. Views directly into the neighbouring houses are also a concern and a respectful distance should be kept between grid points to minimize it.

The actual spacing between the grid points is based on the experience of an exciting settlement in Nuuk. In that settlement the spacing between buildings minimizes the direct views to the neighbouring houses and leaves adequate space for infrastructure, while at the same time achieving the density required. An average spacing of 15 metres from wall to wall is used throughout the settlement and this is repeated throughout this scheme. The point of departure is the 8 x 8 metre houses placed with a spacing of 15 metres between one another, resulting in a 23 x 23 metre grid layout.

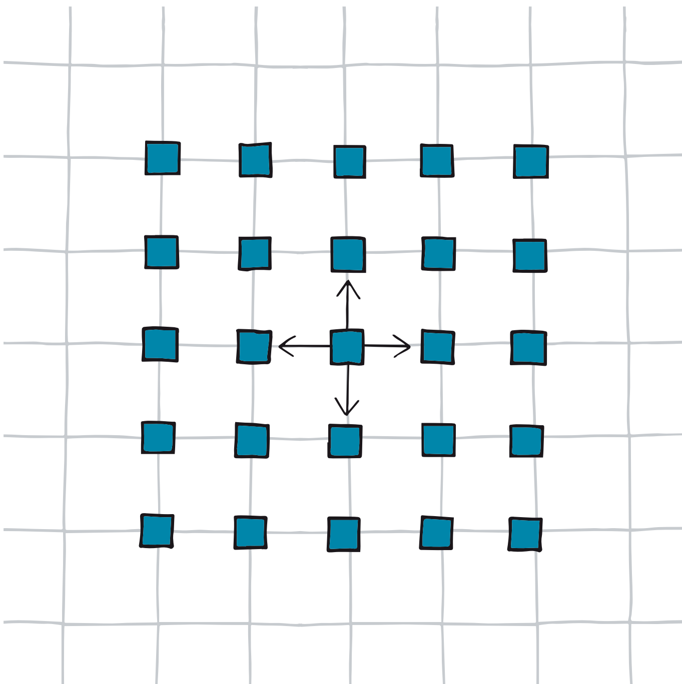


Fig. 24 *Square grid*

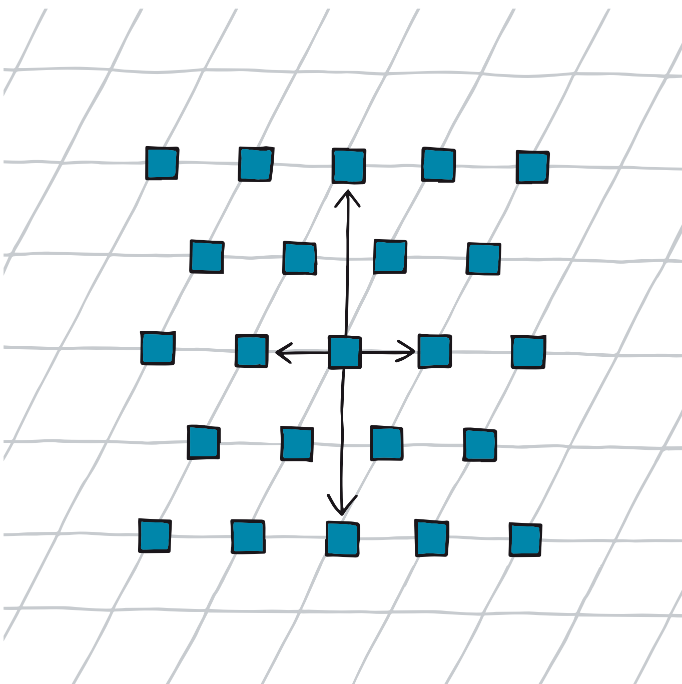


Fig. 25 *Displaced grid*

ORIENTATION

One key thing to understand when implying a grid is that it has a series of lines or directions, which have to interact with the specific context and naturally accommodate its contours and directions. This site is on a volume level largely characterized by the ridge and plateau, where the intersection between these elements is defined as a straight line in the landscape that gives the site its direction. The grid is placed on the site and rotated to match the direction of the site. It naturally accentuates the specific conditions of the site rather than forcing the grid onto the site and creating lines and directions that don't relate to it.

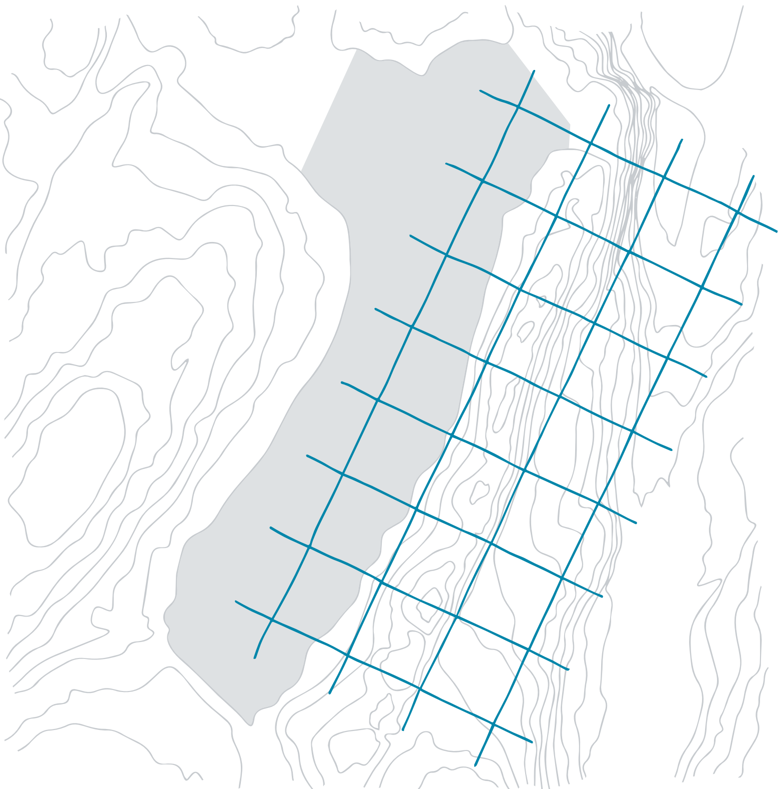


Fig. 26 *Orientation of the grid matches the natural direction of the site*

EXISTING BUILDINGS

As it is uncertain what will happen to the existing industrial buildings and the water tower that is located within the southernmost area of the site, this project acknowledges their function and preserves them as part of the final design. Again, the rhythm and orderly appearance of the grid makes it possible to keep the water tower as a point of impact in the grid that is being enclosed by houses. Instead of weakening the sense of a grid it rather serves as an alteration of visual and spatial continuity and the interruption defines a feature on the site that was introduced before the grid.

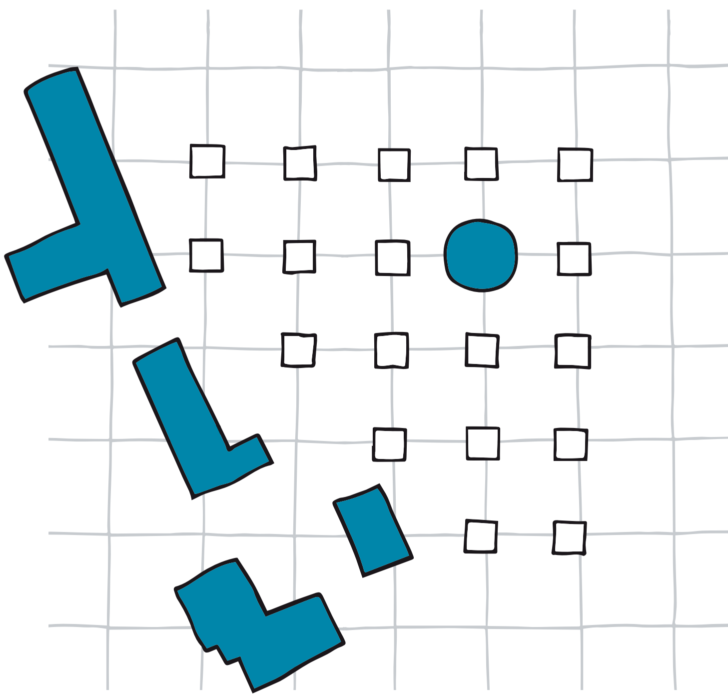


Fig. 27 *Existing building is kept and serves as points of impact in the grid*

SITE LAYOUT
THE SUPERIMPOSED GRID

This resulting site layout is based on the previous considerations regarding the grid and the development of it. The basic idea is the superimposing of the displaced grid on the topography. It transforms the regularity of the grid into a three-dimensional and spatial varied experience. The rigidity of the grid also allows the existing buildings to either interrupt or dissolve the regularity without upsetting the rest of the building mass and some extend these interruptions to serve as points of reference or features in the landscape that even help to accentuate the strength of the grid.

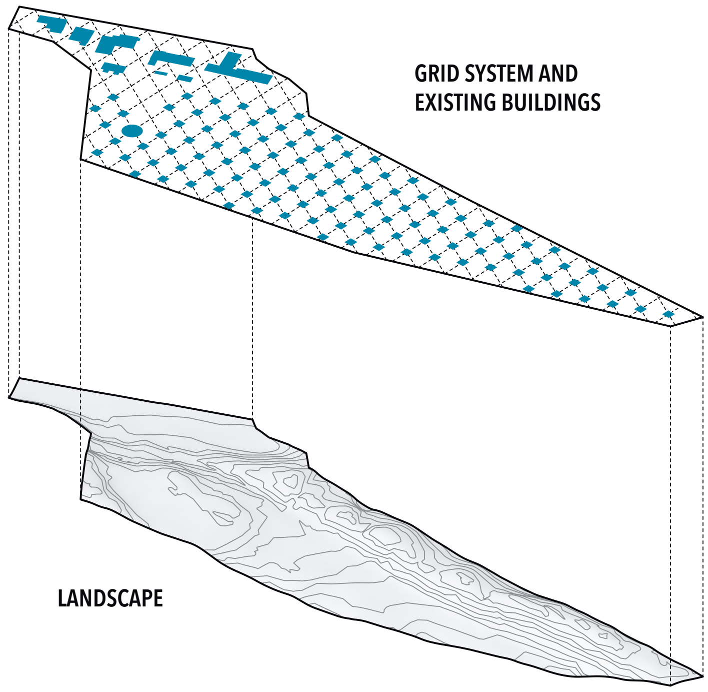


Fig. 28 *Grid superimposed on the landscape*

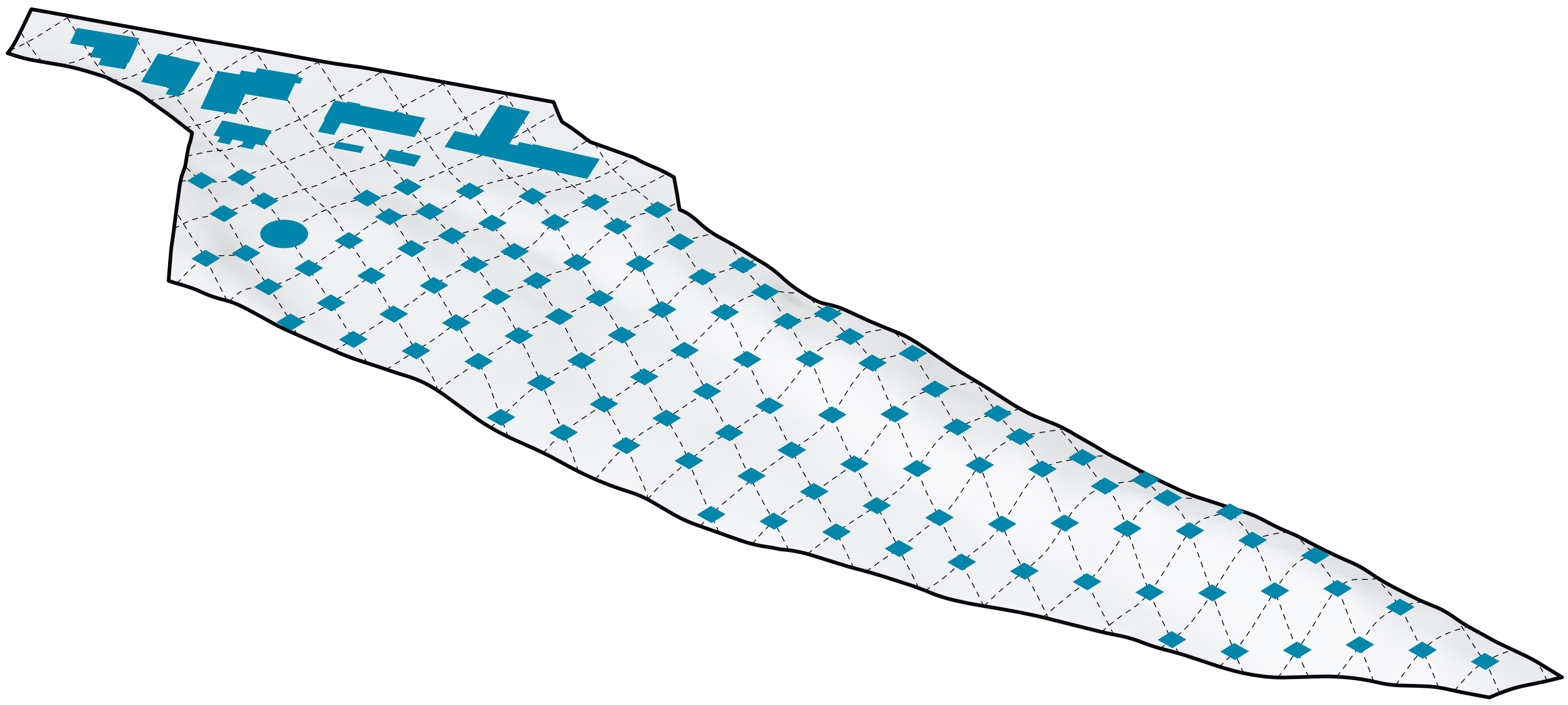


Fig. 29 *Resulting building mass in the landscape*

INFRASTRUCTURE

ACCESSING THE SITE

The roads in this particular context demand certain attention and have to address the layout of the grid as well as the challenging topography. To a large extent the placement of roads in the landscape is dictated by the topography itself and this limits the design options. Moving and modifying large quantities of the landscape is not seen as a good solution as it is made up of solid rock and would prove to be a laborious and costly task. Furthermore the roads have to reach the vast majority of the houses to reduce walking distances in the rough landscape.

One of the key infrastructural challenges of the site is caused by the high ridge that divides the site into two separate sections. The natural response to this is to handle the traffic by two separate main roads – one for the plateau and one for the ridge. If the traffic were only to be distributed on the more easily accessible plateau it would result in walking distances of 50–60 metres across the ridge to reach the furthest houses on the opposite site. The main access to the site is from Kissarneqqortuunnguaq in the southern part of the site. From this point the road splits into the two sections that distribute traffic to the ridge and plateau. There is an already exiting road leading up to the water tower that will serve as a point of departure for accessing the plateau. The movement along the ridge is to the extent possible following the natural curves of the landscape, which means that the road will remain at a consistent height all along.

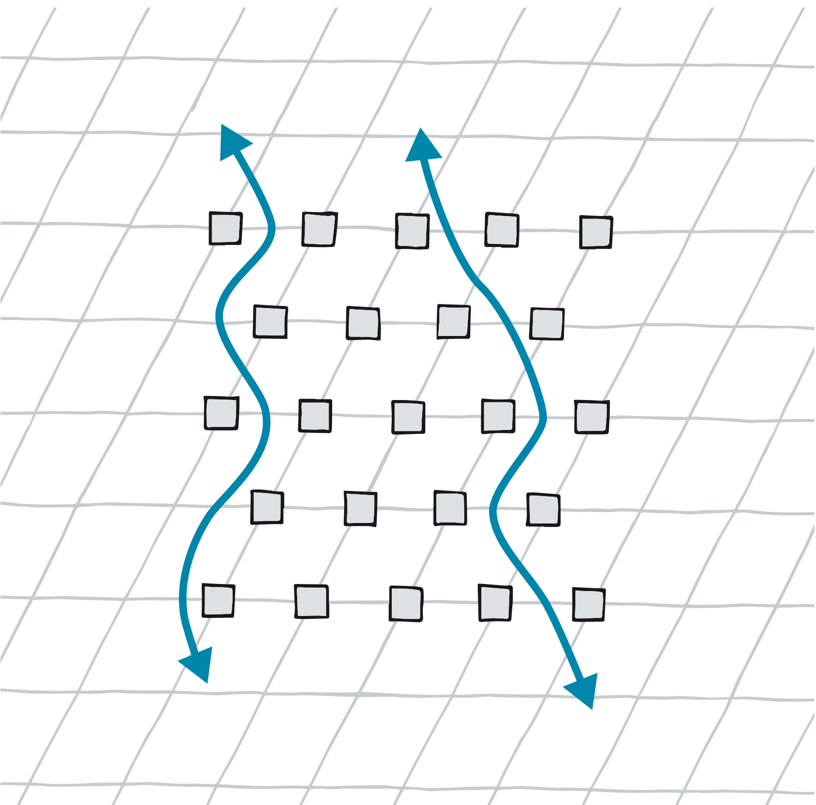


Fig. 30 *Principle for weaving the traffic roads in between the buildings*

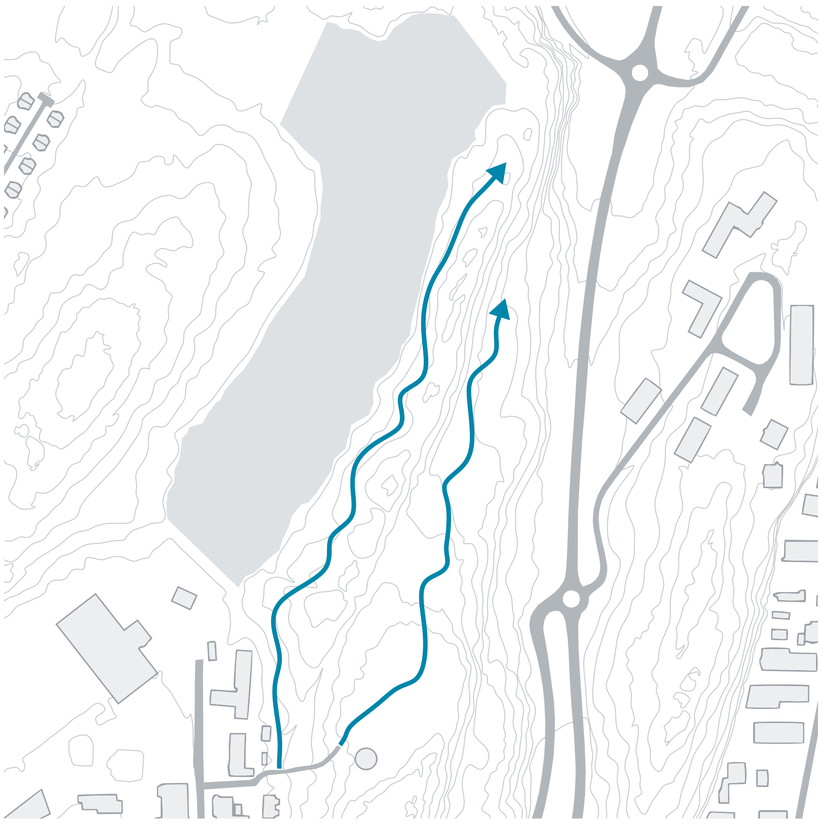


Fig. 31 *Traffic handled by two separate main roads*

IDENTITY IN THE LANDSCAPE

THE USE OF STRIKING COLOURS

In the Arctic and most certainly in Greenland there is a tradition of using a powerful colour scheme in the urban landscape. It counteracts the monochrome tones in the landscape that are present throughout the entire winter and gives life and identity to the cities. Furthermore, the bright, primary colours boost morale during the long, cold winters. The colour scheme can be accentuated though the use of very vibrant colours for some single units, which act as 'lighthouses' in the urban landscape. These 'lighthouses' can counterbalance the rigidity of the grid and serve as reference points in the landscape.

> *Many building designers support their preference for striking colours in buildings by emphasizing the need to counter-balance the cool, drab colours of the Arctic landscape.*
>
> **Strub, 1996: 146**

> *But, Greenland is different in many ways. People wear a lot of clothes during the winter, and often hunt and fish. This means that every person has a personal mountain of stuff that the modern Danish-style house does not easily accommodate.*
>
> **Minik Rosing: CONDITIONS #11/12, p.190**

THE GREENLANDIC HOUSE

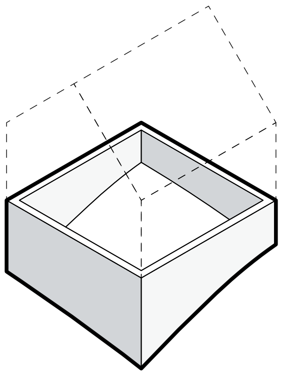
CLIMATE AND ENVIRONMENTAL CHALLENGES

In the past, numerous housing projects have been built around Greenland, which were designed by Danish people for a Danish context. This unawareness of the Greenlandic way of living caused a lot issues for the people inhabiting these buildings. Although they have the same essential requirements, the Greenlandic challenges and the specific needs for housing cannot be compared to Danish housing requirements. The environment of Greenland promotes a different way of living and in combination with the rough landscapes and cold temperatures this presents many specific challenges: the climate and lifestyle need to be accommodated. The following will address some of the key challenges of the Greenlandic context and is based on conversations with Peter Barfoed from Tegnestuen Nuuk and on Greenland building regulations.

Fig. 32 *Staircases, weather porches, sheds and storage areas around the houses is all part of living in Greenland*

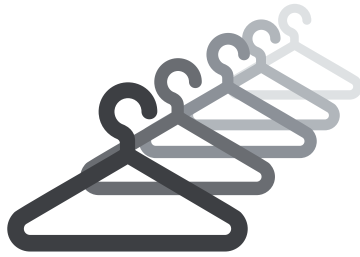
FOUNDATIONS

Concrete foundations with a crawl space are commonly used in Nuuk and throughout Greenland but the foundations can also be shear walls or pillars. The important point here is that the foundations allow the melt water to drain away. The great advantage of the crawl space is that the underside of the building isn't exposed to cooling by the wind, which is a poor energy solution. Furthermore this foundation is more stable during stormy weather.



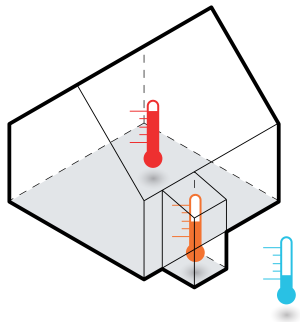
STORAGE

Given the lifestyle and climate of Greenland, the need for storage space is not to be underestimated. In the winter large anoraks and winter footwear are worn, as well as ski boots and wellingtons, which take up quite a lot of space in weather porches and closets. Outside storage area for skis, bicycles, fishing gear, outboard motors, etc. is greatly appreciated as well. Hunting and fishing on the fjord and in trout rivers is a great part of the Greenlandic culture and lifestyle and it is not uncommon that people bring home 5–6 reindeers or a musk ox as well as some fish after a hunting trip. This requires adequate space for freezers to hold the meat.



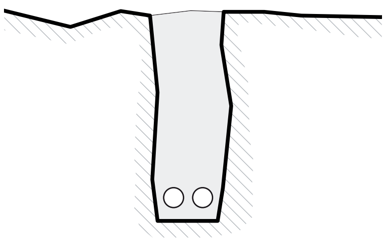
WEATHER PORCH

In Greenland it is common to have a transition space between the actual entrance and outside, also known as a weather porch. It mainly serves as a barrier to reduce heat loss and prevent snow from reaching the heated interior spaces during a snowstorm. The porches can be built in different ways, but usually there is a roofed entrance area in combination with an outbuilding. This means that the weather porch is visible as an object attached to the building mass. Another option is to include the weather porch within the building where the interior wall is insulated.



PIPING

Usually installations such as electricity, water and drainage are routed beneath the surface of the ground in blasted cavities. In some cases the piping may advantageously be placed above ground in insulated channels, which are often made in combination with pedestrian pathways and staircases.

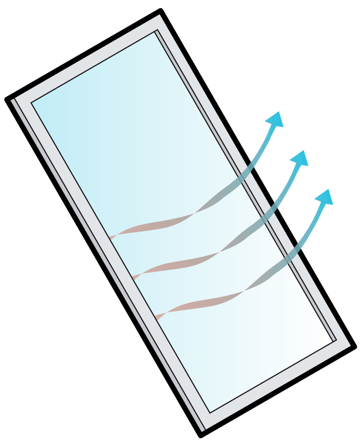


ACCESSIBILITY

Rules have been introduced about accessibility in buildings, but with the terrain and climate conditions these are difficult to enforce. In all public buildings measures must be taken to solve the accessibility issues, which often results in long ramps and lifts. This is the reason why multi-storey housing has been the typology of choice in recent years even though they come with downsides in relation to the outdoor environment and lack of storage area.

SKYLIGHTS

The best solution is to develop a design where skylights can be completely avoided or at the least reduced to a minimum. The fact is, though, that skylights are widely used throughout Greenland and often have leak problems, as the windows are not designed for the climate. The commonly used skylights – such as Velux – are only airtight up to a wind pressure of 700 Pa and in Greenland it is recommended that windows are airtight up 1.600 Pa.



HOUSING CONCEPT

THE SQUARE PLAN

The focus in this project is to develop a housing typology for families that relates to the idea of organizing the master plan in a grid. The specific housing unit that will be detailed in this project is the four-bedroom unit for families; but housing for the elderly and students is of course welcome so long as they are developed based on the same principles to ensure a coherent urban picture. The following addresses the thoughts behind the four-bedroom unit.

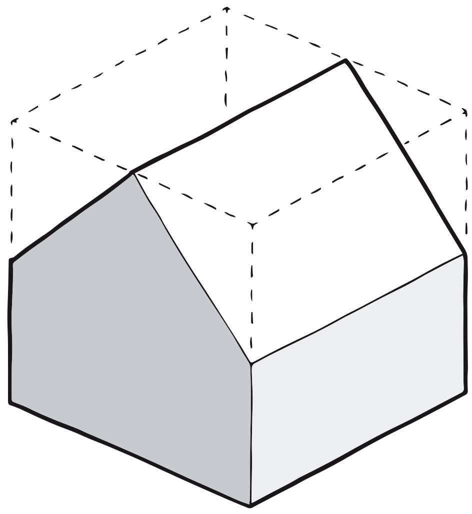


Fig. 33 *Initial compact envelope*

COMPACT ENVELOPE

The concept for the housing takes as its point of departure the Greenlandic settlements where the ambition is to achieve a compact yet efficient envelope both in terms of energy and also in terms of functionality. The characteristics of houses in these settlements is the small and regular footprint that makes the meeting with the landscape easier and by having the functions distributed across two floors reduces the thermal envelope compared to having the same area distributed on a single floor.

FLEXIBILITY IN THE PLAN

In terms of the plan the main idea is to introduce the square that is being divided by a cross, resulting in four equal spaces. The main idea of creating identical spaces is to achieve a high level of flexibility in the plan. The flexibility arises as the spaces can be organized and used for different purposes and the plan layout has the possibility to be mirrored in both directions. This flexibility can be rendered useful given the particular topography of the site where there are significantly different circumstances that the buildings have to respond to. In some cases it might be a good idea to have the entrance facing west, while in others this might be senseless due to the topographical conditions. Furthermore each of the squares is facing two corners of the world, which not only ensure adequate daylight but also enhances the flexibility when a given facade is poorly exposed to light because of the landscape.

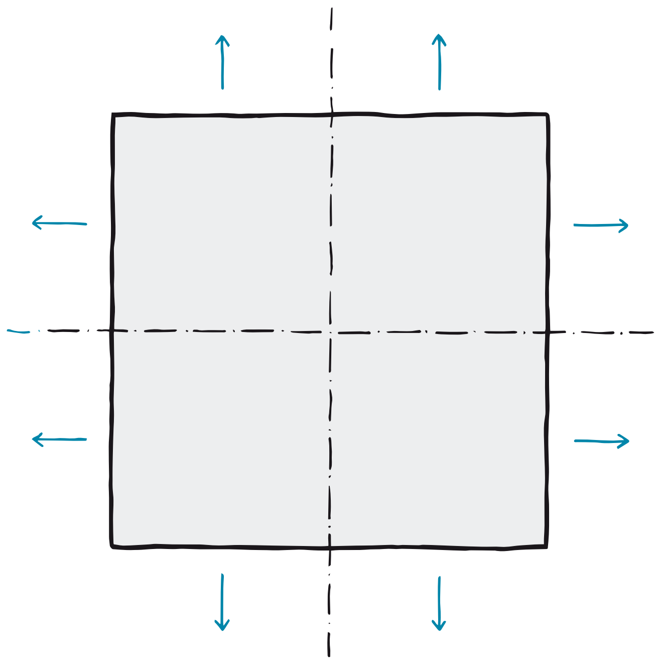


Fig. 34 *Flexibility in the plan*

FUNCTIONAL LAYOUT

The functions within the house are distributed according to their levels of privacy. The bedroom and the two rooms for children are on the top floor and the kitchen, living room and entrance are located on the ground floor. The idea for the entrance is to create a unified room that both serves as the weather porch but also as the entrance. By doing so the simple and square layout of the dwelling is not being interrupted by an attached weather porch. However, in terms of heat loss it is not optimal to have a room heated to +20 °C with a door that frequently is opened to the outside where it might be -15 °C. Therefore the entrance is developed as a semi-heated room insulated against the adjacent rooms.

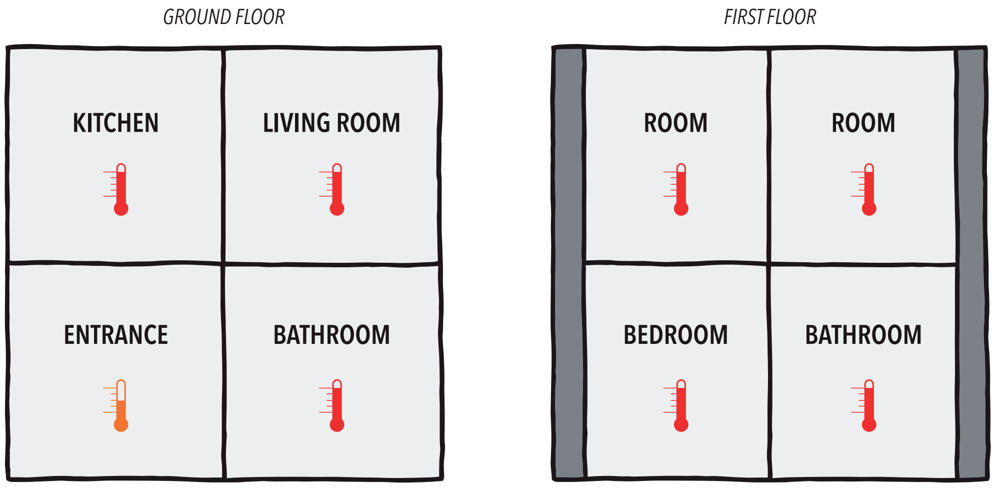


Fig. 35 *Entrance is introduced as a semi-heated space*

STRAIGHT STAIRCASE

The placement of the staircase in the plan is crucial to maintain the qualities and flexibility of the square layout. To reduce the amount of walking area on the first floor the landing of the staircase should be as close to the centre of the plan as possible, to enable the staircase to touch all the rooms and provide easy access. The initial idea was to introduce a straight staircase that could act as a special division in the square while at the same time introducing a hierarchy in the plan. The immediate issue with the straight staircase is that it disconnects the functions in the interior by using the entrance as an internal flow area, which is undesirable when it is a different thermal zone. In addition, it also creates a relatively large walking area on the first floor and, due to the pitched roof and the slim and elongated dimensions of the bedroom, it is difficult to include a bathroom on the first floor.

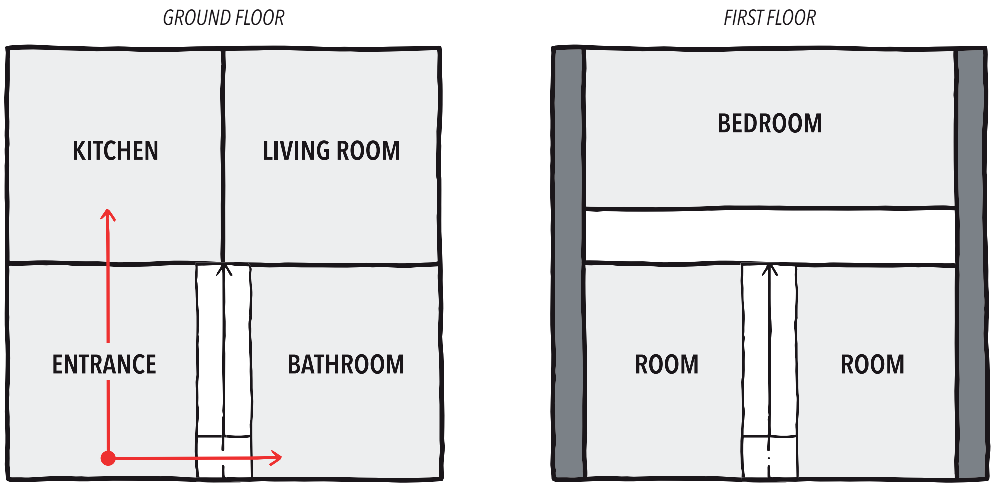


Fig. 36 *The straight staircase causing the semi-heated space to be used as internal flow area*

HALF-LANDING STAIRCASE

This type of staircase solves the internal flow in the houses by having the small distribution area in front of the staircase that touches every room on the floor. The placement of the staircase against a wall rather than in the middle of the house also means that it uses the spaces of the first floor where the ceiling height is at a minimum. Furthermore the rooms on the first floor are more regular, which also makes space for a bathroom. This staircase proves to be much more functional in the plan of the house and still correlates with the original idea of dividing the floor plan by a cross.

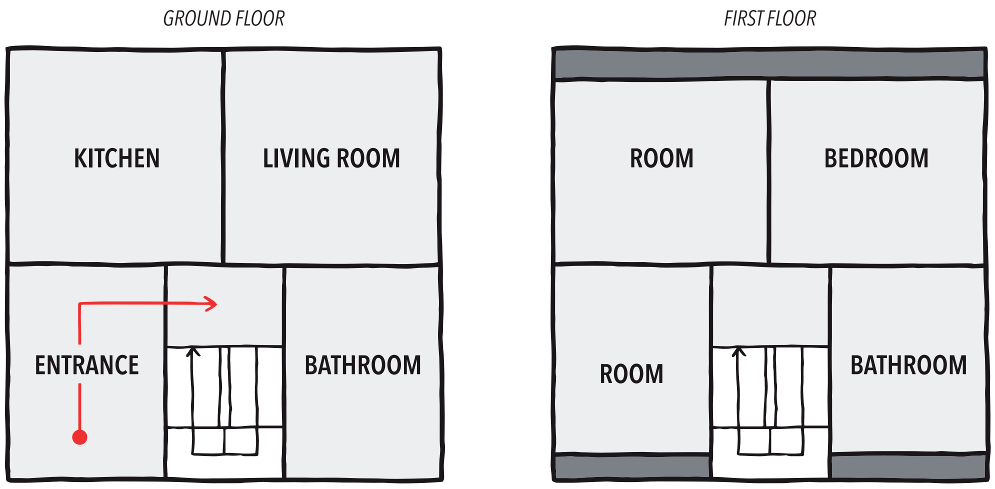
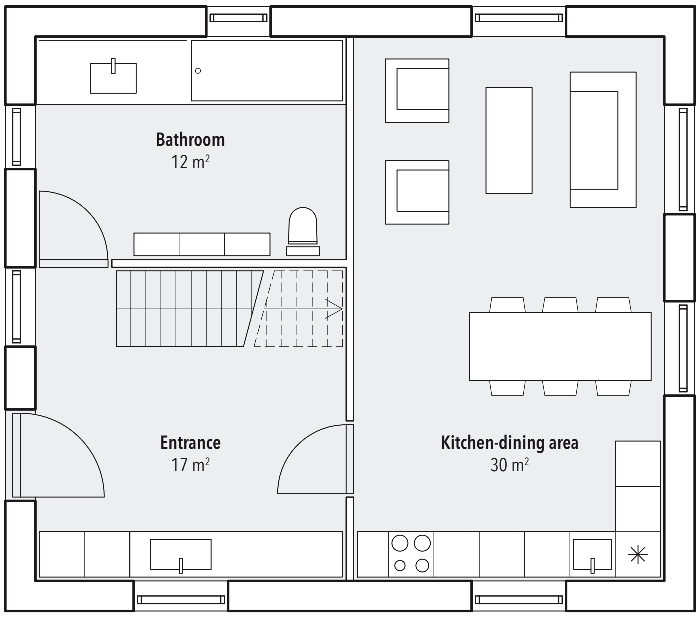


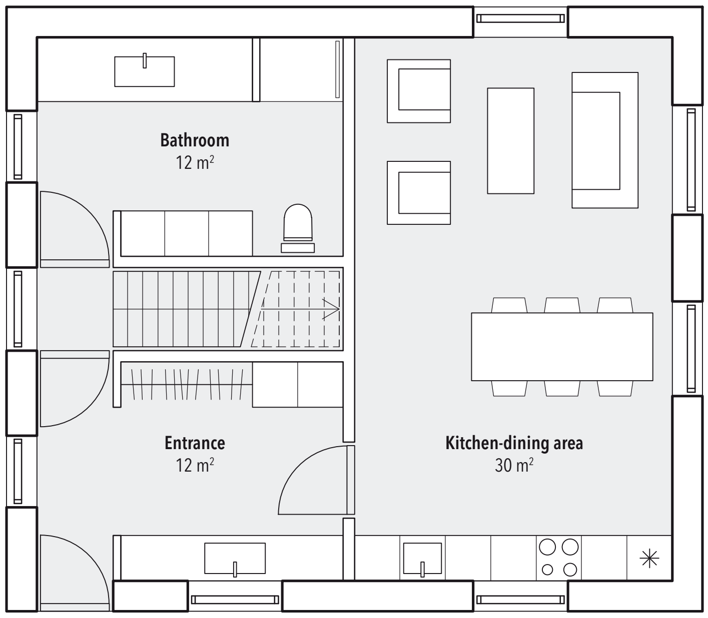
Fig. 37 *The staircase with landing has a small distribution area that eliminates the entrance as flow area*

DEVELOPMENT OF THE PLAN

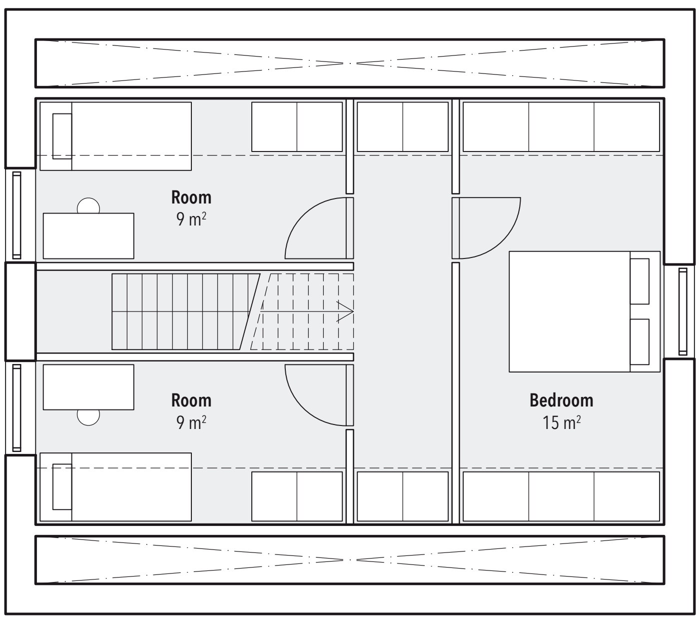
THOUGHTS AND SKETCHES



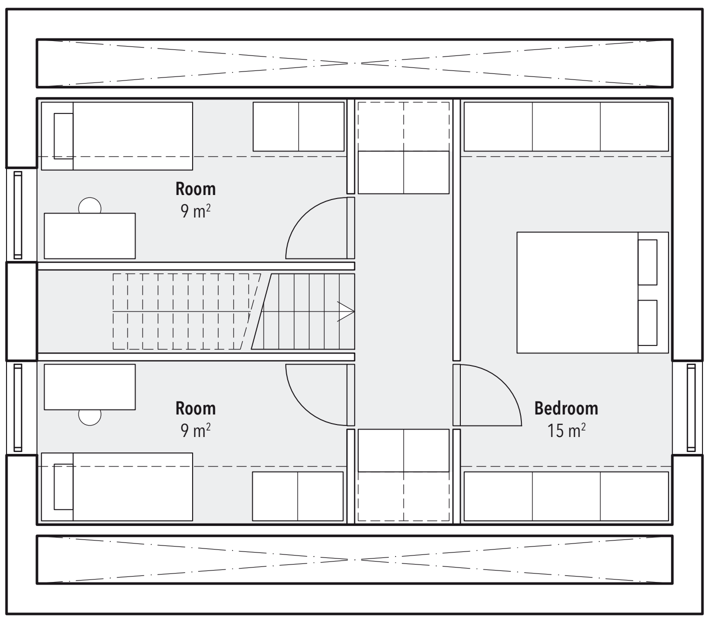
Ground floor



Ground floor



First floor



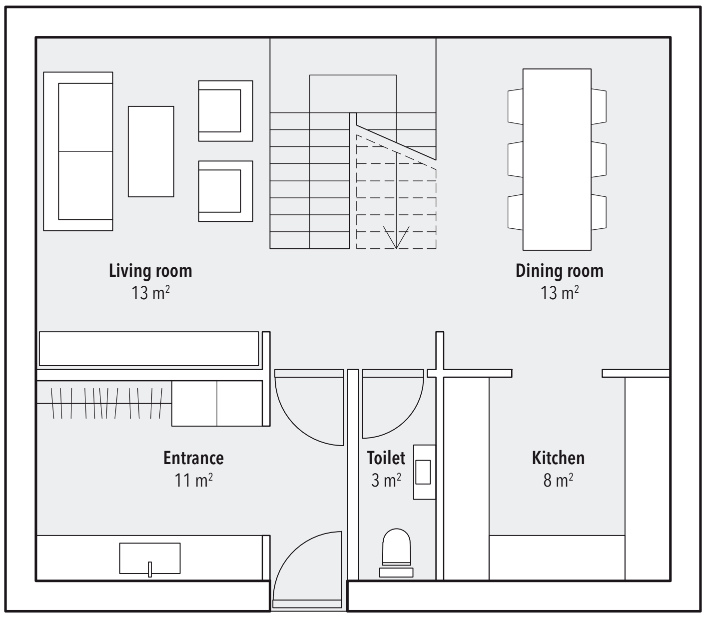
First floor

THE FIRST IDEA

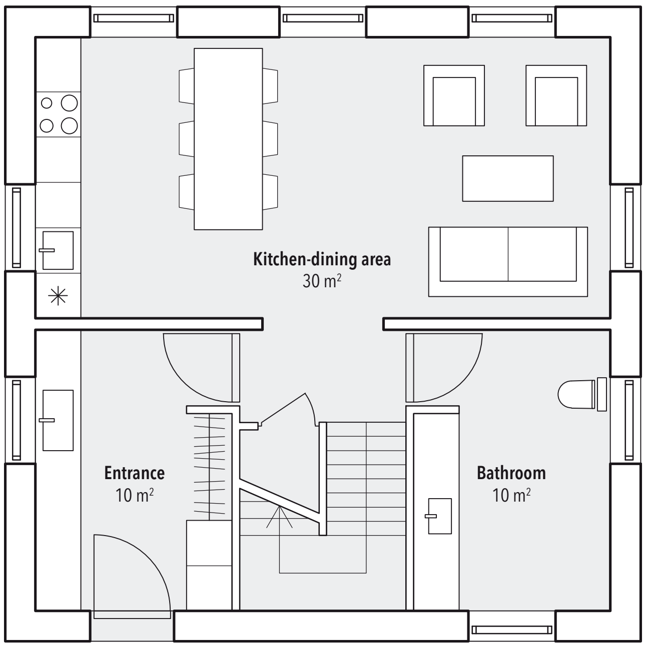
The straight staircase was introduced to spatially organize the plan. The entrance serves as the distribution area that has direct access to the first floor, bathroom and kitchen/ living room. In a scheme where there isn't a bathroom on the first floor, the bathroom can preferably be placed close to the staircase.

THE SEMI-HEATED ENTRANCE

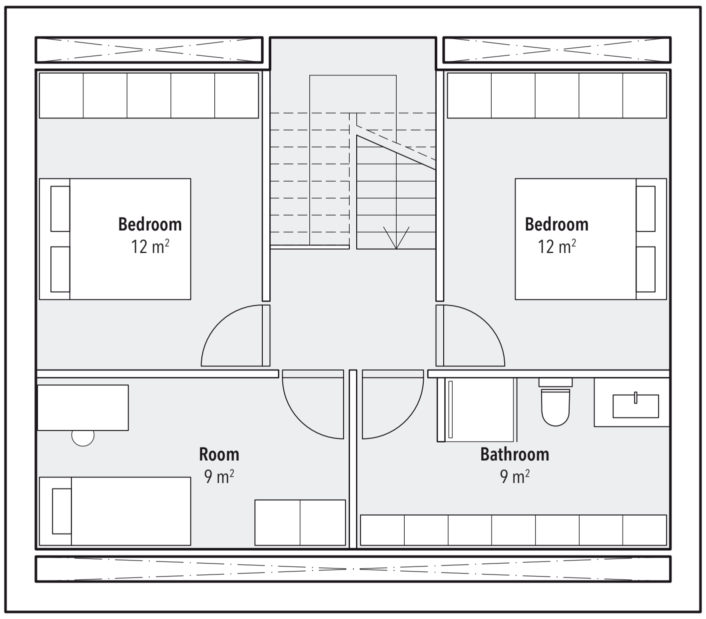
Treating the entrance as a different thermal zone requires it to be secluded from the staircase, and therefore a wall is added next to the staircase. This causes a questionable internal flow, as one has to pass through three doors to go from the kitchen to the bathroom. Furthermore the staircase is becoming an isolated object with less architectural potential.



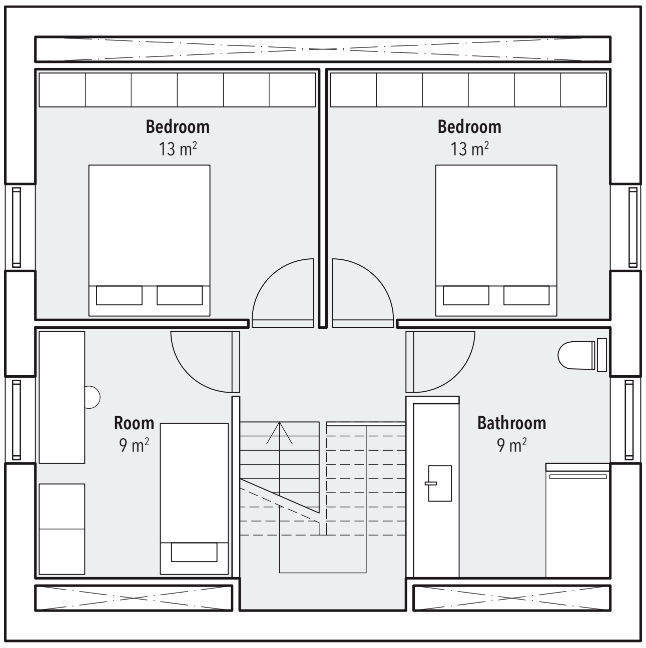
Ground floor



Ground floor



First floor



First floor

THE HALF-LANDING STAIRCASE

The straight staircase largely caused the issues of the internal flow in the house and to solve these matters a half-landing staircase is proposed. This type of staircase within this housing concept establishes a distribution area in front of it that touches every room on the actual floor and thereby improves the internal flow. Additionally, the walking area on the first floor is reduced to a minimum that makes room for a bathroom as well as having two large bedrooms and only one smaller room.

UNIFING THE LVING AREAS

The living room is considered to be too constricted in the previous scheme – even if the staircase is light and transparent in its appearance. To dissolve the boundaries of the living room and dining room they are brought together, thereby also making the space appear larger and undisturbed.

INDOOR CLIMATE

OPTIMIZING FOR ENERGY AND COMFORT

Maintaining a satisfactory indoor environment is a crucial part of our well-being and is subconsciously related to the perception of a space – just as much as the colours, illumination, textures and proportions are related to the perception of a space. It is therefore a necessity to determine the conditions that apply to obtain a satisfactory indoor climate.

VENTILATION NEEDS

The indoor air quality is divided into three classes depending on the level of air quality and thereby the number of dissatisfied people – a high level of air quality will have the fewest dissatisfied people. There is of course a balance between the desired air quality and the energy demand required to achieve it. Especially in the Arctic the ventilation is an energy-demanding task due to the low outside air temperatures. The actual air change rates must be calculated in regards to the CO_2 level and the sensory pollution load caused by the occupants and the building (furnishings, carpets and ventilation). The required ventilation rates are calculated for each category and the energy demand is determined in relation to the category.

As can be seen from the diagram, the sensory pollution load causes the highest air change rates and these values should be used for the following energy studies. The resulting CO_2 level has been calculated based on the air change rate from the sensory pollution loads, and even with the lowest air change rate the CO_2 level is still within climate class A.

Climate class	A	B	C
Dissatisfied	15 %	20 %	30 %
CO_2 pollution from occupants			
Air change rate	0,77 h^{-1}	0,54 h^{-1}	0,34 h^{-1}
Air flow	61 l/s	42 l/s	27 l/s
Allowed CO_2 concentration	650 ppm	800 ppm	1100 ppm
Sensory pollution load from occupants and building			
Air change rate	2,14 h^{-1}	1,52 h^{-1}	0,86 h^{-1}
Air flow	168 l/s	119 l/s	68 l/s
Resulting CO_2 concentration	426 ppm	477 ppm	613 ppm

Fig. 38 *Air change rate according to climate class*

ENERGY AND CLIMATE CLASSES

Determining the actual climate class of the house is a combination of the desired air quality and the energy used to achieve it. A high level of indoor air quality requires a higher air change rate, thereby increasing the amount of energy used to transport and preheat the air as well as increasing the energy loss in the heat exchanger.

The diagram depicts the monthly energy consumption based on the three climate classes. It can be seen that climate class A requires considerably more energy than climate classes B and C. During the summer months, where the heat loss in the ventilation is at its minimum, climate class A still requires a significant amount of energy compared to climate classes B and C. Considering both energy and comfort, the house is ventilated according to climate class B throughout the entire year.

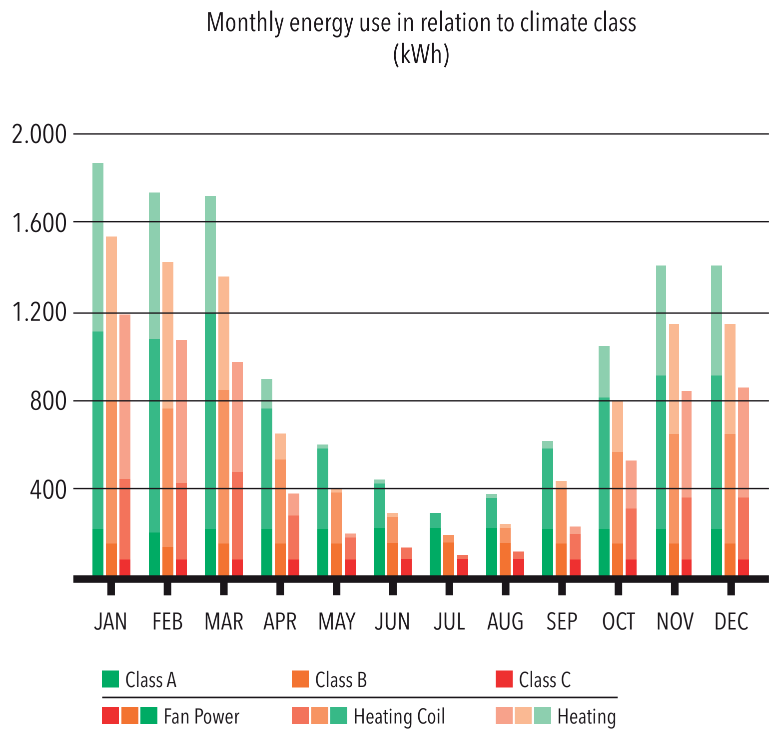


Fig. 39 *Monthly energy use in relation to climate class*

CO_2 CONTRATION

The CO_2 concentration of the house is simulated based on an occupation of four people for 16 hours a day and the simulation depicts a level of pollution that is steady throughout the year when the house is mechanically ventilated. When the mechanical ventilation is supported with natural ventilation in periods where the temperature allows it, there will be a decreased concentration of CO_2 and a better indoor climate.

TEMPERATURE

Even though this building is situated in a cold climate the thermal environment should be analysed to see if there is any excess temperature. As the simulation shows, there will be temperatures above 27 °C in July and August when the building is only ventilated by the mechanical unit. However, by introducing natural ventilation the excess temperatures will be reduced to a minimum.

The reason for the excess temperatures in the cold environment is most likely related to internal heat loads (people and equipment), which is generating enough heat for the room temperatures to climb – at least during the times of day when the solar heat gain and outside air temperature are also at their maximum.

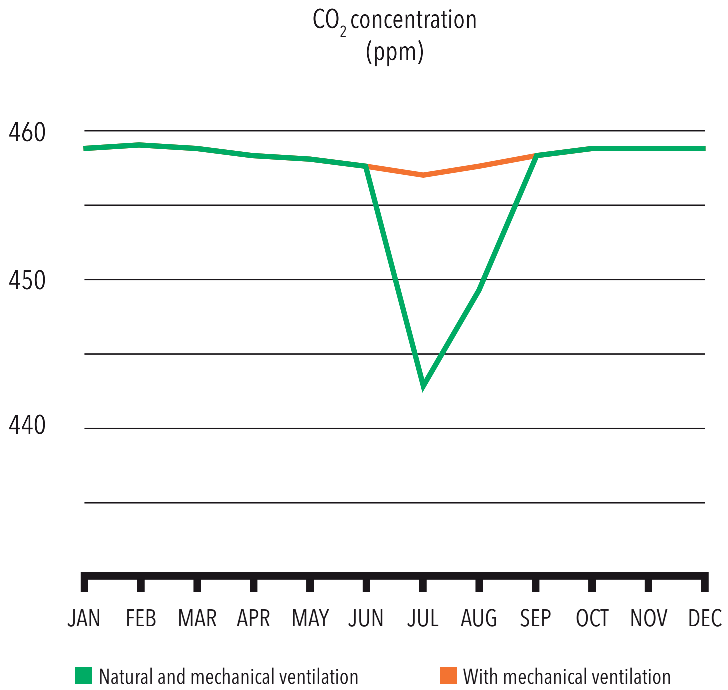


Fig. 40 *CO_2 concentration*

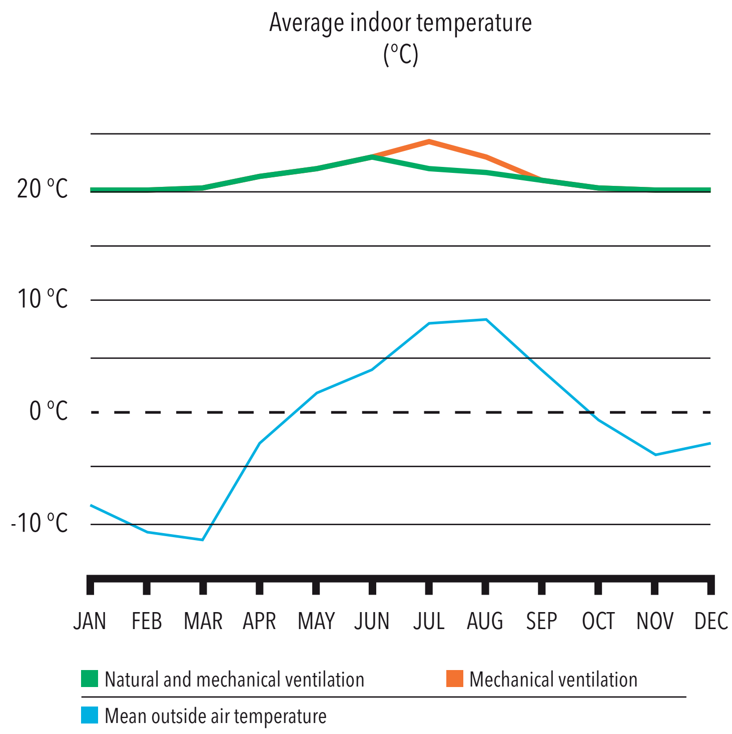


Fig. 41 *Average indoor temperature*

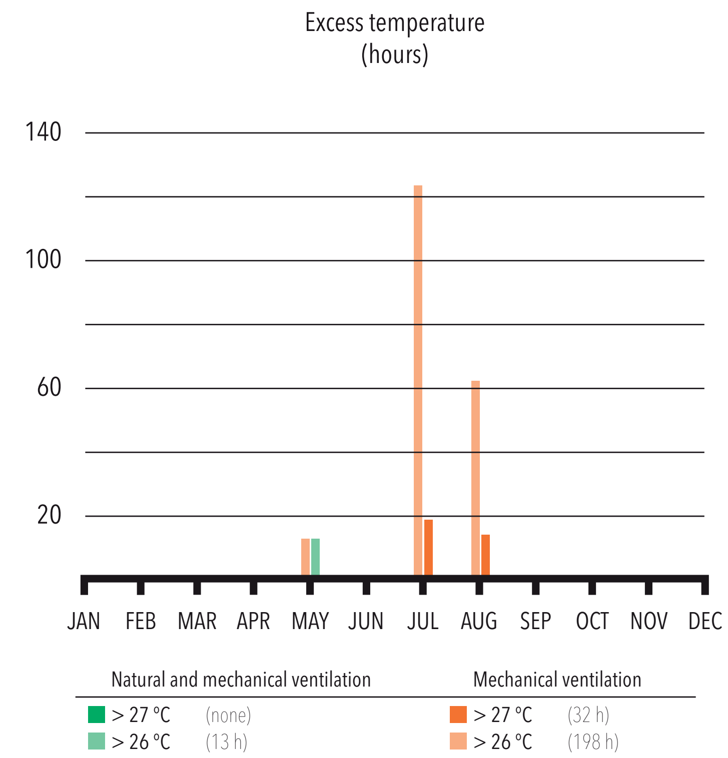


Fig. 42 *Hours of excess temperature*

VENTILATION DUCTS

PLACEMENT OF DUCTS AND VENTILATION UNIT

While determining the optimum air change rate is important to reduce energy and achieve a comfortable indoor environment, one has also to consider the energy required to transport through ducts – reducing the length of the ducts also reduces the energy demand for air transportation. This means the placement of the ventilation unit within the house is crucial and the placement of the ventilation unit is studied in the following cases.

Every room has either a fresh air inlet or an exhaust, which in both cases has to connect to the unit. Kitchens, bathrooms and entrances are required to have exhausts to avoid air pollution spreading from these rooms. In this case the fresh air inlets will be placed in the remaining rooms allowing the fresh air to move from the 'clean' zones to the 'polluted'.

According to the climate class B calculation there has to be a total airflow of 119 l/s for the entire house, which has to be distributed in the rooms. The exhaust airflow will be adjusted accordingly. The ground floor has three rooms that require exhaust and one room that requires fresh air supply. For the first floor there are three rooms that demand a fresh air supply; only the bathroom needs an exhaust. This uneven distribution means that most of the fresh air will travel from the first floor to the ground floor. The idea is to supply the bathroom and entrance on the ground floor with the excess air from the first floor, while the exhaust in the kitchen is supplied with air from the living room.

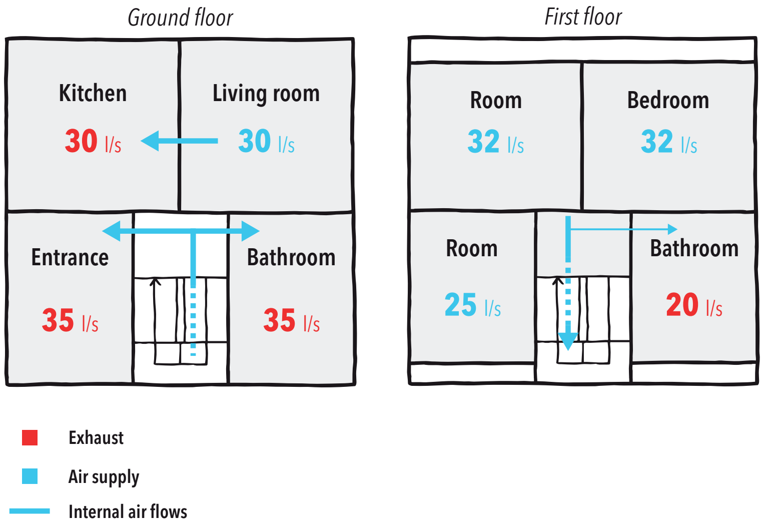


Fig. 43 *Air supply and exhausts in relation to rooms*

BENEATH STAIRCASE

The initial idea was to place the units beneath the staircase to use the unoccupied space for storing the unit and using the space under the eaves for the ducting. However, this solution causes the ducts to be quite long and with a lot of bends to reach all the rooms. Furthermore the ducting on the first floor is colliding with the roof structure and the insulated layer resulting in unnecessary heat loss.

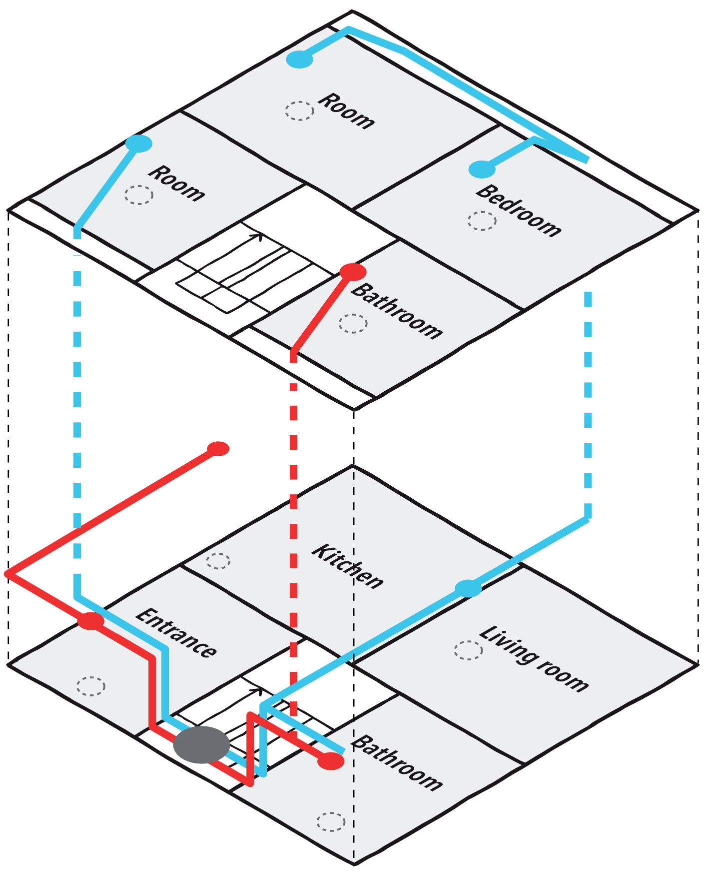


Fig. 44 *Ventilation unit placed beneath staircase*

IN ENTRANCE

The entrance room of the house could also be a possible placement of the unit, as the noise generated by the unit would not disturb the living areas. However, the most immediate issue of placing the unit in the entrance is the lowered temperature of that room, which would cause increased heat loss from the ventilation system. The pipes that are located within the horizontal division between the levels would also interfere with beams that are needed to construct the first floor.

IN THE UPSTAIRS BATHROOM

By introducing an attic in the bathroom in which to place the unit and using the central wall that stretches the entire house, the ducting system can be significantly improved. The central wall must be widened for the ducts to fit, but from that point on there is immediate access to the entire first floor and easy access to the ground floor with a minimal number of bends. The placement in the bathroom also allows the unit to connect to a drain where the water from condensation can be directed. This is considered to be the best solution for this particular house.

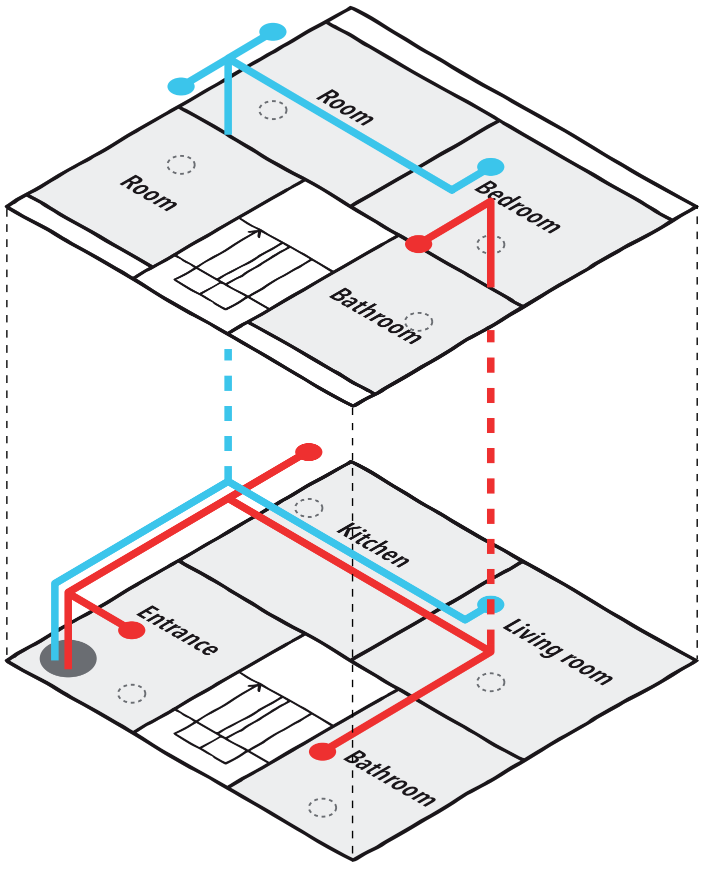


Fig. 45 *Ventilation unit placed in entrance*

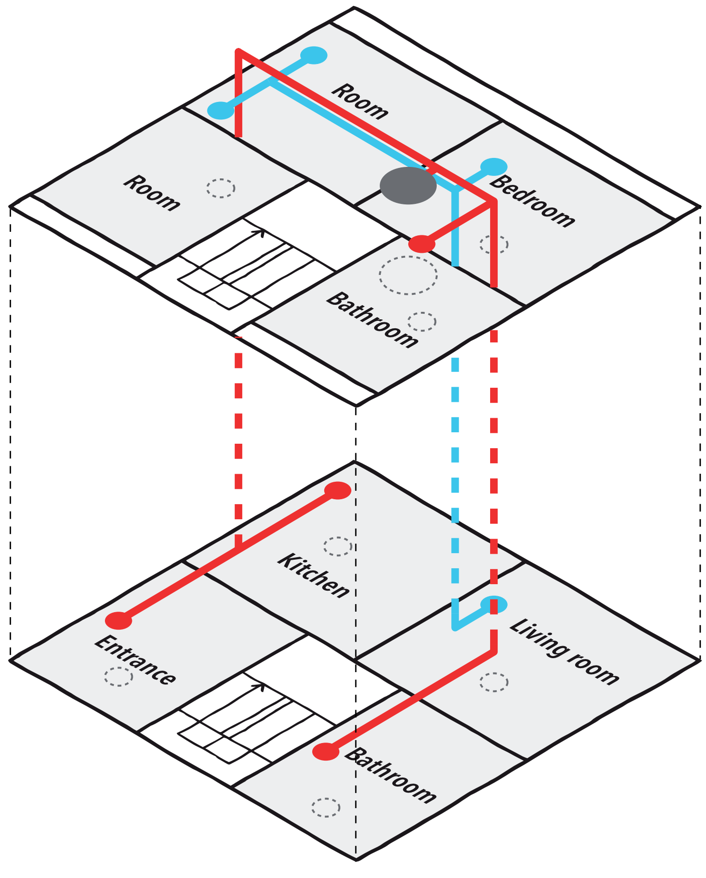


Fig. 46 *Ventilation unit placed in the upstairs bathroom*

ENTRANCE

A STUDY OF COMFORT AND HEATING DEMAND

When developing the entrance as a different thermal environment than the rest of the house one has to consider the thermal environment as well as the energy saving when lowering the temperature. This of course results in a balance between an acceptable thermal environment compared to how much the energy demand is reduced.

When looking at the annual heating requirements it is clear that lowering the temperature of the entrance will reduce the demand for heating in both the entrance and the rest of the house. However, it is important to know that lowering the temperature of the entrance also result in a larger transmission loss from the adjacent rooms. This means that when the heating demand in the entrance, and thereby the energy consumption, is reduced it will cause the rest of the house to have increased energy consumption. But, in every case, lowering the temperature of the entrance will also reduce the overall energy consumption of the house. But lowering the temperature in the entrance does not necessarily mean that there is a constant temperature of 5 or 10 °C. In most cases the entrance would be warmer than the actual set temperature for about a half of the year.

For a person to have thermal comfort there has to be a balance between heat production and heat loss. These factors are highly dependent of the temperature in the given environment, the thermal insulation of clothes and the activity level of the person. Based on the following, the optimal operating temperature of the entrance can be determined.

Metabolic rate is an expression of how much heat a person generates in relation to activity – a seated and relaxed person is generating 1,0 met. For the purpose of the calculation it is assumed that when a person is staying in the entrance for a longer period of time it is in relation to a domestic activity that equals 2,0 met.

Thermal insulation is the ability of clothes to retain heat, measured in clo. The optimum amount of clothing to wear can be determined from the temperature of the room and the activity. Below is listed a clo-value in relation to the room temperature for the entrance based on an activity level of 2,0 met and the amount of clothing one has to wear beside underwear with long sleeves and legs, thick socks, t-shirt and trousers, which is equal to 0,7 clo. The clo-values can be found in DS 474.

10 °C	12 °C	15 °C	20 °C
1,75 clo	1,5 clo	1,2 clo	0,65 clo
Coat Thick sweater Boots Gloves	Coat Thin sweater	Thick sweater Thin shirt	-

Conclusively, it is unlikely that the inhabitants allow a temperature of 10 °C in the entrance given the amount of clothes one has to wear. Also considered is that domestic activity usually requires freedom of movement, which is highly limited by boots, gloves and coats. Taking account of both thermal comfort and energy use, the optimum temperature seems to be around 12–15 °C.

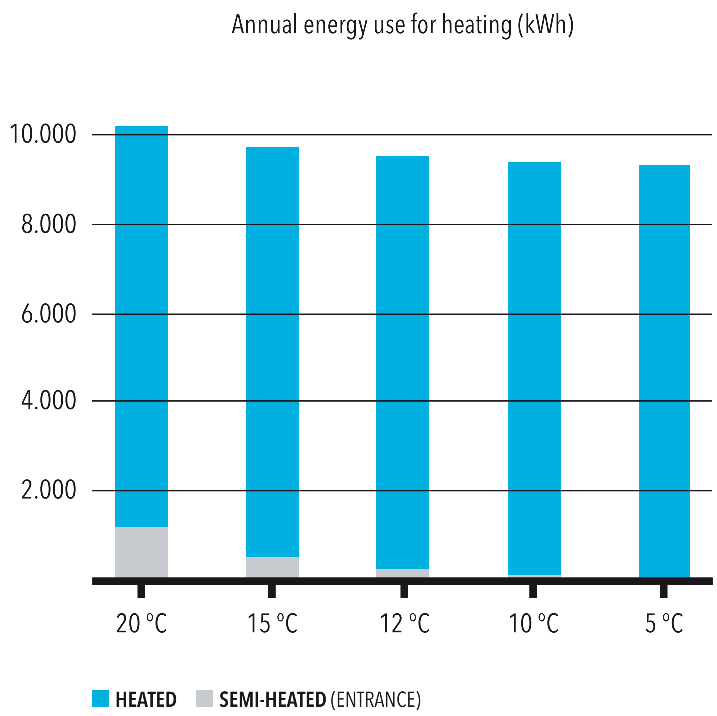


Fig. 47 *Annual energy use for heating (Heating, fan power and heat coil)*

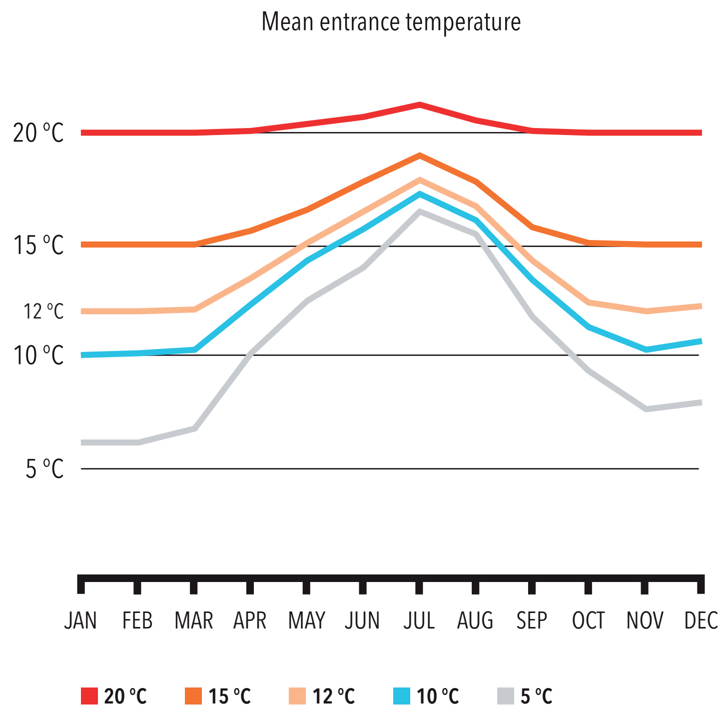


Fig. 48 *Average monthly temperature in the entrance*

ENERGY

SOLAR RADIATION

Any building's ability to capture the heat from the sun is highly dependent on the context in which it is situated. Shading caused by nearby buildings and the topography may have a significant impact on the building's energy performance. At this particular site the ridge will cast shadows onto the adjacent buildings in addition to the shadows cast by the other buildings. The northeast sloping plateau also increases the length of the shadows cast by the southern sun, which may also result in an increased energy demand for these houses. The actual solar heat gain is studied for three cases: one with no shading, one with shading from nearby buildings and one with shading from the ridge and the nearby buildings. This study solely focuses on the energy consumption and solar heat gain and does not consider the amount and quality of daylight in the given cases.

No shading	Shade from buildings	Shade from buildings and landscape
	Solar heat gain	
3671 kWh	3600 kWh	3530 kWh
-	**-1,3 %**	**-3,3 %**
	Energy consumption	
9706 kWh	9763 kWh	9786 kWh
-	**+0,6 %**	**+0,8 %**

The result from these studies shows that the context does not have a significant impact on the energy use. The worst placement of a house, in relation to solar radiation, causes a 0,8 % increase in energy consumption in comparison to a house with no shading at all. The reason for the relatively small loss of energy might be that there is small amount of glazing facing the shaded areas and that there is not much heat to capture from the sun anyway at the time of day when the building is in shade.

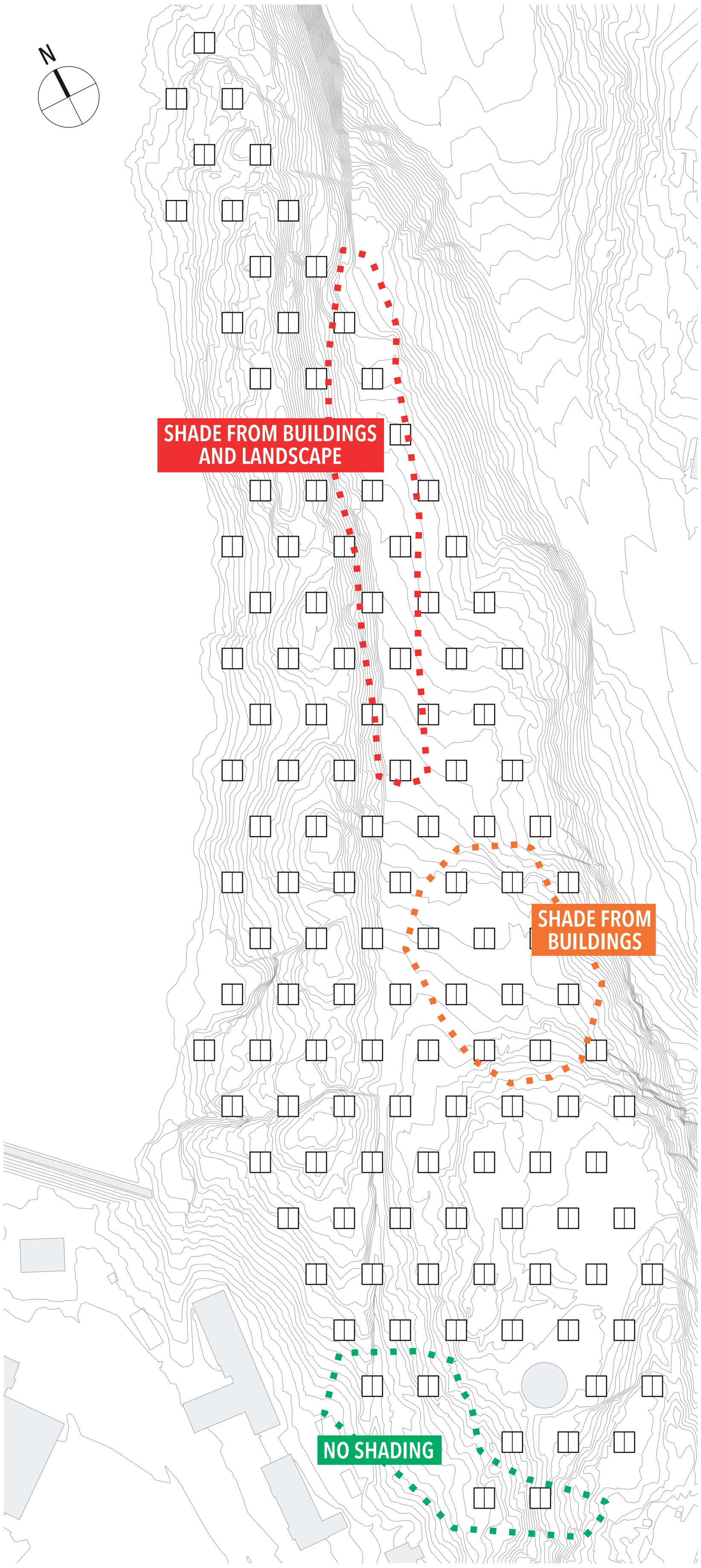


Fig. 49 *Examples of areas with different shades*

BUILDING MATERIALS

CONSTRUCTING IN THE ARCTIC

Construction in the Arctic requires a careful choice of materials. Insignificant things – at least by Danish standards – are crucial to consider when building in remote places where materials are scarce. Usually, the building materials are shipped 4.000 kilometres across the sea from Denmark and even before reaching the site they have most likely been through several means of transport where for thousands of kilometres they can be exposed to air, sun, sea, rain, dirt, and frost. Once the materials reach the site they might be stored outdoors in rough weather for months, as Arctic communities don't have a lot of warehouse space. Some of the most critical aspects one has to consider are listed below (Strub 1996, pp. 142–146).

WOOD

In relation to these aspects, wood is, both as a load-bearing material and a facade material, highly useable in the Arctic environment. In terms of transportation wood is lightweight and compact. As the material is familiar to the local people it doesn't require a team of specialist workers to assemble, and furthermore the wood can easily be modified at the construction site. The maintenance of the exterior wood siding is a matter of applying a sealer that extends the lifespan of the wood, which can be done by the inhabitants themselves. And if the wood panels are damaged or neglected they are easily replaceable. The following is a study of the different types of wood siding that can be applied to the facade.

MAXIMIZE

Service life
Durability
Utility-to-weight ratio
Speed of assembly
Ease of field modification
Ease of repair and replacement
Quality of appearance

REDUCE

Number of different materials
Weight
Shipping volume
Moisture content
Off-gassing

BOARD AND BOARD

It is one of the most basic wooden facades and uses the same board for the bottom and top layer. This type stresses the verticality of the housing as well as adding some depth to the appearance. Colours and texture are accentuated by the contrast caused by the shadows.

PLYWOOD BOARD AND BATTEN

This type of facade is widely used throughout Greenland. It is comparable to board and batten façade, but it is much cheaper to construct as the entire facade is covered with plywood and the batten covers the seams. The cheap appearance of the plywood is diminished when paint is applied.

> *Wood by any measure is a remarkable building material. It is a natural insulator – a poor conductor of heat. Wood has a high utility-to-weight ratio; it easy to work; it is familiar, even in remote communities having no trees taller than five centimetres; it is replaceable; it handsome in colour and texture...*
>
> **Strub, 1996: 144**

BOARD AND BATTEN
A commonly used siding in Swedish farmhouses is the board and batten. It shares some of the same architectural potential as the (plywood) board and board, though with a bit more depth and contrast.

TONGUE AND GROOVE
A result of the tongue and groove facade is an almost seamless appearance only interrupted by small and accentuated vertical lines. The siding is perceived as a flat surface and the boards are perceived as individual objects that in terms of scale make the facade appear quite large.

CLAPBOARD
In terms of construction, this facade uses boards of equal size put on top of one another. This facade emphasizes the horizontal lines of the house and in this case causes it to appear wide and disproportionate.

PRESENTATION
The Greenlandic house

> *The regularity of the grid promotes a coherency in the architectural layout - even when the sense of the grid is being defeated by the vast landscapes.*

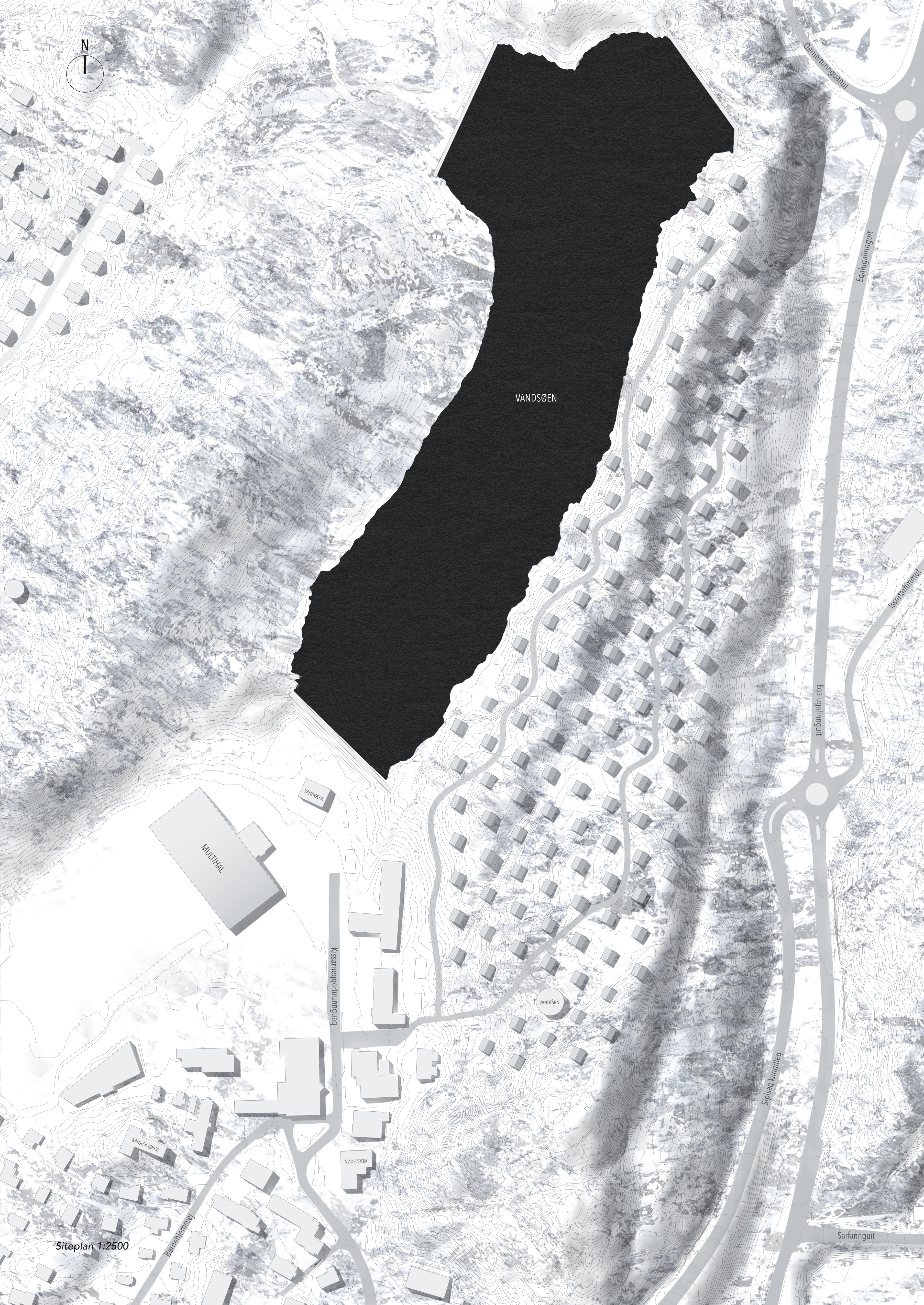
URBAN IDENTITY

EXPERIENCE AND EVOLVEMENT

The organization of the building mass in the landscape is based upon a regular grid that strengthens the character and scale of the landscape through the simplicity implied of the grid. In addition, the evenly distributed houses is diversified and made unique by the undulating landscape while being tied together by the grid as a coherent urban development.

The simplicity of the urban layout allows the area to develop, grow and be personalized without diminishing the architectural idea. Some inhabitants might build terraces other uses the outdoor spaces for storing their fishing gear and snowmobiles. And because of this simplicity, the architecture is not being overshadowed and spoiled by developments and additions - in fact this simplicity of the grid welcomes the personal initiatives that only encourages this urban area to thrive and evolve.

Fig. 50 *View towards the houses that is situated adjacent to Vandsøen*



Siteplan 1:2500

Simplicity and composure is the key words for describing this particular house in Greenland - it ensures a flexible, compact and functional home that responds Greenlandic way of living.

GROUND FLOOR

CLARITY AND SIMPLICITY

The spatial concept for organizing the plan is a symmetrical axis within the square that enforces simplicity and composure, which emerges as an efficient and functional plan in a compact envelope - the gross floor area of both floors combined is 126 m^2.

In Greenland it is necessary to have a secluded entrance that provides adequate space for the winter clothing. The entrance in this house has the sole purpose of storing the winter clothes - though with a table and a sink which functions as a scullery. A utility room has been introduced to handle laundry as well as providing spaces for freezers and storage. In combination with the utility room there has been added a small toilet.

Exactly one half of the ground floor serves as the combined kitchen and living room where there is space for the family and guest to relax. The room is illuminated from three different directions that allows an abundance of daylight as well as maximizing the views to the outside landscapes.

The enlarged wall in the centre of the houses provides adequate space for the ventilation ducts and installations and serves as the thick insulating wall against the entrance. The diffusers from the ventilation is integrated into the timber panels in the interior walls.

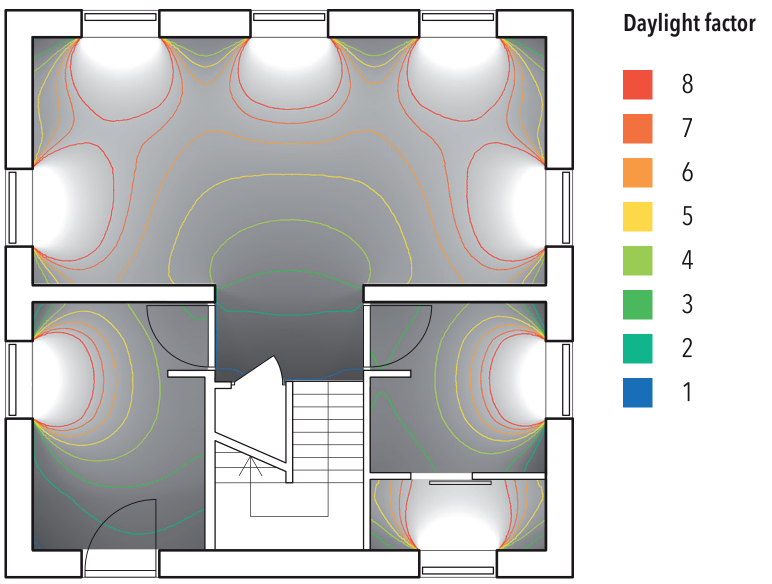


Fig. 51 *Daylight factor on the ground floor*

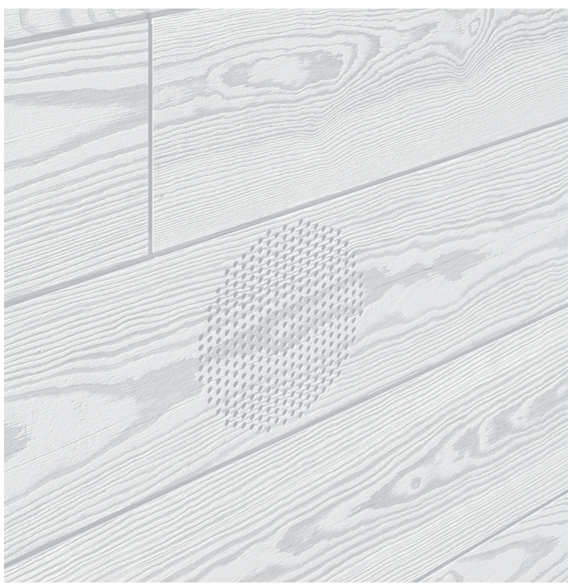


Fig. 52 *Integration of diffuser*

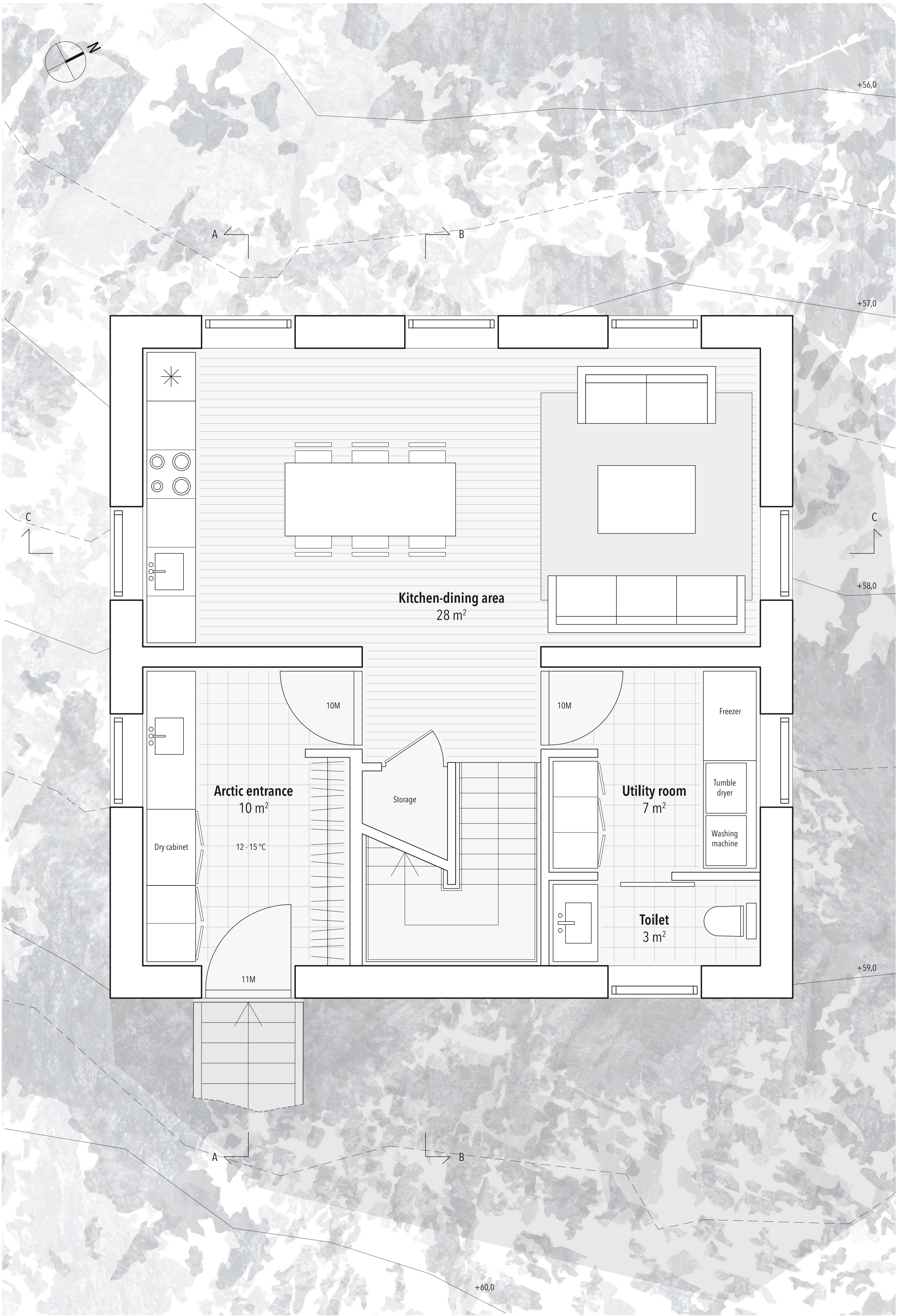


Fig. 53 *Ground floor - 1:50*

"The interior spaces consists of light-hued timber that softly contrasts the sharp and cold exterior environment and contributes to warm and relaxed atmosphere."


Kalaallit Nunaat
LIFE AT THE EDGE

FIRST FLOOR
SECLUSION AND SILENCE

The entire first floor serves as the private sphere of house where one can retreat from the living areas. The rooms on this floor echo the compactness of the envelope – there is not an abundance of space but instead the spaces are used and furnished in a functional manner that accommodates the needs for silence and privacy.

Privacy comes in many different levels and in this small house where the occupants are close to one another it is important that the private rooms also mutes the noise from the house. This requires the doors to close tightly and the ventilation must be silenced. Since the door is basically airtight there has to be introduced separate silenced ducts that allows air to flow out of the room.

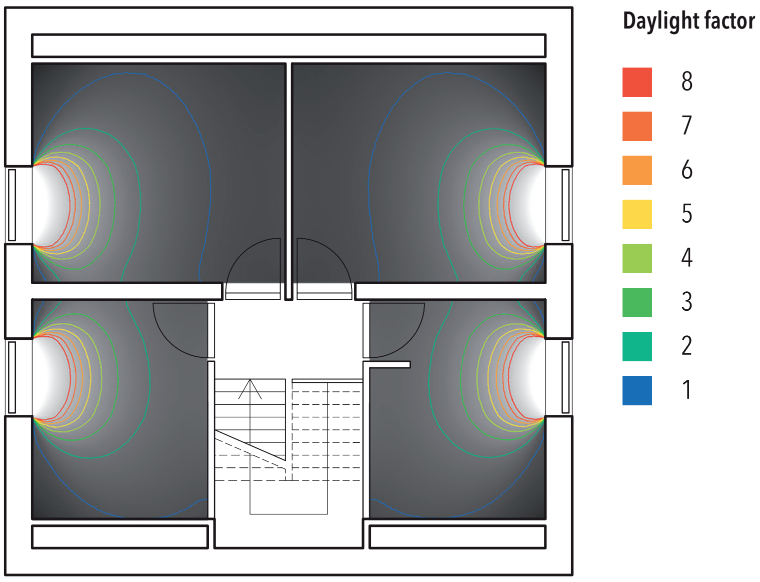


Fig. 54 *Daylight factor on the first floor*

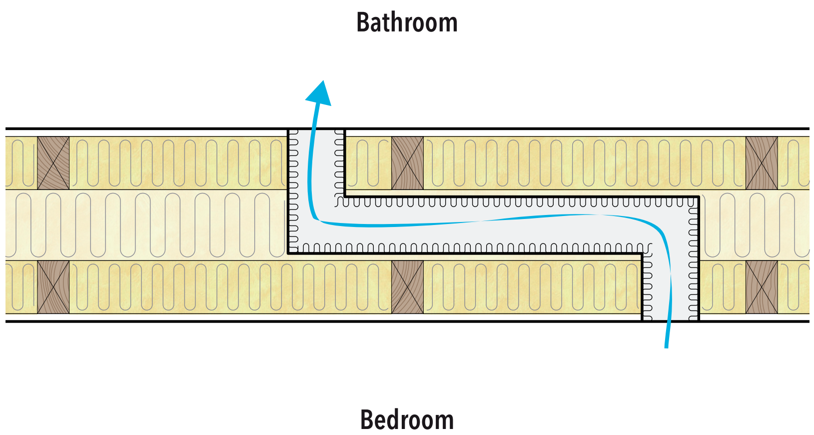


Fig. 55 *Plan view of a duct that mutes sound while allowing airflow between rooms*

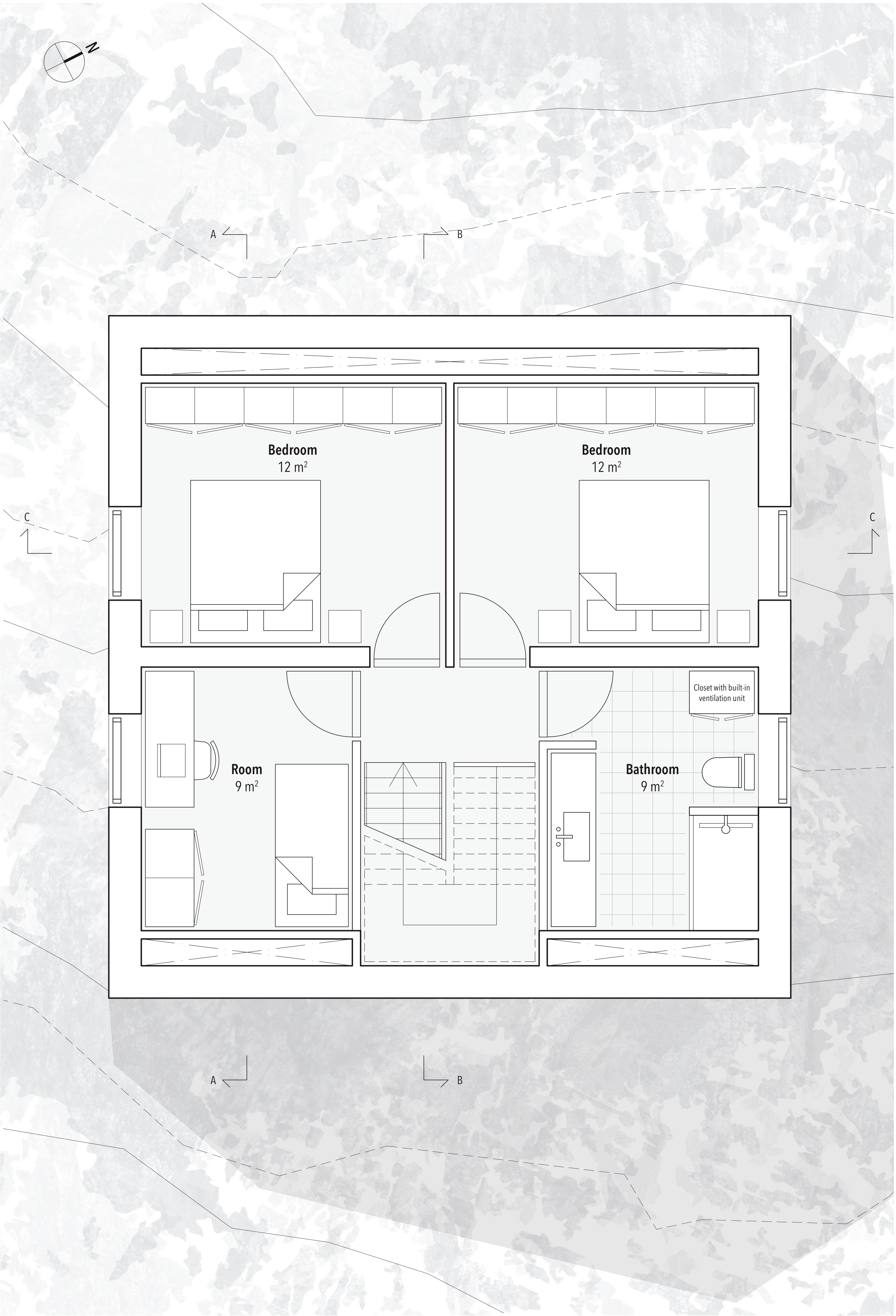


Fig. 56 *First floor - 1:50*

ELEVATIONS
HIERARCHY, PROPORTIONS AND COLOURS

Fig. 57 *Elevation north - 1:50*

Fig. 58 *Elevation east - 1:50*

"The pronounced frames, the shading effect of the siding and the hierarchy of the openings are all key architectural means to resolve the proportions and scale of the facade."

Fig. 59 *Elevation south - 1:50*

Fig. 60 *Elevation west - 1:50*

"The colours and vibrancy of the houses contrasts the monochrome tones in the Arctic landscape inducing life, spirit and excitement as they light up the entire scenery."

ELEVATIONS

EXAMPLES OF COLOURS

Fig. 61 *Examples of colours - 1:100*




SECTIONS
SPATIAL RELATIONS

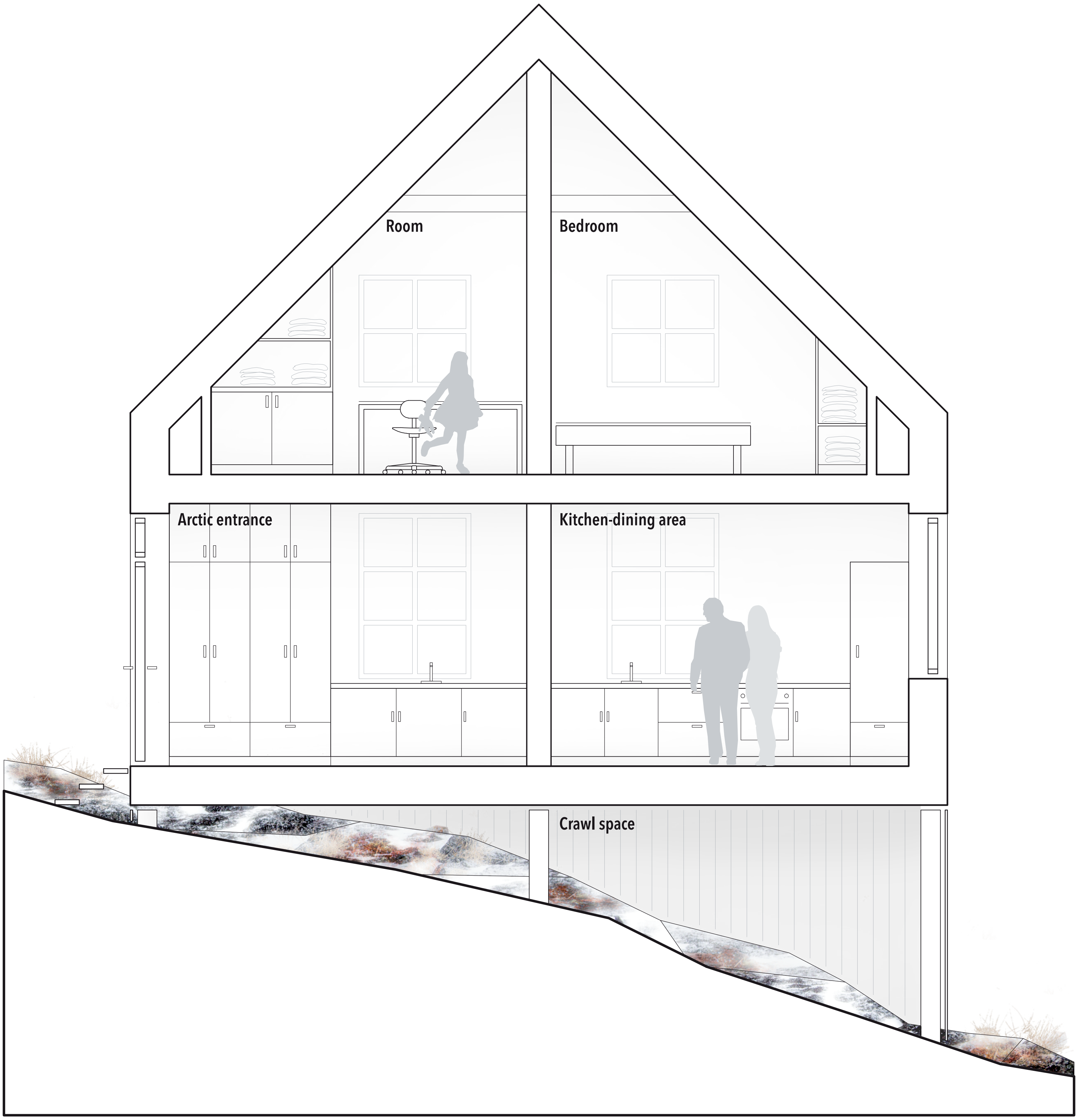


Fig. 62 *Section AA - 1:50*

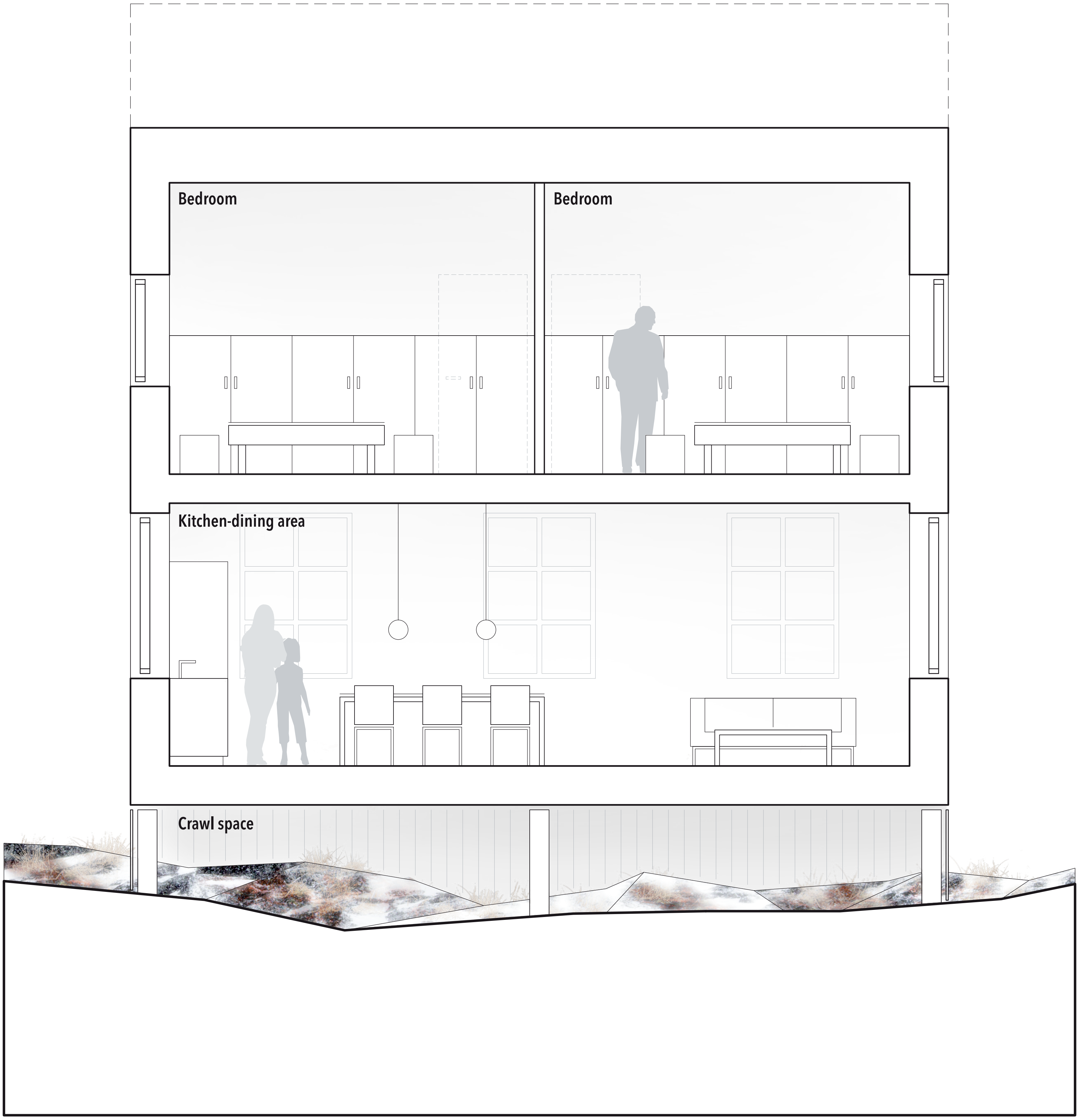


Fig. 63 *Section CC - 1:50*

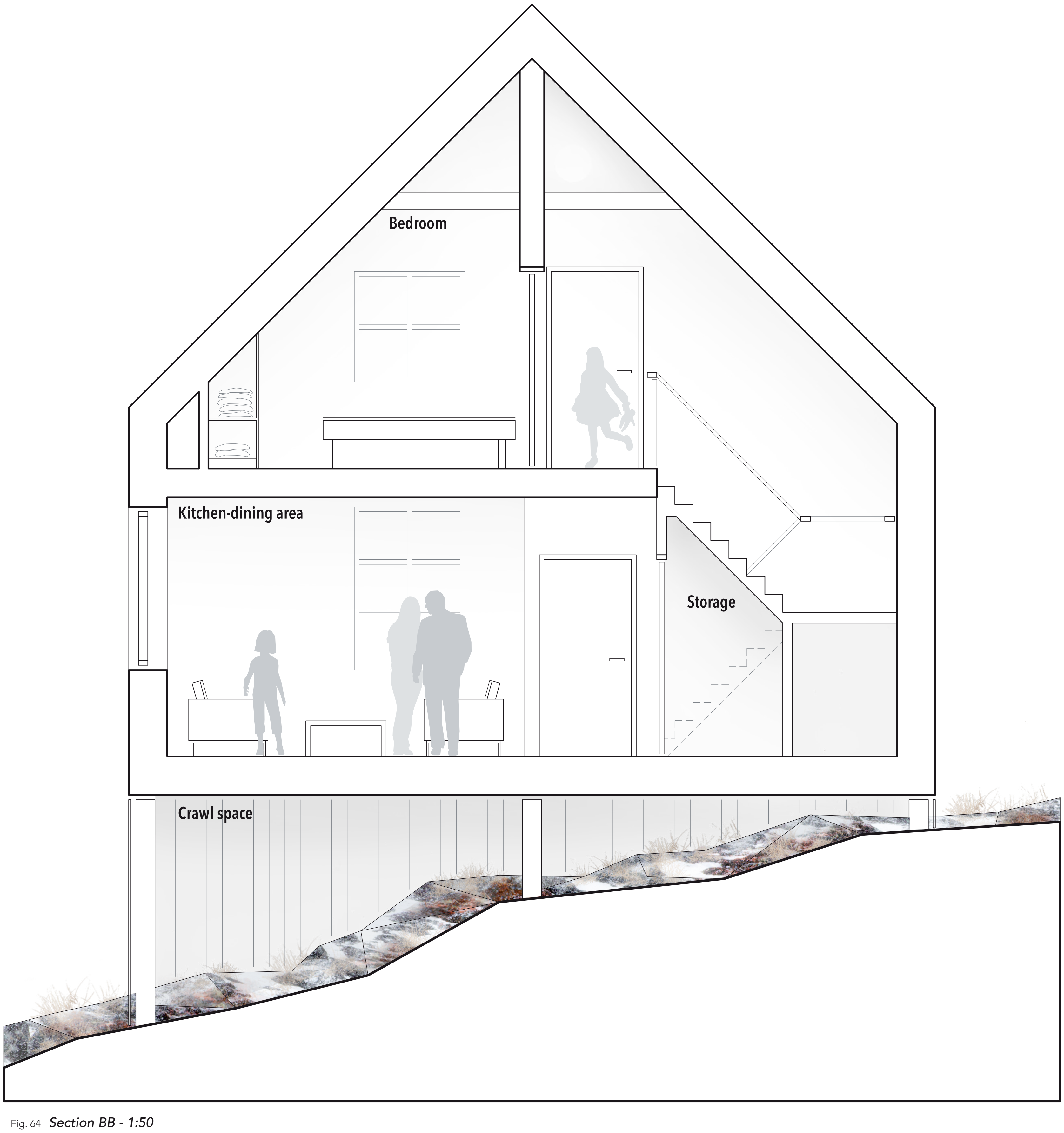
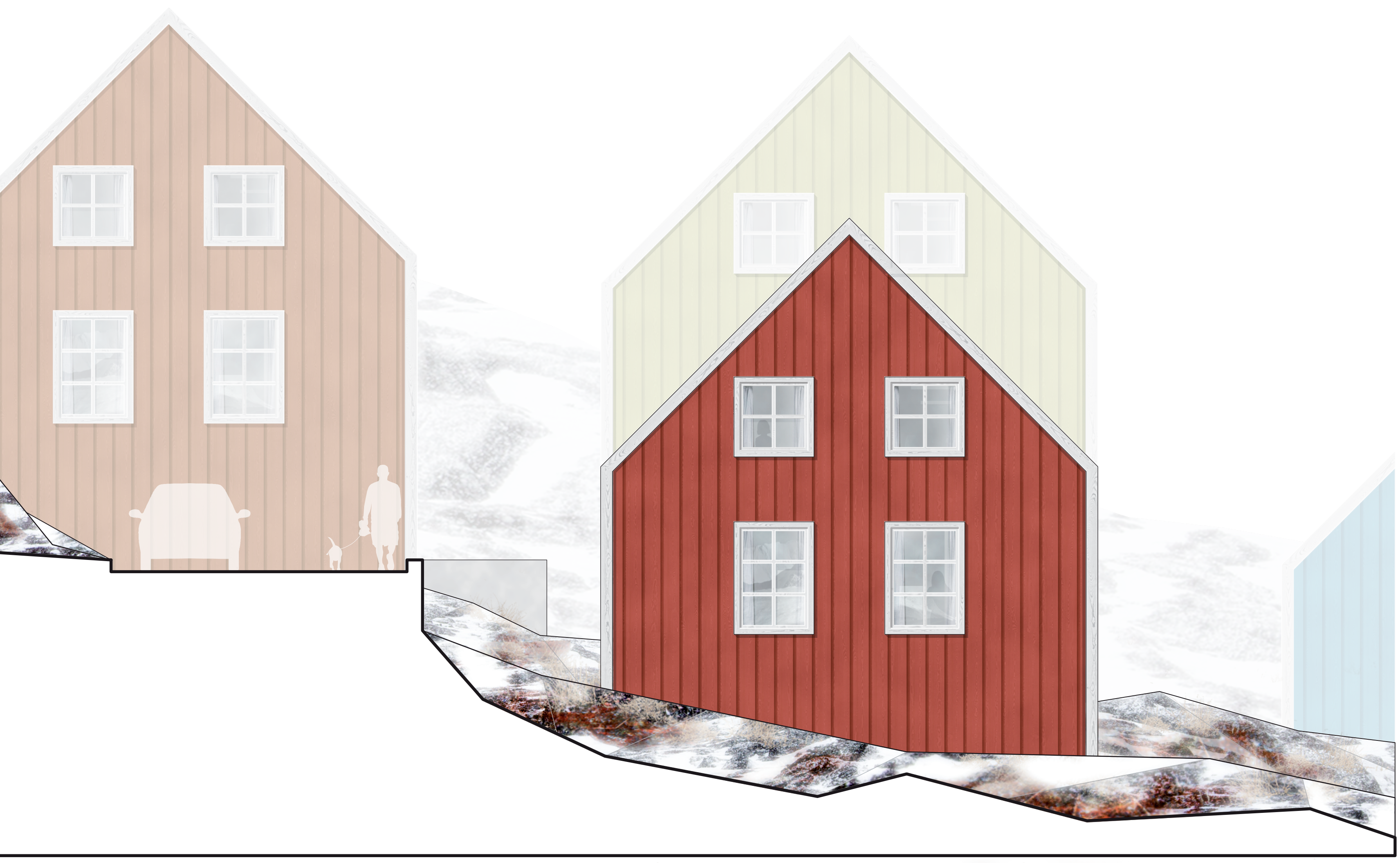


Fig. 64 *Section BB - 1:50*

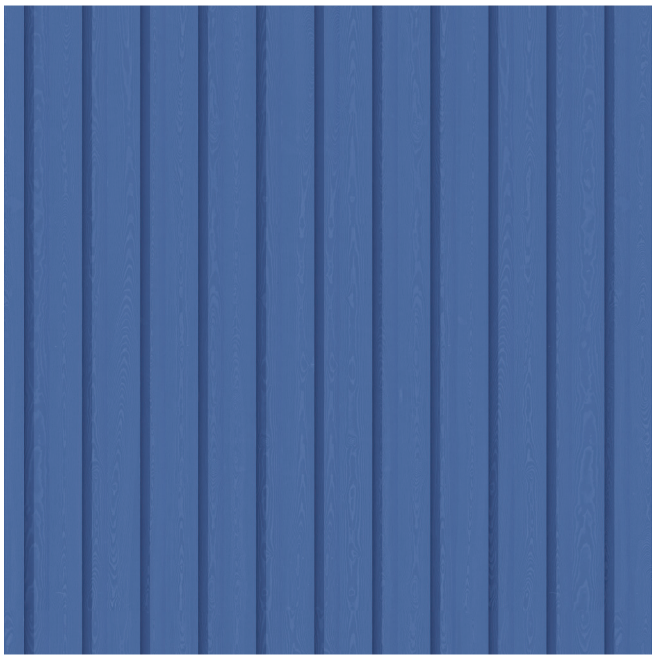
Fig. 65 *A view to the landscape*

> *"The roads on the site are nestled in-between the houses where it moves according to the landscape and the grid."*

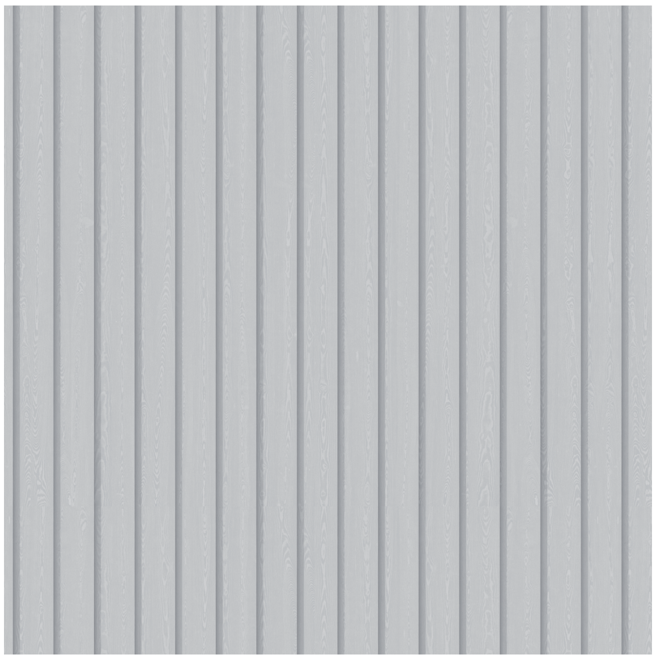
Fig. 66 *Spatial relation between the houses - 1:100*



MATERIALS
TIMBER SURFACES



EXTERIOR SIDING
The coloured board and board siding is used for the exterior where it adds depth and rhythm to the appearance.

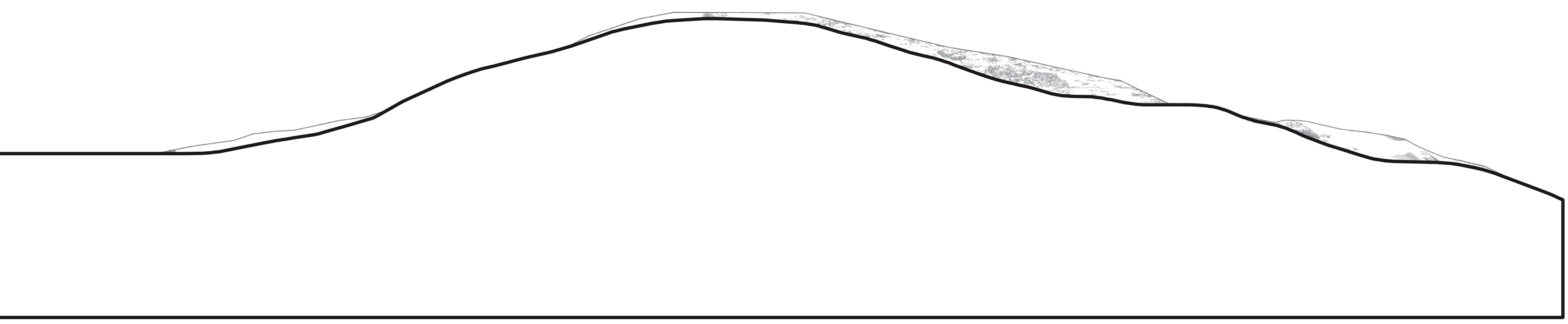


ENTRANCE
The entrance echoes the materials of the exterior to give it a sense of being a transition between the outside and inside elements.

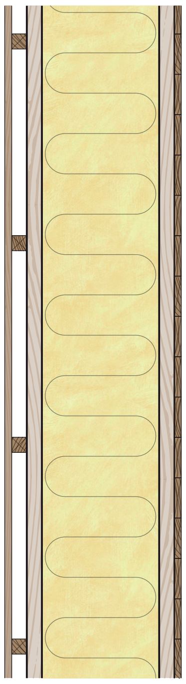
Fig. 67 *Cross section of the site – 1:1500*

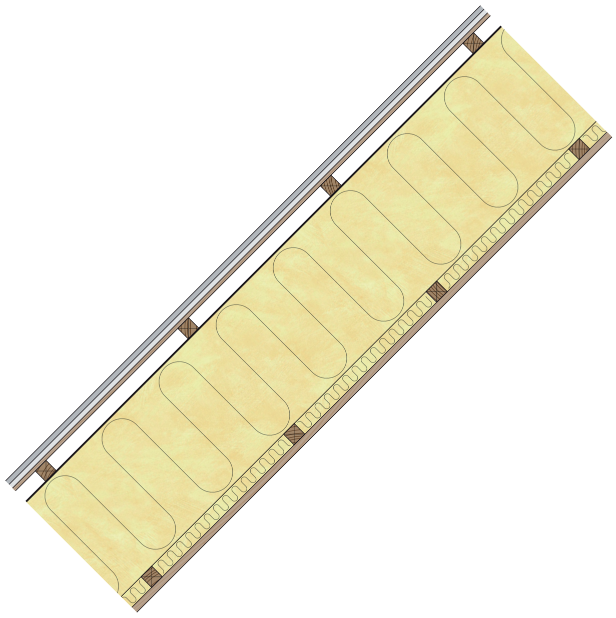
FLOOR
The wooden floorboards add warmth and character to the interior spaces.

INTERIOR WALL
The bright interior walls light up the interior spaces and the horizontal panels seamlessly wraps the entire room.



THERMAL ENVELOPE
CONSTRUCTIONS AND ENERGY FRAME





EXTERIOR WALL

- *Exterior siding (board and board)*
- *Weather-resistant barrier*
- *350 mm insulation*
- *Vapour barrier*
- *Interior wall boards*

U-value: 0,10 W/m²K

ROOF CONSTRUCTION

- *Two layers of roofing felt*
- *450mm insulation*
- *Vapour barrier*
- *Ceiling boards*

U-value: 0,08 W/m²K

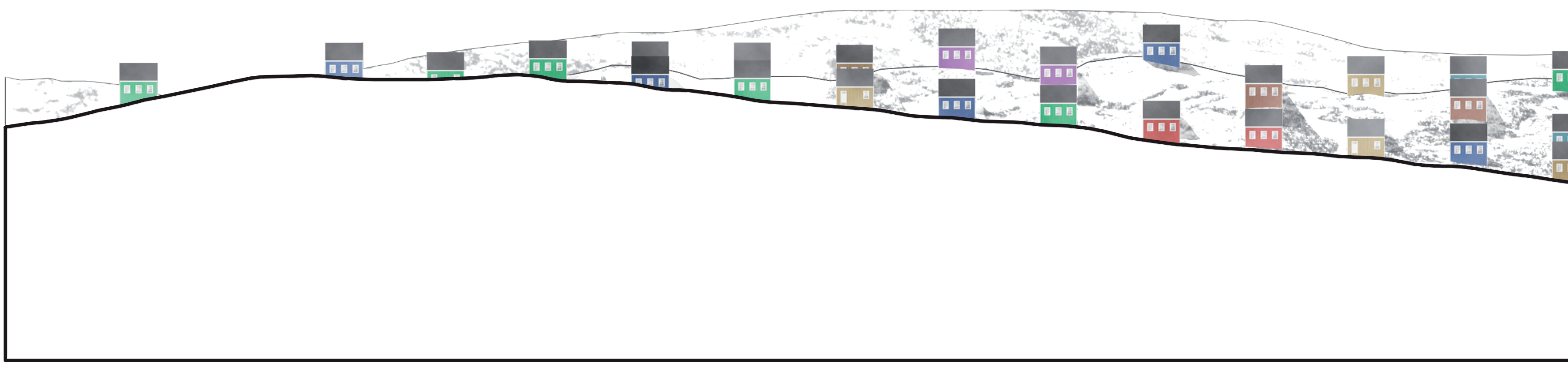
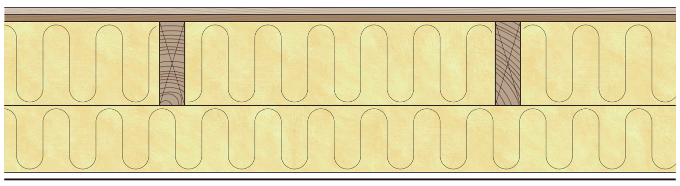
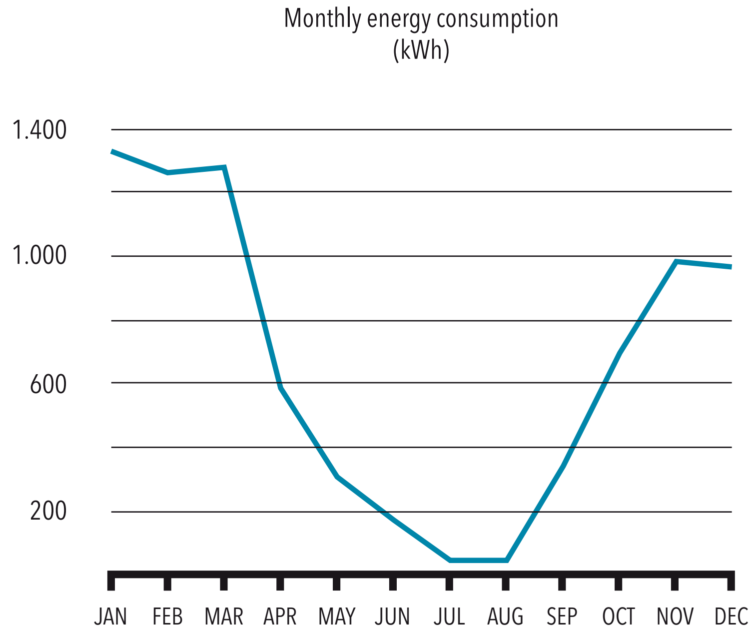


Fig. 68 *Longitudinal section of the site – 1:1500*





FLOOR CONSTRUCTION

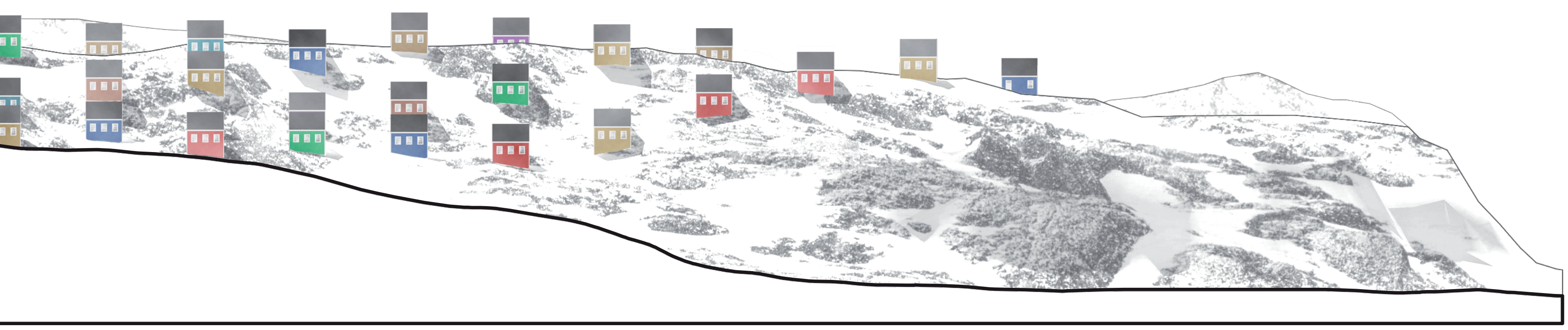
- *Floor boards*
- *Vapour barrier*
- *450 mm insulation*

U-value: 0,08 W/m²K

ENERGY CONSUMPTION

The ambition for this project reach 45 kWh/m² year but the sustainable initiatives proved to be insufficient. The design could have been developed further with an improved thermal envelope as well as optimizing the solar heat gain, but this is considered to be a decent result based on the current regulations from Greenland.

Energy frame: 51,3 kWh/m² year




"The houses are exposed to the ever-changing light and colour of the Arctic sky - from the precise low-angle light to the soft and vibrant atmosphere of the northern lights."

CONCLUSION

The approach of an architectural design in high latitude regions requires profound compassion for its particular context - a building in the Arctic should be more just a building within the Arctic latitudes. This new housing development becomes Artic and certainly Greenlandic in its way of responding and acknowledging the Arctic conditions and celebrating the unique qualities offered by the climate and landscape. The spatial experience of the this new housing development is solely caused topography and landscape which not only enhances the architectural appearance but stresses the scale of potential of the landscape itself.

Placing the houses in a regular grid system accentuates not only the houses but also the power of the undulating landscape on which the houses are built. The grid ensures an architecture that doesn't ignore and dissolve the landscape – an architecture the seems native to its setting.

The colours of the houses makes them appear as bright monoliths in the landscape only stressing the fact the houses represents a series of points in the nature. Furthermore the colours counteract the monochrome tones in the landscape and gives life and identity to the scenery.

The two symmetrical axes in a plan enforce the simplicity and composure that results in an efficient and functional plan. It accommodates the specific Greenlandic requirements in an integrated and compact solution.

Looking at the goals and visions for the project the design proposal echoes a solution that is native to its specific place and setting. Functional, technical and aesthetical initiatives have been solved in a holistic manner that is both valuable for the inhabitants and the local people.

REFLECTION

The design process for this project took its point of departure in the urban scale and the architectural concept for the housing had to follow the urban idea. In this case where the landscape is this distinctive the challenges was first and foremost related to the urban scale. Tools for developing the urban scale has largely been physical models where it is easy and fast to develop schemes and immediately see how they respond to the landscape. During the process and the different iterations, thoughts regarding the urban solutions have also compromised the infrastructure and accessibility of the houses, as it can be difficult to solve at the particular site.

The design process of the housing units derived from the idea in the urban scale and was developed to be flexible and able to adapt to its specific placement in the landscape. Throughout the process it was mainly digital sketches that allowed rapid testing of design proposals with accurate square metres and furnishings in the rooms.

For this project sustainable initiatives has been developed and tested alongside the architecture but hasn't necessarily been key design factor in the design process. The main idea of structuring the entire site with detached houses in perhaps not the most energy efficient solution but from that point on the design has been developed as a compact, efficient and well-insulated envelope which all is initiatives to reduce the energy demand. During the design process the key focus has always been relating to architectural design solutions and the technical and sustainable initiatives were developed according to the design solution – never the other way round where environmental and sustainable design issues becomes the key design parameters.

This project never indented to directly mirror the architectural expression of the settlements in Greenland. However, as the project slowly developed the design leaned more and more towards the settlement architecture – not because of a personal desire or preference but because of all the qualities and potentials that lies within the scattered detached houses. When striving for a Greenlandic design this settlement architecture proves to solve many of the complications related to inhabiting Greenland – the small footprints of the houses makes them easily meet and dress the landscape, the wooden frame around windows and doors, makes the relatively small openings have a scale and drama in the facade expression, the fact that every single house has its own piece of the landscape, which can be used and furnished by the inhabitants. The Greenlandic design is an outcome of the inherent qualities and potentials in the distinctive landscape, the harsh climate and the lifestyle of the indigenous people.

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IMAGE CREDITS

All photograph and illustrations not listed here are captured or created by the author

Fig. 13 - Google Maps <http://maps.google.dk> - 19.02.2014

Fig. 23 - Flickr <https://www.flickr.com/photos/paspog/12838228663/in/photostream> - 26.04.2014

APPENDIX #1

AIR CHANGE RATE CALCULATION

REQUIRED VENTILATION RATE FOR COMFORT (SENSORY POLLUTION LOAD)

It is assumed that the air quality in Nuuk is very good, which results a $C_{c,o}$ value of almost 0.

The ventilation rate for comfort can be calculated from the equation (the pollution from the building has been added to the equation):

$$Q_c = 10 \cdot \frac{G_c + G_b}{C_{h,i} - C_{h,o}}$$

Q_c	ventilation rate required for comfort (l/s)
G_c	sensory pollution load from people (olf) [CR1752, Table A.6]
G_b	sensory pollution load from building (olf/m^2) [CR1752, Table A.8]
$C_{c,i}$	desired perceived indoor air quality (decipol) [CR1752, Table A.5]
$C_{c,o}$	perceived outdoor air quality at air intake (decipol) [GKB, p. 41]

$$Q_c = 10 \cdot \frac{4\ \text{olf} + 0{,}1\ \frac{\text{olf}}{\text{m}^2} \cdot 126\ \text{m}^2}{1{,}4\ \text{dp} - 0{,}01\ \text{dp}} = 119\ \text{l/s}$$

This is now converted to an air change rate based on the net volume of the house (282 m^3):

$$n = \frac{119\ \text{l/s} \cdot 3600}{282\ \text{m}^3 \cdot 1000} = 1{,}52\ \text{h}^{-1}$$

AIR CHANGE RATE IN RELATION $C0_2$ CONCENTRATION

It is assumed that the air quality in Nuuk is 300 ppm as opposed to the commonly used 350 ppm.

The ventilation rate for CO_2 can be calculated from the equation:

$$n = \frac{q}{V \cdot (C - C_i)}$$

n	air change rate in relation to CO_2 concentration (h^{-1})
q	CO_2 pollution from the occupants (m^3/h) [CR1752, Table a:6]
V	volume of room (m^3)
C	allowed CO_2 level in relation to the climate class (ppm) [Table B.4]
C_i	outdoor air quality (ppm)

$$q = 19\ \text{l/h} \cdot 4\ \text{pers} = 76\ \text{l/h} = 0{,}076\ \frac{m^3}{\text{h}}$$

$$n = \frac{0{,}076\ \frac{\text{m}^3}{\text{h}}}{282\ \text{m}^3 \cdot (1010\ \text{ppm} - 350\ \text{ppm})} \cdot 10^6 = 0{,}41\ \text{h}^{-1}$$

A BUILDING IN THE ARCTIC SHOULD BE MORE JUST A BUILDING WITHIN THE HIGH LATITUDES. IT SHOULD BECOME ARCTIC IN HOW IT INTERPRETS AND RESPONDS TO THE ENVIRONMENT AND CLIMATE. IT SHOULD UTILIZE THE TOPOGRAPHY AND LANDSCAPE TO ENHANCE ITS ARCHITECTURAL APPEARANCE. THE COLD LOW-ANGLE LIGHT OF THE SUN CREATES A VISUALLY VIBRANT AND DRAMATIC LANDSCAPE THAT MAKES THE WARMTH OF DWELLINGS EVEN MORE WELCOMING. ARCHITECTURE SHOULD PROVIDE AN INHERENT SHELTER FROM THE ENVIRONMENT AND INSTEAD OF ISOLATING INHABITANTS FROM THEIR SURROUNDINGS IT SHOULD STRENGTHEN THE RELATIONSHIP BETWEEN THEM.