# Resilience and Renewable Energy Planning in Greenland

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SISIMIUT, 7– 9 APRIL 2014

# Proceedings of the 10th Artek Event

# Urbanisation and Infrastructure in the Arctic Challenges to Sustainability

ARCTIC TECHNOLOGY CENTRE

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**Organised by :**
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## FOREWORD

The Artek Event is a recurrent highlight of dedication to research and developments of contemporary and future relevance for the Greenlandic and arctic societies. Each year since 2005, the Artek Events have gathered researchers and engineers from around the world with expertise and interests in arctic engineering and technology with the aim of sharing and assessing the state of knowledge and cooperating on joint efforts to push these ideas further.

In recent years, the arctic societies are increasingly challenged by the need to find ways and means for sustainable societal developments. At the same time, trends and developments like globalisation, climate change and resource scarcity have positioned the arctic regions in the focus of the world community. The growing interests of foreign governments and industries in getting their share of the vast arctic resources constitute substantial opportunities for the arctic societies in meeting the challenges of sustainable societal developments. However, there are also significant risks. If societal and industrial developments in the fragile arctic communities and vulnerable arctic environments are not planned well, monitored carefully and continuously adapted to meet objectives, the long term damages can be devastating.

In this setting, the current Artek Event directs focus on the role of urbanisation and infrastructure in the arctic, both generally and particularly in Greenland, in the quest of sustainable societal developments. It is our sincere hope that the joint efforts of international experts from academia and industry collected in the present proceedings, will contribute positively to this context.

I wish you enjoyable reading.

Michael Havbro Faber

Head of The Arctic Technology Centre, DTU, Professor Risk and Safety

## PREFACE

The Arctic Technology Centre (Artek) at the Technical University of Denmark (DTU) was established in the year 2000 with the purpose of educating Arctic engineers and to carry out research in Arctic technology. Since then much has been achieved; nearly 50 arctic engineers have graduated with a bachelor degree and a wide span of research has been initiated and carried out.

The first Artek Event was held in 2005 in Sisimiut with the title "Energy efficient buildings." Since then, the events have been held on annual basis in Sisimiut for two to three days during springtime prior to the Easter holiday. Each year, a topic of high relevance for the Greenland society and the Arctic has been addressed. Examples of topics of previous events are: "Sustainable energy supply in the Arctic," "Arctic roads" and "Challenges for the Arctic building industry".

The topic for Artek Event 2014 is "Urbanisation and infrastructure in the Arctic – challenges to sustainability." From the fundamental challenges of planning and building in a cold climate to the theoretical framework for urban planning, this year's publications and presenters span a wide range of fields. The diversity in presentations as well as the professional background of the lecturers is an asset to the conference. New contacts have been established and fruitful discussions have taken place across professional boundaries and among different nationalities.

In the last two years, the concept of the Artek Event has changed towards a broader international participation and a formal review process of the proceedings. We strive to select topics for the event and for the sessions that make the conference attractive for professionals of a diverse background. This has facilitated discussions and the exchange of ideas among different professions which normally have little interaction. It has been our ambition to attract participants from private industry, from governments, from academia and from NGO's to the Artek Event.

Unfortunately, not all presenters have been able to find time to write a contribution to the present proceedings. There are approximately 80 participants, and some 30 presentations have been given. Many participants took the opportunity to take part and listen to the interesting talks without giving a presentation. We were particularly thankful to welcome participants that have travelled long distances from abroad to join the conference.

We would like to thank all the reviewers which have greatly contributed to improving the quality of this proceeding. The co-editors, Susan Carruth, Lene Edvardsen, Ulrik Jørgensen and Emma Neale are acknowledged for their valuable efforts in coordinating the review process between reviewers and authors.

The organizing committee for this Artek Event 2014 is: Carl Egede Bøggild, Professor, Arctic Technology Centre, Technical University of Denmark (DTU); Lotte Bjerregaard Jensen, Associate Professor, Department of Civil Engineering, DTU; Ingrid Vernimmen, Secretary, Arctic Technology Centre, DTU; Jokum Møller, Principal, Kalaallit Nunaanni Teknikimik Ilinniarfik , Sisimiut, Greenland; Laust Løgstrup, Director, Qeqqata Kommunia, Greenland; Teit Groth, Head of Section, Ministry of Housing, Nature and Environment, Government of Greenland and Lene Edvardsen, Director, The Norwegian State Housing Bank, Norway.

Carl Egede Bøggild

Professor, The Arctic Technology Centre, DTU

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ARCTIC TECHNOLOGY CENTRE

# Urbanisation and Infrastructure in the Arctic
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**SISIMIUT, 7 – 9 APRIL 2014**

## Proceedings
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# SUSTAINABLE CITIES, FINE; PEOPLE CITIES WILL DO MORE

Jan Gehl, Professor, Dr.Litt., Founding Partner: Gehl Architects. Copenhagen

## Abstract

A people oriented planning approach will address sustainability issues but will –at the same time-do much more for quality of life in the city.
The problems of current city planning are ably illustrated by the photo from the main street of Nuuk shown below. Most of Nuuk is rather concentrated and year round there are numerous people walking in the city. But very little concern indeed for these activities. A dramatic upgrade of the pedestrian / public life environment could lead to more livable, safe, sustainable and healthy cities and may provide more competition to the many ultra short car rides. Bicycling may also be worth looking seriously into in quite many cities across the Arctic.
Lastly a general advise for northern cities. Instead of focussing on the bad, cold days of the year, look at the good, acceptable days. Actually there is a great majority of good acceptable, outdoor days. Enjoy!

## Are sustainable cities also great cities?

Are sustainable cities necessarily fine, livable cities? Time and again there are reasons to think about this question when attending sustainability conferences and reading books about the subject. And frankly there are under the green flag of sustainability presented quite a few projects for buildings ore city districts which are absolutely green and very sustainable but are at the same time quite problematic from a general city quality point of view.

Would city districts with many buildings with greenery floating down from balconies and green roofs, with water collection systems, and topped with windmills and solar panels also be great places to live? Not necessarily so.

Actually a city can have many very green buildings and still not be a sustainable or livable city. Sustainability is one important quality parameter, but quite a few other aspects must be included to address the complex challenges facing cities in the 21st Century.

When the focus of city planning is lifted from a more narrow focus on sustainability to general issues of creating fine cities for people where walking, public life and –where possible- also bicycling are given a high priority we will see that such a policy would actually address several important issues in one stroke: Such a people oriented approach to city planning will provide cities which are more *lively/ livable, safer,* more *sustainable* and *inviting for healthier lifestyles.*

The green buildings and neighborhoods must be an integrated part of a carefully planned people oriented environment, which will in itself invite to green lifestyles, but will, most importantly offer a generally much more livable environment. Sustainability is fine but contemporary cities must do more.

## Two old paradigms and a new one

Two paradigms have dominated City Planning for the past 5 decades:
One being the Modernistic planning ideology with free standing buildings, technocratic, functional solutions and a general lack of concern for the "in betweens". In traditional city building attractive spaces were created by the buildings. In the city districts built on modernistic ideologies one will typically find only windswept "left over spaces" among the buildings. If a team of professional planners and architects had at any point been commissioned to create a city planning system which would discourage walking and life in the city as much as possible, it could hardly have been done more efficiently, than by applying the modernistic city planning principles.

Because this way of building cities have been dominating in the past 50 years we can sadly find that most of the newer cities and districts –also in the colder areas of the Globe- are dominated by this kind of planning, which are not addressing how the cities are used by people, but merely focussed on individual buildings placed more or less freely in the landscapes.
The other significant change of paradigm also dating –in the western cultures- from the period around 1960- has been the car invasion and the ensuing obsession with automobiles and traffic. (In Eastern European countries this obsession came much later –after 1990- but has been incredibly strong, and the love affair with the automobile is still very hot. In China and in other developing economies the automobile invasion is even more recent.)
In all the countries and in all the decades of automobile invasion it can be seen how the traffic has taken over nearly all spaces in the existing cities and totally dominated the principles and design of the new city districts. Both in the older invaded city spaces and in the new car-oriented districts the public use of city spaces have been under very heavy pressure. Neither sufficient space nor quality for the people who use the public spaces have been looked after.

Walking and all types of life in Public Spaces have had a troublesome time during the 5 decades dominated by these two planning paradigms.

As societies have developed we have gradually seen a shift from this mainly quantitative approach dominating planning for a good part of the past 5 decades, to increasingly more concern for qualitative issues.

In the 21st century concerns for livability, safety, sustainability and health have increasingly come to influence city planning. In the global economy cities are increasingly competing on livability / quality of life and by 2014 no less than three different "lists" of "Worlds most Livable Cities" are published every year. Realising that concern for the people who use the cities will be an obvious way to address not only the sustainability agenda but all four issues in a holistic approach, resent years have seen a steadily growing concern for public spaces and public life in cities worldwide.

## Old wisdom was discarded and new knowledge had to be found

By 1960 –when the radical changes in planning principles started to dominate- very little was known about how physical form influenced people activities and quality of life. A lot of knowledge concerning city quality generated through centuries in the old cities and passed from one generation to the next was simply completely discarded by 1960. Laboriously new knowledge had to be gathered through research and experiments over the years. Also in the intervening years many cities and new developments had started to experiment with more people oriented planning principles. The situation at this time in history is that extensive knowledge on how to create good cities for people have by now been assembled and further quite a few cities can by now serve as inspirations and best practice, because people oriented city policies have been carefully tested out in these cities.

This knowledge and these examples form the important background for the change of mindset in resent years and the new city planning principles aiming for *lively /livable, safe, sustainable* and *healthy* cities created through people oriented policies.

## Livable cities: A challenge for cities in all regions and all climates

This general change from quantity to quality oriented city planning and the ensuing new focus on livability will naturally be applicable to cities and districts in all parts of the world, in all regions and in all climates where Homo Sapiens have settled.
City of Copenhagen was one of the first to start pushing back the automobiles from the city streets (Main Street Strøget  pedestrianized, 1962). This policy has during 50 years been refined and have culminated in an official city policy to be "The best city for people in the World" (2009). Copenhagen can repeatedly be found on top of the various lists of "Most Livable Cities of the World".

Other cities like Melbourne, Sydney, Stockholm, Zürich and New York have equally worked with introducing people oriented city planning policies in recent years, and these cities are equally fund among the top cities on the "Livable cities of the world" lists. A direct link between such policies and a high "livability" rating can definitely be found.

## Urbanisation and infrastructure in the Arctic

Turning now from the general description of planning trends and changes in planning ideologies I will use examples from cities in Greenland –primarily Nuuk- as a point of departure, knowing that the problems described can be found in all regions of the arctic. And also knowing that a good part of the solutions will address problems in many other Arctic Cities.

In the conference program is presented a photo from Nuuk – see photo above. In this photo are in a concentrated form illustrated most of the problems developed as a result of the two old planning paradigms: Modernism and Motorism.
Spread over the landscape is a great many individual buildings –displaying a great variety of building forms, materials and colours. Each building representing different sub-cultures in the era of modernism. It is virtually an architectural exhibition where architectural trends from the 1960s, 70s, 80s and 90s,can be studied in detail and due to the lack of screening trees and bushes all details stands out much more clearly than in other regions. For the better or the

worse. Also evident is the lack of spaces formed by the buildings. The buildings are placed more or less at random not according to a coordinated spatial plan, and only after the construction one could start to think about the leftover spaces.
The second aspect very visible on this photo is the dominant position of the car traffic (and parking). A wide road is provided, where the cars can enjoy two, three or maybe four lanes. Leftover space is conveniently allocated for parking.
The third aspect visible on this photo is the total absence of infrastructure for the people who are seen here and there getting along as best they can.
One may get the idea that only a few people walk in Nuuk and that public life is more or less absent because of the climatic conditions.
This is certainly not the case. On the contrary –in all seasons through the year- a great many people are walking, criss crossing the city on the most direct lines. Also much public life is found along the streets or near the important destinations-the supermarket, the library, the schools, the various administration buildings and so on.
Actually Nuuk has an impressive amount of life in the city.
The problem at present being that "the life" is being carried out under very poor conditions. Life was never a prominent part of the concerns in the city planning.

## Challenges from a sustainability perspective

Applying a holistic strategy rather than a more narrow sustainability strategy to a place such as Nuuk a policy could maybe look like this:

1. Create an architecture policy which aims for a more concerted placement of the buildings in order that urban vistas are created and especially in order that the building are created to form urban spaces which invites public life and protects the pedestrians moving through the city. It is taken for granted that all new building complexes are formed in such way that wind problems are reduced, and the accumulation of snow is controlled. Furthermore special concerns should be given to the fact that any building is very visible in all details and for many, many years, which generally calls for a careful attention to form, materials, colours and details.

2. The transport policy ought to be revised in order to place more priority on green mobility –walking (and bicycling)- and down prioritize car traffic. In the cities of Greenland the road networks are very small. It is only possible to drive some 5-10 kilometres in any direction, and often much less. Nevertheless there has developed a high ownership rate of cars and the cities a characterized of a far too high number of really small automobile journeys.

3. Much more should be done to promote green mobility given the fact that the cities in Greenland –like Nuuk- are generally rather concentrated. Distances are –for most citizens- rather small and a great number of journeys in all parts of the year are already carried out by people walking. It would be absolutely obvious to put a much higher priority on walking. The lines used for walking should be documented, in order that these popular routes can be carefully upgraded with better draining, good paving, better lights and ample snow removal, in order to signalize "Please walk as much as possible in our city". It is good for livability, safety, sustainability and it is good for your health.

Most likely a good "Green mobility" should in many places also include infrastructure and invitations for people to bicycle. Some would say that bicycling would not be viable in the arctic regions, yet quite a bit of bicycling are actually taking place in a number of arctic cities. Some cities might be too hilly and some may be too cold, but in a great many other cities bicycling could for most days in the year provide a very useful, practical alternative to

meaningless, short car trips. Many northern cities in Canada such as Edmonton, Saskatchewan and Montreal, could serve as examples where a bicycle culture is being developed. During a recent visit to Saskatchewan we actually found that this city had more good days for bicycling than we had in Copenhagen where bicycling accounts for 37% of the daily trips to work in the city. (And where 70 % of the bicyclists go on cycling through the winter.

Lastly a general advise for northern cities.
Instead of focussing on the bad, cold days of the year, look at the good, acceptable days. Actually there is a great majority of good acceptable, outdoor days. Enjoy!

Copenhagen, February 2014
Jan Gehl

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Also available in Danish, French, Russian & Chinese

# New Arctic Tectonics

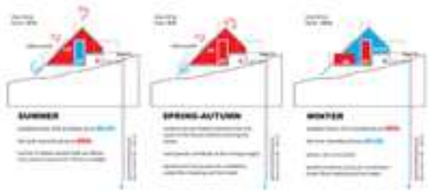
Jens Thomas Arnfred
Tegnestuen Vandkunsten, Denmark

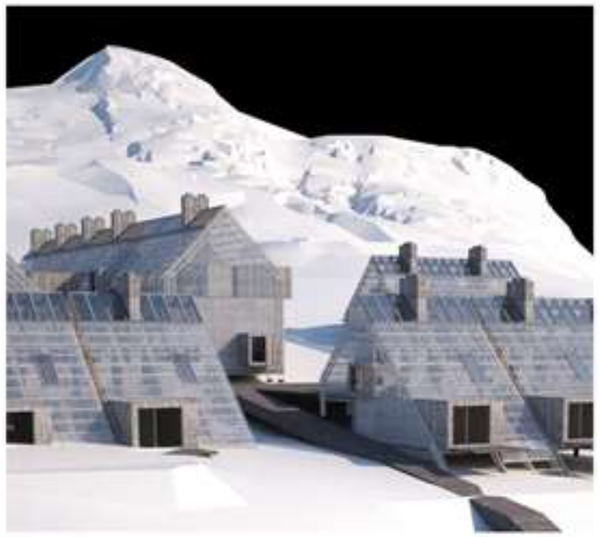
# NEW ARCTIC BUILDING PRACTICE

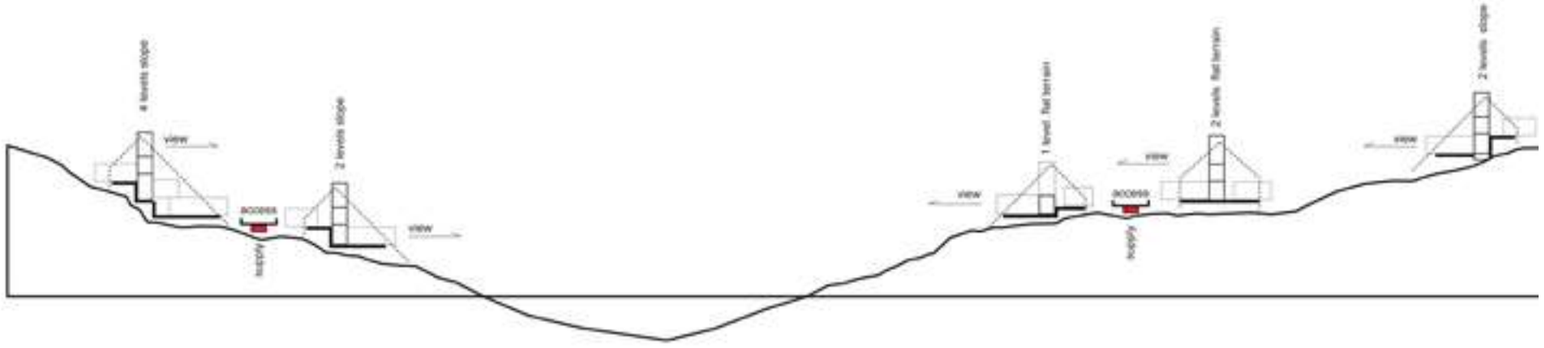
An Arctic building practise is not simply drawings. It's a method, a language, and a game of almost infinite combinations, and its figurations form a dialogue with context and needs - of today and those to come.

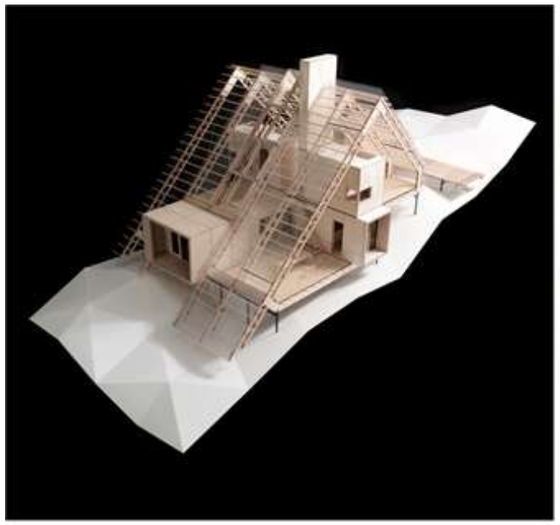
When we build, we occupy land. In Europe we sit on it, matriculate it, fence it in and entrench ourselves behind deeds and property rights.
In Greenland the mountain side is common ground, and we must live by other priorities. Greenland is experiencing growth optimism, but it's necessary to reach a sustainable balance. There must be resources for those to come, and our feet must be placed with the utmost care in the landscape.

Meaningful architecture grows when challenges are soberly observed, and when technical choices are made by gifted craftsmen. It's wrong that Arctic homes are built using the same template as in mainland Europe. It's outside the scope of architecture to make Greenland a happier society. However, one should expect thoughtful floor plans, a distinctive style, rich experiences, and efficient spaces that all contribute to a better quality of life.

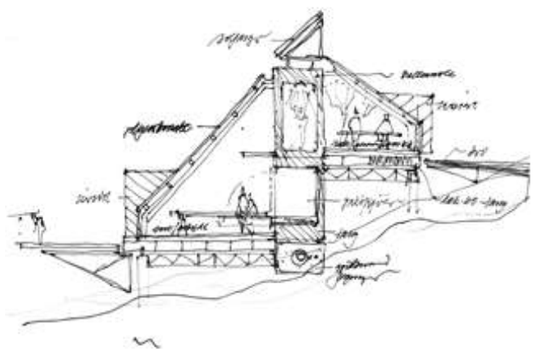


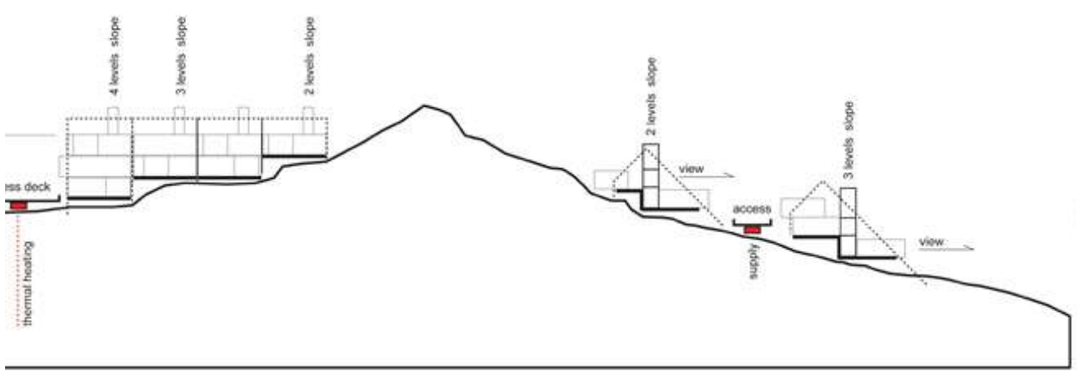



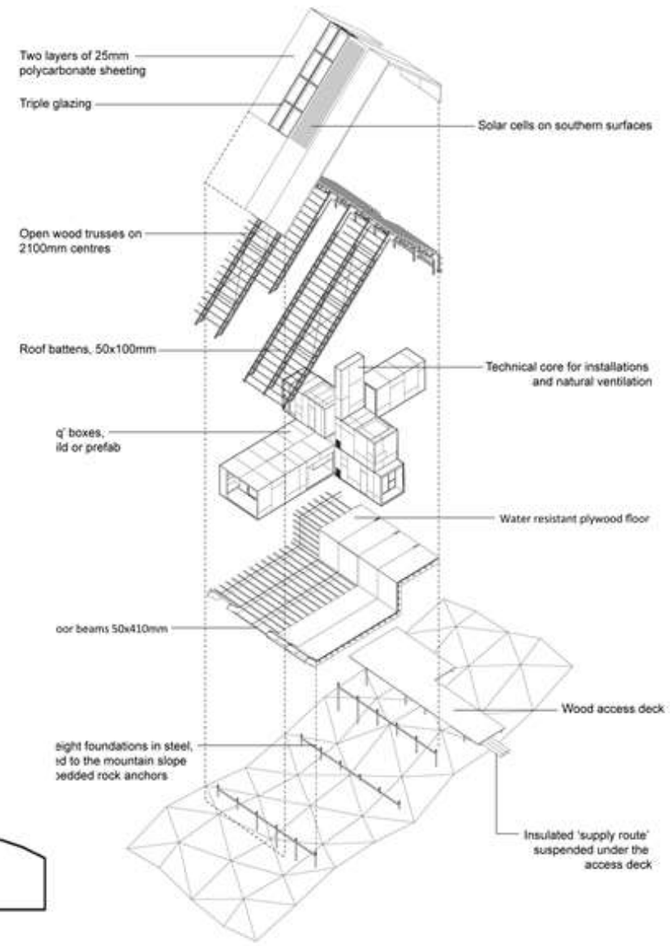




The architectonic elements are: The Lifeline, The base, The skeleton, The skin, The 'paqibiq' boxes. The lifeline is established with supplies, sewage, heat and water. The deck brings people closer together with sequences of narrow passageways, alleys and courtyards 'cultivate' the terrain and define a clear border to the landscape.

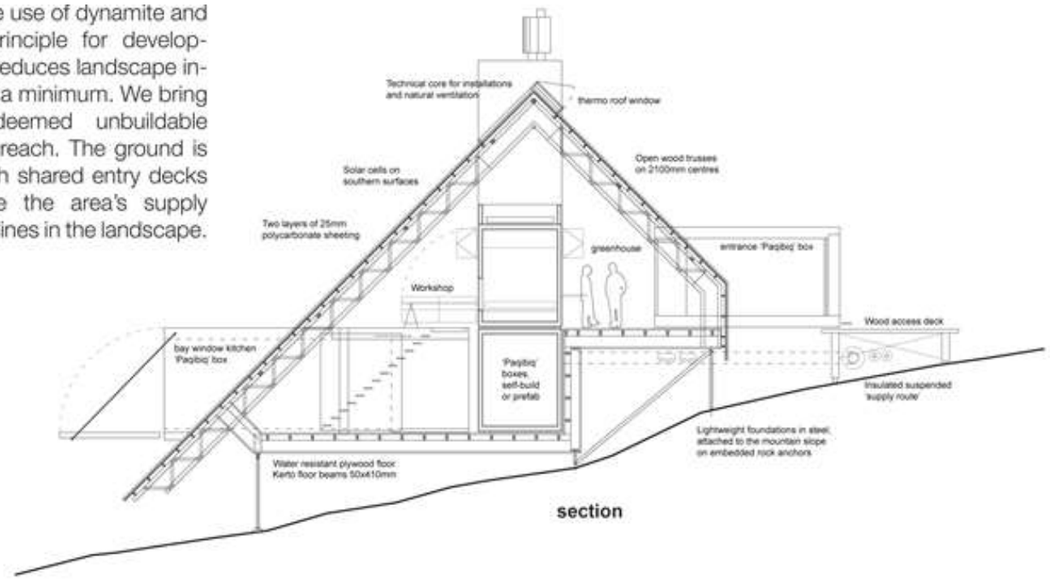




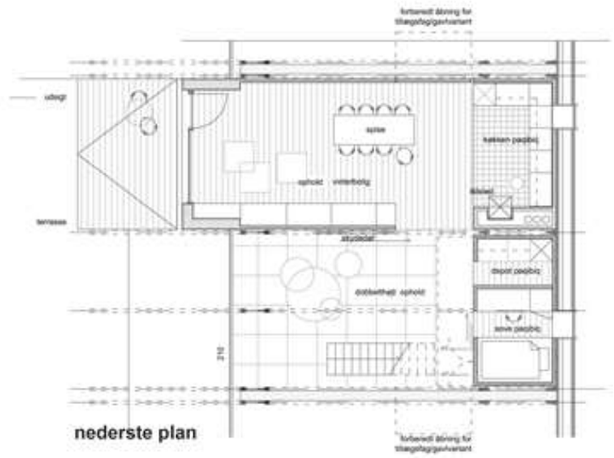

A system of construction only develops into a building practice when its qualities are adopted by those who use it and those who build it. For decades, a change to local hunting culture has increased the number of idle, unskilled hands. This point to a building practise which reduces the need for both craft and heavy machinery, a system which can be handled by small crews on difficult sites with a high degree of independence as was always the tradition in the north.

We forbid the use of dynamite and provide a principle for development which reduces landscape intervention to a minimum. We bring previously deemed unbuildable areas within reach. The ground is prepared with shared entry decks that become the area's supply route and lifelines in the landscape.




section

øverste plan



nederste plan

The base; lightweight foundation in steel, attached to the mountain slope on embedded rock anchors on which the building's floor in the form of seaweed-insulated, light floor slabs, is laid out. The skeleton is formed by partially prefabricated, open trusses, on which The skin, the climate screen, is mounted. It forms high-ceilinged, informal, coarse spaces under the lightweight canvas.
The 'paqibiq' boxes extrude through the facades as points of entry, sheds, balconies, and bay windows framing views. In here we place the basic functions, cooking,


THE LIFELINE - The deck brings people closer together with sequences of narrow passageways, alleys and courtyards 'cultivate' the terrain and define a clear border to the landscape

resting, storage and hygiene. The boxes define a clearer spatial hierarchy by making the small rooms smaller and the large rooms larger. They free up space for other purposes such as workshops, greenhouses and equipment rooms in the high-ceilinged, semi-climatized studio space under the translucent polycarbonate skin. Arctic housing must be able to handle strong light and inevitable darkness. The boxes can shut the light out and they can retain heat. The 'tent' is a transitional zone which holds 10-15 degrees C, and allows activities the climate would otherwise prevent.


the 'paqibiq' boxes

# Block P - and the G60 Policy

Bennetzen, Niels*

**Abstract**

Based on the observation made in the film by Rikke Diemer and Peter Jensen, this paper looks at the Phenomenon of Block P, which was for decades a landmark in the Greenlandic Capital Nuuk. At the same time Block P was a symbol of the concentration policies of the sixties called 'G60'. G60 was an initiative driven by the intentions behind the modern Scandinavian welfare society. It generated an exodus from the traditional settlements to the larger town such as Nuuk. Here, the traditional way of life was almost annulled in extreme, modernist housing schemes consisting of 100m long multistory blocks made of prefab concrete elements and offered to the Greenlanders as cheap, social housing equipped with modern comfort. The story of this clash of cultures is depicted in the film and further reflected on in this paper.

## Introduction

The story of Block P in Nuuk is described in the film by Rikke Diemer and Peter Jensen, and consultant Niels Bennetzen. It is the tale of one of the large modernist housing blocks made of prefab concrete elements that was supposed to help Greenland become a part of "Welfare Denmark." However, it ended up as the very symbol of the Danish administration of Greenland: The so called G60 Policy.

## Block P – and the G60 policy

The purpose of the G60 Policy was to rationally gather the Greenlandic population in the larger fishery cities. This meant centralizing the population away from the unprofitable, unhealthy and outdated hunting-societies in the remote villages and outposts –during a period of time from the mid-1960s, when the population in Greenland exploded.

### Block P – the Intentions

The answer to these challenges was the rational, prefabricated housing construction, which was supposed to immediately raise living standards and health conditions in the country. This as an urbanisation process that was also used in Denmark, for example in housing complexes such as Høje Gladsaxe and Brøndby Strand.

Hence, Block P was, for better or for worse, the symbol of a time of huge social and cultural challenges. But ultimately, it was the wrong building in the wrong place.

*Figure 1: Høje Gladsaxe is a large modernist housing project West of Copenhagen built in 1966, inspired by Le Corbusiers Unité d'Habitation in Marseilles, France which was built in 1952.*

The name "P" itself, is but a laconic statement of how far the Danish administration had reached in their efforts – Block A to O were completed on the "Tuujuk Plain", and there were already new plans for additional blocks from "Q"

onwards through the alphabet. Time would force them to resort to the series of numbers 1 – 10, because they ran out of letters.

**Block P – The Scale**

When the Block was constructed, during 1965 – 66, it was the largest construction in the entire kingdom of Denmark. It was one quarter of a kilometre long, and provided accommodation at one time for an entire 1% of the Greenlandic population.

It was referred to as being so depressing, that it itself was an attraction. But, as it was also put, Paris has the Eiffel Tower, London has Big Ben, and in Nuuk, we have Block P.

*Figure 2: When the Block P was the largest construction project of its time in the entire Kingdom of Denmark.*

When it was built, Block P was the dream of a building according to the standards of the time, with all the modern comforts, including daylight, fresh air, waste shafts, tap water, radiator heating, lavatories and state of the art kitchens.

The 200 meter long and five story tall monotonous, concrete and steel structure was tribute to "The Centralisation Policy", which later proved to be a source of large cultural and social problems.

**Block P – A Machine for living**

Life in Block P proved to be a social housing experiment on fast forward. The hypermodern living-machine was the ultimate symbol of how the construction techniques of the industrialisation could fulfil their promise to bring equality and wealth to the masses, and not only the elite.

Since then, it went wrong. And increasingly for more and more people, very terribly wrong. The switch from a hunter-fisher-sealer society in the small villages to the new city life in Nuuk had high personal and social costs.

**Block P – The demolition**

The maintenance of Block P was neglected and the common joy was replaced with a shared frustration. Family and neighbour disputes, drinking, theft, violence and vandalism were now part of everyday life, day and night.

Block P headed towards a slow but definite transformation into a slum area.

The most resourceful residents moved away, and suddenly Block P had such a bad reputation that demolition seemed more appropriate than an extensive renovation.
Even within a city with as big a housing shortage as Nuuk, demolition seemed to be the only solution.

## Conclusions

The transition from rural to urban areas created severe housing shortages during the mid-20$^{th}$ century in many countries. Large, highrise housing schemes made of prefabricated concrete elements equipped with modern comfort seemed to be a good solution and were favoured by many people in Denmark and elsewhere. Something must have been left out of the equation, and a large number of the schemes seemed to be almost creating social problems everywhere. However, when transplanted to Greenland, this set of solutions merged in the most unfortunate way with Danish administrative policies (G60) and created an explosive situation. It inflicted a complete turnover of thousands of years of Greenlandic culture and way of life whose

consequences are still rolling on. The dark side of the Danish Welfare System was revealed.

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Artek Event

ARCTIC TECHNOLOGY CENTRE

# Urbanisation and infrastructure in the Arctic
# Challenges to sustainability

**SISIMIUT, 7 - 9 APRIL 2014**

## Proceedings
## Peer Reviewed Papers

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# Kvanefjeld: Challenges for establishment and integration of a FIFO workforce

Emma Neale [1*]

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**Abstract**
The concept of enhancing socio-economic growth and development alongside best practice environmental protection has evolved significantly from the days of the Earth Summit held in Rio in 1992, to a commonly applied framework labelled 'sustainable development' today. The Arctic is becoming the centre point of growing economic potential through the results of climate change and technological advancements. There is also a realisation that there is, and will continue to be, substantial changes required regarding urbanisation, settlement patterns, and the strategies and solutions that will allow alignment of these developments with local communities. This paper will focus on south Greenland, and the town of Narsaq, where a globally significant mining operation is planned to be developed. Using the proposed scenario of an accommodation camp for fly-in, fly-out workers, some of the challenges of urban planning in the Arctic and the solutions needed to overcome these challenges will be explored. These will include how a mining company can integrate an introduced workforce, and associated infrastructure, with an existing community numbering less than 1,300 residents. And finally, the challenge of how urban planning design can facilitate social equality, positive intercultural interactions, sustainable living, and recreational activities that promote public involvement.

## 1. Introduction

Greenland Minerals and Energy Ltd (GMEL or the company) is a mineral exploration and development company operating in southern Greenland. The company is primarily focused on advancing the 100% owned Kvanefjeld multi-element project (both light and heavy rare earth elements, uranium, and zinc) through the feasibility and permitting phase and into mine development.

## 2. History and location of the project

The Kvanefjeld project area is located in Southern Greenland, approximately 10km from the town of Narsaq (see Figure 1) and is adjacent to deep-water fjords that allow for shipping access directly to the project area, year round. An international airport is located 35km away, and a nearby lake system has been positively evaluated for hydroelectric power.

Since acquiring the Kvanefjeld Project in mid-2007, GMEL has completed an extensive exploration and scientific research program which includes over 40,000m of diamond core drilling, geological modelling and mine design, metallurgical batch and continuous piloting test work, engineering design and the development of capital and operating cost estimates all of which culminated in a Pre-Feasibility Study being published in early 2012. This follows on from the extensive historical work conducted by Danish authorities and scientists in the 1970s and early 1980s, which resulted in a Pre-Feasibility Study being published by Risø National Laboratory (Risø) in 1983.

GMEL has also completed a flora and fauna assessment for the project area and a number of other environmental baseline studies which have been approved by the Mineral Licence and Safety Authority (MLSA). These studies were conducted by Orbicon, a Danish environmental consultancy company. A number of baseline data collection studies (meteorological, hydrological and air quality) continued through 2013, with final baseline data expected to be collected throughout 2014. These studies will form the basis of the Environmental Impact Assessment (EIA).

Social impact studies have also been progressing, with GMEL engaging the Danish consultancy company Grontmij to assist with the stakeholder engagement program and the development of the Social Impact Assessment (SIA).

In October 2013, GMEL announced that Greenland's parliament voted in favour of removing a long-standing zero-tolerance policy concerning the mining of uranium and other radioactive elements.

The timing of this decision has allowed GMEL to advance the Kvanefjeld Project into the permitting stage and toward mine development.


*Figure 1: A map of the location of Kvanefjeld in south Greenland*

## 3. **Description of the project**

The Kvanefjeld project will consist of an open pit mine, a concentrator plant, a port, accommodation village, tailings facilities, roads, pipelines and power lines connecting the various parts of the project.

The current proposed site layout breaks the project into three main locations, connected by process infrastructure and services. The proposed project layout is shown below in Figure 2.

The first location would be co-located at the Kvanefjeld mine site at the top of Narsaq Valley and would consist of the crushing, milling and flotation circuit (the concentrator).

The second location is the port and mineral concentrate packaging facility situated at Narsap Ilua. Concentrate from the concentrator would be directed here via a pipeline, and the port would be accessed from Narsaq by a 2.5km sealed road.

The third location is the new accommodation village for fly-in, fly-out (FIFO) employees, and would be situated on the northern outskirts of the Narsaq township.

There is a fourth component of the mine site layout which is not included within the scope of this paper. Two options are being assessed for the final location of the refinery, neither of which is considered in this article.


*Figure 2: Project layout for the mine and concentrator*

## 4. FIFO Accommodation camp Narsaq

**Why FIFO**

The fly-in, fly-out (FIFO) employment model is not a recent one, and in Australia for example, is commonplace for remote mining operations.

Typically, FIFO employment requires travelling to a mine site, (usually meaning long distances by air), and living on site for the duration of the rostered period before returning to the town or city of pick up.

There are many reasons that companies offer fly-in, fly-out (FIFO) employment, including:

- Attracting workers to remote and regional locations;
- Providing opportunity for short term employment of construction personnel without expecting them to relocate;
- Enabling companies to respond to changing labour requirements from construction to operation phases;
- Increasing access to skilled labour that might not otherwise be available in the local area.

In the case of Kvanefjeld, the decision to assume a FIFO workforce is based on the need for highly skilled staff not available in Greenland, requirements for large numbers of labour personnel particularly in the construction phase, and to alleviate, to an extent, the pressure of a large workforce on the small town of Narsaq.

In addition to a percentage of foreign employees on a FIFO basis, there will of course be a requirement for local resources both in the form of direct employees as well as many support services that are required for mine site operation.

**FIFO requirements**

As part of the Prefeasibility Study performed in 2012, GMEL considered the accommodation requirements for the project assuming a mine and concentrator only. The study assessed the personnel needs for the three phases of the Project:

- Pioneer phase – construction camp and basic infrastructure are established. Approximate duration of six months with personnel mainly FIFO with additional local employees and contractors estimated to total 450 individuals at peak requirement, and averaging approximately 300 employees;
- Construction phase – the mine is prepared for operation and processing facilities are constructed. Approximate duration of this phase is two years with mainly FIFO personnel and local employees and subcontractors estimated to total 1000 individuals at peak requirement, off peak 669 employees;
- Operation phase – operation of the active mine. The duration of this phase is indefinite. Personnel composed of FIFO (Greenlandic and European) and local employees estimated total approximately 450 individuals.

A detailed study was also undertaken on the accommodation requirements of the identified categories of employees based on where they travel from to work on site:

- FIFO personnel (foreign and Greenlandic workers living in the area only during roster periods, staying only at the FIFO camp)
- Locally recruited employees (employees recruited from the local area of Narsaq/ Qaqortoq/ Narsarsuaq and residing at the FIFO camp while on shift and returning to their house at the end of their rostered period).

There may be employees that wish to relocate to Narsaq from overseas and bring their families. While relocation packages will not be offered by GMEL, this is an option. The population of Narsaq has declined from approximately 3,500 to less than 1,300 over the past years. As a result there is existing vacant housing that could potentially be utilised.

In summary, the requirement for each phase varies considerably. The table below indicates the estimated numbers for labour requirements, and their accommodation requirements under each phase of the project. The actual number of employees

for the project is higher as workers living in Narsaq houses are not included here. This would include administration type staff who will return to their houses at the end of each shift.

| | Pioneer phase (peak) | Construction phase (peak) | Operations phase (average) |
|---|---|---|---|
| Locally recruited | 17 | 33 | 48 |
| FIFO Greenlandic | 17 | 100 | 20 |
| FIFO Foreign | 278 | 548 | 204 |
| Total | 312 | 681 | 272 |

*Figure 3: Summary of employees at accommodation village*

**Camp facilities and design**

The final details of the Kvanefjeld FIFO camp in Narsaq are not finalised. A number of considerations for the facilities and design are being compared and the benefits and impacts of these assessed:

- FIFO and residential staff onsite during shift;
- Support and administration staff housed in local housing separate to camp;
- Worker rooms to sleep two employees during construction phase, converted to single rooms during operation phase;
- All meals provided to accommodation village residents as well as support and administration staff;
- A zero tolerance to alcohol policy while on roster;
- Domestic waste and wastewater management for the accommodation village separate from services provided in Narsaq;
- Laundry/ cleaning services for worker rooms and communal ablutions;
- Transportation from the accommodation village dining hall (after breakfast/ dinner) to the mine site, as well as transfers from the airport;
- Recreational facilities including gymnasium, common room, television;
- Visual appeal of buildings that blend with the local style.

Rosters will range from 4 weeks on, 2 weeks off to 8 days on, 6 days off depending on area of employment and the resource needs during each particular phase.

While not necessarily recognized as infrastructure associated with the accommodation village, employees who move with their families will need access to schools, day care, supermarkets, clubs/ areas for social activities and sports (such as cinema, bar, meeting halls, cafes etc). Details of this will be explored further through the SIA.

Design and layout plans for the accommodation camp will also seek to make the best of its location, with views, sun and winds considered.

## 5. Integration and challenges for Kvanefjeld FIFO

Ultimately, the goal when planning and establishing a FIFO workforce within or nearby to an existing town, is for this to be a smooth transition, benefiting employees, employer, and the local community. Success can be measured on the social, economic and environmental benefits this brings to the host town. It has been shown that a 'social licence' to operate can carry more weight than a formally granted submission.

Strategies that have, and will be employed to overcome the challenges that integration of a workforce can present at Kvanefjeld, are outlined below.

**Stakeholder engagement**

Research and consultation with the host community has to be the first step in successfully integration of a FIFO camp in a remote host community.

GMEL has implemented a stakeholder consultation and engagement program with the purpose of keeping regulators and other stakeholders fully informed about the project. The programme includes meetings with the MLSA, NERI, SIK and EA,

community open days, key stakeholder workshops and public town hall meetings.

Identifying stakeholders and developing a comprehensive stakeholder engagement plan are essential in order to ensure that relevant parties are engaged in the development of the project. An effective engagement process enables stakeholders to consult and to participate so that they are in the best possible position to make informed assessments and decisions relating to the project.

The proposed location of the FIFO accommodation camp on the outskirts of Narsaq is as a result of feedback from the local community. Previously this was considered better located away from the town, however during stakeholder consultation meetings locals communicated that they saw benefits in having the camp located closer to Narsaq. Pending outcomes from the approvals process, this is now the preferred option for the location of the accommodation village.

How the camp is operated and managed will determine to what degree integration between employees and the residents of Narsaq will occur.

**Social cohesion**

Consideration of feedback from stakeholder consultation and using this to assist planning can optimise social, economic and environmental returns.

Planning that incorporates stakeholder feedback, along with collaboration with local authorities to develop facilities shows a commitment by the company to genuinely contribute to the host community. It also improves the likelihood of these facilities being utilised.

Economically, there can be many benefits to the establishment of a regionally located mine site with associated FIFO workforce. Likely areas that GMEL would assess for potential business partnerships include:

- supply of locally grown sheep, fish, agricultural products to supplement (and attempt to reduce) regular shipment of food for the FIFO accommodation camp dining hall;
- locally available support services such as trades for maintenance, sub-contractors etc;
- Encouraging interest in local artists, historical and cultural exhibits that increases profitability for these;
- Establishment of apprenticeship programs for trades associated with the mine.

Ensuring environmental planning is also undertaken at the FIFO camp also goes towards a mind-set that the host community is not a place to be taken for granted.

**Building a community**

In Narsaq, a town with less than 1,300 residents, the challenge will be to avoid a situation of us versus them with regards to attitude of both workers and residents moving to the town, or staying at the FIFO accommodation village.

Cultural awareness training is a commonly used tool to help guide acceptance of differences in cultures, traditions, and ways of living. At Kvanefjeld, this would be provided as part of the induction course for workers at the mine.

Providing opportunities for workers and their families to interact can be achieved through intercultural days, sporting events or other culturally significant days. Social events help develop and improve relationships and discourage an us versus them mentality.

**Home away from home**

Once FIFO workers are recruited, it is then a challenge for companies to retain employees for the required duration, avoiding high turnover rates as much as possible. Accommodation standards and facilities, recreational facilities, access to telephone and internet, organised activities and level of interaction encouraged between employees while not on shift will have an effect on how at-home each individual feels

and this can impact the length of time they stay.

Meeting this challenge of retaining staff also relies on education. In a part of the world where FIFO employment is far from common, understanding the hours involved, the change of lifestyle, lengthy periods of time away from family and friends, and changes to routine will all go towards ensuring less of a shock to new employees.

To assist with supporting worker's wellbeing, strategies can be implemented so that all workers can experience a high standard of living conditions:

- Creating behavioural standards such as no noise after 10pm;
- Locating night shift worker rooms away from communal areas within FIFO camp to minimise sleep disruptions;
- Support for families of workers at camp.

## 6. Conclusions

The development of a large-scale project such as Kvanefjeld will require effective consultation, planning and ongoing monitoring to be successfully integrated into the small community of Narsaq and south Greenland.

Some of the challenges of integrating a FIFO workforce with Narsaq are; avoiding an us versus them culture, creating a common attitude of acceptance to differences in backgrounds, developing a platform for common interests and for relationships to grow, and creating a working environment and home-away-from-home that is first capable of attracting skilled resources and also capable of retaining them for the duration required.

The Kvanefjeld Project is expected to benefit Greenland for many years by providing well paid jobs, corporate and employee tax obligations, and positive financial growth and increased job opportunities. In turn, this can improve living conditions such as housing and education and overall improved lifestyle for those directly employed, indirectly employed, and the positive flow-on effects from these.

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# Sustainable planning of the future north - a subversive approach

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## Abstract

Increasing pressure on northern landscapes and societies from external forces of climate change and global pursuit of natural resources, calls for new and experimental approaches for understanding the landscapes and its on-going processes. The way in which we chose to handle the current situation is crucial and demands 'hands-on' knowledge and alternative solutions in urban and landscape planning. Decades of imposed colonial planning with poor quality modernist architecture has shown its weakness, and the lack of rights for the inhabitants to determine their own future is evident. On the basis of research and architectural practice performed by 70°N over a period time and in varied contexts (competitions, commissions, master studios and research studies) we will discuss the present situation, and the lack of contextual understanding of the northern landscapes. Furthermore, two main cases Maniitsoq, Greenland and Kiruna, Sweden are used to cast light on the complex conditions and the overlaying interests in the landscape, and to discuss the need for a subversive approach towards sustainable planning of the future north. Maniitsoq is an isolated Greenlandic city of approximately 3,000 inhabitants. It faces a challenge of cataclysmic dimension through Alcoa's plans for a new aluminum smelter close to the city - challenging urban structures and density, democracy, cultural integrity and demography. Kiruna is the most significant symbol of mining in the Arctic. The imprint of the mine overshadows any other interest or investment, and has now reached the point where the city centre has to be moved to enable a continued extension of the mining activity.

## 1. Introduction

Most northern and arctic cities are isolated in a larger landscape, constructed on the basis of one predominant industry such as: one mine, one factory (metallurgic industry), fisheries or military activity.

*Figure 1: Metallurgical industry in Nikel*

Even today, after decades of strong post-industrial changes in world economy, industrial structures and demography, these cities are, to a large extent, highly dependent on a few essential sources of income. This means that they in turn are extremely vulnerable for further fluctuations in global economies and of climatic or environmental changes. Taken into account that most northern cities are considerably small - mainly below 10-15,000 inhabitants, and not exceeding the size of 100,000 inhabitants, (with the two exceptions of Murmansk (300,000 inhabitants), and Norilsk (175,000 inhabitants)), they are often highly affected by macro-structural transformations. This, in addition, to a skewed gender distribution is due to the prevailing mono industries. Many of these cities experience difficulties maintaining a healthy demographic diversity.

## 2. The belief in the modernist superiority

The last 100-150 years of implemented urban concepts in the north are seemingly a transfer of technology, architecture and urban patterns known from other provenances and imposed in an endless endeavour to conquer and civilise through urbanisation. An underlying colonial belief in superiority over local knowledge and conditions, has resulted in town planning that has shown little creativity, sensitivity, ability or desire to develop urban structures on the premises given in the landscape, or on the terms of local, social conditions. Lefebvre (1996) discusses the legitimacy of planning in the light of what he calls the practice *to inhabit,* and emphasises the establishment of *highly localized, highly particularized and centralized units* to re-establish an urban unity. Lefebvre (1996) warns against a pretentious expert regime that is not in contact with real life and experience, and can easily be cited in support of a critique of a modernist notion of superiority and (quasi) scientific beliefs:
*Architects seem to have established and dogmatized an ensemble of significations, as such poorly developed and variously labelled as 'function', 'form', 'structure', or rather, functionalism, formalism, and structuralism. They elaborate them not from the significations perceived and lived by those who inhabit, but from their interpretations of inhabiting. (...) their system tends to close itself off, impose itself and elude all criticism. There is a cause to formulate these systems, often put forward without any other procedure or precaution, as planning by extrapolation.* (Lefebvre, 1996)

### 2.1. The arctic utopia

The few examples in architectural history of experimental approaches towards arctic urban planning show a tendency to turn the northern or arctic city into an urban utopia through an idealisation of a 'pure life' under harsh conditions. Well known examples include Ralph Erskine's prospect for Resolute Bay (there are several buildings made by Erskine in Kiruna), or Frei Otto's generic 'proposal for an Arctic City'.

*Figure 2: Resolute Bay illustration by Ralph Erskine, 1958.*


*Figure 3: Frei Otto with model of an arctic city under an air conditioned container structure of plastic roof nets, planned for 15,000 to 40,000 citizens, 1971.*

Erskine's example (among several of same typology) shows enclosed assemblies of buildings - like wolf packs gathering intimately to protect against the harsh outside. Likewise, Frei Otto includes in his concept for an arctic city the notion of the unfriendly arctic conditions to the extreme and proposes a huge dome covering the whole city to provide a total climate control for the inhabitants. The ideas represented in these utopias show an absence of understanding of the context in order to live with and develop life in accordance with the natural given conditions.

Instead, they carry an underlying notion of a western, modernist culture versus nature battle, where Man has abandoned a tradition of interaction with nature in the sense of being part of nature, and ascended into a state of distance or superiority to nature. As Latour (1993) expresses:

*We* [the modern western man] *are the only ones who differentiate absolutely between Nature and Culture, between Science and Society, whereas in our eyes all the others - whether they are Chinese or Amerindians, Azande or Barouya - cannot really separate what is knowledge from what is Society, what is sign from what is thing, what comes from Nature as it is from what their cultures require.*

The criticism of western modernism can be applied to the late 20th century urbanisation (urban colonisation) in the north; with its distancing from inherited knowledge about living in the landscape under its given natural conditions. It represents a forgotten knowledge in Western civilisation since the enlightenment with a lack of improvisational skills and an open-minded ability to adapt to the unforeseen spatial changes applied to the landscape from annual cycles, shifting time and the complexity of what is inevitable to become (with or without the will of man). De Landa (1999) expresses the impact of mankind:

*[U]nlike social constructivism, which achieves openness by making the world depend on human interpretation, Deleuze's approach achieves it by making the world into a creative, complexifying, problematizing cauldron of becoming. Because of their anthropocentrism, constructivist philosophers remain prisoners of what Foucault called the 'episteme of man,' while Deleuze plunges ahead into a posthumanist future, in which the world has been enriched by a multiplicity of nonhuman agencies*.

## 2.2. The failure of arctic modernism

The concept of modernism in this paper refers both to structural ideology, and as in the following to an unconscious town-planning strategy and summarily repetitive implementation of standardised low quality housing blocks.

*Figure 4: Danish modernism imposed on Greenlandic landscapes, Maniitsoq.*

*Figure 5: Wind-accumulating urban structure, Murmansk.*

In Greenland everyone knows the tragedy of the 'Danish' modernist blocks, which were implemented in every small town or village from the 1960s. Likewise, everybody knows about the inevitable *Khrushchyovka* - blocks named after the Russian First Secretary Nikita Khrushchev; a standardized, scarcely insulated, concrete element-housing block built in a number of several million apartments up until the fall of communism.

Figure 5 and 6 illustrate these buildings that are poorly suited for cold weather conditions and not at all adapted to the sometimes harsh climate conditions in the arctic. This counts for both lack of adaptation to local needs and practical use of an apartment due to an absence of understanding of local traditions and social conditions. This allows for a poor indoor climate with the consequence of health risks due to poor

knowledge of building physics with the result of condensation and mold formation, and not in the least it creates high heating costs due to lack of insulation and absence of environmental responsibility. In addition to these challenges of un-sustainability, the rigid modernist housing block, as typology, has shown difficult to place in challenging arctic topographies and terrain with marshes, slopes, rocks and even permafrost. Since the northern and arctic conditions can be highly different and notoriously shifting regarding physical challenges and climate, the modernist buildings often appear alienated and out of proportion in the landscape.

Likewise, the modernist block may cause severe challenges in an arctic urban plan with the danger of channeling wind along rigid building bodies and wide open streets. Wind turbulence might occur over roof tops and create substantial difficulties in providing outdoor spaces sheltered from wind in the summer time. Instead of understanding of the local wind conditions and of making use of the wind to clean streets and walkways for snow during wintertime, unconscious planning in areas with large snow drift might create severe unintended and uncontrolled snow accumulation.

### 2.3. Living in the landscape - extended arctic urbanity

Despite a predominant modernist approach towards urban planning, inhabitants of northern cities seem largely to define their urban lives to a much larger territory than the limitation of the actual city. This means that they define their lives in relation to the shifting seasons in the surrounding landscape (the time spent with different leisure activities), the changing light conditions and the cyclic shifts in nature production (fishing, berries, hunting etc.) to a much higher extent than what is often considered. In northern Scandinavia and northern Russia, the coastal landscapes are affiliated with the fisheries in the same way the inland plateau is defined through long traditions of indigenous practices like fishing, hunting and reindeer husbandry. These are practices that in many cases have shaped cultural encounters that have opened for extended cultural understanding and acceptance, and bears the potential of proceeding into a continuous urban renewal.

The traditional sámi habitation of the landscape, which is dominated by nomadic reindeer husbandry, was not limited to a defined site or single building, but encompassed the entire landscape where the reindeer pastured and migrated. Even in the present condition of permanent sámi settlement, the reindeer husbandry communities like Kautokeino have adapted a habitation structure of scattered buildings, outdoor storage and outdoor handling of practical tasks (slaughter of reindeer and processing of food and hides and handicraft production), developed in a larger landscape into the settlements. Transportation/communication lines (connected to livelihoods) that are directly connected with lines in the landscape, penetrate the settlement, and extend the community territory into a larger landscape. In addition a high level of integrated nature in the inhabited areas is retained.

## 3. A renewed arctic urbanity

Experiences from traditional knowledge about the landscape and its practices, form


*Figure 6: Eight seasons of the sámi landscape - time, space and practice connected.*

the foundation upon which we do research. A legacy of arrogant colonial occupation, significant examples of implemented low standard modernist architecture and additionally predefined urban patterns amplify the need for research and experimentation. Adding environmental challenges and climate change, globalization and growing industrial economic pressure, an open and participatory based renewed understanding of arctic urbanity is required.
In the following we will use two examples from our research and practice: Kiruna, Sweden and Maniitsoq, Greenland to emphasize and highlight crucial concepts connected to a future, sustainable arctic urbanity.

### 3.1. Kiruna - a key example of a constructed modernist city

The mining town of Kiruna was founded in the beginning of the 20th century. Today's population of nearly 20,000 inhabitants has a considerably short history and consists of a population dominated by immigrants (first, second or third generation) to the landscape, originating from all of Scandinavia, but primarily from northern Sweden.
Our relationship to Kiruna has been developed through participation in the international architect competition in 2012 about relocation of the city due to expanding mining activity under the existing city centre. Initial fieldwork consisting of time spent with people in the city and its surrounding landscape, and conversations with the population about daily life, shows significant opinions about the city, the city life, their relation to the mine, which are closely connected to opinions about the mining company, and the integrated relation between the use of the city and the surrounding landscape. Together these aspects form a self-determined vernacular Kiruna identity.
To begin with, all roads lead to the mountain/mine. In all public buildings at the end of streets, there is an opening, whether a view, or a window, that is towards the mountain or the mine. When speaking to people, this is one of the aspects they point out, ''det är en bergstad'' – *it's a mountain city* (70°N, 2012).
The experience of life in Kiruna and the stories told by people describe a contradictory city, both introvert and excluding, yet also welcoming at the same time. The city itself rests in the landscape, with the nearest city 120km away, which means that the inhabitants are continuously using and interacting with the landscape:

*After breakfast, Tuomo drives me over with the boat. I have an appointment to go hiking with Niklas. His cabin is not far away, and we are going back to Kiruna on Monday morning. Only a 35-40 minute drive from Kiruna. A couple of years ago, Niklas moved out to the cabin with his two kids. He rented out his house in Kiruna. They lived their everyday lives here, with no running tap water, no electricity, and were happier than ever. Driving in to Kiruna every day to go to school or work, really didn't seem far. «We had so much time in everything we did. Time to be together, time to play boardgames, time to really talk to each other. There was another closeness in our relation. It's one of the best things I've done.» His cabin is really impressive, both in*

*terms of its placement in the landscape, and its design. It was drawn by some architect in the fifties, and the living-room window offers a panorama of Nikkaluokta and Kebnekaise (...) Every man seemingly knows how to handle a chainsaw, to drive a scooter, to replace a fireplace, to construct a cabin, to fix a car, to shoot an elk, or how to catch a fish.* (70°N, 2012)

Most of the people living in Kiruna have a close relation to the surrounding landscape, through their cabins, which most people have access, through leisure activities and through harvesting of the land's resources like salmon from the river.

*We are invited to Henrik's place for dinner. He has prepared salmon he has caught himself for dinner, together with potatoes and a sweet-and-sour sauce mixed with turkish yoghurt (typical sámi food...). (...) For dessert he serves cloudberries, picked by Henrik's mother on the «lapplandske vidder» (...)*
*«Why we live in Kiruna… You ask yourself the question...what is it actually that makes you want to live here? Being close to the nature is one of the most important things, and living here, outside Kiruna, you can walk out the door, and you are in it. (...) go fishing in the middle of the night, the silence....»* (70°N, 2012)

The fieldwork conducted in August 2012, *Kiruna Stories* (70°N, 2012), forms the foundation for our entry in the competition and gives crucial insight in the mindset of the inhabitants of Kiruna, which in turn is of vital importance for our response to the competition brief. Our most fundamental methodical approach is to make brief but thorough investigations related to concepts and findings in the landscape, and always make a contextualization of the concepts on the basis of people's everyday life, their experiences and their wishes for a new city. We find Lefebvre's vision of the right to the city as a transformed and renewed right to urban life a universal approach to urban life, highly applicable to Kiruna (Lefebvre, 1996).

*Lefebvre's vision of the right to the city is therefore one of radical transformation of urban social and spatial relations. It would transform both current liberal-democratic citizenship relations and capitalist social relations. First, the dominant model of citizenship is entirely upended by the right to participation. Lefebvre's idea entails much more than simply returning to or enlarging the established liberal-democratic citizenship structures in the face of governance change.* (Purcell 2002)

If the inhabitants are to have a right to participation, facilitating institutions must be created and institutional right to participation introduced, which in turn will change the concept of planning, and the governing system that is commonly accepted today. This counts for an acceptance of the complexity in landscape and society, and a methodical approach to handle and to make use of complex knowledge in planning of new urbanities.

### 3.2. Concepts for investigation and transformation

**Time, landscape and practice**

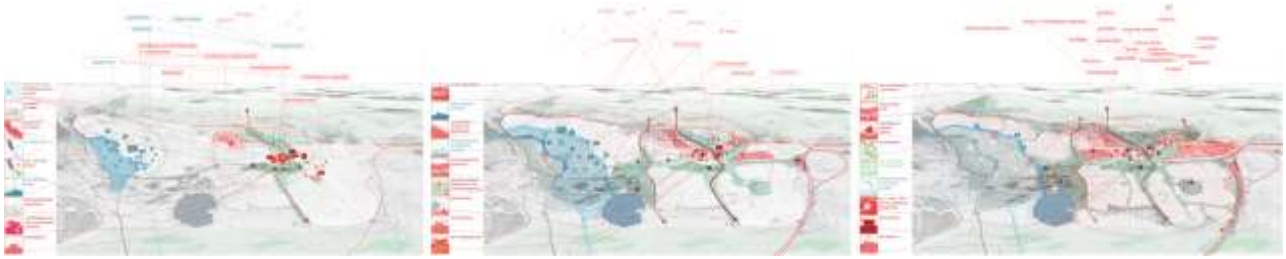

*Figure 7: The new - new programs in existing context / existing objects in new context / new programs in the new city centre / happenings and acts of attention, adieus and establishings in the old and the new Kiruna.*

*There is a crack in everything, that's how the light gets in* is our entry in the competition. The city of Kiruna has existed for a hundred years in the paradigm of the

mine - now a new space of action is unclosed where the city can be transformed into a confirmation of an identity the citizens have supported for a long time - as residents in a vast, eternal and coherent landscape. The people of Kiruna define their territory independently of the city's boundaries and relate their lives to multiple places in the landscape, depending on time, activity and season - as the inhabitants of these mountainous areas have always done. The everyday practice forms the landscape, and the lives of each particular is mutually influenced by the landscape and its coexistence with the city.

**Movement, re-use and borders**

The border is proposed as a dynamic territory, more than just a demarcation between now and then, here and there. The abandoned Kiruna contains a unique story of processes and economy that will forever be intertwined with its future. The retraction is going to happen over a large span of time

*Figure 8: the border - interacting with the existing, activating it before abandoning.*

coincidental processes, where programs and buildings are constantly reinvented, repositioned and reshaped. The proposed concept of *spaces of action* represents openness, activity, participation and democracy. The relocation of the town hall

*Figure 9: The entrained - iconic items of nostalgia: mapping the existing / archives for the future / present history.*

offers a unique opportunity for the municipality to, in a close collaboration with the citizens, plan and prepare the emerging Kiruna and to be present in its own future.

**Gaps, existing and new**

Under the label *nostalgia* we propose to create an archive of artifacts in categories such as: *everyday, icon, contour, tactile* and *message*. The existing is being noted, discussed and proposed a possible future: inscribed in a new context, as a memory documented, archived or preserved - always linking both back and forth in time, coexisting with what is to come, enshrining the new in the known - letting its history be touchable, visible and accessible.

The diversion of the E10 liberates space in the new city centre that, freed from heavy

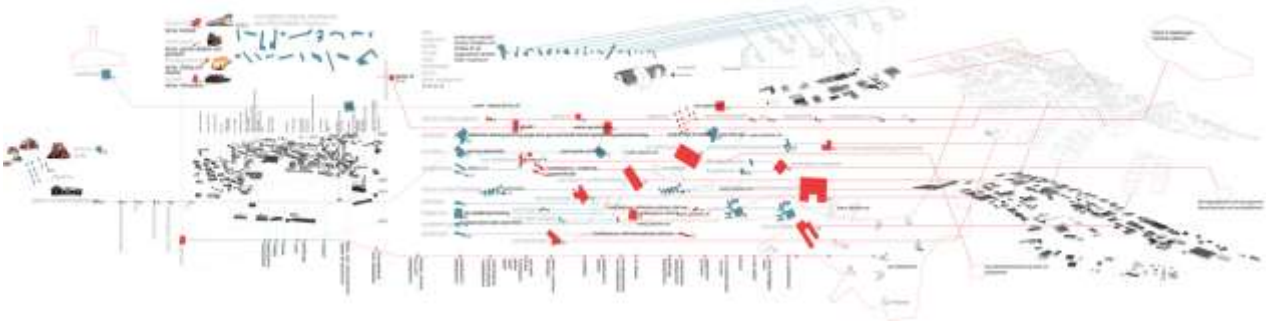

*Figure 10: The move - a city inventory: programs, buildings, functions to relocate, reinvent, reinforce, replace.*

with necessary flexibility and humbleness towards the existing and what is left behind. The reconstruction is an experiment to be created and developed through several

traffic, can transform into a new nature heart of Kiruna. Here we propose an act of *premature gratification* - a sauna as the very first gift from the new Kiruna to its

population, being a point of departure both for imagining the new city, and a catalyst for developing its new centre and recreational infrastructure. The gap represents an opportunity to act in spaces of otherness and chance, both in time and space. Being hands-on, a democratic process demands a relocation and regeneration of 'vast' city space into a new vibrant city centre. By densification and remodeling of the existing, a new compact city will emerge that is interconnected and offers a closer connection between the city centre, the city nature and the vast surrounding landscape.

**The city, everyday life and movement**
Everyday life will transform, and be transformed by, the use of the city. It can lead into more dynamic, sustainable and enjoyable patterns of movement and transportation. By reinforcing the existing qualities and adding new programs, excitement and variation is provided in the city-close nature network - providing and connecting activities and venues, making them accessible all year around - and creating a compact city with multiple, parallel possibilities of movement: ski, snow mobile, bike, or dog-sled. Attractive spots create new habits, movements and nodes, integrating the new centre as an active part of the inhabitants' everyday life from the start - emphasizing the city's connection to the landscape, and the landscape's presence in the city - in an everlasting coexistence.

*Figure 11: New everyday life - integrated movement, landscape, items of nostalgia.*

## 4. Post-colonial Arctic

Greenland is today one of the most attentive landscapes in the north regarding resource extraction. Greenland has become a focal point for global economic interests due to increasing demands for oil and minerals, but also through the melting of the inland ice as a visible consequence of global climate changes. In this context of new global attentiveness and national post-colonial enlightenment, large parts of the island is laid open for future industrial commodification.

### 4.1. Maniitsoq - a symbol of change

In 2009, 70°N was invited by the local government of Qeqqata kommunia to conduct a dialogue based study of the city of Maniitsoq. Maniitsoq, a medium-sized Greenlandic city with 2,800 inhabitants located on a western coastal island, is relating to a total population of 57,000 scattered on an ice-free land area approximately the size of Sweden. Maniitsoq is a shrinking city after a flourishing fishing industry in 1980-90, and has through a long political process been chosen to possibly locate Alcoa's latest planned aluminium smelter, run on hydro electrical power from melting water. The project would have an extensive impact in the landscape with reservoirs, transmission lines, roads, harbour and a new industrial area.

**The global context, political landscape and paradigm shift**
The discussion about the location of the smelter in Maniitsoq adds to a broad debate about Greenland's future, also including the issue of independency from Denmark, and has triggered an ideological battle concerning which type of economy the country should build its future on. Opening for mining, oil and gas exploitation means a paradigmatic shift for the landscapes of Greenland that is absolute and irreversible, and will forever change the possibilities for the inhabitants to run traditional nature based households and hunting. The Greenlanders interconnected use of the landscape carries a complex cultural heritage and defines to a large extent the Inuit identity. The fact that all settlements

and cities in Greenland are considerably small and separated, without road connections or other 'democratic infrastructure', amplifies the challenges of an extensive industrialisation.

**PODs, process and citizen participation**

As a method of survey, planning and preparation we have introduced the term 'Points of departure' (PODs) (70°N, 2010) to reflect upon the present context and the initiation and starting point of a further development. PODs are elements of inherent information or added knowledge that become incidents of opposition or resistance that the city must relate to, acknowledging that it needs dynamism and disturbances to be interesting and vibrant. The inhabitants are in general positive to the aluminium plant and consider the future of the city dependant on it. To be able to approach the complex issues at stake, we have worked closely with the inhabitants to transfer deep

*Figure 12: PODs - places designated as comprising particular qualities, becoming a whale watching path as a premature gratification to the population.*

knowledge about life in Maniitsoq, and to hope and wants for their future city.

*Figure 13: Density - the partly abandoned harbour is proposed as an area for densification and flexible programs.*

**Density, programming and flexibility**

We have surveyed typologies, city structure, topography and infrastructure, and proposed a flexible and dynamic strategy that also considers the possibility of a future - even without the smelter. The strategy prepares some of the easily accessible areas in existing Maniitsoq for development, with a low threshold for fast development. Densification of the existing city is a highly sustainable way of development providing a better integration between the new and the existing housing, services and new institutions, and the strengthening of the obvious qualities in the city and the small-scale landscape.

**Legacy, dwelling and working with the existing**

*Figure 14: Legacy / dwelling - the habitations relate to the exterior landscape, facades and surroundings being used for storage, cooling, drying skins, meat and clothes, suspending skis and sleds, antlers and general decoration.*

*Figure 15: working with the existing - taking traditional use of outdoor space as a potential to use actively in the restoration of the deteriorated modernist blocks, to add variety and diversity and to transfer a pragmatic element to an architectural expression - calling this the concept of inside out.*

Maniitsoq has an ambition for cultural integration, urban development and a future

*Figure 16: dwelling - proposal for new housing at the heliport of Maniitsoq; adapted to site specific topography, climate and view, facilitating for traditional practice, making use of the concept of inside out.*

architecture that can reflect the qualities of Greenlandic tradition, and provide attention internationally. This includes a considerate treatment of the landscape, reuse and renovation of the existing, continuation of a historical heritage and modernisation of cultural iconic expressions. A specific attention has been directed towards restoring of the decayed modernistic housing blocks, to turn them into habitations that are relevant and sustainable both technically (e.g. insulation), socially/culturally (e.g. typology and use) and contextually (e.g. view and microclimate).

## 5. Conclusions

Research and practice has clearly shown that there are possibilities for development of new methods for planning, urban development and renewal in the north. The different conditions and fast vicissitudes demand a deep contextual awareness for inherited knowledge in the landscape. At the same time decades of imposed colonial governance and additional implementation of standardised poor quality modernist architecture, demand a new consciousness for democratic planning processes acknowledging the inhabitants knowledge, needs and wishes, historical legacy and actual use of the space, and basically *their right to the city.* This complex reality opens for new experimental planning processes where the landscape and the people in the landscape tentatively always will be in the front.

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# Citizens and the planning of sustainability of mining

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This paper is a work in progress. Comments and suggestions are welcome.

## Abstract

Greenland's strong political desire to increase self-rule and economic independence from Denmark requires new sources of income and diversification of the economy. Mineral resources and urban centralization are promoted as the key instruments for creating economic independence. This transition will have a large impact on the citizen's everyday life through the ongoing changes of settlement patterns and livelihoods.
The key question of this paper is how the citizens may inform and influence the sustainability of planning and implementation of local raw material projects and urban planning. Further, the paper explores the ongoing development based on theories of democracy and on capacity building. The paper aims at supporting participatory practices in the ongoing transition of the arctic societies by developing the knowledge basis and promoting further research in the field. The paper concludes that the social, economic and environmental sustainability will depend on the degree to which the citizens are engaged in both local developments of specific mining projects, as well as in societal planning where multiple and complex issues are at stake such as urban settlement patterns, cultures, livelihood, jobs, educations, environment, globalization, and intercultural encounters.

### 1. Introduction

Greenland's strong political desire for increasing self-rule and economic independence from Denmark requires new sources of income and diversification of the economy. (Skatte- og Velfærdskommissionen, 2010).

Mineral resources and urban centralization are promoted as the key instruments for reaching this economic independence (Råstofdirektoratet, 2009; Råstofdirektoratet, 2011; Naalakkersuisut, 2011). This transition will imply radical changes on urbanisation and livelihoods and thus impact the citizen's everyday life on a local scale as well as on a societal level (Hendriksen, 2013). As explained by Anne Merrild Hansen in a report on community impacts, debates and decisions are decisive in securing social benefits for Greenland:

*Extractive industries will potentially influence the Greenlandic society dramatically in the future and decisions regarding the development will form the base from which the future society will be built. It is therefore important to debate if and how the development can be formed to benefit Greenland society more broadly*. (Hansen, 2013 pp.19)

A large consensus on the importance of public participation in development can be identified in the Greenlandic contemporary debate in relation to mining projects. However, concurrent critiques have been voiced about the lack of transparency and ways of getting influence. For example, as summed up recently by the *Committee for Greenlandic Mineral Resources to the Benefit of Society:*

*Insufficient, late and overly narrow public participation are major themes in the*

*decision phase of natural-resource projects. (Rosing et al. 2014, pp.30)*

This critique is similar to critiques of mining activities in many other parts of the world, as well as in debates and activities relating to participation in societal development in general (United Nations Economic Commission for Africa, 2004; O'Faircheallaigh, 2010) In this way, the challenges that Greenland faces within the field of developing public participation as part of a sustainable development are related to a more general global quest.

Furthermore, the concepts of public participation should not be seen as a taken for granted or static concept. Neither methods nor objectives for participation can be perceived as universal strategies to fit all societies and situations. Rather, perceptions and practices should be subject to ongoing critical reflections, debates and developments in the specific contextual settings. Thus, the paper aims to support this effort by exploring the existing strategies and experiences in Greenland and by pointing to the need for developing new ways to engage the citizens and local communities in the planning and implementation of raw material projects as a central element of sustainable development in Greenland.

The paper ~~is taking~~has an exploratory approach. It is not based on a systematic survey of participation in Greenland, but includes material from other surveys. The aim is to present a basic theoretical framework for exploring the existing strategies for participation and point to the embedded values, objectives and problems to be dealt with to develop the strategies. Also, I want to state that the concepts of democracy, participation, government and governance are central elements of complex scholarly fields and debates among practitioners and researchers. This paper does not have as an ambition to contribute to these, but to take some of the concepts and discussions to support the ongoing development in Greenland. In this way, this paper is just one step that needs to be taken further.

As an analytical framework, the paper is based on concepts of democracy and capacity building from the governance and planning literature. Two fundamental approaches to democracy from the literature are being presented: the representative (aggregative) democracy, and a more deliberative model. By introducing these very basic concepts into the ongoing process of planning and implementing mineral strategies and projects, the paper aims to discuss the objectives and ways of the ongoing participatory strategies and point to some ways of developing these. A model for institutional capacity that includes social capital, political capital and the capacity to mobilise is suggested to underline the diverse objectives when discussing participatory approaches.

Following the above, section ~~two~~ 2 explores the approaches and objectives in the existing participatory strategies in Greenland, based on the outlined concepts of democracy. The paper focuses on cases from the planning of mining activities and the related strategies pushing for urbanisation. This exploration identifies a need to clarify the objectives of participation in order to support the concrete strategies of participation. The section then points to the problem that the dominant formal approach to participation in the mining projects based on tools such as Social Impact Analysis (SIA) and Environmental Impact Analysis (EIA) are not sufficient for addressing the challenges of engaging the citizens in the sustainable development of Greenland.
This creates the outset for the third section, which focuses more broadly on the need for capacity building. The concept of institutional capacity is used to explore and propose new approaches to mobilising the resources necessary for realising sustainable development. Finally, section ~~four~~ 4 concludes and outlines future experiments and research.

## 2. What are t~~T~~he objectives of public participation?

The concept of public participation is very often used without being explained and its

positive meaning taken for granted, which may hamper the development of ongoing strategies (O'Faircheallaigh, 2010). And just as often, the concept of participation is used interchangeably with the concept of democracy. Consequently, there is a need for clarification and discussion of the meanings of the concepts of democracy and public participation that are used in contemporary Greenland as well as more generally. Not least will it be fruitful to discuss what objectives are embedded in the use of the concepts.

### 2.1 Rights and rational planning

The representative government structures that are dominant in Greenland are not very different from its Danish counterparts, and are also similar to that which can be seen in many European countries, even though there are contextual differences. This also applies to the strong rational planning approach that has been implemented during both the home-rule and self-rule (Janussen, 2003 pp. 40). Examples of this can be seen in the physical and sectorial planning system as well as in the planning of mineral projects.

Fundamental to the representative democracy is that citizens elect some political representatives to defend their views, and politicians are in this context democratically legitimate decision-makers. In this approach, democracy is seen as a form of government; a method for efficient decision making to deliver results (Koch & Ross, 1949). In this perspective, citizens are involved because they have a democratic right, and, importantly, all citizens are in principle equal and count the same (the aggregative principle), which is accomplished in elections.

This focus on representation and rights can be identified in central documents and strategies such as the United Nations Declaration on the Rights of Indigenous Peoples, Indigenous and Tribal Peoples Convention from 1989 and also the Greenland law about raw materials (United Nations, 2007; The Inuit Circumpolar Council, 1989; Inatsisartut, 2009).

Accordingly, in the related rational planning approach, assumedly neutral professionals within their different fields of expertise are supposed to develop plans and solutions that realise the politicians' ideas and objectives in the best way (Agger, 2004 pp.3). This is very clearly the principle in the Planning Act as well as the way mining activities are planned (Inatsisartut, 2010). Thus, basic tools in the process of planning mining activities are international tools such as EIA and SIA (Råstofdirektoratet, 2009; O'Faircheallaigh, 2010; Hansen, 2011). Stakeholder analysis is an entry point to these tools, aiming to provide information to the decision makers about the interests and powers of the different stakeholders.

The approach can be illustrated by the following citation from the project "Promoting public consultation and participation in the industrial development in Greenland", which is made in collaboration between The Inuit Circumpolar Council and the World Wide Fund for Nature:

*The democracy is representative - and politicians can therefore rightfully take decisions on behalf of the people, but when politicians stand before taking such important decisions, it should be a common desire to ensure that the people are consulted to an extraordinary extent.*
(Langhoff, 20013 pp 5 Authors translation)

The basic public participation in formal planning takes the form of consultations, i.e. hearings, very often based on written information, and citizens meetings where local citizens and other affected actors are given the formal right to react to the drafted analyses and plans. As this approach focuses on the rights of citizens, it is not necessarily considered a problem if only a few citizens chose to get involved, as the politicians are considered the people's representatives (Agger & Hoffmann, 2008 pp.13).

From this outset, the basic argument for supporting participation in the physical planning and the planning and development of mining projects is the democratic right to be consulted. Thus, it is assumed that the

democratic participatory processes legitimise decisions and create trust in the government, and thus prevent resistance and conflicts (Hansen, 2011; Langhoff, 2013).

Not in the least being a young democracy, Greenland needs to pursue this democratic approach based on quality and rights. However, the first challenge that this points to is the conditions for realising these objectives of democratic rights. A subsequent challenge deals with whether the formal planning approach is sufficient for actually realising the desired development

## 2.2 Drawbacks of formal planning

Taking up the first challenge, I point to drawbacks in this planning approach that are being discussed in the planning literature and which can also be identified in the contemporary Greenland development.

The formal planning approach and the way this is unfolded in the physical planning and in tools such as the SIA and EIA have the advantage that it organises a complex process in formalised structures that include a series of important aspects that are forwarded by the UN for example, to support environmental and social-economic sustainability (Hansen, 2011). Therefore, the Greenland government has adapted these tools in order to facilitate the development between international companies and local Greenlandic stakeholders. However, a series of challenges needs to be addressed about the way of organising debates on very important future development works (Langhoff, 2013; Rosing et al. 2014).

While the approach takes as an outset that all participants are equal and have the potential to provide appropriate responses, an important global critique is that the approach nevertheless favours some, and mainly the articulated actors that have the resources to react in appropriate ways (Agger, 2008).

Even organised actors such as the municipality association (KANUKOKA), the hunters' and fishermen's organisation (KNAPK) and the new environmental organisations (such as Avataq) often do not have the resources, time and knowledge to engage in the very formally structured processes about complex socio-technical matters (Langhoff, 2013; Hendriksen, 2013; personal interview). The mainly reactive approach demands a lot of resources from the organisations when for example, a series of questions in formal hearings about environment requests immediate and specialised responses (personal interview).

For individual citizens to respond, they have in principle to not only to understand the project and the objectives and consequences in a long time scope. They also have to understand their role and have the capacity to react in an appropriate way. Such formalised processes give precedence to certain forms of knowledge and logics while local forms of knowledge and practises may not fit in and therefore not come into play. Likewise, some responses fit while others are not appropriate within this frame (Jørgensen et al., 2013; Langhoff, 2013 pp.35). Disregarding the amount of information that is being presented in the consultations, a basic problem is that while the planning often is sectorial and highlights certain issues, the citizens take the everyday life as an outset (Langhoff, 2013 pp.34).

Some cases point to the fact that local citizens are not even always aware that plans and decisions processed, even when theyeee have a fundamental impact on their lives are being processed. For example, several fishermen from small settlements never realised that a regulation that intended to abolish fishing from small boats was debated until it was too late to react (Hendriksen, 2013). But how could they have reacted‘in an appropriate way had they been aware?

Furthermore, the processes of debate that are supposed to take place at citizens' meetings may not fit the existing culture of debate in Greenland. Even though cultures are developing along with modernisation, existing features of consensus and

hospitality are likely to not fit the idea of rational responses and debates (Nordic Consulting Group, 2012 pp.11; Langhoff, 2013).

Moreover, as I will address in the next section, how the representative democracy is challenged, which further emphasizes the call for new approaches to participation.

### 2.3 New governance modes challenging formal decision processes

The problems and discussions with participation raised in Greenland as well as in many other countries are being further pushed by an ongoing development that takes place in most western societies that challenges and changes the formal governmental structures. Under the headline of a change from government to governance, the traditional state-centred hierarchical structures are weakened and more multicentered network governance develops in their place (Rhodes, 1997; Healey, 1997; Agger, 2004; Bang & Sørensen, 1999; Skelcher et al., 2011). This is partly due to globalisation, which creates more international levels of government as well as more organisations and businesses operating on multinational levels. Furthermore, pressures on public governmental services have introduced more market based strategies, performance criteria and public-private partnerships (Healey, 1997).

This development is also visible in Greenland, with the decentralisation of schools and privatisation of a series of public infrastructures and companies, which has resulted in a series of public or semi-public businesses. In this way, a series of decision making processes are being moved to semi-public organisations and local boards and projects etc., which accentuates the critique about the formal participatory approaches and calls for new approaches (Ilisimatusarfik, 2011; Nordic Consulting Group, 2012; Sermitsiaq, 2014) On one hand, this change towards governance networks can be perceived as opening up for new platforms for citizens to participate, but on the other hand, the processes as well as the division of public and private are becoming more blurred and participating in the formal processes does not secure transparency and influence.

### 2.4 Deliberation creating new public spheres

Accordingly, in the literature, more deliberative democracy models have been proposed that focus on creating institutional frames for democratic dialogues (Agger, 2004). Here, the emphasis is about creating a clear framework for the dialogue between citizens where they can come up with arguments and justifications for their interests. The dialogue processes are supposed to not only generate new qualitative perspectives but also strengthen people's democratic competences (ibid). From this point it becomes important to create arenas for dialogue and experimentation before making decisions (Agger & Hoffmann, 2008 pp.14). Therefore, in many places in the world experiments on how to develop new forms of dialogue that relate both to representativeness and active, early involvement are being developed (Fung, 2013).

The Tulugaq campaign initiated by the home rule from 2002-2004 to support a sustainable usage of living resources had elements from the deliberative approach in the way it created a new platform for fishermen, biologists, citizens and others to meet (Greenland Home Rule, 2004). The campaign had a diverse set of initiatives, such as local working groups, school programs, events and workshops creating new ways of public debate and learning.

### 2.5 Summing up the challenges

The formal planning approach that is the basic tool in the physical planning and planning of the new raw material strategy is based on the ideas of representative democracy, and focuses on decision making. From that perspective, it will be important to develop the process so that more voices will have the opportunity to inform the process.

The suggested adjustments, such as

staging public participation earlier in the process (Rosing et al, 2014 pp.28), translating information (ibid.:30), information provided by an independent body (ibid.:29), and longer deadlines and better organised meetings (Nordic Consulting Group, 2012) will certainly improve the processes.

Still, the above analysis points to the fact that Greenlandic citizens have very inhomogeneous conditions in relating to participating in these formal planning processes, and therefore the strategies need to be developed more radically to address the objectives of equal rights and inclusion of perspectives. Furthermore, the development of more governance oriented models in Greenland poses major challenges to the representative democratic approach and it points to the question if optimising the existing model of consultation will match these challenges? There seems to be a need to more radically reflect and develop the participatory practises in Greenland. New approaches are necessary to support the development, and the Tulugaq campaign stands as an important case to learn from.

To support the individual and collective gains from mining projects, there is a need for developing much stronger ways for different actor groups to engage in the projects. This will be argued for in the next session.

## 3. Developing public participation

Inspired by Fung (2013), I point to some important debates and choices when developing the public spheres for sustainable development. The basic questions of who, what, why and how need to be addressed when developing the strategy for participation (ibid). In practice, the questions are of course closely interrelated. They also all relate both to an overall debate of how to develop the public participation, as well as concrete design choices in specific processes. In the following sections, I will try to develop some aspects of these questions.

### 3.1 Why – what are the objectives?

As shown in the above sections, the question of "why participation" needs to be addressed more explicitly in Greenland to develop the strategies of public participation. In this section, I suggest more objectives than the formal democracy that are the focus of the existing strategies.

Participatory processes are to a growing extent seen not only as legitimising but also as vital resources for actually realising solutions and visions (Healey, 2004). For example, it will be essential for the development of mineral projects to support a sustainable development that the citizens adapt towards learning new competences and exploring new ways of organising life. The mobilisation of citizens to unfold and execute a sustainable transition seems to be crucial, however not really addressed by the existing formal strategies for participation.

The collaborative planning theorists point out that there are several important outcomes of policy dialogues themselves. This point is important to develop the democratic practises and hence the capacities. They are often invisible, or underrated, as they are seen through the lenses of the modernist paradigm of government and accountability. (Innes & Connick, 2003). This is problematic since many important outcomes, such as trust, reciprocity and social capital, are important capabilities for collective action and decision-making.

The concept of institutional capacity focuses on the quality of the complex webs of relations involved in a governance process, which interlinks all the actors in collective actions in governance processes (Hoffmann & Agger, 2013 pp.5). Polk (2011) formulates a framework for assessing institutional capacity and sustainability learning.

- Social capital is analysed by looking at the character of the *relational resources* an activity creates. Here, one can distinguish between *bonding social* capital, referring to building links within

a group and *bridging social capital,* building links between groups (Putnam 2000).
- Intellectual capital is analysed by looking at the *knowledge resources* referring to both formal and informal types and expertise that are achieved through a process.
- Political capital is analysed as the *mobilisation capacity* activities referring to the degree to which the actors are put into play in the policymaking processes. (Hoffmann & Agger, 2013 pp.5)

As an example, the Tulugaq campaign was staging local dialogue workshops in several settlements facilitating a process where the different forms of knowledge and different perspectives and practises could meet and develop across existing boundaries (Greenland Home Rule, 2004). These processes supported the creation of relations and bridging social capital across the different groups of actors. Furthermore, it mobilised a series of actors that beforehand were not articulating their perspectives in a public forum. Thus, it enabled more sorts of knowledge to come into play and produce new knowledge and mutual learning.

In this way, the campaign supported institutional capacity to be built, which is very important in the development of democratic practices.

### 3.2 Who should participate?

As indicated above, the existing participatory strategies have difficulties in recruiting citizens and mobilising their resources (Hansen, 2011; Langhoff, 2013; Rosing, 2014).

In general debates, as well as in local projects, important questions for debate have to deal with whom to involve. It will not be enough to lean on the individual groups to take responsibility for participating. There is a challenge of how to mobilise the very diverse groups in the processes and at the same time build the institutional capacity to participate.

The civic society's capacity to participate is often related to the lack of tradition in Greenland for organising. This is addressed by the Committee:

*In order to ensure that civil society can obtain the necessary level of feedback from public hearings, it is necessary to strengthen NGOs and capacity building. Supporting local organisation could be an important step.* (Rosing et al., 2014 pp.30)

And during the last decades, a series of cases of new non-governmental organisations (NGOs) can be identified that may improve the democratic capacity, e.g. Transparency International Greenland, Avataq, ICC Greenland and Nuuk Kangerluata Ikinngutai/Nuuk Fjords Venner. More network-based organisation of citizens and other local stakeholders can be identified around the debate of Kvanefjeld. Research in European countries have shown that citizens seem to be less interested in organizing in formal organizations but more likely engage in more informal and ad hoc based networks (Bang & Sørensen, 1999). However, whether this trend can be linked to Greenland, or if other aspects are at play, cannot be concluded here. But supporting different forms of organization may sustain the building of institutional capacity.

The question of 'who,' however, also deals with how the citizens are regarded. The representative approach focuses on the citizens as voters and the formal planning focuses on feedback (as in the citation above). In this regard, some citizens become weak as they are not able to fit into the formal approaches used, as was the case for the fishermen mentioned above. They need help to respond appropriately to the staged process. The deliberate approach and the collective planning approach are focusing more on the citizens as important capacities to support the development. In this approach, citizens' participation creates a mutual learning process between citizens and government that aims at qualifying the visions as well as the ways to reach the goals. Citizens get a better understanding of the various aspects in the projects, and how institutions

work. Additionally, professionals and politicians develop their knowledge and skills in dialogue with citizens. Participation thus promotes empowerment and contributes to the development of democracy (Agger & Hoffmann, 2008 pp.12).

In this way the fishermen are not weak, as they a have strong knowledge on the lives being lived and the local area and these capabilities are central for developing sustainable development.

### 3.3 What - Scoping the issues at stake

The scope of issues and planning processes is the third important aspect for realising the potential of the participatory process. This point is underlined by Hansen (2013) in the Background paper for the Committee for Greenlandic Mineral Resources to the Benefit of Society:

*Decisions about where, when and under what conditions industrial activities are permitted are generally made on a case-by-case basis, without a comprehensive plan and regulatory strategy that identifies scope, intensity and direction and consequences of activities judged appropriate and desirable. There seems to be a need for* ***comprehensive planning.*** (Hansen, 2013 pp.19)

Agreeing very much with Hansen and the need for supplementing the single cases with more overall and comprehensive approaches, this analysis still raises the question of how this comprehensive planning is scoped and carried out. Another layer of formal planning process will not be sufficient.

The raw material projects together with the large scale energy potential in Greenland have been promoted over the last few years as the basic strategy by both the government as well as key actors in the Greenlandic society (NIRAS Greenland, 2007; Jervelund & Winther, 2010; Greenland Development, 2010; NIRAS Greenland, 2010). However, recent discussions have suggested a more diverse approach that also includes tourism and fishing and other biological resources as basic potentials for income (Delaney et al., 2012; Grønlands Økonomiske Råd, 2012; Hendriksen et al., 2013; Rosing et al., 2014).

This strategy opens for more opportunities for citizens to participate actively in the development of the society (Hendriksen, 2013; Delaney et al., 2012).

### 3.4 How to organise the participation

Each process or project is unique, and therefore a precise approach to 'how' cannot be described. In the end, the processes must be planned to fit the local conditions and resources. However, I want to point to some potential aspects.

The question of 'how' follows very much the discussions in the former sections. The formal planning approach could be supplemented with more open and comprehensive approaches at all levels.

Using scenarios may be a relevant method for discussing complex issues, and can inspire and qualify the debates and strategies in relation to different possible futures and at the same time keep openness (Rosing et al., (2014).

Local development processes are needed to support capacity building if local societies are to engage in, for example, mining projects or other new potential livelihoods. One example of the processes is outlined by Rambøll (2013)in a project of developing sustainable tourism. This process was very much built on mobilizing and connecting existing local resources. Due to this process of networking both human and non-human potentials, a local embedded capacity building was facilitated. This corresponds very much with newer resource based approaches such as 'Asset based community development' (Agger & Hoffmann, 2008 pp.102).

Another important potential deals with using intermediary actors to facilitate the development and learning processes between different actors and positions, like facilitating the interaction between government and local communities. Employing such intermediaries over on a

longer time period may also support the learning processes and the capacity building in society about participatory processes (Læssøe, 2001; Hoffmann & Agger, 2013). Cases of intermediaries facilitating processes can be seen in both the Tulugaq campaign as well as in the sustainable tourism projects mentioned above. Universities are also often used as an intermediary actor that can work as bridge builders and evaluators to support learning.

Following up on this, a final aspect that is important to point to is the need for experimentation and learning in the field. A key point of this paper is to emphasise the need for systematic experimentation with supporting participatory and capacity building processes. Also, here universities and NGO's can be important players in reaching this goal.

## 4. Conclusions

By presenting basic theoretical concepts about democracy and public participation, this paper demonstrated that in Greenland there is a need for discussing the criteria for citizens' participation strategies when planning for urbanisation and raw material initiatives. Thus, the paper points to more objectives for citizens' participation, in headlines:

1. To support the democratic development, including legitimacy and empowerment of citizens.
2. To create better solutions based on local knowledge and input and avoid conflicts and oppositions.
3. To support common responsibility for the visions and strategies and engage the citizens as resources in realising the objectives.

On this basis, the paper additionally points to the fact that the existing participatory strategies rooted in the formal democratic approach focusing mainly on legitimacy needs to be discussed and developed. Not just for the problems with the processes that have identified by others as referred to above, but also because the existing strategies are not sufficient for engaging citizens in the challenges that Greenland faces regarding the need for new livelihoods and urban strategies. The paper points to four important questions that may help the debate on how to develop the strategies: The discussion of 1. Why – what are the objectives? 2. Who should participate? 3. What is the scope? And 4. How is best to organise the participation?

Finally, I want to address some fields for future research to follow up on the points of this paper. First, there is a need to follow up on the concepts presented in this paper and by adding more empirical data discuss the challenges and potentials for developing the participatory strategies in this way. Second, the first concrete local mining projects are being planned, and there is a need to try out and experiment with the capacity building around these and evaluate new ways of participation. And finally, international conversations within this field are important. Identifying cases in other parts of the Arctic or globally that may inspire the participatory approaches has large importance. And as mentioned the need to develop the participatory approaches in Greenland are similarly recognised in most parts of the world and therefore the experiences developed in Greenland have relevance for other societies not at least other Arctic societies other or societies with mining activities.

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Personal interviews

**Personal interviews**

A series of personal informal and formal interviews have been conducted from 2002-2014 with persons in public and private businesses and organisations on existing trends and challenges. Notes have been written immediately afterwards.

# New possibilities for infrastructure in South Greenland

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## Abstract

Recently, the big challenge in South Greenland is the lack of efficient infrastructure – both on sea, land and in the air.
Communication by boat has always been the traditional mean of communication in Greenland. In the last decades it has been a mixture of privately and publicly driven boats. In the last municipal plan for Kujalleq Municipality we have ~~is~~ designed a vision of regular services connecting all towns and villages in southern Greenland.
In southern Greenland the distances between the towns, the villages and the sheep farms are short. Therefore roads have always been an issue and a road network is emerging. Communication by plane has first priority according to the governmental policies. Qaqortoq was the only larger town that did not get an airport back in the 1990s. The obstacles and possibilities in changing the airport-structure in South Greenland from having an international airport in Narsarsuaq to ~~get a~~having a regional airport in Qaqortoq is the current issue.

## 1. Introduction

More than 1000 years ago Icelandic Vikings found their way to Greenland and settled in "The Eastern settlement" in South Greenland. They established main shipping links between Greenland and Europe and weak shipping links to Vineland (Northern America), which were used annually. This allowed Greenland, even at that time, to be a part of a globalized world based on trade and exploration.

## 2. By ship

Even today the dominant means of transportation of goods to and from South Greenland is still by ship.
Royal Arctic Line has a monopoly in serving the towns of Nanortalik, Qaqortoq and Narsaq by big feeder ships with weekly connections to all towns on the west coast and connections to Denmark via Nuuk or Nanortalik. While the 11 small settlements ~~is~~ are served by smaller ships (RAL settlements services) every second week.

In the future, new kinds of goods will appear. Mining and oil exploration gives new challenges for transportation systems. Two of the current mining projects in South Greenland, the mine at Kuannersuit/ Kvanefjeldet near Narsaq and the mine at Killavaat Alannguanni /Kringlerne near Qaqortoq, both intend to build their own new ports to ship the raw materials overseas. Off shore oil exploration, needs ports with big depth and large areas for storing supply and materials. There has been analysis about the possibilities of developing a harbor for off shore activities, and at the moment, both Narsarsuaq and Narsaq are possible locations. Passenger transportation by ship has, in the last decades, been a mixture of privately and publicly driven boats. Arctic Umiaq Lines Sarfaq Ittuk is the only publicly driven passenger vessel serving South Greenland, with weekly connections to the major towns on the west coast. It is an important alternative to flying due to the lower prices travelling to the same destinations. Internal passenger transportation in the region is only possible by private or charter boats

and it does not provide a regular and proper service to the citizens in the region. In the last municipal plan for Kujalleq Municipality, we have designed a vision for regular boat routes connecting all towns and settlements in South Greenland.

*Figure 1: Plan for boat routes*

The operators and boats approved for passengers are already present in South Greenland (two big vessels type Targa 37 and 3-4 smaller type Targa/North/Vikness). However, they have to be organized and coordinated in a kind of public-private partnership. Some of the money, which is today used on service-contracts (with Air Greenland), could be used to finance a part of this regular boat service. In 2013, one of the boat operators in South Greenland examined the possibility of operating a boat service by a small Hovercraft. It was found that it would save fuel and travels with a higher speed, but unfortunately, it could not be financed at the time.

## 3. On land

In South Greenland, the distances between the towns, the settlements and the sheep farms are short, especially in the northern part of the municipality – the two towns Narsaq and Qaqortoq, the settlements Qassiarsuk, Narsarsuaq, Igaliku and Alluitsup Paa and 20-30 sheep farms scattered in between. Therefore, roads have always been an issue in South Greenland. During the last 20 years dirt roads have been established between the sheep farms and the nearby settlements. Today, we have about 200 of km roads in South Greenland.

The next step could be proper roads between Qaqortoq-Narsaq-Narsarsuaq and Alluitsup Paa. In the current Municipal Plan 2011-2022 there is a road map of future roads and the areas for the roads has been reserved.

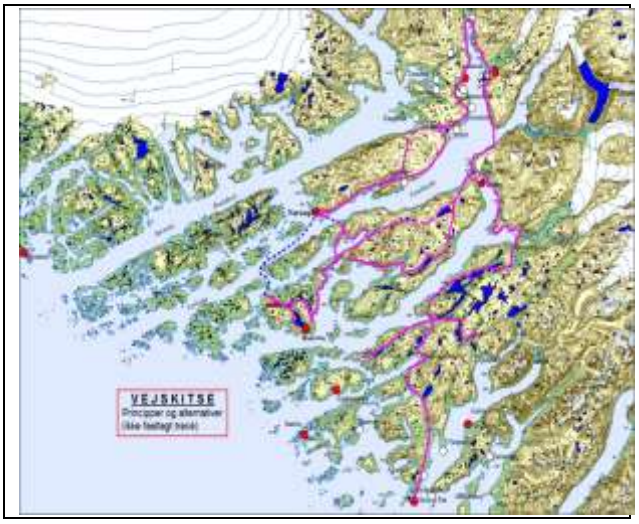


*Figure 2: Plan for the road network*

Proper roads will be a great advantage for developing the area – Narsaq and Qaqortoq will be connected and will be one unit for the labor force.~~,~~ I~~i~~t will be easy for students to study in both towns and the interaction between the towns will increase. The road network could also be an opportunity for the coming mining projects to get better access to the towns, the ports and the airport. The small settlements will be better connected to the towns and all the sheep farms will get better access to the marked roads and then to the services in the towns. Additionally, a road network will improve the tourism in the region. Today it is difficult and expensive for tourist to get around in the region. With proper roads it will be much easier. On the Faroe Islands they did it, ~~on~~ in Iceland they did it – so we can do it in Greenland too!

## 4. By plane

Communication by plane has first priority according to the governmental policies.

Greenland has 13 airports, so most of the larger towns have an airport. Even though Qaqortoq is the fourth biggest town in Greenland, it has no airport. Instead, the three towns in South Greenland have only heliports, which are served by small Bell 212 helicopters. It gives a low capacity and comfort, ~~bad~~ and has irregular schedules.~~ity~~ The only airport in South Greenland is Narsarsuaq Airport, which has a 1799 meter runway. This runway length allows for cross-Atlantic flights, so Narsarsuaq has direct flight connections to Copenhagen and Iceland in the summer time.

For a long time, an airport near Qaqortoq has been an issue. Therefore, the Greenlandic Government asked the Transport Commission to study how to solve the problems in South Greenland ~~due~~ in relation to transportation. The result of the work in the commission was that they recommended that a new airport be build, near Qaqortoq to replace the airport at Narsarsuaq. The logic was that most of the passengers through Narsarsuaq came from Qaqortoq and that it would be economically beneficial for the society to avoid the added transport from Qaqortoq to Narsarsuaq. Another important question is the length of the runway. If it is 1199 meters it can only be operated by regional flights, but if it is 1799 meters it can be operated by Atlantic flights.

The Greenlandic Parliament granted money in 2013 and 2014 to make further investigations about the location of an airport near Qaqortoq with a 1199 meter runway. In this investigation, the possibility of extending the runway to 1799 meters is being examined. In 2014, the Municipality has also launched an investigation about an alternative use of Narsarsuaq Airport. Some ideas are in the field of a support-airport for mining and off-shore activities, while other ideas are in the field of tourism. It is promised from the government that the final decision about a new airport near Qaqortoq will be made in 2014.

## 5. Conclusions - Multi-modality

As the description above presents, most of the discussions and decisions about infrastructure are made individually, according to their separate element – at sea, on land and in the air. This means that the interaction of multi-modality is not present in planning in Greenland.

In my experience in traffic planning in South Greenland I have found that we can achieve better solutions if we take a more holistic approach where the different means of transportation (ship routes, roads, air- and heliports) ~~was~~ are ~~put together~~combined in a coherent solution. This would require that the authorities, funding sources and transport companies must be in a closer dialogue and cooperation.

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# Resilience and Renewable Energy Planning in Greenland: Proposing a Biologic-Geologic Spectrum

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## Abstract

Using a combination of thematic analysis and studio-based planning proposals in West Greenland, this paper proposes that there is more than one interpretation of resilience in renewable energy planning.

All energy transitions, from one system to another, are protracted and unpredictable, and the transition to a renewable energy system is proving no exception. Such a transition is particularly amplified in the context of Greenland – a country undergoing rapid transformation in many fields, including energy. Resilience theory offers an approach for how to plan for this energy transition, but how to translate resilience theory into planning practices remains underdeveloped.

The paper begins by outlining some of the challenges in planning a transition to renewable energy, and sketching Greenland's energy landscape. It then discusses the key characteristics of resilience thinking, before proposing that a continuum of approaches to embedding resilience – from biologic, responsive readings to those more geologic and resistant – could provide planners with multiple interpretations of resilience. The paper concludes by illustrating this spectrum with situated planning examples and reflecting on the capacity of a Biologic-Geologic spectrum to create more place specific energy planning practices.

## 1. Introduction

History demonstrates that energy system transitions are unpredictable, complex and protracted affairs (Smil, 2010). In the transition from hydrocarbon based energy systems to those fuelled by renewable sources, these traits will be exacerbated due to the developed world's entrenched reliance on energy, the rising levels of socio-economic levels in developing countries, and an ever increasing global population.

Greenland provides an amplified context in which to consider the forthcoming energy transition. Unlike much of the deindustrializing developed world, this vast, yet extremely sparsely populated island stands at the threshold of industrialization, contemplating oil and gas extraction along side other energy-greedy large-scale developments. However, Greenland already produces 70% of its civilian energy from renewable sources (Kingdom of Denmark, 2011, 30) with the capacity for much more. It has no national energy grid, but a relatively high energy per capita consumption (Statistics Greenland, 2013, 24). It is in the frontline of climate change, and the poster child for the perils of global warming, yet many see fossil fuel extraction as its greatest hope for socio-economic development. In other words, Greenland's energy landscape is one of compressed timelines, simultaneous and sometimes contradictory opportunities, shaped by, and on the threshold of shaping, global energy systems.

There is much debate on how to plan and manage a transitioning energy system; a debate that is mirrored in all infrastructural planning sectors. One approach that has seen rising prominence over the last five years is resilience theory. Allied with, but distinguished from, sustainable development and systems thinking, resilience theory focuses on the capacity of a system to respond to, and cooperate with, inevitable change and stress while maintaining integrity. This emphasis on the capacity to flex with change, holds promise for guiding a turbulent and unpredictable energy transition, but what resilience might mean, in practice, for renewable energy planning remains unclear. How might resilience theory be translated into practice? How could resilient energy planning be interpreted in the Greenlandic context of highly-dynamic transformation?

This paper begins with a brief outline of some of the planning challenges of the energy transition, followed by a sketch of Greenland's energy landscape. It proceeds to outline what resilience is, and how it differs from other related terms, referring particularly to Nassim Nicholas Taleb's work on AntiFragility and the Stockholm Resilience Centre's Arctic Resilience Interim Report. It then suggests that dealing with the unfolding of time is the continuous thread connecting all of these terms, and, drawing on the work of Smudge Studio and Stan Allen, proposes that alternative interpretations of how resilience in energy planning can simultaneously exist. The paper suggests that these interpretations be organised across a spectrum – from those that are quick to respond and flex and might be termed biologic, to those that endure, slowly adapting to change and might be called geologic. After describing potential examples of these alternative interpretations of resilience through studio-based design work in Greenland, the paper concludes that understanding a place – both its spaces and its speeds – is fundamental to embedding resilience into energy planning, in Greenland and beyond.

## 2. Energy Transitions

### 2.1 Challenges and Obstacles

The transition from a hydrocarbon- to renewable-based energy system will impact landscapes, communities and regions throughout the globe. Vaclav Smil has written extensively on energy systems and behaviours. In 'Energy Transitions: History, Requirements, Prospects' Smil writes extensively on historical examples of transitioning from one energy system to another, postulating that this pattern will inevitably be repeated in the coming hydrocarbon-to-renewable transition:

*Because of the requisite technical and infrastructural imperatives and because of numerous (and often entirely unforeseen) social and economic implications (limits, feedbacks, adjustments), energy transitions taking place in large economies and on the global scale are inherently protracted affairs. Usually they take decades to accomplish, and the greater the degree of reliance on a particular energy source or a prime mover, the more widespread the prevailing uses and conversions, the longer their substitutions will take. (*Smil, 2010 viii*)*

We are overwhelmingly a fossil-fuel based society and as such the transition to a renewables based energy system is likely to take place over many decades, even generations. The long timeframe of the transition will be punctuated by a number of certain uncertainties (Naustdalslid, 2013) that fall roughly within three main domains of change in renewable energy planning: technological, climatic-physical, and socio-political. Technological changes will occur as the renewable industry matures, either frustrating or enabling advances, for example the development of efficient and economical storage of energy from renewable sources. The climatic-physical context is changing, and as renewable energy draws directly from the land and climate, using the bio-physical environment as raw resource, changes in this domain impact the capacities available, locally and globally (AMAP, 2011). Lastly, the socio-cultural changes ahead are hugely

influential, emerging as both necessary adaptations to the changes in other domains as described above, but also themselves instigating external transformations through individual, community and governmental actions. Taken collectively and simultaneously over many decades the above describes a highly complex system, unfolding over time, steeped in uncertainty.

## 3. Greenland's Energy Landscape

### 3.1 Recent Renewable Energy History

Prior to the 1990s, Greenland had very little in the way of renewable energy, relying heavily on imported fossil fuels, supplemented by a mixture of microhydro, small-scale solar and limited waste-incineration. In the wake of the first oil crisis, it was decided to develop hydroelectricity capacity, and in 1993 a plant at Kangerluarsunnguaq was commissioned. By 2005, the Tasiilaq dam was also completed and the construction of Qorlortorsuaq dam was in progress.
Also in 2005, the Self-Government of Greenland published "Grønland Energi 2020", a strategy report outlining Greenland's plans for developing energy infrastructure and systems until 2020 (Government of Greenland, 2005). When it was written Greenland was already advancing along the large-scale hydropower route towards increasing renewable energy the report committed to continuing to do so, seeing other renewables like solar and wind, and hydrogen as a carrier - as peripheral or distant.

In 2011 'The Kingdom of Denmark's Strategy for the Arctic 2011-2020', (Kingdom of Denmark, 2011) confirmed that then 60% of Greenland's energy was from renewable sources, the vast majority of this being from four hydropower stations (Sisimiut was completed in 2009). This figure has now risen to 70% following the inauguration of the Illulisat dam in 2013. The remaining 30% includes the energy consumption in Greenland's many small settlements that are still reliant upon diesel generators.

There are some caveats on these impressive figures that hold some sway on future prospects. GE2020 states that:

*This report covers all known and predictable energy supply and demand opportunities. Energy supply for large energy-intensive industries and mining is not treated…*" (Government of Greenland, 2005 13).

Regardless of ambitions for socio-economic growth, GE2020 also assumes a slow down in energy consumption increases due to substantial energy efficiencies. Despite these qualifications, it is evident that Greenland has made impressive progress towards becoming independent from carbon. The country is in a transitional phase and energy is inextricably bound up with this transformation.

### 3.2 Energy Futures

Over recent years, there has been a collection of interesting pilot schemes and experiments with other forms of renewable energy in Greenland, including its storage and distribution: an exploration catalysed by the difficulties of the geology, geography and demographics of the country. Interestingly, Greenland has become a successful pioneer of smart metering – devices that allow two-way communication between the electricity grid and the consumer. One reason for its successful piloting in Greenland is that the contained, small communities it is serving enable Greenland to act as an ideal test-bed for new technologies and ideas, compared to much larger communities with sprawling and complex infrastructures.

Greenland's energy landscape displays two distinctive and significant characteristics – it has the natural resources to potentially produce exponentially more energy than its population requires and, simultaneously, it is a quintessential example of highly dispersed and decentralised communities with no unified energy infrastructure. These characteristics point simultaneously

towards two distinct schools of renewable energy development – centralised, grid-based export on one hand, and decentralised, community led sustainability on the other. Such duality renders Greenland a very interesting context for future renewable energy planning discourse.

### 3.3 Diversified energy landscape?

The above sketch of the Greenlandic energy landscape, and its future potentials, suggests that Greenland has much to gain from furthering its renewable energy capacity and knowledge, despite its oil and gas hopes. A planned increase in population, rising prosperity and education, the potential for greater independence, less reliance on external sources, the potential for export etc. – all factors that suggest the consideration of renewable energy development in parallel with other big industries could diversify the economy and expand the horizons of the country; after all, oil, gas and mining are finite economies. Greenland potentially has the capacity to expand its green-tech industry and knowledge, becoming a region of exploration in both sides of the renewable energy solution debate – super-grids and self-sufficient communities – relevant to many territories around the world.

## 4. Resilience and other approaches

### 4.1. Planning the unknown

The concatenation of unpredictable and intertwined changes as described above, in Greenland and elsewhere, points towards the need for an energy landscape that can deal with inevitable stressors, emerging variables and altering contexts. This need exists outside of energy planning; in many planning fields the need to deal with change is growing in conjunction with the rising number of natural and man-made disasters in the wake of climatic change and socio-economic instability. Consequently, there are competing ideas for how to frame and approach planning in times of transition.

### 4.2. What is resilience?

One of the leading ideas in this field is the concept of resilience. Resilience theory was born in ecological theory, defined as the capacity of a bio-physical system to recover from disturbance while maintaining its integrity (Folke, 2006). The notion is also employed in engineering and psychology, with varying meanings, however this paper will build upon the Stockholm Resilience Centre's definition, in particular referencing the Arctic Resilience Interim Report as published in 2013 (Arctic Council, 2013). The ARIR defines resilience as:

*The capacity of a social-ecological system to cope with disturbance, responding or reorganizing in ways that maintain its essential function, identity and structure, whilst also maintaining the capacity for adaptation, learning and transformation.* (Arctic Council, 2013 viii).

Resilience places great emphasis on understanding feedback loops and systems, using particular terminology such as regime change, panarchy, drivers etc., to describe the complex processes of socio-ecological systems – all of which render it highly appealing for energy transition planning. However, this mode of systems thinking has its detractors and competitors.

### 4.3. The Green debate - Resilience , sustainability and anti-fragility

There remains plentiful debate on whether to employ sustainability or resilience as a goal in planning. The definition of sustainability continues to be thoroughly argued in both academic and industrial contexts, but while it is etymologically rooted in enduring, in creating balance and harmony, resilience is anchored in ideas of cooperating with change, fluidly adapting and transforming with a changing context. It is this perceived difference, whether semantically or ontologically, that is the cause of friction. Nassim Nicholas Taleb is the author of 'Antifragile – things that gain from Disorder' (Taleb, 2012). His ideas on antifragility present an additional optic on the subject, where antifragility is distinct from both sustainability and resilience:

*Some things benefit from shocks; they thrive and grow when exposed to volatility, randomness, disorder, and stressors and love adventure, risk and uncertainty… Antifragility is beyond resilience or robustness. The resilient resists shocks and stays the same; the antifragile gets better.* (Taleb, 2012 3)

While interested in the same subject matter, respective advocates of sustainability, resilience and antifragility clearly have different framings on *how* to achieve successful, green, system design, and, critically, whether tenacity or mutability is a better strategy.

### 4.4. Interpreting resilience

While this paper's purpose is not to provide a comparative analysis of these three terms, it is important to note an important commonality: the need to plan in and with time, thinking beyond static, fixed plans. They all move away from conventional master planning and linear thought. Their divergence is really on how to deal with the processes of time as events unfold, varying from slower-resistance-tenacious modes to faster-responsive-mutable notions.

Rather than get caught in semantics, this paper uses the term eresilience throughout, focusing on exploring practical tactics for exploring these alternative interpretations of resilience.

## 5. The biologic – geologic spectrum

### 5.1. Constructing a spectrum of approaches for dealing with Time

The two poles of how to deal with change over time – the resistance model and the responsive model - are here proposed not as opposites but as two ends of one continuum called the Biologic-Geologic spectrum. This proposed spectrum is influenced by the work of Smudge Studio and Stan Allen, both of whom discuss perspectives on time in design.

### 5.2. Making the geologic now – smudge studio and geologic approaches to design

The idea of lengthening the perceived timeframe of human thought and action is examined in detail in "Making the Geologic Now", edited by Smudge Studio and contributed to by a wide selection of artists, thinkers, designers and scientists (Ellsworth & Kruse, 2012). The central thrust of the publication is that in this anthropocene epoch we must take responsibility for the often very long-term impacts of our actions, thinking in geologic scales of time rather than the human lifespan. This urging to think geologically is centred on the idea of deep time, and by employing examples from art, design and engineering, from the storage of nuclear waste, to photographing orbiting satellites, and geo-poetry, the book illustrates the entanglement of human and non-human forces on earth, seen from both large spatial scales and long temporal scales. The publication is not a strategy or manifesto, but an uncovering of the inevitability of the geological: using the term beyond the literal to underline that human processes and systems, however slow and almost invisible, are responding and contributing to long term change.

### 5.3. Stan Allen – From the biological to the geological

Stan Allen, who has written prolifically on architectural theory as well as practice, also employs the term Geological in his essay "From the Biological to the Geological" (Allen, 2011) as published in Landform Building, although with a different perspective on the expression. The essay begins with an interrogation of what he calls the Biological turn in architecture – a fascination with producing architecture that is more fluid, adaptable, and responsive to change (Allen, 2011 20). There has indeed been a trend in architecture and urban planning over the last decade, in parallel with the development of parametric modelling in particular, of attempting to bestow aliveness upon architecture and planning, seeking ways of creating architecture-as-biology. However, Allen argues that architecture-as-biology is

doomed to remain metaphorical, only ever representing an image of being alive, not performing it ontologically:

*Architecture is situated between the biological and the geological – slower than living beings but faster than the underlying geology. Resistance and change are both at work in the landscape: the hardness of the rock and the fluid adaptability of living things.* (Allen, 2011 22)

Essentially, Allen suggests that architects and planners accept the timeframe and speed of their discipline and embrace that it is related simultaneously to, and situated somewhere between, both biological and geological framings.

### 5.4. Conceptualising a spectrum of approaches

Despite different intentions and definitions, both Smudge Studio and Stan Allen build a case for a greater understanding of the nuances of designing in and with time, drawing upon the 'natural' environment for reference, specifically urging us to (re)embrace the geological timescales of architecture and planning. In particular, Allen's framing dovetails with the differing interpretations of what resilience might mean discussed earlier in this paper – calling for *both* enduring and responding, *both* geology and biology.

Drawing these theoretical framings together, a new perspective on what resilient energy planning might be is here proposed. While Smudge Studio uses the term "geologic" metaphorically as synonymous with deep-time thinking. This paper suggests that biological processes are just as instructive for thinking in deep-time, simply using a different set of tactics for dealing with time. In this way, it is proposed that both biologic and geologic are re-contextualised and given equal status, suggesting that they coexist in reciprocal relationships to create and evolve the landscape, each offering a different means of modelling resilience in deep-time.

Deploying the idea of a biologic–geologic spectrum means refuting the idea of finding a singular, one-size-fits-all solution to embedding resilience in planning. A spectrum tolerates multiple interpretations of resilience, sanctioning differing understandings of what a resilient energy plan can be, whether it leans more to Biological or Geological tactics. They are not seen as opposites or a black and white choice but degrees on a continuum that work together.

### 5.5. Biologic approaches

A more biologic approach to resilience could be described as being one of fast response. Biologic tactics are characterized by enduring-through-changing: responding and adapting quickly to external drivers of change, persisting through means of fluidity, flexibility and agility. Its strength lies in its capacity for reinvention, a tactic which could be realised through the recycling of elements; the ability to be scaled up or down; to be light on the ground requiring minimal substructure and investment; to be an intermediate or short term remediation project; or to be owned and managed by many. Such an approach can be allied with decentralised energy planning, dispersed and distributed in composition. An example would be the existing solar energy culture in Greenland, where panels are bought individually and privately, self-mounted and managed off-grid.

### 5.6. Geologic approaches

Geologic approaches could be described as being slower, focused on enduring-through-resisting, accumulating and extending. Geologic strategies aim to maintain integrity and structure despite a changing context, gradually adjusting and redirecting over long time spans. Its strength lies in its capacity for reuse, which could be realised through re appropriation of existing infrastructure; acting as a monument or catalyst for bigger change; building in excess; or reprogramming materials and knowledge. This approach is allied with centralised energy systems, which are usually larger, requiring greater capacity, but with longer life-cycles. An example would be a hydroelectric power station, a

huge investment for a country, designed to last for generations.

## 6. Studio based research - imagining Greenland's energy landscape through biologic and geologic optics

Three pieces of studio-based design work form the basis of empirical research in this project. Each is placed on a different location on the biologic-geologic spectrum, and in a different location in west Greenland. The studio work is on-going - each is briefly described below as a way of grounding and illustrating the thesis, and the last is accompanied by some visualisations.

### 6.1. Biological: distributed and open energy communities

Kapisillit is a small settlement with a permanent population of around 70, plus a number of summer residences. It is isolated, with very little fixed permanent infrastructure, and like many Greenlandic settlements, its future is uncertain, suffering from emigration to bigger towns and a changing climate. Currently, a diesel generator is the primary energy source, but some private homes have mounted solar PVs and thermal collectors. This planning proposal suggests that the settlement could reduce its reliance on imported diesel using a diverse mix of energy production types, owned and managed by the community themselves, using contemporary communication technology. Building on programmes like the Open Source Ecology's Global Village Construction Set it seeks to enable residents to create a low-tech energy infrastructure, tailored to their needs, which can be constructed gradually and economically in parts, using common materials and skills (Open Source Ecology, 2011). A mix of different energy types – solar PVs, solar thermal collectors, wind, fish based biogas etc – help to flatten the seasonal curve and by distributing it throughout the settlement amongst residents, the community share the communal resource. Trading energy credits using mobile phone technology, and downloading energy infrastructure patterns online keep the infrastructure accessible and light on the ground, building local knowledge and skills. A workshop with students from the Architecture School in Aarhus is planned for May 2014 to explore this approach.

### 6.2. Geological: constructing heritage in Ivittuut

Ivittuut occupies a significant place in both Greenlandic and international history. Home to the biggest site of cryolite in the world – an element previously used to make aluminium – it was an important global location during the first world war, and due to this, the town also became an American military base. However, cryolite became obsolete in aluminium production and consequently the mining industry in Ivittuut died. Since then, the military base, located 5km away in Grønnedal has been relocated to the capital, and all that remains is a ghost town - disused military and mining infrastructure awaiting demolition. However the settlement is also close to a site with great potential for hydropower and, this region also has potential for the mining of rare earth elements (Nukissiorfiit, 2005). The proposed plan suggests two things – one is the reuse of the existing mining infrastructure to create a new laboratory of energy, where education and experiments with innovative renewable energy production in the sub arctic climate take place – for example tidal energy or large scale flywheel storage - gradually building a new centre of research in Greenland. The second is the creation of a sixth hydroelectric power station in Greenland, designed to be accessible for tourists and locals alike, and with future potential for trans-national export. Combined, these two interventions are designed to gradually build Greenland's green-tech capacity, while simultaneously strengthening an active eco-tourism sector. Here a geologic approach continues to build on the existing layers in the landscape, while triggering a wider change in identity and program.

### 6.3. Biological/geological hybrid : A blossoming solar in Nuuk

The capital city of Nuuk is one of five urban areas in Greenland currently supplied by hydroelectric power. Located in Buksefjorden, the plant supplies almost all of the city's electricity needs. However by 2030 it is expected that the growing population and prosperity of Nuuk will outpace that of the supply (Bizopoulos & Koutsos 2013). One option is to further extend the hydroelectric plant but this is extremely expensive. This design proposal instead considers solar energy as a supplement and complement to the hydroelectricity supply, mitigating a return to reliance on diesel or oil. In this way the proposals aim to combine the Geologic and the Biologic, asking the two tactics to work in reciprocity. The solar energy plan is approached as a family of three separate but linked ideas, each progressively more invasive and 'permanent' than the last:

A. Harbour side containers: re-appropriating shipping containers, fitting them with solar panels and using for increasing tourist trade of tours and crafts etc., at new harbour.

B. Public staircases: adapting existing urban stairs, retrofitting them with PV canopies and Solar Thermal balustrades, using a secondary solar grid.

C. GeoSolar system: a fully fledged community solar system. Borehole field beneath a public park, covered by a cold mine in winter. Fed by city-wide solar panels.

This family of interventions is designed to have the capacity to be deployed in various speeds and scales, depending on contextual drivers and adaptations, for example if the extraction of REE in Greenland intensifies, if safe findings of Greenland oil or gas are made etc., the incentive to expand solar energy will be impacted. In this way it is hoped that this approach of a family of differently geared members, some faster, some slower, can collectively respond to various future scenarios. The interventions are also designed to learn from one another, building on previous experience and 'feedbacking' skills and materials where possible. The mapping, illustrated below, describes two different scenarios – one where the three proposals are quickly deployed, and the other where they are more slowly rolled out with interruptions and graceful failures. This type of mapping is a way of thinking ahead in time, drawing out how the design can be resilient to different circumstances.

*Figure 2: work in progress – Harbour side Containers in Nuuk (Carruth 201*

*Figure 2: Public Staircases in Nuuk* (Carruth 2013

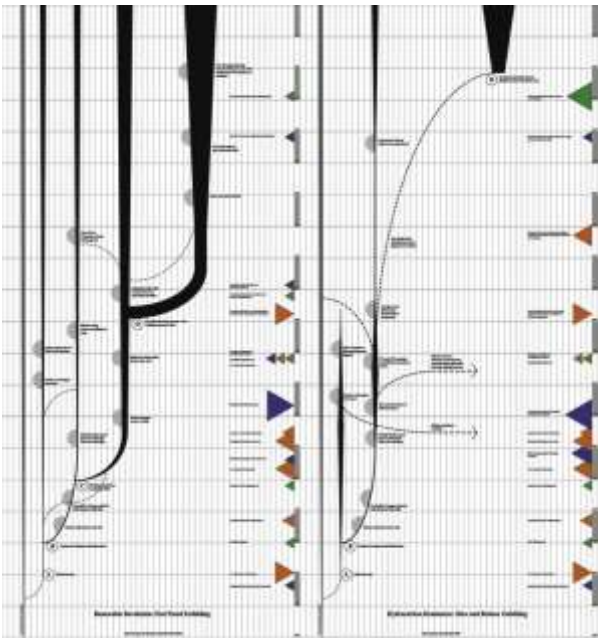

*Figure 3: Mapping Resilience of Solar Blossoming in Nuuk. Fast scenario on left, Slow scenario on right. (Carruth 2013)*

## 7. Reflections – Building Definitions, Landscape Thinking and Place Specificity

The proposed Geologic-Biologic spectrum contributes to building a definition(s) of resilience that is particular to renewable energy and planning, rather than simply borrowing the overarching logic from other fields. Studio-based, place-specific empirical experiments enable investigations into concrete, pragmatic tactics, and in doing so illustrate that there is more than one strategy for building resilience within this field, due to the huge variety in contextual conditions.

It must be underlined that 'Biologic' and 'Geologic' are not intended to be understood as opposites but as related, and often reciprocal, processes at work in the landscape, with blurred distinctions between them. Viewing them together as one holistic 'landscape' allows for the complexities of classification to be embraced, creating a more inclusive approach to building resilience. A related pertinent question is how one decides where on the spectrum to situate an energy plan for a specific location. Here, it seems useful to turn again to Smudge Studio's urging to consider deep-time, that is deep pasts as well as deep futures. Investigating the deep past of a place – the practices, habits, speeds and scales that have constructed the topos over time – combined with building scenarios of deep futures – possible future conditions based on other research and estimates - can inform this decision by leading to increased awareness of the broader context of a plan, temporally and spatially.

Lastly, it should be noted that the attention here is on energy transitions – that is, a period of change rather than finding a fixed final solution. In reality the transition period will be decades if not generations long and so change will be the norm. This transition, from a fossil fuel dependent world to one powered by renewable energy will require the expertise of many disciplines. The Biologic-Geologic spectrum is intended to contribute from a planning and architectural point of view, bridging scientific and artistic practices.

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# Experimental investigation of the pavement temperature distribution in seasonal frozen area: Impacts of solar radiation, snow cover and surface layer material

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## Abstract

Pavement temperature is of major interest due to its potential damaging impacts related to pavement properties. In the present paper, a field large scale asphalt pavement experimental system has been built in Harbin Institute of Technology. Field experiments were carried out in order to investigate the impact of solar radiation, snow cover and surface layer material on the temperature distributions through the depth of pavement profile. The comparison between pavement temperature with and without building shading indicates the crucial role of solar radiation on the pavement temperature in the daytime. Regarding snow cover, the daily pavement temperature difference at 2cm depth is found to be an exponential function of snow depth. The "snow depth insensitive" regime is established, for which the snow of different depths results in almost the same pavement temperature distribution. The subsequent discussion concentrates on the impact of asphalt layer on the undisturbed ground temperature distribution characteristic. Comparisons of experimental results reveal the negative role of asphalt layer to the ground temperature stability.

## 1. Introduction

The safety level of most civil engineering structures is linked to the probability distribution of the thermal loads they sustain while in service. In the case of roads, pavement temperature is one of the most relevant thermal parameters, not only in describing the thermal conditions at a given location but also in assessing the potential impact of temperature change on pavement performance (Humphrey, 2008). Recently, the pavement temperature distribution in seasonal frozen area is of major interest. Several studies indicate an increased probability of occurrence of events inducing both cracking and frost heave/boiling due to the change of temperature in pavement structure (Hermansson, 2004). Therefore, understanding the pavement temperature distribution characteristic in seasonal frozen area is of high priority to analyse the pavement performance and give suggestion for pavement maintenance and preservation.

Despite this, availability of pavement temperature distribution characteristic is surprising limited. Around the world, the most commonly used approach relies on two weather-related parameters: annual average air temperature and annual amplitude of surface temperature variation. The two parameters are then used with a simple harmonic relationship that has the

amplitude decaying exponentially with depth. This formulation was presented by Southgate in 1968. After that, a number of current methods dealing with evaluation of temperature in pavement are developed using air temperature data. Akiyama (1976) indicates the relationship between asphalt pavement surface temperature and air temperature follows an exponential relationship on sunny days and a linear relationship on cloudy days, respectively. Long–Term Pavement Performance (LTPP) program performed a correlation analysis to identify potential independent variables. Results showed low pavement temperature not only related to air temperature but also associated with the standard deviation of the annual low air temperature. Liu (2005) pointed out that maximum pavement surface temperature had a 1℃ increment corresponding to average air temperature 1℃ increasing. Liu (2011), and Qin (2011) pointed out that surface temperature is related to air temperature and could be determined by the daily highest- and lowest air temperature. All of these approaches assume air temperature plays an important role in pavement temperature. However, they neglect factors including snow cover, solar radiation, and surface layer material on the pavement temperature distribution.

In the present study, a large-scale asphalt pavement experimental system is designed and carried out. Based on the experimental measured data of pavement temperature under different conditions, the quantitative relational degrees of snow cover, solar radiation, and surface layer material are expected to be revealed.

## 2. Study area and datasets

### 2.1 Study area and climatic data

The studied area in this paper is applied to Harbin, in Heilongjiang Province, China shown in Figure 1. Harbin, with a total land area of 53,068 square kilometers, is located in southern Heilongjiang Province. As the prefecture is rather large, its latitude ranges from 44°04′ to 46°40′N, and the longitude from 125°42′ to 130°10′E. The main terrain of the city is generally flat and low-lyling, with an average elevation of around 150 meters. Under the Köppen climate classification and continental polar air, Harbin features a monsoon-influenced, humid continental climate with very cold winters and mild summers.

*Figure 1: Map of Harbin, China*

### 2.2 Large-scale asphalt pavement experimental system

To analyze the pavement temperature distribution in seasonal frozen area, measured data from field large scale asphalt pavement experiment performed in Harbin Institute of Technology is used.

A field asphalt pavement system has been built at Harbin Institute of Technology in 2011 (Figure 2). It provides a means of collecting experimental data for the purpose of studying the pavement temperature distribution in seasonal frozen area. The design parameters for this system are listed in Table 1.

*Table 1: Design parameters for asphalt pavement system*

| Structure layer | Material | Thickness(m) |
|---|---|---|
| Surface course | Asphalt concrete | 0.10 |
| Base course | Cement stabilized crushed stone | 0.30 |
| Subgrade | Clay | — |

Twenty-six thermocouples are embedded inside the pavement to measure the pavement temperature at different depths (Figure 3). In order to identify the impact of asphalt layer on the undisturbed ground temperature, several thermal sensors were also embedded in the undisturbed soil nearby the experimental system (Figure 3).

The uncertainty of the thermal couple is ±0.1℃. Additionally, a data recorder is used to collect all the data in twenty-minute intervals from November 2011.
Hourly observed weather data, such as: ambient air temperature, solar radiation, wind speed, wind direction, and precipitation, were recorded by automatic meteorological station installed at Harbin Institute of Technology (Figure 4).

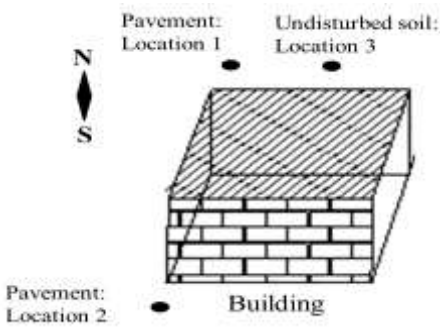
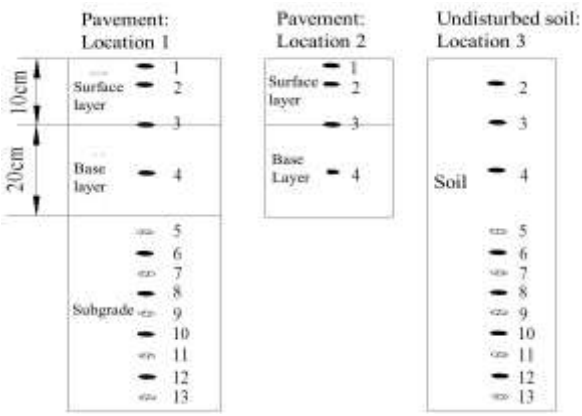



*Figure 2: Test locations*




Sensor 1:2cm depth; Sensor 2:5cm depth; Sensor 3:10cm depth; Sensor 4:20cm depth; Sensor 5:40cm depth; Sensor 6:60cm depth; Sensor 7:80cm depth; Sensor 8:100cm depth; Sensor 9:120cm depth; Sensor 10:140cm depth; Sensor11:160cm depth;Sensor 12:180cm depth;
Sensor 13:200cm depth.

*Figure 3: Thermal sensor arrangement*

*Figure 4: Automatic meteorological station installed at Harbin Institute of Technology*

## 3. Results and discussion

### 3.1 Impact of solar radiation on pavement temperature

In the following paragraphs, we present the result of a comparative study for different shading conditions to investigate the role of solar radiation on pavement temperature. As shown in Figure 2, two test locations are selected in this study. Location 2 is in the front of the building which is exposed to the sunshine, while location 1 is on the north of the building. Compared with location 2, less solar radiation arrive at location 1 due to the building shading effect.
Measured pavement temperature for the two locations at the depth of 2cm is illustrated in Figure 5. The weather condition during experimental period is listed in Table 2.
As can be seen from Figure 5, during November 14-16, 2011, the pavement temperature at 2cm depth at night is almost at the same level, while there is a significant difference in the daytime. The maximum temperature difference at 2cm depth between the two test locations is 7.5℃. Considering the weather condition during the experimental period, the phenomenon is mainly caused by solar radiation. Building shading has an unneglectable effect on pavement temperature.
Furthermore, during November 17-18, 2011, there is no obvious difference in pavement temperature at 2cm depth. The maximum temperature difference at 2cm depth between the two test locations is 0.2℃. This is mainly due to the weak solar

radiation in sleet and light snow condition. This phenomenon verifies that solar radiation is an important factor to pavement temperature.

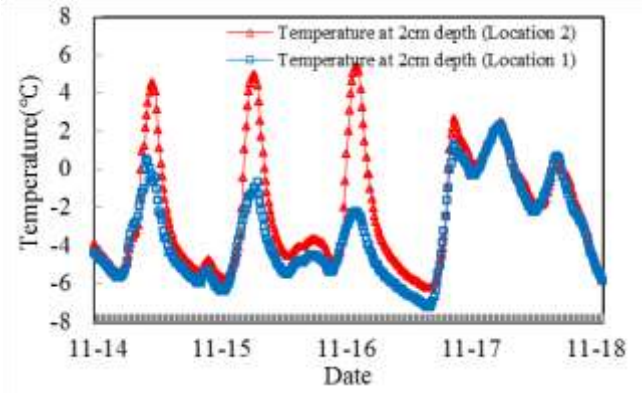



*Figure 5: Impact of solar radiation on pavement temperature*

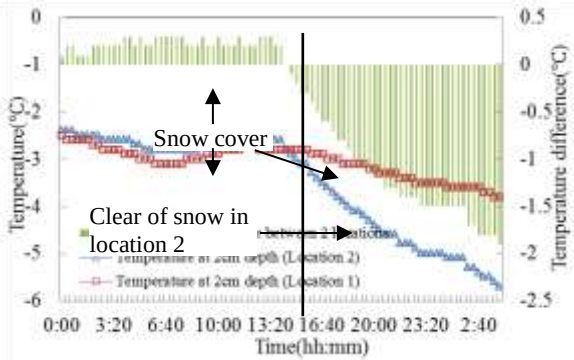



*Figure 6: Comparison between pavement temperature with and without snow cover*

As aforementioned, snow cover can prevent the heat loss from the pavement surface and keep the pavement warmer. Next, we will discuss the impact of snow depth on the insulating effect of snow based on the collected data. Its impact can be indicated by the ratio of daily pavement temperature difference at 2cm depth to daily air temperature difference (P/A).

| Date | Nov.14 | Nov.15 | Nov.16 | Nov.17 | Nov.18 |
|---|---|---|---|---|---|
| Weather condition | Fine | Fine | Fine | Sleet | Light snow |

*Table 2: Weather condition during test period (November 14-18, 2011)*

### 3.2 Impact of snow cover on pavement temperature

The influence of snow cover can be explained by Figure 6. Experimental data from the two test locations on March 8, 2012 were adopted. Note that snow covers location 1 during the experimental period, while the snow at location 2 is cleared away from 1:30 pm. Therefore, we can compare two sets of data to investigate the role of snow cover on pavement temperature.

As illustrated in Figure 6, the pavement temperature with snow cover fluctuates slightly for the two test locations. The maximum temperature difference between the two locations is 0.3℃, which is mainly caused by the system sensor error. When the pavement surface is free from snow for location 2 from 1:30 pm, pavement temperature at 2cm depth decreases sharply, while the maximum temperature difference between the two locations increases significantly. This indicates that once snow covers the pavement surface, it forms an insulating layer and the pavement below will stay warmer than if the snow were not to accumulate.

Figure 7 illustrates P/A exponentially decreasing with the increasing snow depth. It indicates that the value of P/A decreases rapidly with an increasing shallow snow depth, and tends to be stable after some snow depth, which is named as "snow depth insensitive regime". As shown in Figure 7, with the snow depth of 2cm, P/A is 56% comparing to 119% with the clear pavement surface. In the snow depth of 5cm, P/A reduces to 21%. Furthermore, when the snow depth reaches to 18cm, P/A is 13% which is slight less than that with the snow depth of 5 cm. Therefore, it is reasonable to recommend "5cm" as the threshold of snow depth insensitive regime.

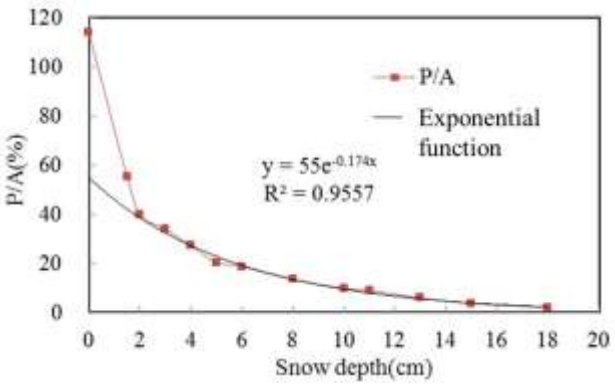


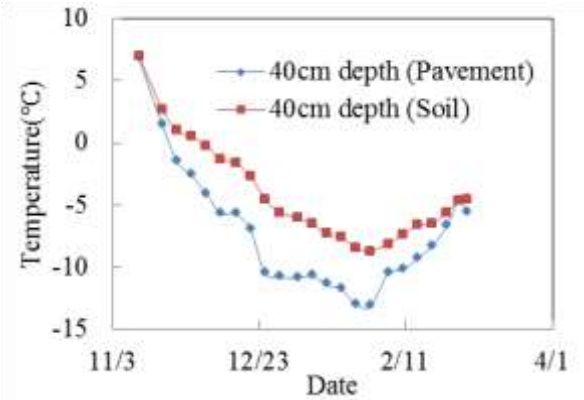

*Figure 7: P/A vs Snow depth*

### 3.3 Impact of surface layer material on pavement temperature in winter

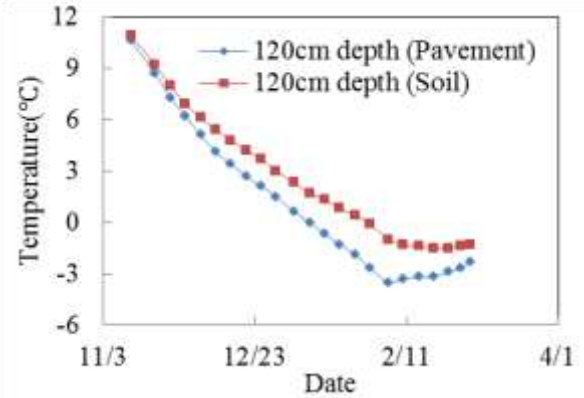
As we know, the thermal properties of pavement material is significantly different from that of undisturbed soil. The purpose of this part is to get explicit insight into the impact of surface layer material on pavement temperature in winter.

Figure 8 shows the variation of the ground temperature with and without pavement material from November 2011 to March 2012. It can be clearly seen that due to the higher thermal conductivity and thermal diffusivity of pavement material, the thermal regime of pavement is easier to absorb/release heat from environment in winter.

Impact of surface layer material on the frost depth is demonstrated in Figure 9. As shown in Figure 9, pavement material results in the frost depth of 180cm, which is deeper than the undisturbed soil frost depth of 160cm. That is to say, there is a negative role of pavement layer on the ground temperature stability. On the other hand, compared with the undisturbed soil, pavement material makes the freezing-thawing period two weeks earlier.




(a) 40cm depth




(b) 120cm depth

*Figure 8: Comparison between ground temperature with and without pavement material*

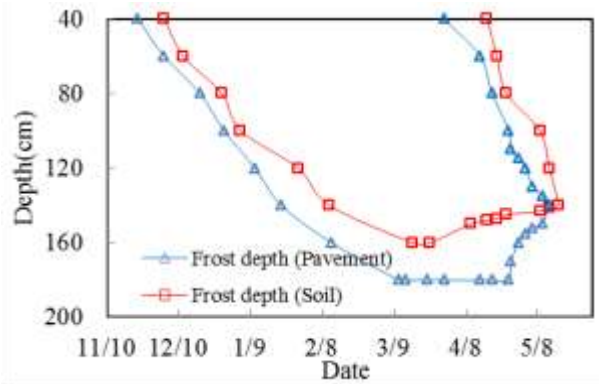



*Figure 9: Comparison between frost depth with and without pavement material*

## 4. Conclusions

In this paper, a field large-scale asphalt pavement experimental system has been developed in Harbin Institute of Technology. It provides a means of collecting data for the purpose of studying the pavement temperature distribution in seasonal frozen areas. Based on the

measured data, we discussed the important role of solar radiation, snow cover and surface layer material to pavement temperature distribution characteristic. The following conclusions can be drawn from the present work:

(1)The comparison between pavement temperature with and without building shading indicates the crucial role of solar radiation on the pavement temperature in daytime.

(2)Once snow covers the pavement surface, it forms an insulating layer and keeps the pavement below warmer than if the snow were not to accumulate.

(3)P/A exponentially decreases with the increasing snow depth. The snow depth of 5cm is suggested as the threshold of snow depth insensitive regime.

(4)Due to the higher thermal conductivity and thermal diffusivity of pavement material, the thermal regime of pavement is easier to absorb/release heat from/to environment which results in the aggravation of frost depth in winter.

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# Enhancement of a MBR treating sewage by low intensity ultrasound at low temperature

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## Abstract

The biological treatment of urban sewage in cold area has been facing ~~with~~ poor removal efficiency due to the impact of low temperature. The performance of a membrane biological reactor (MBR) enhanced by low intensity ultrasound with effective volume of 22L operated at 7~8℃ was investigated. The results showed that the ultrasound can improve the performance of a submerged membrane biological reactor treating low temperature sewage at short hydraulic retention time (HRT). The optimal parameters of ultrasound were 28kHz frequency, 0.27W/L power density, 15min irradiation time per 24h. On the condition of 2.6h HRT, the effluent COD and $NH_3$-N of ultrasound-assisted MBR decreased to 10~20mg/L and 5.8~7.9mg/L. The membrane cleaning cycle extended from 17d to 19d means that ultrasound can reduce membrane fouling at low temperature. Fluorescent staining results have shown that ultrasound at optimal parameters could improve membrane permeability by 8% and increase dehydrogenase activity by 59.30%. The enzyme activity changed under ultrasound radiation was mainly due to the transformation of the enzyme molecular conformation.

## 1. Introduction

Membrane biological reactors (MBR) with a long solid retention time have been applied widely in wastewater treatment, which present numerous advantages over conventional activated sludge process. However, long hydraulic retention time (HRT), which directly related to the reactor volume as well as the construction and operational costs, is still needed at low temperature. So, investigating the performance of MBRs treating low temperature sewage in short HRT and developing measures to strengthen its effect are of great significance. Membrane fouling is another major obstacle ~~that~~ blocking the widespread application of membrane bioreactors.

Research on ultrasound application in biological engineering shows that the appropriate amount of ultrasonic radiation can enhance bioactivity (Wu J. Y. et al., 2002; Shi L. C. et al., 2003; Pitt W. G. et al., 2003), therefore the addition of ultrasound during the operation of MBRs could offer an effective way to improve the

biological waste treatment efficiency at low temperature. For each type of biological reactions, there exists an optimal ultrasound density and irradiation time. The improper processing time and processing level is unfavorable for increasing sludge activity (Liu Y. Y. et al., 2003; Gao D. W. et al., 1999). Schläfer et al. (2002) studies the impact of low intensity ultrasound on bioactivity. They found that the intermittent ultrasound irradiation could considerably enhance the bioactivity, whereas the continuous ultrasound irradiation couldn't increase the bioactivity evidently. In conclusion, intermittent irradiation should be adopted when using ultrasound to enhance the bioactivity, at the same time, the appropriate interval should be chosen as well.

Accordingly, we chose two reactors at low temperature (7-8℃) to carry out contrast tests, and ultrasound was loaded in one of them. The experiment studied the increase of biological removal efficiency of COD, $NH_3$-N within 24h after the treatment by low intensity ultrasound, thus we made a systematic optimization choice on power density, irradiation time and irradiation interval. Afterwards, we investigated the fortification of MBRs treating low temperature sewage and the effects of reducing the membrane fouling and discussed the mechanism of enhancement of the biological sewage treatment by low intensity ultrasound at low temperature.

## 2. Materials and methods

### 2.1 Experimental set-up

The schematic of the lab-scale submerged MBR used in this study ~~was~~ is shown in Figure 1. The effective volume of the bioreactor was 22L. A hollow fiber membrane module (FP-T0008, China) was submerged in the bioreactor. The synthetic wastewater was continuously supplied by a peristaltic pump (BT00-600M, Longer Precision pump Co., Ltd, China) from the storage tank. The membrane filtered effluent was extracted by a pump of the same model operating intermittently with a cycle of 8 min on and 3 min off. The hydraulic retention time was 2.6h. Filtration operation of the lab-scale submerged MBR was conducted with the constant flow rate mode of 10L/($m^2$·h). To maintain a constant water level in the reactor, a level sensor was used. The pressure gauges were installed in order to monitor the variation of the trans-membrane pressure (TMP) between the membrane and suction pumps. The filtration was stopped when the TMP reached 30kPa.

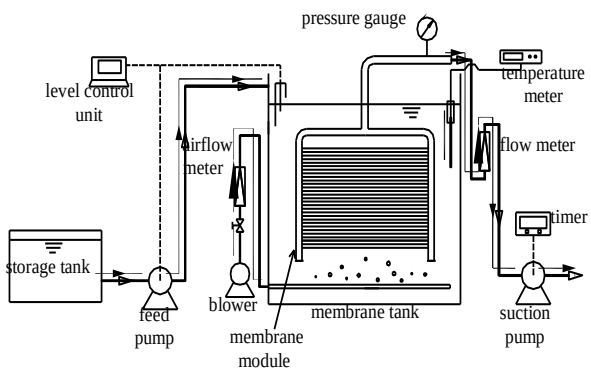


*Figure 1: Schematic of the laboratory-scale SMBR set-up*

The synthetic wastewater was composed of glucose, ammonium chloride ($NH_4Cl$) and dipotassium hydrogen phosphate ($K_2HPO_4$) as the main nutrition. The average concentration of influent COD was 440mg/L (COD: N: P=100:10:2). Sodium bicarbonate ($NaHCO_3$) was added to the

wastewater to adjust the mixed liquor pH to 6.8-7.2. The bioreactor was aerated at a flow rate of 0.32m$^3$/h and was inoculated with sludge from Taiping Sewage Treatment Plant, Harbin, China. The concentration of activated sludge suspension was 8000±200mg/L. The membrane bioreactor was placed in a refrigerator to meet the operation temperature of 7-8℃. In the bottom of bioreactor, enhanced by ultrasound, the ultrasonic transducer was set up, and was connected with the ultrasonic generator outside the reactor through conducting wire. The ultrasound frequency was set at 28kHz, with power at 0.13W/L（effective water volume), 0.27W/L and 0.4 W/L, respectively. Radiation time was 10, 15and 20 mininutes, respectively.

### 2.2 Analytical methods

Measurements of COD and $NH_3$-N in the influent and membrane effluent mixed liquor suspended solids (MLSS) in the bioreactor were performed according to the standard methods of APHA (1995). Dissolved oxygen concentration in the reactor was measured by a DO meter (Oxi 330i, WTW, Germany).

The analytical method of dehydrogenase activity is the improved TTC- determination on dehydrogenase activity with the reducing agent $Na_2S$ and the extracting agent Acetone (Zhou H. et al., 2006). Fluorescent diacetate（FDA）and Rhodamine123 (Rh123) were used to show the change of membrane permeability and that of trans-membrane potential respectively（Lu Q. et al., 2006）.

Two techniques-PCR amplification and denatured gradient gel electrophoresis (DGGE) were implemented to analyze the structure and the dynamic of the communities in the reactor under different conditions. To amplify the primer (Nuebel U. et al., 1996) we adopted Dcode$^{TM}$ Gene mutation detection system ( Bio-Rad Laboratories) to realize the DGGE electrophoresis to PCR. To get the gel image, the gel after silver staining was scanned by UMAX PowerLook 1000 scanner

## 3. Results and discussion

### 3.1 The optimal parameters of ultrasound

In this experiment, we schematize the percent change of COD (or $NH_3$-N) removal efficiency (*Re*) in terms of time t, *Re* was expressed by formula（1）.

$$Re = \frac{Rs - Rc}{Rs} \times 100$$

（1）

In formula:

*Re*=increasing percent of COD（or $NH_3$-N）removal efficiency, %;

*Rs*=COD（or $NH_3$-N）removal efficiency in MBR installed ultrasound, %;

*Rc*=COD（or $NH_3$-N）removal efficiency in control MBR, %.

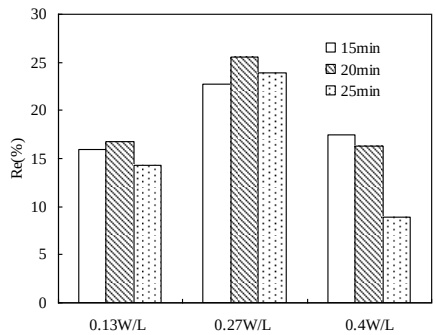


*Figure 2: Improvement of COD removal treated by ultrasound at different power densities and irradiation time.*

The percent change of COD (or $NH_3$-N) *Re* after ultrasonic radiation with different power density and different irradiation time is shown respectively in Figure 2 and Figure 3, *Re* is the average value within 24 hours.

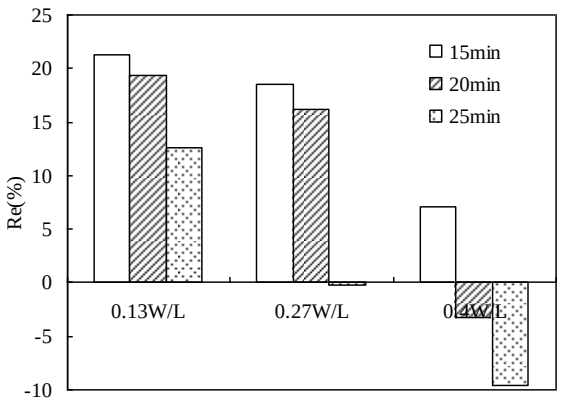


*Figure 3: Improvement of $NH_3$-N removal efficiency treated by ultrasound at different power densities and irradiation time.*

Comparing Figure 2 with Figure 3, we could see that in the process of low intensity ultrasound enhancing MBRs treating sewage at low temperature, there exists several differences between the optimal conditions applied to COD and those applied to $NH_3$-N. Prophase research findings show that, low temperature has a greater impact to $NH_3$-N removal efficiency. Thus, we give priority to the enhancement of $NH_3$-N removal in sewage by ultrasound. In conclusion, the ultrasonic parameters conforming to this experiment are chosen as: frequency 28kHz, power density 0.27W/L, irradiation time 15min, interval 24h. With these conditions the ultrasonic energy consumption is 4.05W•min/L.

### 3.2 The effectiveness of MBRs treating sewage by ultrasonic enhancement at low temperature

Water samples were collected 6 hours after the completion of the ultrasonic irradiation. The increase of COD and $NH_3$-N total removal efficiency in MBR installed ultrasound and blank test are shown in Figure 4 and Figure 5, respectively.

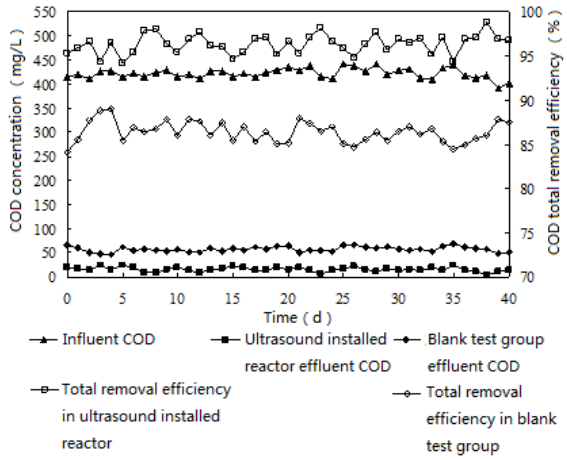


*Figure 4: The effect of ultrasound on COD removal efficiency in MBR*

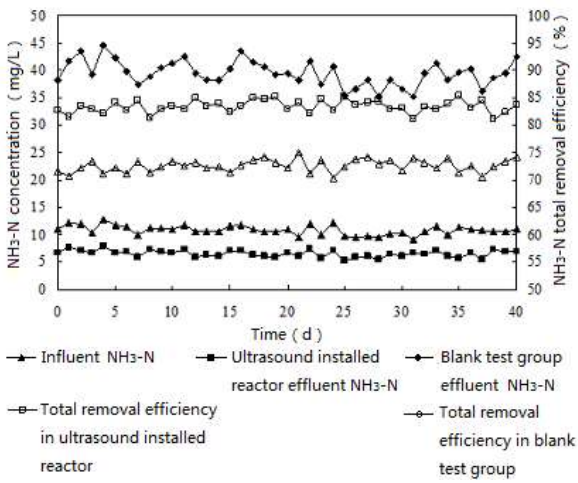


*Figure 5: The effect of ultrasound on $NH_3$-N removal efficiency in MBR*

From Figure 4, we could tell that after the installation of ultrasound in the reactor, COD total removal efficiency grows from around 87% to around 96%, the increase rate is 7%-13%. The concentration of COD in MBR falls to 40~50mg/L, which in effluent, after separation by membrane, falls to 10~20mg/L.

As shown in Figure 5, the effect of ultrasound increases the total removal efficiency of $NH_3$-N in sewage at low temperature from 70%-74% to 81%-85%. Re is raised by 13%-16% with the aid of ultrasonic enhancement. The concentration of $NH_3$-N in MBR decreases from 11.5-14.5mg/L to 7.5-9.8mg/L, which in effluent decreases from 10.5-12.8 mg/L to 5.8-7.9mg/L.

### 3.3 Discussions on ultrasound controlling membrane fouling

From Figure 6, it is shown, 17d after the set-up of membrane cleaning, the transmembrane pressure in the control test MBR raised to 31.8kPa, which means cleaning is needed. In order to clean simultaneously the membrane module in the reactor installed ultrasound, the control group which did not reach cleaning point continued running. Under 0.27W/L ultrasound, transmembrane pressure grew relatively slow, and increased to 30kPa after 19d, while transmembrane pressure in control group already increased to 41kPa. In the reactor installed ultrasound, membrane module fouling was decreased by periodical ultrasonic irradiation, which extended the membrane cleaning cycle from 17 days to 19 days.

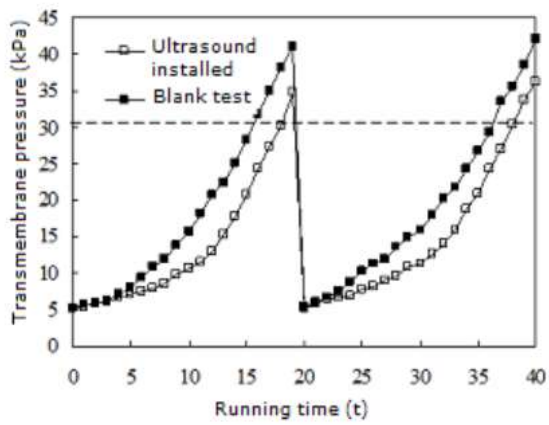


*Figure 6: Comparison of transmembrane pressure with and without ultrasound*

During the first four running days, the two reactors had fundamentally the same transmembrane pressure, while the membrane pore blocking played the leading role. During the next ten days, ultrasonic irradiation controlled the development of membrane fouling, and transmembrane pressure in MBR installed ultrasound increased slowly, while the formation of a cake layer led by concentration polarization played the leading role. After 14 days running, the effect of decreasing membrane fouling by ultrasound fell remarkably. At 19$^{th}$ day the chemical cleaning of membrane in two reactors were operated, the later variation rule of transmembrane pressure was in accord with that before cleaning.

The effect of ultrasonic wave on membrane fouling in different stages during membrane module operating cycle is caused by the ultrasound cavitations, due to the fact that under cavitations the gas nucleus in mixed liquor of the reactor is activated. The mixed liquor generates a very high shear force which acts on membrane module, and cleans up the contaminants attached to

membrane materials. However, the ultrasonic irradiation works only on the membrane fouling caused by concentration polarization, while it doesn't work on the membrane fouling caused by other factors such as membrane pore blocking (Liu L. et al., 2008). This determines that in the experiment ultrasonic irradiation could only control membrane fouling during a short time, at the later stage of the MBRs operating, the increased rate of transmembrane pressure couldn't be controlled even if ultrasound was installed.

Although ultrasonic waves prolong membrane cleaning cycle for only 2 days, it proves feasible that the enhancement of MBR biological treating effect at low temperature and membrane fouling control could be achieved at the same time. To control better membrane fouling at low temperature, ultrasonic power density, the form of ultrasound transducer and the placement of transducer in the reactor all need to be further studied.

### 3.4 Preliminary study on mechanism of ultrasonic enhancement of biological activity at low-temperature

#### 3.4.1 The ultrasonic effect on membrane permeability

Figure 7 shows the ultrasonic effect on membrane permeability by means of fluorescence spectrophotometric method. The result illustrates that under the ultrasonic treatment at the same power density, when irradiation time is extended, the membrane permeability increases; under the same irradiation time, as power density increases, membrane permeability also increases.

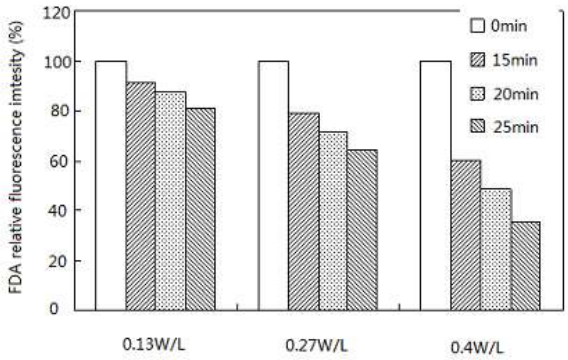


*Figure 7: The effect of ultrasound irradiation on the permeability of cell membrane*

The perforation effect caused by ultrasound contributes mainly to the increase of microorganism membrane permeability. Micro gas nucleus is activated by ultrasonic effect on fluid, and these micro gas nuclei are called cavitations bubbles, which vibrate, grow, retract and then collapse. High temperature, high pressure and swift current engendered in the instance of collapse change the lipid bilayer of cell membranes, so that membrane permeability increases (Thompson L. H. et al., 1999; Crum L. A., 1995; Li Y. S. et al., 1995; Feng R. et al., 1991).

Ultrasonic effects to membrane permeability could explain the increasing of COD, $NH_3$-N removal efficiency. When power density was raised from 0.13W/L to 0.27W/L, the increase of membrane permeability was in the range that microbial cell could accommodate, which does good to the exerting of functions of cell membrane. Under this ultrasound power, the micro pores engendered on cell membrane could self-repair within a given period. With this reversible change of membrane permeability, cells won't be injured. When power density increases to

0.4W/L, cell membrane permeability increase greatly, and the micro pores engendered on cell membrane are too big to assure cell self-healing; irreversible change of membrane permeability happens and it influence microbial cell metabolism.

### 3.4.2 The effect of ultrasound on enzyme activity

The degradation of organic pollutants is implemented by enzymes in activated sludge, among them dehydrogenase plays an important role. In this experiment, 2,3,5-triphenyltetrazolium chloride (TTC) was used as indicators to determine dehydrogenase activities. Achromatic TTC was reduced to red trityl (TF) by dehydrogenase, which proves that, the more TF is engendered from unit volume sample in a unit of time, the higher dehydrogenase activity is. Table 1 shows the comparison of dehydrogenase activity at the different ultrasonic power ~~density~~ densities, with radiation time of 15mins.

*Table 1: The effect of ultrasound at different power densities on dehydrogenase with radiation time of 15 min.*

| Power density（W/L） | Dehydrogenase activity（μgTF/mL·h） | | Increase（%） |
|---|---|---|---|
| | Control | Ultrasound | |
| 0.13 | 150.37 | 198.54 | 32.03 |
| 0.27 | 149.86 | 238.73 | 59.30 |
| 0.40 | 150.61 | 204.37 | 35.69 |

The results demonstrate that, dehydrogenase activity in the reactor installed ultrasound is higher than that in the blank test reactor, which means that low power density ultrasonic irradiation could improve sludge activity in membrane bioreactor. However, sludge activity increased by different low power density ultrasound varied. 0.27W/L ultrasound could increase dehydrogenase activity by 59.30%, followed by 0.40W/L, 0.13W/L, which increase respectively dehydrogenase activity by 35.69%, 32.03%.

The degradation of organic works by biochemical enzymatic reaction; enzymatic reaction velocity reflects enzyme activity. Enzymatic reaction velocity depends on two factors: the mass transfer efficiency and the enzyme conformation. Ultrasound could change enzyme activity by affecting both factors (Feng R. et al., 1991).

As active biological molecule enzymes, its activity depends fundamentally on the reasonableness of enzyme conformation. When ultrasound works on enzyme molecules, the released energy may cause the change of enzyme conformation, and then affect enzyme catalytic activity. Reasonable enzyme conformation could increase enzyme catalytic activity; however, the unreasonable one even destructible change, will decrease enzyme catalytic activity (Lü P. et al., 2004; Jia J. Q. et al., 2009). Low strength ultrasonic treatment could lead to the increase of enzyme molecules energy, which could then lead to the slight change of enzyme conformation, both of which make the ultra structure of enzyme molecules more flexible, and then present higher catalytic activity (Sala F. J. et al, 1995; Ding Q. Z. et al., 2009), like the effect of 0.13W/L and 0.27W/L ultrasound. High strength ultrasound could cause a further increase of enzyme molecules energy, which could lead

to a further change of conformation to incline to unreasonable one, which would block enzyme catalytic activity, and the result would be enzyme inactivation. Certainly, 0.4W/L ultrasound is not too strong to make dehydrogenase activity lose its activity, it merely abates the increase of enzyme activity comparing to 0.27W/L ultrasound effect. It is possibly because that, for some dehydrogenase molecules sensitive to circumstance, 0.4W/L ultrasound is too strong. This kind of ultrasound changes enzyme conformation a little more so that enzyme activity decreases, thus sound intensity like 0.13W/L, 0.27W/L are appropriate.

## 4. Conclusions

In summary, the low intensity ultrasound can improve the efficiency of sewage treatment in membrane biological reactor (MBR) with short hydraulic retention time (HRT) at low temperature of 7-8℃and mitigate the membrane fouling simultaneously. The optimal parameters of ultrasound were 28kHz frequency, 0.27W/L power density, 15min irradiation time per 24h. On the condition of 2.6h HRT, the effluent COD and NH3-N of ultrasound-assisted MBR decreased to 10-20mg/L and 5.8-7.9mg/L compared to 42-65mg/L in control. The membrane cleaning cycle was extended by two days by using ultrasound and by reducing membrane fouling at low temperature. The study on the mechanism of ultrasonic enhancement showed that 0.27W/L ultrasound irradiation 15mins every 24h could improve membrane permeability by 8% and increase dehydrogenase activity by 59.30%. The enzyme activity was changed by ultrasound mainly by the transformation of the enzyme molecular conformation.

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# Analysis of anti-freezing strategy of solar collecting system in severe cold areas

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## Abstract

In this study, a novel anti-freezing strategy, using the remnant thermal energy in vacuum tubes as the heat source, was proposed to prevent freezing for the solar collecting system in winter nights. The strategy was investigated and analysed experimentally and the system process, especially the controlling principles were presented in detail. A series of tests were carried out under different weather conditions to verify its effectiveness in Harbin, China. Finally, the economy and the feasibility of the proposed strategy were also discussed. From the experimentally obtained results, some important conclusions and suggestions have been acquired, which could be helpful in the design and improvement of solar heating or centralized hot water systems in severely cold areas.
Keywords: anti-freezing strategy, freeze protection, solar energy, severe cold areas.

## 1. Introduction

As a sustainable and promising energy, solar energy is getting increasing attention due to its cleanliness and renewability. Solar thermal collecting systems have been widely utilized over the world. However, solar energy systems are mostly limited by the intensity of solar radiation, the variation of outdoor air temperature and types of solar collectors (Li et al., 2007; Muneer et al., 2008; Ayompe et al., 2011; Du et al., 2013;). It is one of the serious problems in severe cold areas, that the pipes and devices of solar collecting system would be frozen because of the low outdoor air temperature. However, the studies on anti-freezing measures are relatively few.

Toth et al. (2002) presented one kind of solar collector fabricated from plastic transparent insulation materials (TIM) saving auxiliary anti-freezing measures, which can result in significant cost reduction in solar water heating systems. Zhao et al. (2007) analysed the performances of five familiar anti-freezing methods used in solar water pipes in winter. All these anti-freezing strategies and measures only can be used in small buildings and suitable for small domestic hot water systems. For large-scale solar heating or centralized hot water system, the universal measures utilized by users to prevent freezing includes electric tracing bands, antifreeze fluid, and heating the outdoor devices and pipes by hot water in thermal storage tanks, etc. However, the method of anti-freezing by hot water requires extra power, energy consumption of the pump and thermal energy of hot water. Meanwhile, it is expensive and not safe enough by electric tracing bands. In real projects, the use of antifreeze fluid as the heat transfer medium in solar energy system was much popular in severe cold areas. For large-scale solar energy systems, the required volume of antifreeze fluid was huge because of the large fluid capacity of the system. Further, the initial cost would be increased with the increasing concentration of antifreeze fluid. In addition, because of its

viscidity and corrosiveness, antifreeze fluid with a high concentration was disadvantageous to the system. Therefore, it is necessary to decrease the concentration of the antifreeze fluid and increase the economy of the solar energy system in severe cold areas.

Currently, the concentration of antifreeze fluid was decided according to the local ambient air temperature. The freezing point of antifreeze fluid should be higher than the ambient air temperature at a certain range (EN 12975-2-2006; GB 50495-2009). Taking the city of Harbin (in severe cold areas) for example, the suitable concentration of antifreeze fluid was 50% (its freezing point was -33.8°C) in consideration of the calculated temperature of the exterior heating (-26°C) in winter. In winter nights, with the cooling of air temperature, the fluid temperature in solar collectors and pipes decreased gradually. As the water capacity was small in pipes, the fluid temperature can decrease from 30°C to 0°C, or even lower than it in a few hours even though the insulation was sufficient. All-glass vacuum tube collectors have larger water capacity, better insulating properties and higher fluid temperature than the pipes, which is a relatively better choice for solar collecting systems to resolve the issue of freezing. As the capacity of all-glass evacuated tube collector is large, the fluid temperature in it is high when the solar collecting mode finishes, and the remnant thermal energy which can't be extracted from the vacuum tube can be used for anti-freezing of the outdoor pipes indeed.

Therefore, a novel strategy using the remnant thermal energy in vacuum tubes as the heat source was proposed in this paper to provide freezing protection of the solar collecting system in winter nights. A series of experiments were carried out in severe cold areas in Harbin, China. The purpose of this study was to analyse the change of fluid temperature in the solar collecting loop (also can be called the anti-freezing loop) and to research the economy and reliability of the proposed anti-freezing strategy. The suitable concentration of antifreeze fluid was also discussed in the paper which can provide a key reference for the design of solar thermal utilization systems as well as the selection of antifreeze concentration to improve the economy of the system.

## 2. System introductions

### Description of the system

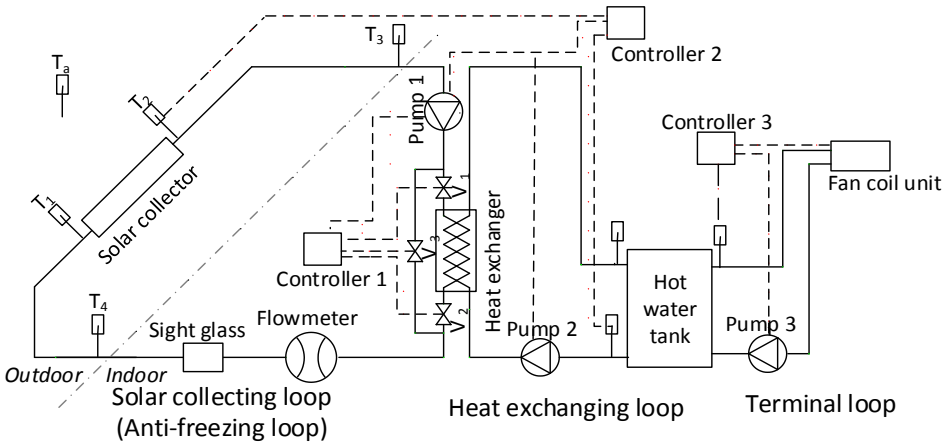


*Figure 1: The schematic diagram of the system*

According to technical code for solar heating systems (GB 50495-2009), the suitable type of solar thermal system for severe cold areas was an indirect cycle system filled with antifreeze fluid or air in solar collectors, and the terminal heating mode was floor radiation or hot air heating. Thus, an experimental platform was built in terms of the recommendation in above references in Harbin, China, as illustrated in Figure 1. The experimental system was built to research the effect of anti-freezing and solar collecting performance in winter of severely cold areas, and hence the equipment types and the installation slope of solar collectors were considered in winter conditions.

The experimental system consisted of the solar collecting loop (anti-freezing loop), heat exchanging loop and terminal heating loop, as well as the data acquisition and controlling system. In this system, a glycol-water mixture was used as the antifreeze fluid and the solar collecting loop was an open-loop subsystem. The gross area of solar collector in the system was 3.5 $m^2$ arranging in south-north direction. The outer and inner diameters of collector tube were 58 mm and 47 mm, respectively, and the total length was 2 m. The total area of heat exchanger was 0.3 $m^2$, and the capacity of the thermal storage tank was 150 L. The system is shown in Figures 2 and 3.

*Figure 2: The system's solar collectors*

*Figure 3: The systems interior loop*

Controller 1 was used to realize the control of the pump and valves in anti-freezing mode realized by a 16-channel serial relay with programming. The control principles will be introduced in the following section. Controllers 2 and 3 were differential and thermostatic temperature controllers respectively, both of which were used in solar collecting mode. The temperatures were measured by T-type thermocouples with ±0.2°C accuracy after calibration using a first grade standard mercury-in-glass thermometer with accuracy of 0.05°C. The flow rate was tested by a glass-tube rotameter (LZB-15) with a flow range of 25 to 250 l/h and 1.5 grade accuracy. In addition, automatic an electric tracing band was added on the outdoor pipes and connected to a single phase electronic energy meter to count the power consumption for comparison of anti-freezing methods with the proposed strategy in the paper.

**The proposed anti-freezing strategy**

Two operation modes can be realized in this system: solar collecting mode and anti-freezing mode. On sunny days, solar energy can be absorbed and transferred into thermal energy by the fluid in solar collectors. Therefore, the temperature of the fluid is raised in the system operated in the solar collecting mode. In the nights and overcast days, as there was no solar radiation, the fluid temperature in solar collector and outdoor pipes was much lower. In this condition, some strategies must be applied to prevent freezing of the loop. However, the initial and operational costs were diverse for different anti-freezing measures.

In the proposed anti-freezing mode, a by-pass loop was set to avoid the freezing of the heat exchanger. The anti-freezing loop was marked with red arrows, as shown in Figure 3. The switching of both operation modes was realized by the controlling of valves. The hot fluid in solar collector was circulated by a pump to the outdoor pipes, where the fluid temperature was lower. It can ensure the fluid temperature in outdoor pipes is higher than its freezing point to prevent freezing.

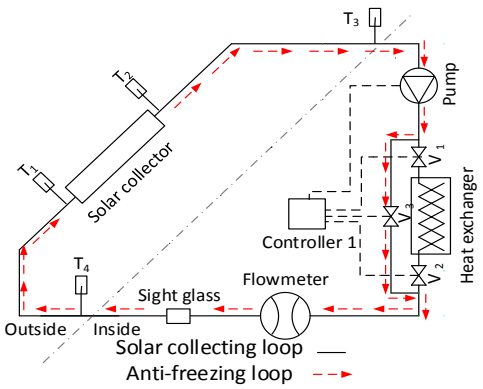


*Figure 4: The anti-freezing loop and the parameter settings for system 1*

Two identical systems (system 1 and system 2) were built to compare the effect of different anti-freezing measures. The optimal concentration and flow rate of the fluid have compared to get the best parameter values. The thermocouples of $T_1$ and $T_2$ were set at the inlet and outlet of the solar collector respectively. $T_3$ and $T_4$ were located on the pipes where freezing was easy to happen.

**The control principle of anti-freezing mode**

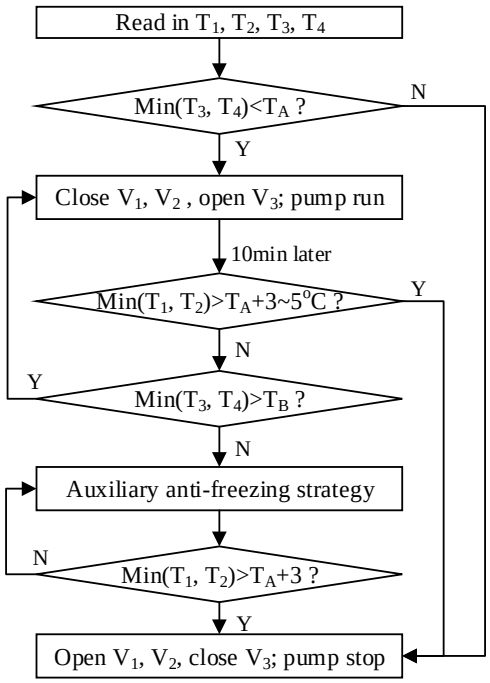


*Figure 5: The flow chart of the control principle of Controller 1*

A control system was designed to ensure the automatic operation of anti-freezing mode. The flow chart of the control principle is given in Figure 5.

All of the values of $T_1$ to $T_4$ were recorded by the data acquisition instrument and can be read in the control system. For system 1, it was obvious that the value of $T_1$ and $T_2$ were higher than $T_3$ and $T_4$. Thus, the anti-freezing mode started according to the value of MIN ($T_3$, $T_4$) at the set point of $T_A$, which can be set to equal to the value of freezing point of the fluid or higher than it. The operation time was set based on the pipe length of the loop and the flow rate of the fluid. If the operation time was too long, the power energy of the pump was high and the economy of the strategy could decrease. Otherwise, the thermal energy from solar collector can't be conveyed to the outdoor pipes if the operation time is too short. In the paper, the operation time was set to 10 minutes and can be adjust in practical projects. The fluid temperature in solar collector was decreased gradually with the decreasing of the ambient air temperature in the nights. When the value of $T_1$ and $T_2$ was close to $T_A$, it meant that the amount of

thermal energy that could be used for anti-freezing was small and the temperature rise of the fluid in the pipes was relatively low by circulation. In this situation, MIN ($T_1$, $T_2$)> $T_A$ + 3-5°C was set to judge whether the intermittence circulation for anti-freezing mode should be stopped after running for 10 minutes. If it was not, continuous circulation was needed to avoid frequent starting and stopping of the pump. Strictly speaking, when the fluid in the pipes was at flowing status, especially turbulence status, freezing could not happen even at the temperature of freezing point but rather at super cooled conditions. Further investigations were needed to decide the value of super cooling degree, which was influenced by many factors including the velocity of the fluid and the diameter of the pipes. So the value of $T_B$ can be lower than the freezing point of the fluid in fact (in this system, $T_B$ was set equal to the value of freezing point). If the values of $T_3$ and $T_4$ were lower than that of $T_B$, the fluid in the pipes would freeze and then another auxiliary strategy was recommended in this condition, such as an electric tracing band or using the thermal energy in storage tank to provide heat for the pipes. The practical operation results show that the operational time of the auxiliary strategy was very short and only happened in extreme weather conditions.

An ethylene glycol solution with volume concentration of 20% was employed in this experiment. The values of $T_A$ and $T_B$ were 0°C and -8.9°C, respectively, and the starting value of continuous circulation for anti-freezing was 4°C.

## 3. Results analysis

The experiment was carried out according to the proposed anti-freezing strategy and operation mode as introduced above. Here, the anti-freezing effectiveness and the temperature change in the anti-freezing loop during winter nights were discussed, as well as the long-term operational effect. In the experiment, the concentration of antifreeze fluid was 20% with the freezing point of -8.9°C. The monthly average air temperature was tested during the heating season in Harbin, China, as seen in Table 1.

| Month | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| Average air temperature(℃) | 4.2 | -6.5 | -17.7 | -18.4 | -13.9 | -2.4 | 6.7 |

*Table 1: The monthly average air temperature during heating season*

### The anti-freezing effect on typical nights

Generally, the temperature of fluid in solar collectors was still at a high level, though the solar collecting mode had been finished, which was advantageous for anti-freezing in one night because the thermal capacity was large and the fluid temperature was high enough. Usually, solar collecting mode lasted from 9:30 am to about 4:00 pm on sunny days, and the fluid temperature was above 20°C at 6:00 pm. The effect of the anti-freezing strategy can be seen in Figure 6.

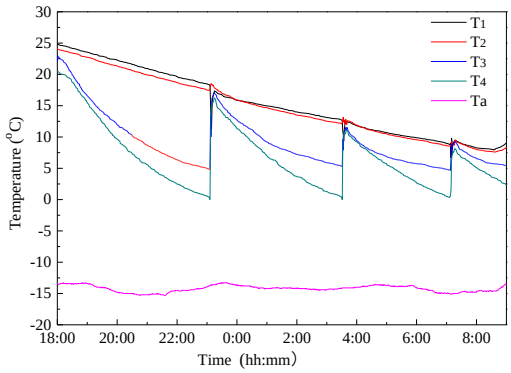


*Figure 6: The operation effect of anti-freezing mode (1)*

It can be seen that the fluid temperature at the inlet and outlet of the solar collector ($T_1$, $T_2$) decreased slowly in night, with the lowest temperature of 7.5°C ($T_2$) at about

8:00am. The anti-freezing operation had almost no influence to the fluid temperature in solar collectors. On the contrary, the trend of changes in $T_3$ and $T_4$ were much more obvious and these solar collectors were easy to freeze even though it was well insulated. The fluid temperature in pipes could decrease gradually if the ambient air temperature was much lower. The proposed anti-freezing strategy was started operating at 11:07 pm, 3:31 am, and 7:08 am, respectively, when the lowest temperature reduced to $T_A$ (0°C) and lasted for ten minutes each time, and the total operation time for anti-freezing was about 30 minutes in one night.

Another example was that the anti-freezing operation time was much longer though the values of the ambient air temperature had no significant difference, as seen in Figure 7. The operation time of the intermittent circulation was 60 minutes from 6:00 pm to 5:00 am of the next day. Besides, continuous circulation was continued from 5:30 to 8:10, when the smaller value of $T_1$ and $T_2$ was lower than 4°C, as seen in Figure 8. The total operation time for anti-freezing mode was about 3.7 hours in one night.

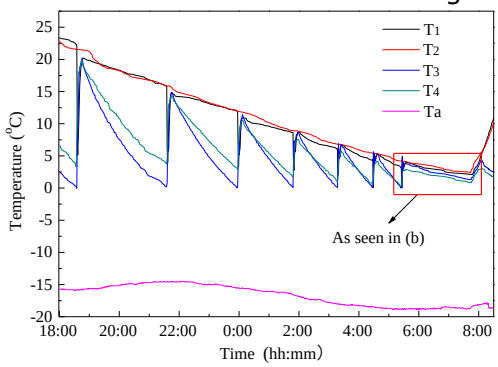


*Figure 7: The operation effect of anti-freezing mode (2), for both intermittent circulation and continuous circulation*

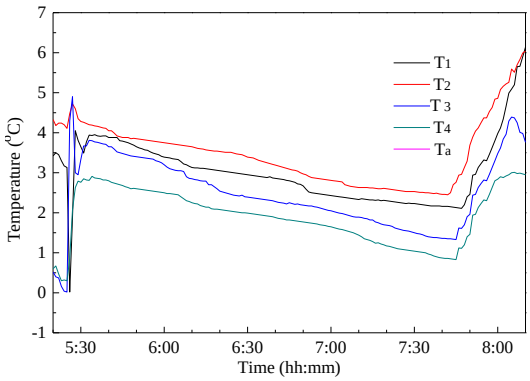


*Figure 8: The operation effect of anti-freezing mode (2) for continuous circulation*

**Effectiveness of long-term operation**

The anti-freezing operation mode was continued from October 15, 2013 to January 31, 2014, covering the coldest months of December and January. The operation time was recorded during this period. Taking the month of December, 2013 as an example, the daily average operation time was about 70 minutes, and no more than 50 minutes for most of the month. There were only 4 days that the operation time was longer than 120 minutes. As seen in Figure 9, the total operation time was 2300 minutes (about 38 hours) in the month. In addition, the monthly total operation time of October, November, and January 2014 was 0, 21, and 62 hours, respectively.

As mentioned above, December and January were the coldest months in Harbin, China. However, the anti-freezing operation time in January was much longer than that in December.

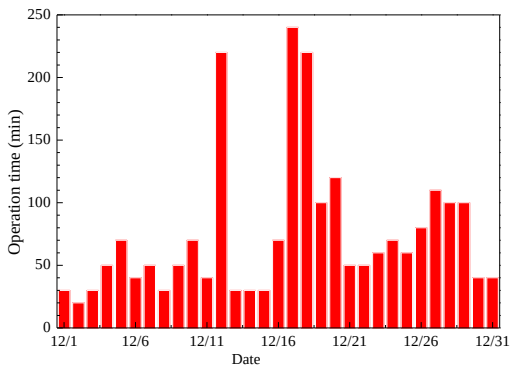


*Figure 9: The operation time of anti-freezing mode in December, 2013*

One of the most important reasons was that the anti-freezing operation time would be

extended in continuous operation mode with the decreasing of the air temperature. According to the existing operation time of the anti-freezing strategy, we can assume that the monthly total operation time in February, March and April are equal to those in December, November and October respectively. So the total operation time of the proposed anti-freezing strategy can be estimated as 187 hours during the heating season.

| Anti-freezing measures | The proposed strategy | Electric tracing band | Only ethylene glycol solution with high concentrations |
|---|---|---|---|
| Basic parameters | The whole operation time during the heating season was 187 hours;<br>A safety coefficient of 1.3 was multiplied;<br>The power of the water pump was 0.1 kW;<br>The local electricity price was 1 RMB/kWh; | The power energy over the night was 2.7 kWh every night;<br>To assume the running time of the electric tracing band was 110 nights;<br>The local electricity price was 1 RMB/kWh; | The capacity of solar collector (20 tubes) was 52 L;<br>The total capacity of the loop was 79 L;<br>The mass of the ethylene glycol was 42 kg;<br>Its price was 10 RMB/kg;<br>The period of validity was 3 years; |
| Operation expenses | 24.3 RMB/Year | 297 RMB/Year | 0 |
| Initial cost | 500 RMB | Length of the materials was about 21 m;<br>The initial cost was about 50 RMB; | The yearly expense of ethylene glycol was 140 RMB for one group of solar collector; |
| Besides | Ethylene glycol solution with concentration of 20% was used;<br>The yearly cost was about 46.6 RMB; | | |
| Total cost over a ten-year period | 1209 RMB | 3020 RMB | 1400 RMB |

*Table 2: The economic comparison of different anti-freezing measures*

## 4. Economic analysis

The economy of the proposed anti-freezing strategy was analyzed and compared with other two strategies: electric tracing band and antifreeze solution with high concentration (ethylene glycol solution was used here).

For the proposed anti-freezing strategy, the initial cost was about 500 RMB for the valves and controlling apparatus. Besides, some power energy was consumed by the water pump and the operation time was about 187 hours through the whole heating season. Here, the total operation time was multiplied by a safety coefficient to guarantee the extreme weather condition.

An electric tracing band was added on the anti-freezing loop to calculate the actual

consumption of electrical energy when it was set to prevent the freezing of the outdoor pipes. It was tested from 18:00 to 8:00 the next day in December for a period of ten nights. The consumption of power energy was recorded and the average value was 2.7 kWh per night. On the basis of the local meteorological parameters as shown in Table 1, we assume that running time of the electric tracing band was about 110 nights during the heating period (the running time in November and March were both ten nights and all nights during November to January). Thus, the total consumption of power energy during the whole heating season can be gotten, as seen in Table 2. In fact, the actual operation days and the running hours every night would be longer than the estimated value of 110 nights.

In addition, the volume of the Ethylene glycol solution and its expenses were also calculated in Table 2. Here, the suitable concentration of ethylene glycol solution was 50% according to related codes.

The expenses of the three different measures and the economy were analyzed based on the experimentation platform. It was necessary to point out that the expenses of ethylene glycol solution with high concentrations was calculated based on only one group of solar collector. In real project, dozens or hundreds groups of solar collectors would be used for solar heating or centralized hot water systems, and then the total water capacity of the loop would be very high. In this condition, the expenses of ethylene glycol could be increased hugely with the increasing area of solar collectors. Therefore, the anti-freezing methods only by ethylene glycol solution with high concentration were uneconomic for large-scale solar systems. However, the initial cost and the operation time of water pump for the proposed anti-freezing strategy showed little change in different projects. Its operation expenses to prevent freezing mainly depended on the power of the pump. The yearly operation cost was only 243 RMB if the power of pump was 1 kW, which was far less than that of other two measures. However, it is better to take auxiliary measures for freezing prevention in extreme conditions when the proposed strategy was used.

## 5. Conclusions

The current method for determining the concentration of antifreeze fluid according to the ambient air temperature in solar systems was problematic, which often led to a higher concentration than needed, and therefore a higher cost. The suitable concentration of antifreeze fluid should be determined through comprehensive consideration of solar system form, thickness of insulation layer and the anti-freezing control strategy, as well as the ambient temperatures.

A novel anti-freezing strategy was proposed to prevent freezing in this study in Harbin, China. The practical operational results showed that the strategy could meet the demand of freeze protection and the economically, it was much better than conventional measures, especially for large-scale solar systems. Test data suggested that the proposed anti-freezing strategy was viable and could reduce the concentration of antifreeze fluid from 50% to 20%, or even much lower in some cases without freezing. The results in this paper

can be used to improve the economical property of the solar collecting system and to provide a key reference for the application of solar energy in severe cold areas.

## Acknowledgements

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# Introduction of flexible monitoring equipment into the Greenlandic building sector

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## Abstract

Greenlandic winters are long and cold, so living inside a heated and properly ventilated space requires a significant amount of energy. It is assumed that in mechanically ventilated buildings, significant amounts of energy for heating can be conserved by adjusting ventilation flow rates according to the actual demand of occupants. Traditional solutions available on a market consist of a controller and the sensors in a living space detecting occupancy and activity (movement sensors, $CO_2$ sensors, humidity sensors, etc.). The controller needs to be programmed and maintained by an expert and the sensors need to be hardwired to the controller. In Greenland, where price of labor is very high and availability of experts is limited, installation of such control system becomes expensive. Particularly in case of renovation of existing buildings the costs of hardwiring the sensors can be very high. One possible solution to the above is to use wireless sensor network (WSN) technologies. A prototype wireless monitoring and control system is demonstrated on a renovation of a ventilation system in the new dormitory Apisseq in Sisimiut, Greenland. The existing mechanical ventilation was running at a constant air flow even during unoccupied hours which resulted in a very high heat demand. It was estimated that installing the WSN system will bring annual savings of 1,600 € at the investment of 8,000 €. This paper describes a setup of the system and discusses its advantages and disadvantages.

## 1. Introduction

The Arctic climate is cold, so living inside the heated buildings requires a great amount of energy. In Greenland, households account for 25 % (85 % is heat and 15 % is electricity) of total energy consumption (Statistics Greenland, 2011). The average heat consumption of households in Greenland was 387 kWh/m$^2$ in 2009 (Statistics Greenland, 2011). Additionally, another 25 % of the Greenlandic energy is used to deliver energy and water to consumers (including households) therefore, the real contribution of households to the overall energy use is higher than 25 %. With intention to reduce the $CO_2$ emissions, the overall energy use needs to be reduced accordingly. Given the amount of energy used in buildings, these cannot be excluded from the process of energy conservation. To reduce the energy use, buildings have become more insulated and air tight. Furthermore, the buildings need to be equipped with advanced heating, ventilation and air conditioning (HVAC) systems to ensure a healthy and comfortable indoor environment. It has been shown that

optimizing the operation of HVAC systems according to occupants' actual demands can bring substantial energy savings (Nielsen and Drivsholm, 2010; Laverge et al., 2011). However, installing the conventional wired control systems may become costly as the expenses related to installation of these systems are high.

Special cases are buildings in remote regions like Greenland, where availability of professionals is limited and price of labor is expensive. Advanced monitoring and control systems might get rejected for their high initial price and thus long payback time.

The possible way to reduce installation costs is the use of a WSN to monitor and control buildings. In the previous paper, (Heller and Orthmann, 2014) the requirements for use of WSN technology in buildings were discussed and the current literature reviewed. It was concluded that the WSN technology has by far not been developed to its full potential. Studies dealing with this topic are mostly theoretical and based on computer simulations, (Tachwali, Refai, and Fagan 2007, 439-444; Sklavounos et al., 2013) or pilot studies without full scale implementation of the technology (Bhattacharya, Sridevi, and Pitchiah 2012, 422-427; Kim, Jung, and Kim 2010, 145-150; Preethichandra 2013, 1306-1310).

The purpose of this study was to implement a WSN based monitoring and control system into an existing building in use. This should bring energy savings without negative effects on indoor air quality (IAQ). Moreover it should be demonstrated that the return on investment is higher than in the case of conventionally wired solution. The ease of installation and functionality should be introduced to the local construction community.

## 2. Building description

The studied building is a dormitory for engineering students in Sisimiut, Greenland. It was built in 2010 with the intention to demonstrate energy efficient building in which modern technologies not yet commonly used in the Arctic could be installed and tested. Previous studies undertaken in this building have shown, that the poor design of ventilation systems causes that the building to be constantly over-ventilated (Kotol and Rode, 2012), which in such cold climate results in very high energy use.

**Layout**

The building has a circular shape and consists of three floors: a ground floor with technical rooms and two upper floors with flats, laundry and a common room. There are 33 single room flats for one student and four double room flats at the gables of the building (see Figure 3).

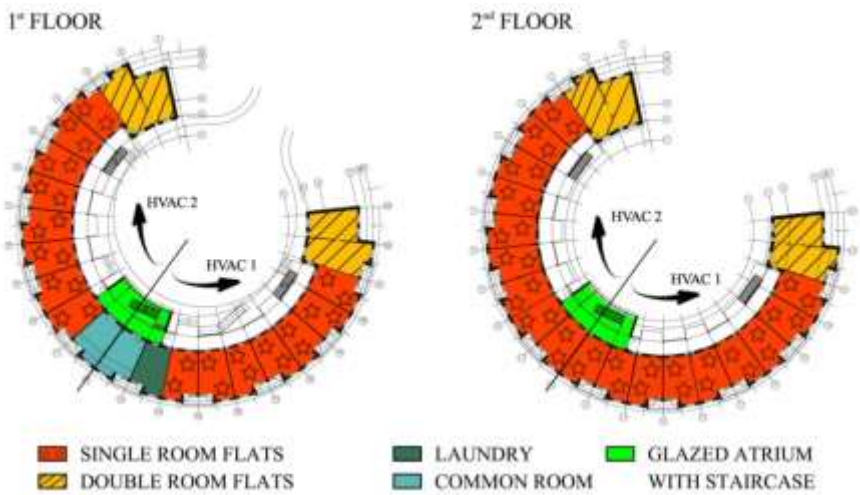


*Figure 3: Floor plans of the engineering dormitory Apisseq*

Both Kotol and Roade (2012), and Vladyková et al. (2010) outline a more detailed description of the building. The annual heat demand was estimated at 160 MWh/yr for space heating and 80 MWh/yr for domestic hot water (DHW). In total, the predicted annual heat demand was 240 MWh/yr or 169.7 kWh/($m^2$·yr). However, the measured annual heat demand in 2012 was 310 MWh/yr or 219.7 kWh/($m^2$·yr). Out of which, 18 % (55.8 MWh) was dedicated to the heating of the ventilation air. This, in terms of running costs resulted in total annual energy bill of 30,000 € in 2012 (of which 5,400 € was related to ventilation air heating).

**Ventilation system**

The ventilation system consists of two identical HVAC units. Each of them is providing ventilation to half of the building as shown in Figure 3. The units deliver fresh air to living space of each flat and extract the polluted air through range hoods and bath rooms in each flat. The supply air is delivered at a constant rate whereas the exhaust air flow can be increased in case of increased humidity in bathrooms or cooking activities. But under normal operation the ventilation is balanced and provides an air change of 1.1 $h^{-1}$. Nevertheless, the current Greenlandic building regulation (GBR) (Direktoratet for Boliger og Infrastruktur, 2006) requires a minimal air change of 0.5 $h^{-1}$. The GBR also requires that both the kitchen and the bathroom should be equipped with air extraction rates of 20 l/s and 15 l/s, respectively. This additional requirement was likely the reason for designing the constant ventilation rate of 20 l/s (air change of 1.1 $h^{-1}$). Nevertheless, the required extraction rates from kitchens and bathrooms is meant to be available when needed and does not have to be on at all times. It is expected that substantial energy savings can be achieved by reducing the ventilation air change according to the actual demands (occupancy) without negatively affecting the indoor air quality.

## 3. **Methodology**

To detect the actual occupancy and estimate the right amount of ventilation air needed for the space, $CO_2$ concentration is often used. Some European standards suggest that in case of demand controlled ventilation where indoor $CO_2$ concentration is used as an IAQ indicator, the ventilation rate can be adjusted in order to maintain the indoor $CO_2$ concentration below a certain level [1000 ppm (Danmark. Erhvervs- og Byggestyrelsen, 2010) or 500 ppm above outdoors (Dansk Standard, 2007)]. The minimal air change of 0.05 l/s·$m^{-2}$ to 0.1 l/s·$m^{-2}$ (Dansk Standard 2007) should however always be maintained.

**Experimental setup**

In this study the ventilation system in one half of the building will be adjusted to reduce ventilation rates according to actual demands of the occupants. The other half of the building will remain unchanged to provide a reference case for an evaluation of the improvements.

Due to the design of the ventilation system and the fact that the building is already in use, the space for improvement is rather limited. For that and for economic reasons, it would not be economically feasible to control the air flow on a room level. Nevertheless, as the building is a dormitory

for students with similar schedules, it can be expected that their daily routines will have a similar pattern for a majority of the time. Therefore, the air flow will be regulated centrally on the ventilation unit level.

Although the air flow will be adjusted centrally for the entire half of the building, it is still important to make sure that none of the flats will be insufficiently ventilated. Therefore, a $CO_2$ sensor will be placed in each flat. To avoid excessive installation costs related to hard wiring each sensor, the sensors will communicate wirelessly with the central node. The central node will evaluate levels of $CO_2$ in the rooms and then send a control signal to the actuators which will adjust the air flows. The actual air change will be controlled in a range between
0.02 $h^{-1}$ and 1.1 $h^{-1}$ in order to maintain the $CO_2$ concentration in each room below 1000 ppm.

Furthermore, the central node will be accessible online. This will further reduce the costs as all the programming, calibration, software maintenance, troubleshooting and data collection and evaluation can be done remotely from anywhere in the world.

## 4. **Hardware**

The Libelium Waspmote platform creates the foundation of the setup and was preferred because of its modularity, which made it possible to build custom nodes for specific purposes.
The experimental setup consists of three different node types (each designed for a specific purpose), a signal amplifier and damper actuators which control the airflow.

**Central Node**
The central node creates the wireless network. It can be used as a router for message passing and it saves data from the network in constant storage. Additionally, the node enables online access and remote control. The coordinator node selected for this experimental setup is the Meshlium ZigBee-PRO-AP.

**Sensor Nodes**
The sensor nodes monitor $CO_2$ concentrations in each flat and send the data to the coordinator node. The proposed system contains 18 sensor nodes, or one in each flat. The main components of the nodes are Waspmote ZigBee PRO, Gases Sensor Board v2.0 and solid electrolyte $CO_2$ Sensor TGS 4161. Each node has a 6.6 Ah battery which will be able to power the node for one year. Additionally, each node will be powered from the electrical grid as a backup.

**Control Node**
The control node (Waspmote ZigBee PRO) receives the commands from central node and by means of two actuators (Belimo TF24-SR) adjusts the supply and exhaust damper positions (and thus air flows). Because the voltage range given by control node is 0 V to 3 V and the actuators require a signal from 0 V to 10 V an amplifier was needed. For this purpose a programmable relay Siemens LOGO which is already a part of the building's inventory was used.

## 5. **Economy**

Excluding the Belimo actuators and Siemens LOGO relay, which are already

installed in the building), the retail price of the wireless solution is 8,000 € (according to Table 1).

For comparison the price of the wired solution would be 16,000 € (according to Table *2*).

Costs of programming the hardware were neglected as they will likely be similar in both (wired and wireless) solutions and will be marginal compare to the whole investment.

*Table 1: Price estimation for the wireless solution*

| Item | Price (incl.VAT) |
|---|---|
| 19x Waspmote ZigBee PRO | 3,800 €, |
| 18x Gases Sensor Board v2.0 | 2,160 € |
| 18x Solid electrolyte $CO_2$ Sensor TGS 4161 | 880 € |
| Meshlium ZigBee-PRO-AP | 660 € |
| Installation of the sensors | 500 € |
| **Total** | **8,000 €** |

*Table 2: Price estimation for the wired solution*

| Item | Price (incl.VAT) |
|---|---|
| 18x $CO_2$ sensors (Vaisala CARBOCAP® GMW 22) | 6,000 €, |
| Programmable logic controller with web server (Prolon PID 4000) including installation | 4,000 € |
| Installation of the sensors | 6,000 € |
| **Total** | **16,000 €** |

It is expected that the adjustment will reduce the heat demand of the actual ventilation unit by 50 %. That yields an annual energy savings of approximately 15 MWh/yr or 1,600 €/yr at current heat price (107 €/MWh). The return on investment for wired and wireless solutions is shown in *Figure* and *Figure* .

## 6. **Discussion**

The price of wired solution is higher partially due to use of different $CO_2$ sensors. The Vaisala sensors use more accurate technology and do not require such frequent calibration (the manufacturer guaranties 5 % accuracy over the course of

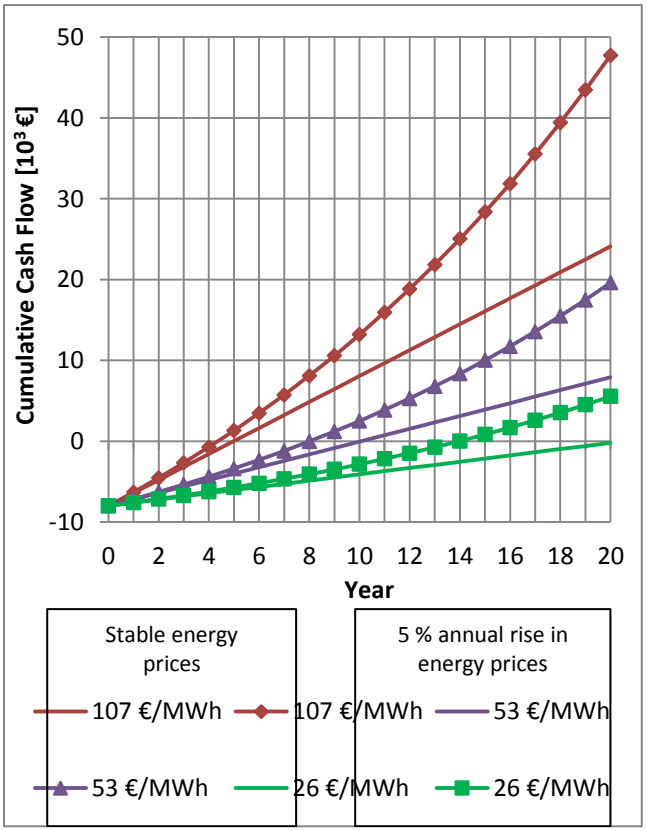


*Figure 2; Return on investment of the wireless solution*

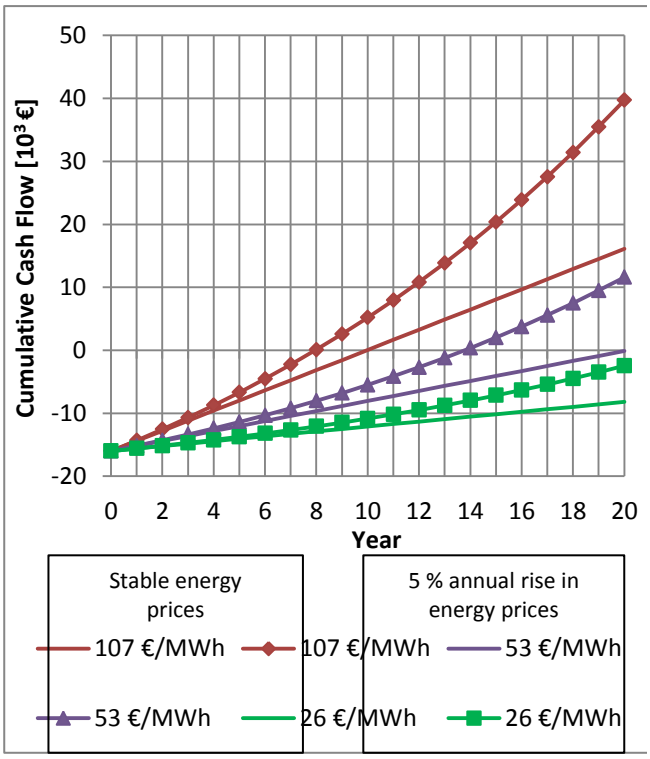


*Figure 3: Return on investment of the wired solution*

five years). On the other hand, the wireless solution allows remote calibration as frequently as required by the sensor manufacturer, and therefore more accurate sensors might not be needed.

Installing the wireless solution only requires attaching the sensor nodes to a wall in each flat and connecting the central node to the internet. The rest is done remotely. This is less labor intensive than wiring each sensor through the finished building in use. Moreover, it does not require highly skilled professionals to perform this work.

The actual payback period will strongly depend on the real energy savings and will also be affected by the energy price as shown in *Figure* and *Figure* . However, even if the energy price remains constant (107 €/MWh), a payback time of the WSN solution is 5 years compare to 10 years in case of wired solution.

One of the advantages of WSN solution is its flexibility and expandability. If in the future the system needs to be expanded by large number of sensors (e.g. controlling the ventilation system in the other half of the building), these can simply be added to rooms without a need for additional central nodes. This is contrary the wired solution, which has a limitation in maximum number of inputs from sensors. Once this number is reached, additional hardware must be installed.

A possible drawback of the WSN solution can be its robustness and long term reliability. These will be tested during the experiment.

## 7. Conclusions

It was found that it is economically beneficial to use WSN technology instead of traditional wired solutions in remote areas with expensive labor and limited availability of highly skilled professionals. The simple payback period is five years, which will likely be even shorter in the future due to increasing price of energy. The real energy savings and actual payback period along with the reliability of the WSN system needs to be confirmed by the experiment.

## Acknowledgements

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# Housing and planning adapted to the climate in northern Norway

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**Abstract**

In the northern and mountainous areas with no trees and strong winds, drifting snow can be a major problem for daily life, and should thus be an import concern for the planning of residential areas. The most important factors to consider are the design of the access roads, choice of location and the design of the houses and landscaping of the area.

In the beginning of 1980s, the Municipality of Hammerfest and the Norwegian State Housing Bank (NSHB), initiated a housing development, which was specially adapted to areas with high winds and large amount of snow accumulation. A development area in Fuglenesdalen in the town of Hammerfest, was chosen as a test site. Snow on the ground in this area remains for up to half a year. Additional buildings in this area must be designed with regards to the gusty winds and enormous snowdrifts.

The climate is changing, with more extreme weather to come in the future. First and foremost, we must assume greater and more intense precipitation. Temperature increase, more rapid and frequent temperature fluctuations and more wind is also likely. Climate change is an important issue for NSHB, and the primary goal for NSHB is to ensure adequate and secure housing for all. The new climate conditions force local authorities, planners, architects and the construction industry to face new and tough challenges. And this necessitates climate adaptation of our built environment as well as placing it high on the political agenda.

## 1. Introduction

From the turn of the 20th century and to the period between the two world wars, the housing situation was precarious in rural areas and the towns in northern Norway. An overwhelming lack of housing occurred at the end of World War II in northern Norway as a consequence of the region being razed to the ground and it urgently needed to be rebuilt. With a lack of private funding in the post war period, the only solution was to establish a state-owned housing bank.

The Norwegian State Housing Bank was established by the Parliament on March 1, 1946 "to provide central and local government support for reconstruction and new building." Since its foundation, NSHB has remained the Norwegian government's most important tool for implementing its housing policy and it has played a key role in the development of the Norwegian welfare state.The Norwegian State Housing Bank`s primary goal is to ensure adequate and secure housing for all citizens.

*Figure 1: Hammerfest 1944-45.*

Finnmark, including Hammerfest as well as North-Troms was destroyed by the German practice of scorched earth tactics in 1944-45 during the period of the German Army retreating from the North Eastern Front. Given the harsh climate the lack of shelter made it difficult for the advancing Soviet forces. The people of the North were forcibly evacuated and all buildings were destroyed, mainly by burning.

NSHB played a major role in replacing 20,000 homes in the north which were destroyed by the war. The major challenges in northern Troms and Finnmark led to the creation of a separate department in Hammerfest. About 90 % of housing construction in the north was funded through this office. The planners of reconstruction were mainly architects and engineers who had job experience from the South, but adapted it to the northern setting and developed and implemented new types of drawings for the new buildings. The cities and towns that emerged in the post-war period were characterized by organization and order, and stood in contrast to the earlier "self - grown" settlements.

Hammerfest and other places along the coast were the most attractive areas for


*Figure 2: The first office of the Norwegian State Housing Bank, established in Hammerfest March 1st, 1946.*

housing construction in early development after the World War II. This concentration of population in coastal areas placed new requirements for zoning, site plans and individual housing.

In the beginning of the 1980s, the Municipality of Hammerfest and NSHB initiated a housing development, which was specially adapted to areas with high winds and large amount of snow accumulation. A development area in Fuglenesdalen in the town of Hammerfest, was chosen as a new test site. Snow on the ground in this area remains up to half a year. Additionally, buildings in this area must be designed in

response to the gusty winds and dominance of snowdrifts.

The purpose of developing a pilot project in full scale in Fuglenesdalen, was to find the best practice of planning and developing processes in order to reach the most favorable settlement in view of the climate conditions of the area.

## 2.Background

In the northern and mountainous areas lacking trees and with strong winds, drifting snow may be a major problem for the daily life, and should thus be a focal point for the planning of residential areas. The most important factors to take into account are the design of the access roads, the location and the design of the houses and the landscaping of the area.

Hammerfest is a major port for fishing, oil and gas in Northern Norway with approximately 10,000 inhabitants. It is situated at a latitude of 70 degree 40` North. In the 1970s, further development of the town was extended to the area of Fuglenesdalen, Field 1, 2, and 3.
Fuglenesdalen is located north of Hammerfest in a height of 100 m above sea level and has since the mid 70s been the municipality's main site for housing. The area is heavily exposed to winds from both the northeast and southwest and has no vegetation to provide shelter from wind and the weather.
The climatic conditions in Fuglenedalen compares to 1200 m.asl. in the southern part of Norway, which is a harsh mountain climate, despite being at an altitude of 100 m.asl. When developing residential areas in this valley, there are major challenges with snowdrifts blocking roads and homes. And in addition, the most exposed buildings are faced with major maintenance expenses.


*Figure 3: City centre of Hammerfest and Fuglenesdalen*

*Figure 4: City centre of Hammerfest.*

The climatic conditions at this altitude are very harsh compared to the conditions at sea level. Severe snow problems with blocked access roads, entrances and houses totally covered by snow are prevailing in this area. It was thus decided to focus on climatic conditions when

planning the next two areas to be developed, namely Field 4 and Field 6.

*Figure 5 : View of Fuglenesdalen.*

The climatic conditions both in summer and winter are special in the far north of Norway compared to the more southern latitudes. There is midnight sun for two months, but despite constant sunlight the average summer temperature remains 10 degrees C during the summer. In the winter, there is lack of sunlight for two months and frequent periods where strong winds and snow fall occur.

**3.Field 4, Fuglenesdalen**

The Municipality of Hammerfest`s most important housing estate in the 1970s and the 1980s was Fuglenesdalen, a climatically harsh area on the outskirts of the town. The most attractive housing estates in Hammerfest were developed at an early stage. By then it had become necessary to develop into areas which put strict demands upon regulation plans, and on each particular dwelling such as was the case in Fuglenesdalen Field 4.

A long term research program on areas and housing in demanding climatic areas, was carried out by Professor Arne K. Sterten and Architect Anne-Brit Børve in cooperation with the Municipality of Hammerfest, named "Test Project Field 4 Fuglenesdalen" (ref. Husbanken (1987): Husbankhus for hardt klima). And they set the following main aims for the project:

**The project 3 main aims:**

- To have limited amount of drifting snow deposited close to the entrances and the garages.
- To create areas for outdoor activities that both has sun and is sheltered against cold winds
- The access roads should be easy to keep open during snow storm periods.

Through its regional office in Hammerfest, NSHB was involved in the project. Early on NSHB offered an extended loan to climatically adapted dwellings and later engaged their own architects to develop housing models for the area of Field 4. Both of the involvements were new for NSHB's role in the housing market in Norway.

After comprehensive data collection and analysis of local climate and model experiments, Professor Arne K. Sterten and Architect Anne Brit Børve developed a master plan where climate impacts in the field can be reduced. The plan constituted of a system of external and internal earthwork, wind and snowfences and field planted vegetation (the field was basically without shrubs and trees). The roads in the area were planned in such a way as to reduce and rationalize the snow removal. A number of provisions and recommendations for each lot with regard to land allocation and the design and location of residence and garage was made. This was done to

promote a better adaption to local climate than had been seen earlier, in line with the development plan's intentions. Screening of outdoors areas to extend the short summer season had also been an important factor in the master plan.

In the physical plans for the area the protection against the winds and the drifting snow are essential factors, and the houses built in Field 4 have different degrees of climate adaption. Key components of planning regulations was made by Professor Arne K. Sterten and Architect Anne Brit Børve.

## Key components of planning regulations:

Moderate the load of weather with:

- Outside and inside earth wall, snow screens and vegetation.
- Traffic system developed to reduce traffic and increase the efficiency of the snow clearance.
- Shape of the site which gives a possibility for having a short distance from the road to the entrance and sheltered outdoor spaces.
- The garage is placed so that drifting snow is reduced in front of it.

**Climatic conditions – criteria of house design in Field 4:**

The NSHB office in Hammerfest participated in the "Working group for better environmental and climatically adapted dwellings in Northern Norway". On behalf of the group, Architect Anne Brit Børve conducted the report "Functional requirements for housing in climate vulnerable areas."
The interest for climatically adapted housing was growing in NSHB and as Field

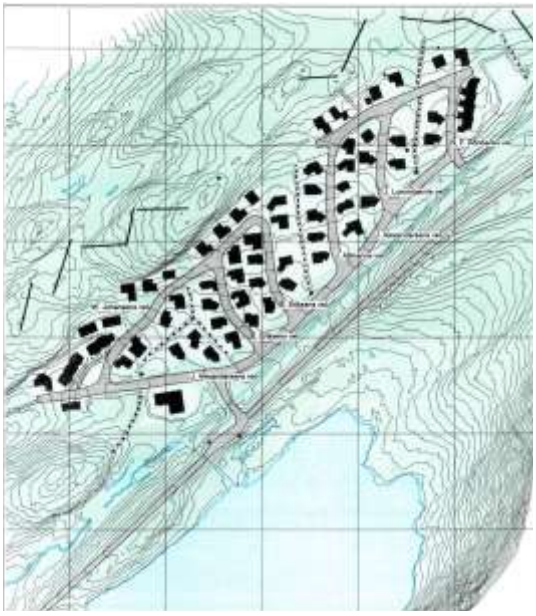

*Figure 6: Building structure Field 4*

4 in Fuglenesdalen was developed with some misaligned varieties of standard houses, it was found absolutely necessary to encourage the development of appropriate housing types for Field 4.

**The Norwegian State Housing Bank then offered increased loans for house which fully or partially fulfilled the following criteria:**

- Has the house and garage been placed in accordance with the planning regulation?
- Has the house been placed in a way to prevent snow piling up at the entrance?
- Does the house have an alternative entrance?

- Has the house been aerodynamically designed with the back side towards wind and weather?
- Have rooms with low temperature requirements placed at the back side of the dwelling?
- Does the house have common living rooms facing outdoor-space/sun/view?
- Does the house have the front side and protected outdoor-spaces facing towards sun and view?
- Is the balcony facing the south, and has the balcony been placed above ground floor level?
- Has the house been climatically adapted through materials/technical solutions?


*Figure 7: Principles for regulation plan*

These criteria were designed by NSHB on the basis of the information from Professor Arne K. Sterten and Architect Anne Brit Børve by zoning, regulations and recommendations.

Experience has shown that these criteria are not enough to overcome the "resistance" of the market. Only a few self-builders showed interest. Beyond that, little interest was shown by the market or by new owners. Therefore, NSHB initiated the development of house types, with emphasis on the criteria recommended and offered loan for the adaptation.

*Figure 8: Principles for house design.*

The outcome of the process has been that in Field 4 "The Norwegian State Housing Bank pilot project" has suceeded in buildingapproximately 30 houses and 1 connected dwelling with 8 apartments.

*Figure 9: House, Field 4*

## 4. Field 6, Fuglenesdalen

In the mid 1980s the Municipality of Hammerfest planned a new housing area, Field 6. During the planning process of this area, both the Municipality and NSHB wanted to make use of the experience obtained from field 4. An important issue was to let the field undergo coordinated planning. In doing so, all plans would be ready for potential self-builders when the building sites were assigned.

The main aim of the project "Climatically adapted dwellings in Field 6, an experimental project – Hammerfest" by The Municipality of Hammerfest and The Norwegian State Housing Bank, was to develop new types of housing by keeping the harsh climate conditions in mind. It was also important to gain experience from building these types of housing in full scale, and thus to gain new knowledge of climatically adapted housing and their environment.

*Figure 10: Field 4, Fuglenesdalen*

*Figure 11: Field 6, Fuglenesdalen.*

It was requested that the field should undergo a partially coordinated design. The dwellings should be designed before the plots were assigned to the house builders in order to avoid the problems facing Field 4.

In the 1980s and 1990s houses in Field 6 were designed by five architect groups, and the aim has been to make good dwellings that are well adapted to this area with strong wind and snowdrift.

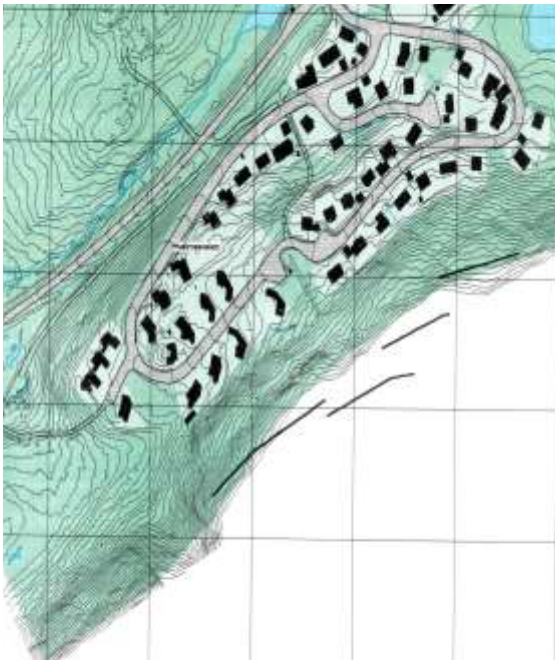

*Figure 12: Building structure Field 6*

**The main aims have been:**

- To develop new dwellings types based on the harsh climatic conditions found in Field 6.
- To draw conclusions about these houses by building them to full scale and thereby gaining new insight to climate adaption of dwellings.

The project has had little influence on the building regulations, because the regulations were made at the same time as the project started. The main focus has therefore been on the buildings. The project gained funding from the Ministry of Local Government and the Norwegian State Housing Bank.

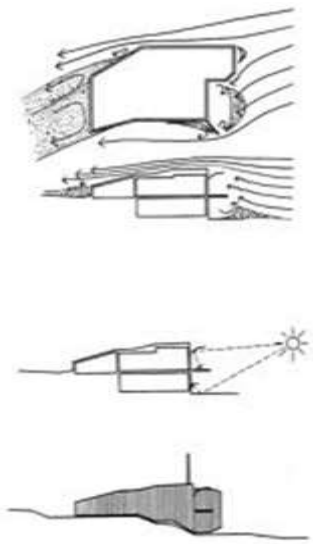

*Figure 13: Principles for house design*

Background information necessary for the house designs was established by the time of designing houses for Field 6:

- Building regulations existed.
- Analysis of the climatic conditions for this part of the field were available, together with the criteria for house design prepared by Architect Anne Brit Børve for this project.
- Models of this part of the field at scale 1:200 were made, one for each group of architects.

The outcome of the project was that 27 houses were designed, most of them as single family houses. The plots were then assigned with the clear conditions stating that designs presented should be built. Small changes of the building regulations have been made afterwards. The houses have all undergone smaller to larger changes, but mainly changes related to internal plans. In Field 6, all the 27 designed houses have been built since.

*Figure 14: House, Field 6.*

## 5.Mellomvannet (Field 5), Fuglenesdalen

The Municipality has recently regulated a new housing estate in the same area in Fuglenesdalen, in partnership with NSHB. The residential area was planned with a focus on climate change, housing and planning adapted to the climate, universal design and energy efficiency, and taking

into account previous experience of area Field 4 and Field 6.

There is demand for private housing relatively close to the city centre, especially for families with small children. The goal of the municipality is to develop a housing estates with good quality and high satisfaction factor. Unlike previous climate fields, the principles for climatically adapted housing and planning has been addressed through the whole design process of the new field in Fuglenesdalen, Mellomvannet (Field 5). In regulatory efforts, focus was on good outdoor areas and the architectural quality of homes, both individually and collectively. Areal + AS was engaged by the Municipality of Hammerfest to prepare a zoning plan for the new field, Mellomvannet housing estate in Fuglenesdalen (Field 5). As subcontractors, Areal + used the Lark Architects to create the artwork of the plan and for being an architectural adviser, as well as Cowi to prepared a feasibility study for municipal technical facilities. The start-up meeting with the municipality was held from 26th to 27th of April 2007.

The Norwegian State Housing Bank office in Hammerfest supported the project and assisted with expertise and funding under the regulation process.

**The vision and main aim has been:**

The Municipality of Hammerfest wants the new residential area to realize quantifiable and verifiable characteristics regarding climate change, energy efficiency and universal design. It will offer great family homes with outdoor areas which extends the summer season. The properties, individually and collectively, should be of high architectural quality.

*Figure 15: Design for Mellomvannet (Field 5).*

NSHB wants the process of planning, development and realization of the area to contribute to skills and knowledge development. And further that this process demonstrates the feasibility of residential high-quality individual plots and is an example for best practice in the region.
These ambitions resulted in a detailed development plan with a design handbook that will inspire and guide builders to carry out the aspirations of the regulation plan.

## 6.Multivision Program "Blue Winter"

In order to focus on the challenges associated with climatically adapted houses and areas, the Norwegian State Housing Bank has made a multivision program, "Blue Winter", presenting examples of the work in this field (ref. AV-Kontakt AS and Husbanken (2001): DVD Blue Winter). Pictures, music and arctic voices visualize this beautiful and climatically harsh part of the country north of the Arctic Circle. The examples in the "Blue Winter" presentation are mainly gathered from the climatically adapted houses in Hammerfest Field 4 and 6, but include also examples from the "Bo i

Nord" in Tromsø and from "Polarbo" in Spitsbergen.

The opportunity of staying outdoors in the vicinity of the house is a very important aspect related to the quality of living in a climatically adapted house. The location and shape of playing grounds and recreational areas are vital (ref. Husbanken (1994): Vind og Vær. Håndbok i klimatilpassing av bebyggelse i vindutsatte strøk i Norge).

A winter plan which is a part of a municipality plan is therefore an adequate means of making optimal use of outdoor areas. Efforts should be made to consider winter and summer use of these areas as a whole in order to avoid conflicts.

The Norwegian State Housing Bank`s main mission is to stimulate to quality thinking on all levels in the planning process from first ideas to ready built housing areas.

## 7.Conclusions

The primary vision for the Norwegian housing policy is adequate and secure housing for all.

The Housing and Building Department in the Ministry of Local Government and Regional Development is responsible for implementing the government's housing and building policy. Housing and building policy objectives are achieved through financial and legislative instruments, competence development, guidelines and information.
The Norwegian State Housing Bank has, since it was established in 1946, been the State`s main instrument in order to achieve this goal.

In the 1980s, "good housing areas" were placed on the agenda. This indicated a new policy within NSHB which meant that focus was turned from demands on single dwellings into focus on whole housing areas and distributing information on good house planning in new and existing areas. This happened at the same time as the planning of climate fields began in Fuglenesdalen, Hammerfest. This has then resulted in NSHB having a central role in coordinating climate adaption.

The residential areas of Fields 4 and 6 in Fuglenesdalen were planned and developed in the 1980s as so-called climate fields. The planning for the new climatically adapted area, Mellomvannet (Field 5), also in Fuglenesdalen, was completed in 2011.
The term climate field means that in the planning and development phase special attention is placed in the difficult climatic conditions of this area.

In connection with this work, there has been made extensive analysis of local climate, which has led to the development of housing types and model tests to study wind and deposition of removed snow in residential areas. There have been several reports that evaluate Field 4 and Field 6 prior to the operation and availability of the settlements, as well as the way the field function in relation to the main climatic factors such as wind, snow and sun. Important experience was also gained by the planning- and development processes as well as concerning implementation and follow-up processes.

It will be interesting to follow the construction process for the new climate field Mellomvannet (Field 5). The development of the residential area will begin in spring 2014. The ambitions in this field was to apply the past knowledge and experience from the earlier climate fields in Fuglenesdalen.This experience resulted in a detailed development plan with design handbook that will inspire and guide builders to carry out the aspirations of zoning. For monitoring of the construction process was recommended to establish a project group with participants from the municipality, NSHB, Area + Lark and Cowi. Such a "Climate Group" was also established for climate fields 4 and 6 and had positive impact on the proposed measures, both for housing and outdoor areas.

The climate is changing, more extreme weather is expected in the future. First and foremost, greater and more intense precipitation is expected. Temperatures increase, more frequent and severe temperature fluctuations and more wind is also likely. The new climate suggests that the local authorities and the construction industry face new and tough challenges. Climate adaptation of our built environment has to be high on the local political agenda and finally research on housing and planning must be translated into practical measures.

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# Climate as a premise for designing livable, urban environments in northern conditions

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## Abstract

The paper presents approaches to understanding climatic conditions and notably winter, as factors in planning and designing Northern cities. A winter city has been defined as a Northern community where negative effects of climate are mitigated while positive aspects are reinforced. These approaches are analyzed on a conceptual level from four integral components constituting the lived environment: functions, structure, sensory environment and meanings. The subject is first outlined with a short review on the previous research and winter city solutions proposed during the previous decades, after which the focus is turned to these solutions' nature and their relation to livability. Identified approaches to winter city planning and design emphasize different aspects of winter, which justifies the need for common concepts and an integrated approach when assessing the issue. In the end, some viewpoints and future research paths on winter city design process and winter city development's relation to sustainability are formed.

## 1 Introduction

Cities are in constant interaction with the surrounding climate. Climate, more than any other natural system transcends all the boundaries of nature and human activities. It sets both direct and indirect limits to spatial environment. Climatic forces have shaped and do shape worlds' bio-regions and all the life forms have adapted to these conditions. (Hough, 1995, p.245). At the same time, humans shape their surrounding micro-climates by building: survival in harsh conditions has been seen to be largely dependent on the ability to protect (Matus, 1988, p.10).

The majority of Arctic and subarctic populations live in cities. However, urban planning and building have not been widely researched in the context of northern "winter cities". Northern cities are to a large extent planned based on modernistic, universal planning principles, which have been challenged since climate and energy questions have pushed design of sustainable urban structure into political agenda. A winter city can be defined as a northern community where negative effects of winter season are mitigated while the positive climatic features are reinforced. The sustainability of winter cities requires creative approaches to challenges posed by climatic conditions: how does a community deal with snow, cold and darkness in relation to energy consumption, traffic, services and other aspects of everyday life, while enhancing the advantages, opportunities and beauty of the winter season? How should a northern winter city function and in what ways is it different from its southern counterparts? In this paper I will discuss climate as a premise for designing Northern cities and analyze what kind of connections a city and its surrounding climate – notably winter – could constitute from the viewpoint of livability.

This paper is part of the research conducted within a multidisciplinary research project *Integrative Urban Development Concept: Case Sustainable Winter City* (INURDECO 2012-2014). The project has a broader scope in investigating integrative urban development practices, tools and block-level concepts that are needed in the design and construction of a sustainable winter city. These practices are tested and piloted on a Living Lab experiment in city of Oulu, northern Finland, where a new Hiukkavaara neighbourhood for 20, 000 inhabitants is being constructed. The central area of the neighbourhood is being designed as a sustainable winter city. As a part of the research project, the city of Oulu will create a winter city strategy, which will be one tool for implementing winter city design principles.

*Figure 1. How is the winter present in our urban environments? Are we aiming for enhancing it or are we trying to eliminate it? Is winter treated as an aesthetic possibility or does it also have functional qualities?*

### 1.1 Structure of the paper

The principle aim of this paper is to describe possibilities for comprehending the relationship between northern climate and urban environment: what characteristics arise, if surrounding climate is taken as a premise for design?

The paper has three main parts. First, I give an overview of the research on Northern urban climate and outline different solutions presented on winter during the previous decades. After that I examine these approaches – plans, design ideas, publications and research – on a conceptual level and form descriptive categories. The analysis is based on a pre-set theoretical framework (Rönkkö, 2012). According to this theory, the built environment must be perceived as a holistic, lived entity consisting of actions, structure, sensory experiences and meanings. To conclude, I will discuss applying winter city principles into urban land use and design as well as raise some questions for future research on how these approaches fit into the framework of sustainability.

## 2. An introduction to winter city research

### 2.1What is winter?

Winter is closely related to the conception of climate as a part of it, although not a synonym to it. Within urban environments, climate influences primarily comfort and health of the people as well as energy consumption and air quality (Eliasson, 2000, p.33). In addition to these, the secondary effects of climate have consequences on practically all the activity happening in a city. Winter is a multi-dimensional concept without an unambiguous scientific definition. It consists of different climatic elements – snow, wind, cold, darkness etc. – which constitute together different weather conditions and seasonal variation. It is

impossible to define winter as a single occurrence, since its different aspects hold different meanings and values. As a working definition, this paper takes winter to mean the northern season of extreme weather conditions. Winter is perhaps the most definitive part of Northern climate as its most challenging feature. It is important to understand that winter has a measurable as well as an interpreted, cultural dimension.

### 2.2 Research on northern urban climate

The reasons behind linking urban planning and design with climate can be traced to various contexts, including the environmental and ecological movements and research that emerged in the late 20th century as well as the critique on poorly designed outdoor spaces in modern suburbs (Westerberg 2009, p.133). Nowadays, climate change can be expected to revive interest in links between climatic and urban processes.

Eliasson *et al.* (2007, p.72) divide the research on urban climate conditions in two main categories: architectural research searching for design solutions and climatological, quantitative research. A branch of climatological research has focused on examining the relationship between built form and climate: i.e. what kind of forms reduce wind and snow drifts (e.g. Børve, 1989) or how to maximize solar exposure on street level (e.g. Matus, 1988)? Detailed microclimate analysis have become part of the research during the 21st century (Chen & Ng, 2012, p.120). Human dimension has also been taken into account, for example, through examining the experienced thermal comfort in different outdoor spaces (e.g. Eliasson *et al.*, 2007). However, the man-climate relationship cannot be understood based merely on analyzing physical climatic conditions. Nikolopoulou and Steemers (2003) state that only 50% of outdoor climate experience can be explained by objective, physical and physiological factors: the experience is also affected by subjective experience, expectations, sense of control, naturalness of the environment and need for sensory stimulation. The applicability of climatological research to design and planning practice has been questioned (Eliasson, 2000, p.72).

In addition to research, winter city ideas have been approached through architectural explorations, ideas, plans and utopias drawing their inspiration from northern climatic conditions. Kimmo Kuismanen (2008) divides climate-related design based on the used design tactics: "hard" solutions rely on high technology and energy use whereas "soft" options are based on climate, ecological research and tradition. "Hard" solutions can be seen to have their roots in Arctic city utopias conceived during the Cold War. These massive, omnipotent structures relying on the newest technologies protected the whole city from the effects of climate. The concept of full protection from the climate has its followers. For example, in the city center skyways, underground passage systems and other covered public space and circulation typologies developed in the latter half of 20th century. Partly as a reaction to these, a "soft" bioclimatic line of design evolved. Bioclimatic principles aim at manipulating the microclimatic conditions of a site through built form, openings, orientation, vegetation, landscaping, materials and colours (Pressman, 1995, p.4; Matus, 1988, p.1). Ralph Erskine has been seen as one the pioneers of bioclimatic design with his Arctic town proposals, surrounded by windscreen buildings (Collymore, 1982, p.24). In addition to architecturally inclined solutions, there are other ideas on taking advantage of the material dimension of winter. For instance, snow and ice can be treated as economic and recreational possibilities and energy resources. Winter has also been connected to economic goals, proposing the possibility of an economic growth through developing winter-related branches of business. The will to find and promote design solutions for northern cities has led to the creation of various kinds of reports, guides and strategies especially in Northern America. The concept of "winter city" is closely tied to international Winter Cities Institute established in the 1980s, although design approaches' significance in scientific

terms has been questioned (Ebrahimabadi, 2012, p.6).

Due to the range of proposed solutions, objectives behind climate-related research and design are equally various. Saeed Ebrahimabadi (2012, p.15) defines the focus of architectural solutions having been mainly on mitigating climate discomfort in public spaces. Those relying on bioclimatic principles combine this integrally with an intention to reduce energy use.

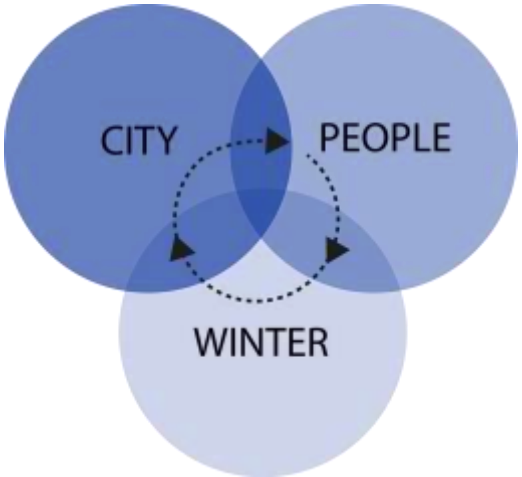


*Figure 2. The winter–city–human relationship. Climate-related research and design can be understood through this tri-partite model: different disciplines have focused on examining different liaisons between the three components. This paper focuses on describing what kind of connections a city can form between winter and humans.*

Research and design have certainly expanded the knowledge on the relationship between climate, city and its users, but there is a shortage of an integrated research approach (Eliasson *et al.,* 2007, p.72). Divisions to architects' designs and more scientific approaches or to "hard" and "soft" approach focus more on the methods, thus not taking into account the proposed, ideal winter city environment itself and how winter and climate are present in it. This is the practical interest of this paper.

## 3. Describing the presence of winter in a city through livability framework

How are climatic factors and winter reacted upon, when viewing through different aspects of the built environment? In this paper, the question is approached through a pre-set framework defined by Emilia Rönkkö (2012). According to the framework, the environment we live in has spatial and temporal, as well as syntactic and semantic dimensions. These dimensions interrelate and constitute each other, forming together the entity of the lived environment composed of four integral viewpoints: *functions* (temporal-syntactic), *built structure* (spatial-syntactic), *sensory environment* (spatial-semantic) and *meanings* (temporal-semantic).

Two main approaches form a basis for understanding winter-related actions: protection from the negative aspects of climate and exposing its positive features. Seeking balance between these, and thus avoiding over-protection, is seen as desirable (Pressman, 2004, p.17; Ebrahimabadi, 2012, p.15). In the following, these strategies of averting negative and capitalizing positive aspects of climate are analyzed in the context of winter cities through the previously mentioned four viewpoints.

### 3.1Functions

A city includes various functions from commerce to residence and to social and cultural activities. How does the changing climate affect operating conditions and how are the functions synchronized with the surrounding climate?

One approach to organizing functions in a winter city has been to create *stable* conditions all year round by detaching activity from the climate. Creating public spaces indoors, organizing the circulation through covered routes or creating hybrid buildings have been ideas to establish stable operating conditions. Jan Gehl calls this kind of approach a "one season city" (Gehl, 1990, p.28). Instead of benefiting from all the four seasons, the city is given a

fifth, constant and artificial season. Conceptually speaking, stable functioning in all weather conditions is also aimed, when heating sidewalks or developing more effective snow plowing tactics, for instance.

*Figure 4. Offering full protection and separating people from winter by creating covered passages and indoor public spaces has been one design approach to winter.*

The opposite approach could be called a *differentiated* "multi season city": all the

*Figure 3. Heated sidewalks are a means to maintaining stable conditions for pedestrians all year round*.

seasons function in different ways, using different tactics. In the northern culture, this has often meant an emphasis on enjoying summer, whereas the winter season deserts public spaces. Since the winter season is often seen as a defendant in northern culture, some winter city solutions introduce similar, differentiated tactics towards winter to make seasons equally attractive by promoting winter activities such as skiing and skating. If infrastructure required for these does not adapt to other seasons, they must be activated by other means. Thus, seasonally changing activities might require more resources, yet at its best differentiated approach can act as an interest-creating factor, making all the seasons attractive by offering changing functions according to seasonal changes. This approach is also present in endeavors to develop specific branches of winter city economy: different

solutions have been proposed to promote winter tourism, develop recreational facilities, winter clothing industry and product testing which can profit from cold, harsh conditions. Opinions differ, though: Ulla Westerberg sees endeavors towards activating winter season and tackling its "climatically induced handicaps" by planning for social contact and activity as comprehending city life through southern examples. According to Westerberg, climate-related planning should make cities inviting even without crowds of people, therefore truly anticipating seasonal changes in behavior (Westerberg, 1996, 57).

*Deciduous* solutions fit between the two previously discussed approaches: the same infrastructural object or activity adapts to changing seasons and weather conditions: sidewalk patios are equipped with detachable walls or heaters in the winter, streets are left snowy in order to make skiing, sledding and other forms of winter transportation possible and iced lakes and rivers are transformed into skating facilities.

### 3.2 Built structure

Functions need physical infrastructure – spaces, streets and buildings – to be able to operate. The viewpoint of built structure examines these means of organizing the physical environment. What kind of spaces are formed and how does the structure correspond to climatic factors?

Surviving in northern conditions requires protection: limits posed by climate are stretched by construction. Therefore, one obvious way of reacting to winter can be identified as creating *protected* spaces. In addition to complete separation from the climate by creating indoor spaces, partial protection in urban spaces has been also proposed by using lighter, smaller scale typologies – canopies, atriums and heated sidewalks, among others.

Another approach to built environment can be defined as exposing to beneficial aspects of climate by using climatic factors as *building materials*. Bioclimatic design is based on this principle: wind drifts snow into desired places thus reducing the need for maintenance, public places are orientated to catch all the sunlight possible, deciduous trees are planted to give shade in the summer but allow the sunlight pass in the winter and so on. Climatic factors also have energy potential. Snow and ice can also be used as concrete, yet temporary construction materials – ice to skate on, snow walls to protect from the wind. It is interesting to note, that using climate, such as snow, as a part of the construction can at the same time protect from the unwanted effects of climate – an igloo being perhaps the most iconic example of this. Material dimension of climate explained above must always be activated or evaluated by people (Westerberg, 1996, p.51).

*Figure 5. Canopies are a small scale structural solution used to protect the most central outdoor areas from weather impacts.*

*Figure 6. Wind can be regarded as a part of the construction and even as one building material of a sloping roof: the form lets the wind blow snow off the roof, thus reducing structural load and the need for shoveling.*

Maintenance and protecting measures on a smaller scale (e.g. clothing) can allso contribute to the dimension of the built structure. This forms interesting relationships between the scales of protection and shifts responsibilities between different actors. Which climatic challenges should be taken care of through physical structure and what role does maintenance play? Can responsibilities be shared by giving users a responsibility to adapt in a bottom-up manner if the structure itself does not give enough protection?

### 3.3 Sensory environment

People don't just operate in a space but also observe it through senses. Sensory experiences are an interface to derive meanings from the physical environment: thus, these dimensions cannot be separated from each other.

One viewpoint on sensory winter is *intensifying* the winter experience. For instance, snow and ice are proposed to be seen as beautifying and fun-creating resources to be used to create added value to the wintery environment – ice fountains, snow constructions and sculptures are some of the proposed design ideas. Creating places where snow and darkness can be experienced have been proposed. On the other hand, winter can be experienced as dark and miserable period of the year. This viewpoint aims at protecting from the dull and sensory deprived winter environment through adding elements of interest to it – in other words, *colouring* winter for example by using seasonal lighting and bold, bright colours. Since climate is experienced through senses, practically all the winter city ideas concerning physical structures have also an interest in affecting the sensory environment. The interest is more functional than aesthetic in many cases, though. For instance, creating thermal comfort, reducing slipperiness or protecting from the harsh wind contribute to forming a "reduced" winter experience.

*Figure 7. Seasonal lighting can be understood as colouring winter – lights fight against sensory deprivation during the dark season.*

*Figure 8. Elements of winter, notably snow and ice, can be used as structural and aesthetic materials in urban spaces, thus intensifying the role of winter in the sensory environment by allowing it to be experienced.*

### 3.4 Meanings

The dimension of meanings is cross-cutting in relation to the viewpoints discussed before. Meanings explain the observed world around us, yet also further define choices and activities. What kind of meanings are given to winter in an urban environment?

In contemporary cities, climate is often seen as a hindrance for everyday functions. Vladimir Matus has analysed this as a secondary need: a cultural desire to be a part of the global culture has led to organizing life in northern regions in a southern way (Matus, 1988, p.18). Practically all the proposed winter city solutions intend to facilitate life during the winter. However, they do not necessarily aim at attaching positive meanings to it. Conceptually, making winter more bearable through better physical design or sharing information and educating people on how to cope in wintery conditions for instance to not see winter as a hindrance for desired functions. However, there seems to be a branch of actions aiming more consciously at transforming attitudes and meanings given to winter towards a positive direction, seeing it as an asset for activity. This is proposed to be achieved by organizing different winter-related events and activities and promoting a positive winter brand. Approaching the winter life by modifying meanings can be seen conceptually as an opposite to the structural protection.

### 3.5 Contradictory viewpoints and overlapping principles

The previously discussed viewpoints are combined together in figure 10. Found concepts can be combined under the dichotomy of protection and exposure, both aiming for enhancing livability during the winter in their own ways. These approaches must not be understood as excluding each other, rather they form different combinations together. Protection in one dimension of the environment can enable exposure in others and vice versa. For example, as discussed before, seasonal lighting can be defined as a form of protection from the viewpoint of sensory environment (reducing sensory

*Figure 9. Organizing winter-related events that take advantage of the climatic conditions, for example by turning the darkness into a possibility to experience with lighting, can help transform attitudes more positive towards the winter season.*

deprivation), yet it actually "exposes" the climate by shaping attitudes towards winter more positively and supports the seasonal, deciduous or differentiated nature of functions. Even though protection is often defined as the means for humans to survive in challenging conditions, examining winter city approaches from different viewpoints indicates that exposure to climate can also be seen as a means of supporting survival, and therefore being a form of adaptation.

Even though protection and exposure must be seen as interlaced principles, they illustrate that not all options are possible at the same time. Challenges come from the coexistence of overlapping and contrasting opinions and goals. Gerald Mills (2006) proposes a scale hierarchy for implementing climatic principles.
The achievement of objectives is dependent on actions at lower scales, yet these actions themselves are limited by decisions implemented at higher scales. For example, solar access on building scale might be limited by high density, if not taken into account in early phases of design. Reacting to winter can be seen as a wicked problem, right or wrong solutions do not exist. Uncertainty, contentiousness, multiplicity and complexity are concepts used to describe the nature of climate-related incidents. However, if successful, solutions to complex problems have an ability to create win-win situations, which eventually have broader benefits to the community. (van Buuren *et al.,* 2013, p.33). For instance in the context of winter cities, snow has been proposed to be piled in locations where it can be easily exploited for recreational purposes, which would in turn lead to increased recreational activity and thus well-being. Objectives should also be examined through different user groups, whose expectations of a livable environment might vary greatly and even oppose each other.

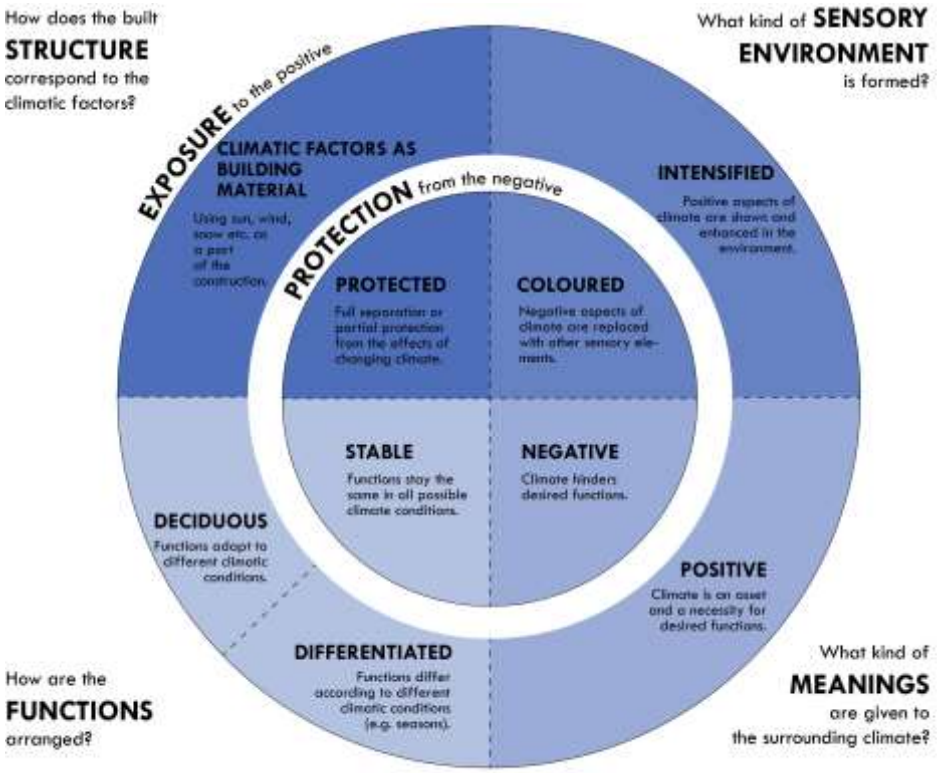


*Figure 10. How are winter and its climatic factors reacted upon, when viewing through different aspects of the lived environment? Examining winter through different viewpoints shows the complexity of the issue: single right or wrong solutions do not exist.*

For example physically active users and children can see the changes in weather as an adventure, whereas stable operating conditions often please user groups with reduced mobility.

## 4. Alignment of climate issues to planning and design practice

Winter is not necessarily a new function requiring more space, but a condition, which affects land use and activity patterns. Thus, there is a need to align climatic issues with spatial planning practice (van Buuren *et al.,* 2013). Surrounding climate has a self-evident need to be noticed in decision-making especially when designing in challenging conditions, but as discussed, there are no unambiguous approaches.

The lack of using climatic principles in planning practice has even been noted in research. Reasons for this range from unclear responsibilities and lack of knowledge to attitudinal, institutional and political reasons. (Ryser & Halseth, 2008; Eliasson, 2000). However, design professionals have been noted to have a strong identity on being capable of dealing with climate in their work (Tøsse, 2013). There is no framework, which would combine different kinds of studies and illustrate the advantages of accounting for urban climate on a routine basis in design decisions (Mills, 2006, p.74). Where climatologists have contributed to urban design, it has often been in a formalized manner where climatic concerns are an overriding factor. This does not recognize planning realities, where climate issues are rarely a dominant concern. First ambition is to satisfy and facilitate socioeconomic ambitions and only secondly, to meet the climate constraints (Mills 2006, p.74; van Buuren *et al.,* 2013, p.52).

In order to be able to take climate consciously into account, the present practices touching climatic issues must be examined and more importantly, verbalized. My hypothesis is, that some forms of coping with climate must already exist in planning and design practices as tacit knowledge, but these are not always formed into tangible principles. How are responsibilities shared and in which phases of the process are climatic issues discussed? Are the coping strategies proactive or reactive? Do they minimize potential damage and take advantage of the surrounding conditions, or are they inclined towards coping with the consequences? (van Buuren *et al.,* 2013). Within the ongoing research project, this is going to be examined in city of Oulu by conducting semi-focused interviews with planning professionals.

It is important to understand that protection and exposure can be approached through various tactics. For example, robust, decisive, governmental actions and more flexible, self-organizing, bottom-up strategies emphasizing the occupant adaptation are both possible in achieving protection as well as exposure. Therefore, a more fundamental question lies in what the departure points for an ideal winter city are. Holistic understanding of the connections between a city and its climate are essential. The concepts formed in this paper through the fourfold framework can work as a tentative frame for verbalizing the issue.

## 5. Sustainable winter city?

In addition to examining livability, winter city actions also need to be assessed in terms of sustainability. In the 21st century, this is often understood as a need to address simultaneously the problems of climate change mitigation and adaptation. Linking winter city planning to climate change is particularly relevant, since examining current practices in cities of extreme climates, such as northern winter cities, also generates knowledge on adapting to climate change globally. Finding sustainable ways to reduce vulnerability to today's climate enhances resilience for future changes as well (Resilient Cities, 2013, p.13).

Winter city solutions can be considered as adaptation tactics, but their relationship to climate change mitigation requires further examination. For instance, solutions like using heaters in outdoor spaces or not building densely in order to leave adequate

spaces for snow storage enhance adaptive capacity to climatic conditions in the short term, but can be questioned in terms of long-term mitigation (Howard, 2010). How can protection be executed in accordance with mitigation requirements? Moreover, to what extent should we emphasize dependence on regional conditions by establishing winter-related functions, if climate will change drastically in future? There seems to be a demand for flexibility.

Secondary impacts of extreme weather, such as the effects on people's use of different travel modes, economic impacts, outdoor spaces, recreation, café culture and the 24-hour city are not systematically included in climate change adaptation considerations (Wilson, 2006, p.617). In this regard, examining winter through the concept of livability – which in itself is a secondary need compared to primary, ecological and environmental goals of climate change mitigation and adaptation – could also contribute to understanding climate change actions from the viewpoint of social sustainability.

## 6. Conclusions

This paper analyses the presence of winter and climate in an urban, lived environment on a conceptual level. Proposed connections between urban and natural, climatic processes can be coarsely divided into two main categories. Protecting measures aimed at decreasing the dependence on climatic conditions, making a form or an activity an event in its own right. Exposure to the surrounding climate takes advantage of the local conditions and therefore increases the dependence on them.

The used approach is horizontal, focusing on describing a winter city environment that has been considered ideal in design and research. Complex problems such as climate and winter cannot be approached with the same solutions everywhere. Therefore, vertical case studies in different contexts, ranging from goal-setting and design processes to post-occupancy research would be central for providing information on causality between different solutions and their applicability.

Within the ongoing research project, further interest on the topic lies in examining the connections between winter and planning processes as well as connecting proposed solutions to sustainability. The concepts presented in the paper help to verbalize possible roles of winter and climate in an urban context, thus opening viewpoints on the specific nature of northern cities. They form tentative viewpoints for future research on identifying and forming sustainable winter-related planning and design strategies and solutions for northern cities.

## Acknowledgements

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# Field work architecture: Experimentation in the Arctic as basis for education in sustainable architectural design.

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**Abstract**
This paper addresses a Masters in Architecture, which aims to develop a site-specific understanding of architecture, as a response to present and future global challenges, through research by design, prototyping and direct on-site involvement. In close collaboration with local communities, science and technology, this Masters course engages in critically enhancing architectural performance, sustainability and resilience while exploring new formal and spatial languages that enrich our build environments and our daily lives.

## 1. Introduction

It is the premise of this paper, that architecture should be designed via a thorough understating of the context it will exist in. When in conjunction with science and technology, and embraced critically by architects, it can offer new architectural solutions and vocabularies. This methodology is a vital tool in a contemporary architectural education, and in turn demands new forms of pedagogical strategies. In this paper, I will unfold experiences and proposals for a hands-on, fieldwork based methodology for an architectural design education based on Arctic sites specificity.

## 2. Point of Departure

Present global challenges clearly show how a new understanding of the built environment is paramount for a resilient approach to the way we live as societies. Use of resources, climate impact and population growth, are a few of the many challenges that have placed in question the way we build and have built. This is relevant to both existing urban contexts as it is to new areas open to habitation. One approach in navigating these challenges proactively is to engage in a thorough understanding of the context one is to inhabit and build in. This not only implies research and understanding of local knowledge as well as participatory involvement of the end user, but also a refined perception of the local natural phenomena. Within this context, one has to critically view not only the present practice of architecture but also its education.

Regarding the field of architectural education, the approach outlined in this paper and which has been carried out in two different university courses for the past four years, and soon to be applied to a third, is based on highly tuned specificity. In other words, to investigate site and context through active field work in order to inform the architectural design process in the most thorough manner possible.

## 3. Methodology

The general methodology used during these courses was based on a four phase process; preliminary research, device construction, field work, brief description and project design.

At the start of the semester, after having selected an area/geography/site as the focus for the year, students gather facts and data at a distance, spanning as wide as possible in the fields of research and contacting relevant institutions, to have a broad understanding of the specificities of the geography, climate, history and culture of the area in question. This research allows the students to focus on a specific architectural challenge, while possessing an understanding of the cultural and historical values culture in the site in question.

The second phase focuses on how to explore the context once on site. To do so, students design and construct a "device", which allows them to engage directly with the site as a surveyor, or investigator. This serves a double purpose, both to test materials, performance and constructions at 1:1 scale, in the site in question, and to relate to the site through a construct, allowing for a focused investigation into a particular aspect of the site.

This experience has proved to be very enriching to students, who often for the first time, understand the impact of severe weather, challenging geographies, and cultural architectural solutions to similar problems. Simultaneously, they appreciate the difficulty of design if it is to be robust and resilient, while discovering alternative solutions, offered by nature itself, or lost building traditions.

## 4. Sites: The Arctic

Within the spectrum of sites that this methodology has been tested (Pyrenees, Venice, Mojave Dessert, Fukushima-Japan) perhaps the most fruitful and relevant has been the expeditions to The Arctic.

The Arctic conditions, due to its extremes, urgency and fragility, allows for an excellent test scenario into site-specific architectural design. In this context, specificity is almost unavoidable, since any disregard for the conditions at hand, translates into an almost immediate failure in design or at best, and unsustainable one.

*Figure 1: A sonar system used to determine insulation levels of compacted snow. Svalbard, Norway (Pikk & Lindberg, 2013).*

*Figure 2: "Arctic Poppy Biomimicry" prototype for an active façade system via natural mimicry. Svalbard, Norway. (Hochreiter, 2013).*

Iceland, Greenland and Svalbard have proved to be excellent platforms to test and train this methodology and students have developed inventive proposals that deal with the severities of these geographies, and often turned challenges into assets.

## 5. Case Studies

Three case studies will be presented: Investigations in Greenland, Iceland and Svalbard.

The Greenland investigation was a personal test developed by my own practice (MAP Architects) in relationship to our participation in the exhibition for the Danish Pavilion in the 13th Venice International Architecture Biennale, "Possible Greenland".

*Figure 3: Mylar shelter tests in Ilulissat, Greenland (Garcia, 2012).*

*Figure 4: Mylar shelter tests as seen from the interior in Ilullisat, Greenland (Garcia, 2012).*

This test was carried out in Ilullisat, during a four day dogsled journey into the frozen ice fjords in the month of February. The principal aim of the investigations was to test the capacity of MYLAR (Biaxially-oriented polyethylene terephthalate (Bo PET)) to insulate and capitalize on body heat. MYLAR allowed certain level of translucency, and sun insulation allowed for an immediate rise in temperature difference of 5 degrees Celsius, raising the factor to 15 degrees Celsius when inhabited. A night stay allowed for a "comfortable" interior temperature of 0 degrees Celsius and -15 degrees Celsius outside.

This simple test, allowed us to start developing more robust insulating solution using this otherwise cheap and extremely light material.

The Iceland expedition was carried out with 16 students from a bachelor studio at the Bartlett Architecture School of the University College of London.

During the Iceland expedition, one investigation stood out for its acute understanding of the potential of low temperatures as an active material. Student Lisa McDanell, designed a prototype shelter, which she inhabited for five days, based on an outer, elastic textile membrane, which could shape shift according to prevailing winds, and freeze to full rigidity through a process of continuous water spraying.

*Figure 5: McDanell's (2012) prototype shelter and elastic membrane in Iceland.*

Through a series of pulleys and spray nozzles, she was able to shape and direct the elastic membrane form the inside of her shelter. This allowed for specificity in wind protection from night to night, using the below zero temperatures to her advantage. This solution became a key element in her architectural proposal later during the year.

The last case study was an expedition to Svalbard. Student Daniela Miller, concentrated her investigation on the potential of ice as a building component.

*Figure 6: A closer look at shelter and elastic membrane McDanell (2012).*

Through a series of molds and casts, she was able to freeze tiles of ice, test their structural potential insulation factor by capturing air bubbles, and reflection and refraction qualities. It was this latter aspect which became the most enriching, allowing for a spectrum of light qualities in the public space during the long winter months.

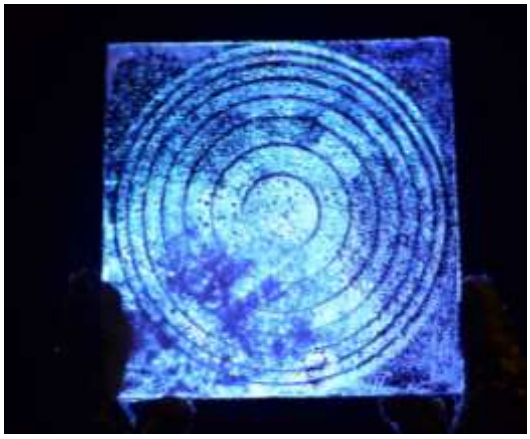

*Figure 7: The reflection and refraction qualities of ice tiles in Svalbard, Norway. (Miller, 2012).*

*Figure 8: A researcher examining the ice tiles in Svalbard, Norway (Miller, 2012).*

## 6. Conclusions

A site-specific architectural design process, which can allow for alternative solutions and which in turn is resilient and sustainable, is best developed through a process of investigations on site, at the educational level. Few places offer such a relevant experience and case-study potential as the Arctic, doubled by the fact that this region itself is in need for an alternative architectural approach that is more acute to its context, its changing and fragile reality, and it's challenging culture.


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*Figure 1: (Pikk & Lindberg, 2013).*
*Figure 2: (Hochreiter, 2013).*

*Figure 3: (Garcia, 2012).*

*Figure 4: (Garcia, 2012)*

*Figure 5: (McDanell's, 2012)*

*Figure 6: (McDanell's, 2012)*

*Figure 7: (Miller, 2012)*

*Figure8: (Miller, 2012)*

# Crowd Sourcing: New local incomes by education and mass distribution of low cost technology

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## Abstract

This paper suggests how the concept of crowd sourcing, which means to distribute problem solving and production to a network of people, can be used to make supplementary local income opportunities in the Greenlandic cities and settlements, while at the same time contribute to secure future stable national incomes from the tourism and mineral industry.

Nautical charts and updated ice reports are essential tools for marine navigation. However, very large areas of the Greenlandic waters are not covered by nautical charts and the current inshore ice service only covers the southern part of Greenland.

The idea is to educate the local population – moving frequently around in the areas - in the use of new, low-cost technology data collection methods. The technical solutions must be inexpensive and simple to operate and effective data collection reporting systems must be present.

## 1. Introduction

Greenland is facing several major changes and challenges. Two of them are the demand for supplementary local income opportunities in the settlements, and the necessity to secure future stable national incomes from the mineral industry.

The concept of crowd sourcing, which basically means to distribute problem solving and production to a network of people, can be used to encounter these major challenges.

This paper describes, on a conceptual level, two different crowd sourcing application examples, adapted for the local challenges in Greenland. A few other previous and future utilities will be outlined.
Increased activities are expected in the Greenlandic waters. This includes mineral exploration and production, along with tourism. Whether or not these naval activities will actually take place is not a topic to be discussed in this paper, but if so, the crowd sourcing principals could be useful in order to prepare the society for the challenges.

## 2. The understanding of Crowd Sourcing in this paper context

In the literature numerous definitions of crowd sourcing exits, in addition to several subordinate descriptions of the concept. In this paper though, the meaning has been limited to a method of how to collect valuable data by delegating out the work to a network of people. One well known example within this line of this definition is the worldwide "Open Street Map" initiatives build on crowd sourcing principles and open data platforms.

Whether or not the crowd sourcing contributors could actually get monetarily paid for their effort is also subject for

ideological discussions. Butin this paper it is assumed that they will be paid by either the authorities, private companies, or other organisational bodies, because of the potential economic benefits for the stakeholders.

Traditionally, very low wages ~~in~~ are seen in crowd sourcing projects (maybe just 1-2 USD per hour) and it may be because "crowd workers" are often considered independent freelancers rather than employees that are not guaranteed a minimum income. In Greenland though, there are potential economic benefits by substitution of the existing data collection and observation methods that could pay a large amount of the wages to the crowd workers. In addition the scope could be expanded, for example, by enlarging the geographic coverage of the data observations.

## 3. Challenges and crowd sourcing solutions

### 3.1 Nautical Charts

Nautical charts are essential tools for marine navigation. However, very large areas of the Greenlandic waters are not covered by nautical charts. The time frame for full covering charts is multiple decades with the current surveying pace.

The idea is to educate the local population in the use of low cost technology data collection methods, as GPS/Sonar equipment mounted on their private boats. The technical solutions must be mass distributed, relatively inexpensive and simple to operate. Operational data collection reporting systems must be connected and if necessary developed further.

A commercially developed crowd sourcing system for Nautical Charts already exists in the United States, and has also been tested in Antarctica. Within the specific area of navigational charts The Danish Data Agency has initiated an analysis of crowd sourcing including user requirements, future prospects, the economy and a proposal for the further process.


*Figure 4: Example of an unsurveyed area (upper right corner) in a Navigational Chart from Antarctica (Van Norden, 2013).*

The reliability and precession of the nautical charts is of course of great interest to the captains traversing the sea and straits of Greenland. Accuracy analysis of the Crowd Sourced data compare to the official charts has been carried out, and shows promising results.

Of course the Danish Data Agency, who is responsible for the nautical charts in Greenland, would risk its name and reputation, if the quality of the crowd sourced data ~~is~~ does not ~~living~~ live up to the usual chart standards. Therefore a chart level classification system could be an idea, following the philosophy that a poor nautical chart would be better than no chart at all, which is often the case in Greenland.

*Figure 5: Simple equipment for making crowd sourced nautical charts. www.argus.service.com/www.hydro-International.com*

The work is done on behalf of the Government of Greenland and should be completed in the spring of 2014.

### 3.2 Ice Service

Information about the actual ice situation is essential for marine navigation, but the current inshore ice service only covers the southern part of Greenland. The ice service has identified a long term demand for inshore ice reports further north along the west coast up to the Disko Bay.

Today, the ice service is located in the Narsarsuaq Airport in Southern Greenland, and the crew has a dedicated helicopter available all year round for a total contracted cost of approximately 750,000 USD/year.

The observations consist of regular helicopter patrols, where the observer produces a simple list of text of the ice situation in the local fjords and bays. The observations are a supplement to satellite observations.


*Figure 6: Ice observations from helicopter flights. The product is a simple text list of local fjords and bays as well as a comment to the presence of ice (DMI, 2013).*

Some of these observations could be carried out by the use of small airborne drones, given that the permissions from the Danish Transport Authority are obtained, under the necessary safety precautions and coordination with the air traffic control.

As soon as local weather conditions allow, local drone operators, living in the communities, could launch their drones. A mission could probably take 2-3 hours (50-80 km / hour) with preparation, flight and data downloads.

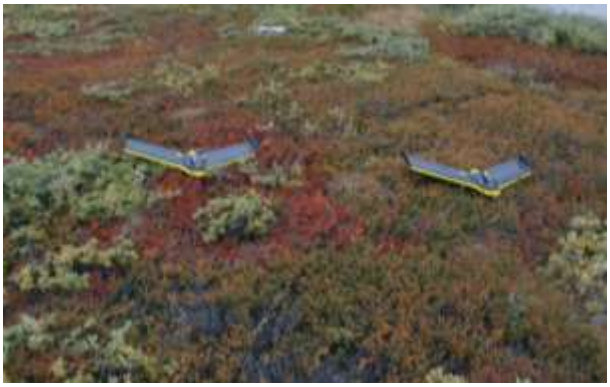

*Figure 7: Two fixed wing drones ready for simultaneous flight (COWI, 2013).*

When returning, data it is transferred to a computing unit and automatically processed. A final report is auto-generated and sent to the ice service when the first network connection is available. After validation of quality, the official ice report is published. The whole process should be as automatic as possible, so that ice reports have high validity and to avoid bottlenecking.

Larger ships navigating in Greenlandic waters are required to send weather and ice informations via the GREENPOS system every 6 hours, but currently the ice service at DMI does not use these informations actively because of frequent poor data quality.

On the vessels of the Royal Arctic Line there are some fixed live web cameras showing the ice conditions just in front of the ships, which the ice service uses every so often, as a contribution to the ice reports.

Pictures of ice conditions taken (crowd sourced) from small private boats could be a future development possibility.

## 4. Other examples

The crowd sourcing principles could also be relevant for other types of applications that include monitoring the environment and nature. Several circumpolar pilot projects have already been performed for example, under the Conservation of the Arctic Flora and Fauna group settled by the Arctic

Council. Typically by crowd sourced observations from photos and/or text report forms to count species etc.:

- Ornithology
- Zoology (Polar bears, caribous etc.)
- Ecology
- Plant biology

In some of these projects the local communities have been involved very closely in the monitoring and nature resource management. The Pisuna project did this in 2008-2011 in four communities in the Disko Bay and Uummannaq districts.

The incentive or potential for considering crowd sourcing should again be that the current observations are often insufficient and very expensive to carry out, ex. helicopter based caribou counting.

A possibility within mineral exploration could be:
- Collection of geophysical data as magnetic and gravimetric data could perhaps be done by crowd sourcing principles, as less than half of Greenland is covered today.

## 5. The necessary conditions for success

Several educational and organisational factors must be fulfilled for the potential success of the money earning crowd workers.

The crowd workers must be educated to receive instruction orders by appropriate communication forms, to use the technical equipment and finally to deliver the collected data back to the customer, whether it be a governmental body or a private company.

Local educational organizations should be involved in the knowledge build up process, by arranging courses and assisting on ad-hoc basis with technical problems or solutions.

But the most important factor is that the crowd sourced data cannot be collected more efficient in a traditional way. And there should actually be a potential for an economic benefit by using crowd sourcing methods.

## 6. The local and national economic perspectives

The local income potentials are very difficult to estimate~~, —~~. The economic potential should be seen in relation to the ~~but on the other hand they should be compared to the~~ very expensive methods used today. For example, using helicopters or dedicated vessels to perform data collection has proved to be costly. The income levels are relatively small in the communities today, and it could be a ~~welcome~~ much needed supplement to the existing incomes for the catchers and fishermen.

The national income potentials could be even bigger, because stable and predictable logistics of the businesses within the mining sector is essential to the willingness to invest in the first place and later on for the ongoing profit and resulting economic royalties to the Greenlandic government.

## 7. Conclusions

Further work on the analysis of crowd sourcing including user requirements, future prospects, the economy and a proposal for the further process should be carried out within the specific sectors.

Pilot projects should be initiated, followed be large scale test and finally, if successful, enter into daily operations.

## Acknowledgements

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# Driving forces in the Greenlandic urbanization

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## Abstract

Generally urbanization is recognised as a natural development where the population is mowing into the larger towns driven by e.g. better job opportunities, larger product and service supply and better education and health services, and it is often argued that this is also the driving forces for accelerating changes in the Greenlandic settlement pattern.
Resent research problematize to what extent this logic is so simple?
Also in Greenland, with its 56.000 inhabitants spread over 17 so-called towns and 58 settlements, there is a clear correlation between settlement pattern and job opportunities. But to a high extent the distribution of jobs and trades are a consequence of political and/or administrative decisions or lack of it. Based on a relatively mechanical reproduction of Danish and European economic understanding a centralization of trade and public service has been implemented to reap the rewards of expected large-scale benefits. This has resulted in limited economic and productivity effect. In this regard the consequences of the extreme Greenlandic island economy and micro state characteristics, where more than half of the public revenues is financed by Denmark and EU, is underestimated. This centralization has left geographical regions with limited livelihood and at the same time a lack of utilization of local resources and trade opportunities. Additionally the Greenlandic so called larger cities are ended in an un-sustainable economical situation manly depending on public financed jobs or social support and with limited export oriented value creation.
It will be disused how the previous and present urbanization interact with a sustainable development and what is the core prerequisites for sustainable towns and settlements.


*Sisimiut harbour 2013.*

## 1. Introduction to urbanization

Urbanization and thus concentration of people in a limited area, along with migration away from rural and outlying districts, is an international trend. The driving forces in the urbanization process are many and varied, but there are clear commonalities. Most often, populations or parts hereof leave areas where they feel that living conditions will deteriorate, and migrate toward larger settlements where they expect or hope that the living conditions will at least be better. This main driver of urbanization is true whether in the case of poor third world countries where people are fleeing rural areas due to drought, falling world prices for their crops, foreign companies purchasing or otherwise acquiring their land, wars and conflicts, etc. Or whether it applies to the more peaceful process in the rich western countries where there is a migration from the old rural areas currently characterized as outer or peripheral areas, partly because of the ever-increasing mechanization and centralization of food production, and because the manufacturing jobs that were originally established in each country's low-wage areas, have been moved to low-wage countries. When employment opportunities in the agricultural sector disappear and industrial workplaces are outsourced, it inevitably initiates a negative spiral that gradually undermines local community livelihoods and thus the service functions and jobs attached to them, such as schools, shops and services, and local crafts.

Urbanization Trends in the rich Western countries are often supported by a social desire for the streamlining of a number of public or semi-public service functions, such as replacing small local hospitals with larger district or regional hospitals to collect the municipal administrations in fewer but larger units etc. With urbanization, a significant concentration of business and thus jobs in and around the urban centers is often the case, and there will typically be a link between emigration rates in the outer areas and the geographical distance to the nearest urban center where the 'edge habitats' that are close enough to an urban center that daily commuting makes sense. For those areas where daily commuting becomes difficult or impossible, a demographic imbalance is the norm, in which young people are leaving to seek work, or to get an education and then not come back because job opportunities are lacking, limited, or not perceived as attractive. This makes the remaining population increasingly older, and a disproportionate share of job opportunities for people of working age will relate to caring for the elderly.

Because Greenland historically has had a very close bond with Denmark, and even for a time was a Danish county, and today is part of the commonwealth with autonomous status, for decades there has been a conscious desire on a variety of social fields to compare Greenland with the Nordic and Scandinavian countries. This trend is reflected in a number of reports and investigations that are directly or indirectly engaged with the Greenland urbanization trend (Naalakkersuisut 2011; Skatte- og Velfærdskommissionen 2011; NORDREGIO 2010; NORDREGIO 2010 b; NORDREGIO 2011; Transportkommissionen 2011). This means that the analysis and understanding of the Greenland urbanization trend is based primarily on a Danish frame of reference, possibly without proper regard to Greenlandic characteristics. The key question of the paper is thus whether other factors that influenced human settlement development in Greenland than what is applicable to Denmark and the other Nordic countries? The paper also explores selected conditions that are important for the development of the Greenlandic settlement pattern.

## 2. A micro-state of many island economies

One of the essential characteristics of Greenland with its 56,000 inhabitants is that in terms of demographics and economics it is a micro-state, albeit in a geographic sense, Greenland is the world's largest of its kind. At the same time, the Greenland micro-economy, with its 17 so-called cities and 58 settlements, is in practice divided into a number of island economies without the possibility of daily commuting between the settlements due to

a lack of transportation infrastructure. In addition, there is a very limited internal trade between these settlements, so only approx. 15% of all trade in goods takes place within Greenland, while the vast majority is direct sea transport between the port of Aalborg in Denmark and each individual dwelling in Greenland, possibly via a Greenlandic port where goods are unloaded onto smaller ships. (Royal Arctic Line 2007, 2008, 2009, 2010)
A characteristic for micro-states is that their domestic market is limited, and their import very large, which means that to maintain the trade balance, exports must also be very large. (Nielsen 2000) Even though Greenland has a proportionately big export, Greenland has only during a very short period since the introduction of home rule in 1979, succeeded in achieving a trade surplus, while in the vast majority of this time there has been a significant deficit.

Another characteristic of micro-states is that they usually have a mono economic dependence on one or a few export

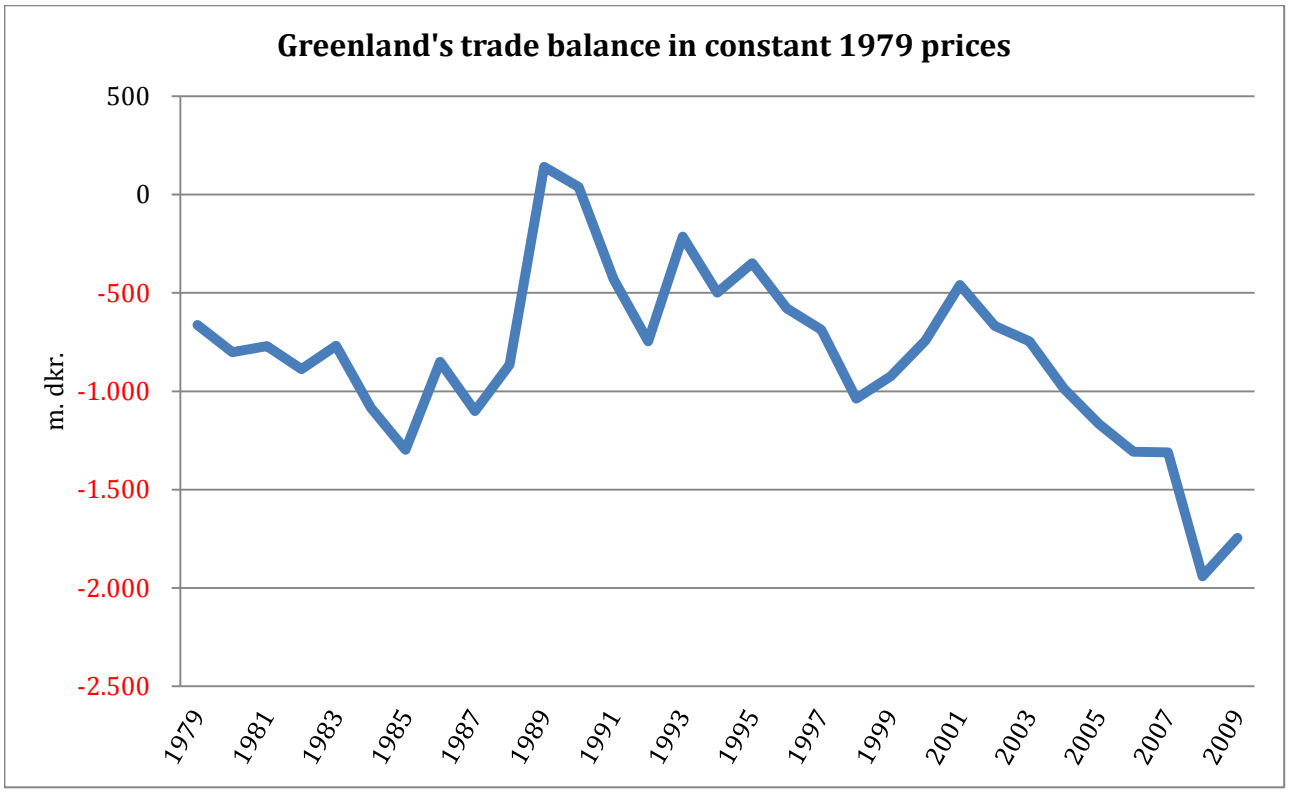



*Figure 1: Greenland's trade at constant 1979 prices from 1979 to 2009. As can be seen, Greenland has had a significant trade deficit throughout the home rule period, except in 1989 and 1990 when there was a very modest profit. (Based on Statistics Greenland)*

*Sisimiut fishing habour and factory 2013. Photo: Kåre Hendriksen*

products, and for Greenland, it has throughout the period of modernization of the post-World War II era been fish and shrimp.

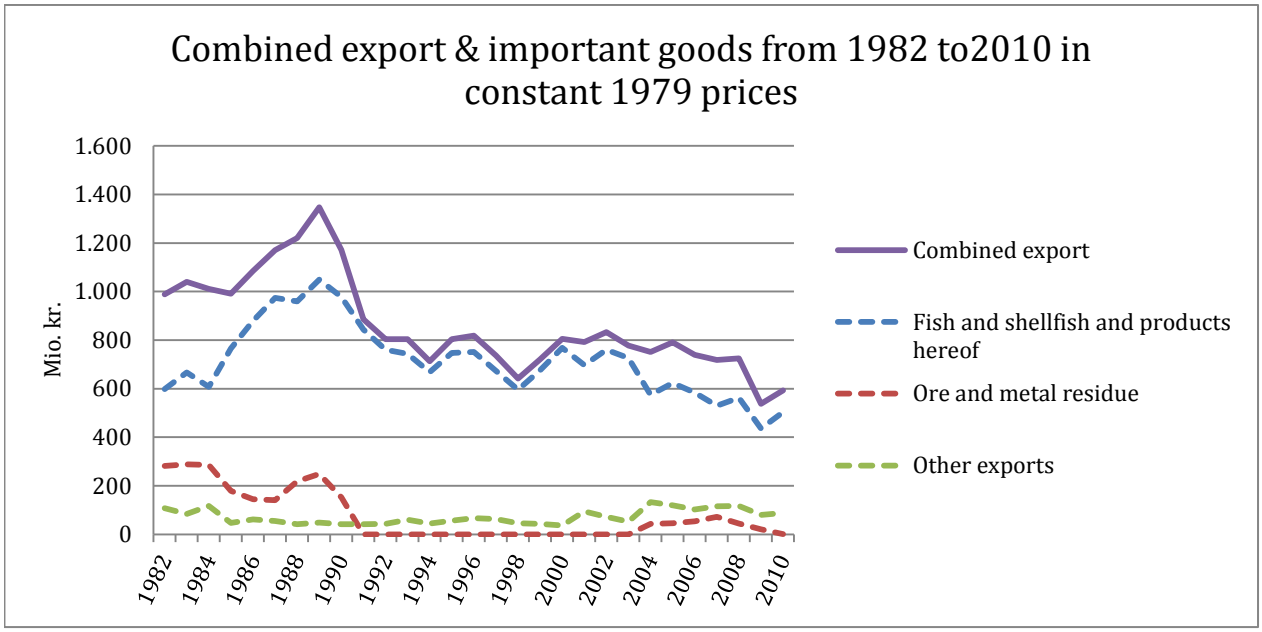



*Figure 2: The key export product groups from 1982 to 2010 at constant 1979 prices. As noted, the only significant exports for the period, in addition to seafood, are lead and zinc ore from the mine in Maarmorilik, which closed down in 1990.*

Throughout this period of modernization targeted attempts were made to diversify the economic base to include more export-oriented revenue streams in order to ensure a sustainable economy. Thus, one of the economic conditions for the Danish plans for the modernization of Greenland, the G50 and G60 plans, has been significant investment in mining and quarrying *(Grønlandskommissionen 1950; Boserup 1963; Grønlandsudvalget 1964).* Since then, there has been a focus on, among other things, building a tourism industry, exports of other natural resources such as spring water, the establishment of an aluminum smelter, etc., without any of this significantly reducing the mono-economic dependence on exports of fish and seafood. For some periods, there has been relatively limited mineral extraction for export, but the only economic effect of this has largely been limited to labor wages and income tax, and since the interwar era export of cryolite from Ivittuut, socio-economic impact of natural resource extraction has been modest for Greenland.

At the same time, micro-states often face the challenge of their population base being so small that it is difficult to ensure the necessary breadth of skills and the volume needed to sustain a modern society within their own ranks. This is also evident in Greenland, with a high dependence on external labor.

Another characteristic of Greenland is that each dwelling in reality functions as an island operation in relation to all essential infrastructure areas. As previously states, there are no roads between the Greenlandic cities and settlements, and transport infrastructure is reduced to expensive aircraft or helicopter flights. The extent of this is so limited that it is not even possible to commute on a daily basis between major settlements, and for the smaller and smallest settlements the service functions on a weekly or fourteen-day basis. At the same time, the regularity of transportation is limited by climatic conditions which cause many cancellations. In addition to aircraft and helicopter flights, modest passenger ships serve some settlements, internally in some districts as well as between some districts, however, these do not permit daily commuting and have large seasonal fluctuations and are often limited by ice and weather conditions.

The same applies to infrastructure areas like power, which again with very few exceptions run as island operations targeting only a single settlement. This is a costly supply structure that requires local backup, and which inevitably leads to irregularity, as there cannot be relied on supply from the outside. Another area is telecommunications, which on most of the west coast is covered by a continuous relay chain system with transmitter and receiver stations on selected mountain peaks and centers within the individual settlements, while the other districts rely on sattelite connections. Both solutions are costly and have limited capacity along with inevitable breakdowns.

These issues of island operations are an inevitable consequence of the fact that Greenland is on the one hand a micro-state with a very small population, and on the other hand an extremely large country, as well as a consequence of the geographical and especially climatic conditions. Hereby, Greenland is markedly different from the other Nordic countries. Certainly, there are in Norway, Sweden - and also Denmark - Areas of island operations, but these are exceptions. In the Nordic region, the binding together of even the most isolated settlements with e.g. road and ferry services, electricity supply systems, and telecommunications transmission via cable has been surprisingly successful, and inevitably, this, for better or worse, has had impact on settlement patterns and thus urbanization.

At the same time, these issues with island operations are central to the understanding of the society's economic dynamism and the economic coupling to patterns of settlement, where in the analysis of the Greenlandic economy there is a marked tendency basing the analyses on a Danish or Nordic frame of reference. A market economy rationale assumes a number of economic laws, which are projected onto Greenland, the isolated island economies of which do not have a volume that enables real market competition and independent technological development. Departing from general market logic, a larger market enables a wider and larger supply and thus more competition and lower prices, and, on that logic, this leads to fewer but larger settlements along lower prices - that is, if the individual market has a volume that enables real competition. But there are reasons for questioning whether a less decentralized settlement pattern or even a collection of people at select settlements will change significantly the economic challenges of island operations. The settlements will still be too small to allow them to operate freely on actual market conditions, and the need for imports will probably rise significantly because the possibility of sustaining and economy of subsistence hunting is reduced. The change in settlement patterns will not in itself increase exports, and thus the trade deficit is increased. (Hendriksen, 2013)

## 3. **A subsidized national economy**

The almost permanent deficit in the Greenland trade balance means that the Greenlandic economy depends to an extraordinary degree on remittances, and thus subsidies, from Denmark. The Danish government, and to very modest degree the EU, finance half of the government-related costs of operating Greenland when the direct Danish expenditure on fisheries, ice reconnaissance, the judicial system, etc. are included.

There is nothing unusual in the fact that, internally in a country substantial financial transfers or subsidies are provided to select areas, where the typical beneficiaries often are outlying districts, but also urban ghettos. The unusual aspect in the case of Greenland is partly the sheer scale of the matter and partly that Greenland to such a far extent has autonomous status. That a very large part of the Danish direct and indirect subsidization of Greenland is then returned to Denmark, because the vast majority of exports of goods and services takes place here, is not relevant in this context, where the focus is on the understanding of the Greenlandic urbanization trends.

Historically, it has been a deliberate policy objective from first the Danish Greenland Administration and since the Greenland

Home Rule and the Greenland Self Rule to release the Greenlandic economy from dependence on the Danish subsidy, however, without the efforts significantly changing the relationship of dependency.


*Day of the children in the village*

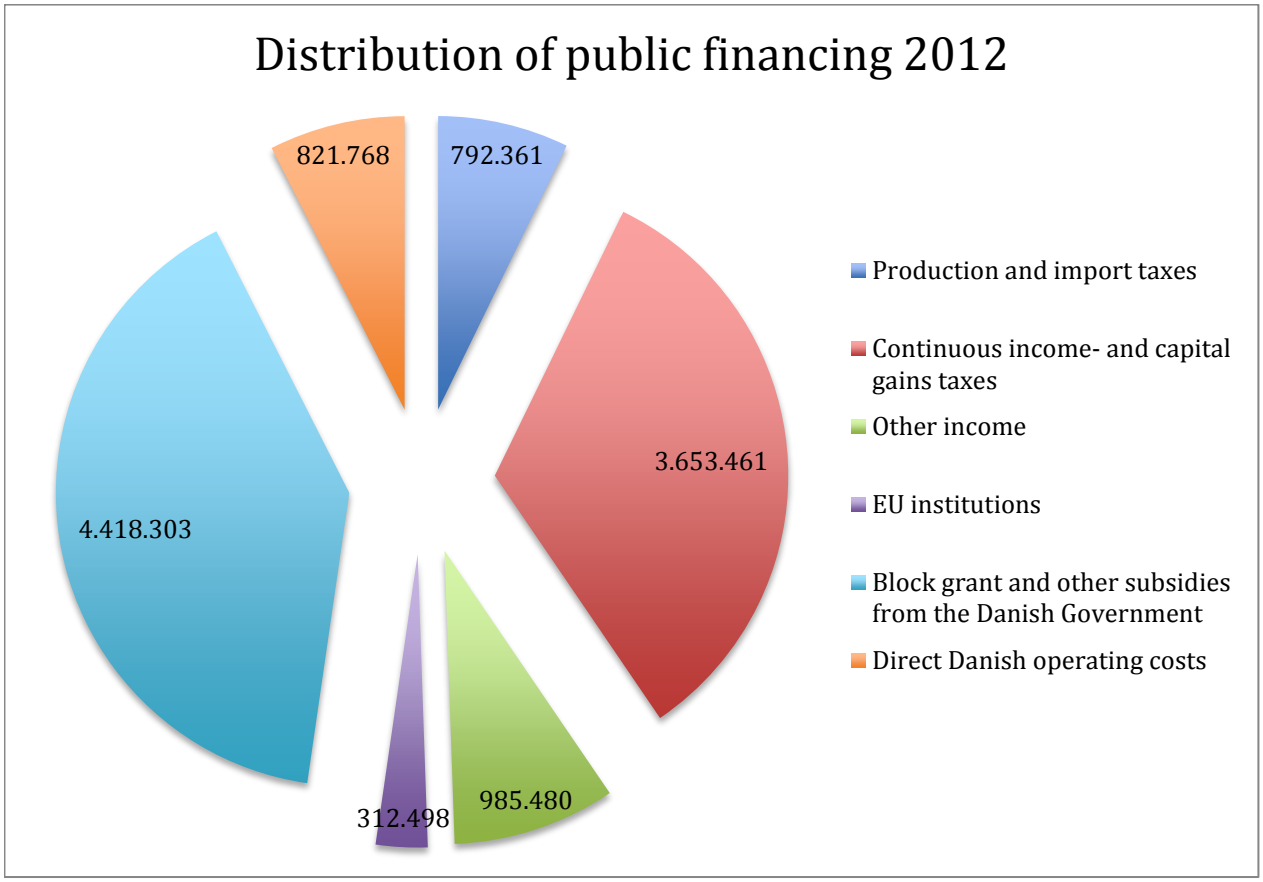



*Figure 3: Distribution of the main sources of funding for the public economy of Greenland, which includes self-government, municipal and state government spending for 2012. As shown, Denmark, and to a lesser extent the EU, finances half of public spending. (Source Statistics Greenland)*

*Sarfannguit 2013. Photo: Kåre Hendriksen*

## 4. The decoupling of settlement and industrial basis

Historically, the Greenlandic settlements and since cities and villages were located solely on the basis of the possibility to exploit the local resource base - most often living marine resources. Therefore, the natural and man-made fluctuations in the resource base has resulted in a very high mobility, where people are moved by the possibilities, and this has led to the depopulation of settlements, villages and some cities, while others have emerged.

With post-war modernization, the evolution of settlement patterns assumed a more systematic form. The Danish Greenland Administration sought to encourage people partly from the smaller settlements and partly from the cities of the outside districts, where the main occupation was hunting, to move to the major cities on the west coast stretching from Nanortalik to Ilulissat, so that they could engage in fishing for mainly cod either as fishermen or workers in the fishing industry. In some cases it was even administratively decided to dismantle settlements and move people to the nearest town, and in 1972 the Danish government's policy of centralization culminated in the closure of the coal mining town of Kutdligssat (Qullissat), which only a few years prior had been Greenland's third largest city. The Danish centralization policy sparked protests in Greenland, which were largely key to the establishment of the home rule in 1979.

In the first decade of the home rule, measures to stimulate the industrial development of the individual settlements through e.g. establishing a system of purchase and storage plants, while in a number of settlements service houses, meeting rooms, coin laundries, shower facilities, etc. were built, and in many settlements without a store, stores which also served as post office, fuel sales, pay phone etc were established. The focus on a decentralized settlement pattern was based on the desire to exploit local resources locally combined with a more ideologically based intention to take care of the 'original Greenlandic culture'. But proportionately, most investments still flowed to the larger cities. (Bro 1993; Grønlands Statistik 1996 til 2004).

To develop and administer the Home Rule, a central government in Nuuk was built around officials from Denmark, recognizing that there was not sufficiently skilled staff in Greenland. Naturally, the Danish officials came with their Danish frame of reference, and many of them were inspired by the 1960s' anti-authoritarian youth rebellion and supported decentralization and 'development on the premises of the people'. (Lauritzen, 1989; Lauritzen 1997) However, due to overuse and inadequate financial management, in 1987 the treasury had a deficit of nearly half a billion dkr. (Danielsen mf. 1998), and from 1990 the cod disappeared from the seas around Greenland, so most seafood purchase and storage plants in both cities and settlements went unused. The combination of deficits in public finances and a sharp decline in export earnings brought Greenland into a recession and required public spending cuts. Slowly, there was a transformation of economic policy away from a balanced geographical development, and thus from the focus on small decentralized units back to the known market economic tools that involved rationalization, economies of scale, and cost optimization. The Central Administration continued to grow, and a good part of the leading Danish officials were gradually replaced with other Danish officials with a more business-economic frame of reference, a development that coincided with the growth of neoliberalism in Western countries. Due to the Danish frame of reference the central administration came to reflect the Danish administration in its composition and structure, albeit in a smaller version, and the municipal administrations also became small copies of the Danish. (Hendriksen 2013)

In an attempt to compensate for the cod fisheries, which in reality collapsed for a long period, fishing was increasingly focused on shrimp, while halibut fishery was also gradually upgraded. And in an attempt to optimize the export incomes from fishing there has been a considerable centralization of mainly shrimp fishery with

a marked decrease in the number of participating ships, while the number of trading posts fell from 16 districts in 1994 to four in 2012. There is no unequivocal relationship between the distance from the fishing grounds and the location of existing purchase and storage plants. The choice of location has rather been based on a desire to provide local jobs to the largest cities. The processing degree of shrimp has been volatile, but over the past 25 years, in the order of 75% of shrimp has been exported as whole frozen shrimps with their shell (Statistics Greenland 2014 a), and thus with no other processing than the cooking that often takes place on the trawlers. However, there has been a slight tendency for increased processing in recent years. The reason for the high export of largely unprocessed shrimp is partly world prices, which has periodically been highest in shrimps with their shell, but just as much, the processing is moved to low-wage countries, hoping to optimize profits. Thus, the publicly owned Royal Greenland operated shrimp peeling factories in Thailand for decades.

Where the value of shrimp in 2013 accounted for 47.5% of total exports, halibut accounted for the second largest single item with 26% (Statistics Greenland 2014 b). For halibut, the employment effect is somewhat more nuanced, with about half caught by large trawlers on the banks off West Greenland, and the remainder being primarily caught by small boats and dinghies and in winter with long lines off the sea ice in northern Greenland. For this part of the catch, an obvious link between residence and business basis is evident. On the other hand, there is again a very modest degree of processing for halibut, with around 80% of the catch over the last 25 years exported as whole frozen fish, albeit with some variation in the percentage from year to year. Again, the explanation is partly the world market and partly that a large part is sent for processing in low-wage countries, including Royal Greenland's plants in Poland.

As seen in Figure 2, despite centralization and rationalization of fishing as well as the relatively high export of unprocessed raw materials the export value of fish and shellfish over time has failed to maintain. Meanwhile, Royal Greenland has several times ended up with significant deficits that the government has had to cover in order to avoid that the group went bankrupt, latest in 2010, when the Treasury had to contribute half a billion dkr. Paradoxically, it has many times been the non Greenland parts of the group that has resulted deficits so large that it threatened Royal Greenland's existence and the government had to intervene.

The centralization of fisheries and purchase

*Qeqertartarsuaq is on of the towns left back with very little fishing and possibilities for first sales of fish and shellfish. Photo: Kåre Hendriksen 2009*

and storage plants and the partial outsourcing of processing has left a number of towns and villages without or very limited industrial base attached to the location of the settlement.

## 5. **The public centralization**

In parallel, there has been a significant centralization of a number of public functions where most publicly or semi-publicly owned corporate offices and administrations gradually has been gathered in the capital Nuuk, and correspondingly, higher education has gradually been concentrated in a few cities. The most important change in this direction is probably that the 18 Greenlandic municipalities were merged into four large municipalities in 2009, and as a consequence the majority of the city administration and the associated jobs has been gathered in the four municipal center cities. For a city with 1000 to 2000 inhabitants and a total municipal population of 2-3,000, municipal work is quite a large part of the employment opportunities for people of working age, and as jobs disappeared in the wake of the merger of municipalities, many sought to move with the jobs. Consequently, there has been a massive brain drain from the previous towns that were municipal centers, and as a result of this depopulation, a number of services along with the building and construction sector is facing a crisis in the former municipal cities.

Another centralization trend has been that since 2011, the former 16 health districts have been compiled into five health regions, which on the one hand removed jobs at the former district hospitals, and on the other hand means that people have very far to the nearest staffed hospital. For a large part of the population, this involves several days of travel by public transport, unless an emergency evacuation is made, which is often hampered by weather. The argument for this centralization has been partly economy and partly to improve health service. In relation to the economy, there is no apparent benefit, as some of the most isolated districts where the majority of the population is spread over many small settlements were among the country's cheapest hospital districts, even when evacuations are recognized. (Hendriksen 2013). Time will tell wheter significant increases in quality will take effect.

At the same time, there has been a number of societal and political changes that has increased the cost of living and poor service levels in the smaller towns and settlements. To name just a few, the 'uniform price system' in retail, introduced by Denmark, where a given product costs the same everywhere in the country, was abolished in 1994, and since then the public subsidy to the government-owned retail chain Pilersuisoq has been gradually phased out. The consequence has been a sharp increase in prices on a number of vital groceries. Another example is that the flat-rate for electricity and water was abolished in 2005, meaning that the publicly owned utility Nukissiorfiit should use the 'true-cost prices' yet still with a certain but limited public subsidization. The consequence was that electricity prices in most places in the country today are 2.5 times higher than in the major cities where the public has brought hydropower plants, and water rates in most places is 3 times higher than the cheapest 'big cities'. Here again is a paradox, since the public subsidization does not unequivocally benefit the most expensive areas.

## 6. **Urbanization factors**

When the decoupling of localization and the use of the local resources, which over the years has been a fact for a number of cities, is coupled with the administrative and political centralization tendencies, a large number of towns in Greenland is left without a substantial basis for existence or business. For the towns that no longer have fishing or purchase and storage plants of importance and which no longer serve as municipal centers, the economic base is reduced to the most basic operation of the city, such as school, kindergarten, elderly care, minimal municipal administration, renovation, retail, and some service industries. All these things are directly or indirectly funded by the government and

ultimately the Danish subsidy of Greenland. Inevitably, a large visible and invisible unemployment arises, and when commuting to another settlement is not possible, for many it does not make sense to stay. At the same time, most cities are located so that the base for subsistence hunting and fishing is not particularly good, and in any case, the population too large for all the unemployed to live off the subsistence hunting, that is locally available. People start to look elsewhere, and as always in this process, the resourceful are among those who move first, creating a downward spiral.

For part of the settlements a corresponding dynamic arises. It becomes less meaningful to stay put when livelihoods are no longer coupled with exploiting the local opportunities and resources, often because there is no option to sell skins locally, and again there is a tendency of the enterprising and resourceful inhabitants moving first. But for the settlements with a clear link between localization and utilization of local resources through hunting and / or fishing, the dynamic is often another, regardless of wheter the base of existence and the economic base is based on subsistence economy where the catch is sold by informal channels over much of the country, or in the case of registered income through the selling of fish to local purchase and storage plants. For these settlements a stable or growing population is often the case, while the internal dynamics are considered good. (Hendriksen 2013)

In the debate over Greenlandic settlements there is a general misconception that people that live in what is defined as settlements result in higher costs for the government than is the case for the urban population. While a systematic review of the direct and indirect public dwelling-related costs in fact shows that the public cost per. inhabitants in settlements and cities are generally, but there are major differences between the settlements, as there are big differences between the cities. At the same time the total public expenditure on the social group that includes unskilled, fishermen and hunters, as well as the population of working age outside the labor market, is significantly lower for the settlements than for the same population in the cities. This is because this population in cities often end up as unemployed on benefits, while in the villages are more likely to be fully or partially self-supporting. (Hendriksen 2013)

It can be said that the above urbanization trends are comparable to those seen in Denmark and the other Nordic countries. But there are two crucial differences.

First, for the majority of the population (which includes unskilled, hunters and fishermen and the population of working age outside the labor market) in cities that have lost municipality status, and in the settlements, there are nowhere to move to. For a very large share of this population will it, to the extent that they move, not be a question of moving for work, but moving from a place that they perceive as more or less futile. To a large extent, these are the same urbanization trends known from third world countries. That one moves in the hope of a better life. The fact that this process is not currently happening to a far greater degree in Greenland is due to a number of factors. First, that people are aware that there are no jobs to move to in the larger cities, and that it is difficult to find a place to live, and secondly, in Greenland there is a social security system that for most ensures a reasonable life where they live. In addition, many have for a time tried to stay in one of the larger cities, but it did not work for them, they did not find work, they felt marginalized, or they did not function socially, or any number of factors. And so they returned to a smaller community with a different way of life, to family and friends, and where it is also to some extent possible to supplement livelihoods through subsistence hunting and fishing.

Secondly, there is the significant difference from Denmark and the Nordic countries that urbanization in Greenland is much more a consequence of administrative and political decisions than the consequence of the development of commercial and economic structures. As shown, Greenland's

export income declined, as did the number of jobs in export income generating industries, and consequently Greenland's dependence on the Danish subsidization has not diminished. That the value of the Danish subsidization primarily has ended up in Nuuk and to a lesser extent in a few other 'big' cities, is a choice and it is not clearly justified by 'where the best value for money is', or 'where the most value is created', as the public costs per. inhabitants in these cities do not differ considerably from other settlements. Similarly, the location of the Greenland shrimp fishery, which comprises almost 50% of total export value, is based more on administrative and political opinion on where revenue and jobs need to be anchored, than on the location of the resource base.

In a city like Nuuk, the main industry is based on the administration of the country, and that is what makes the city the country's richest, which is not abnormal for a capital city. As shown in Figure 4, Home Rule wages (now the Self-Rule) almost solely funded the combined local income tax when Nuuk was still an independent municipality.

*Sisimiut 2013. Photo Kåre Hendriksen*

## 7. **Discussion**

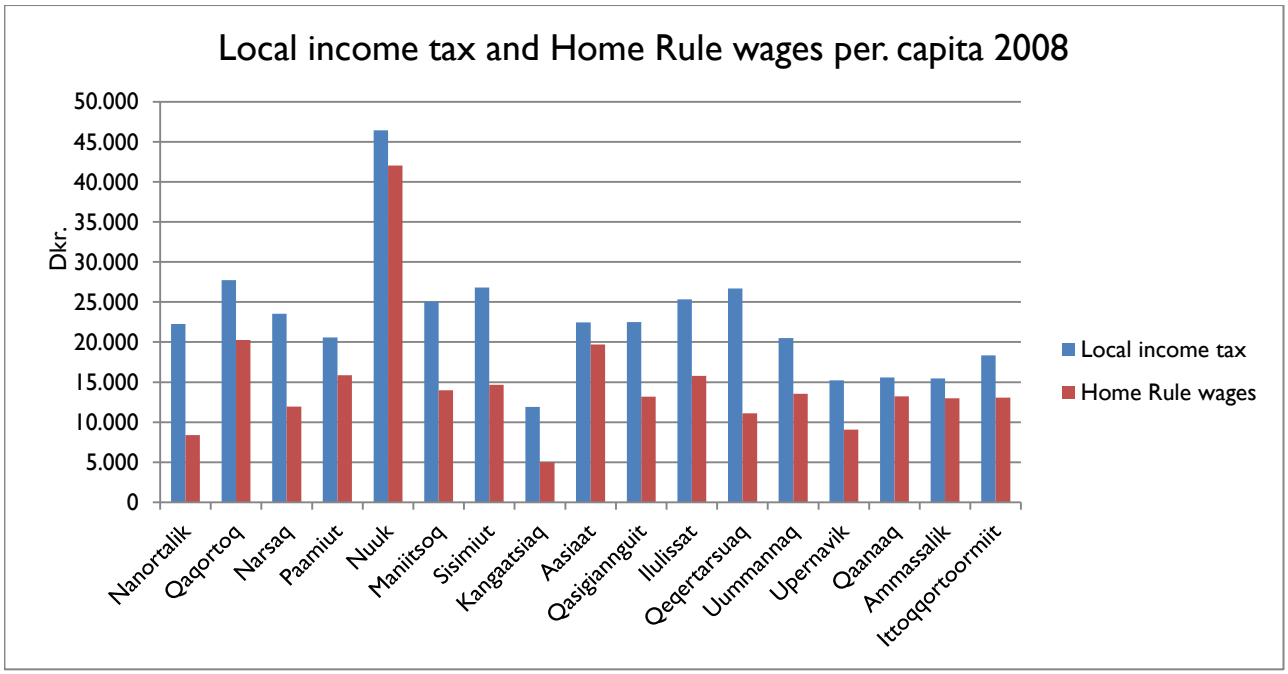


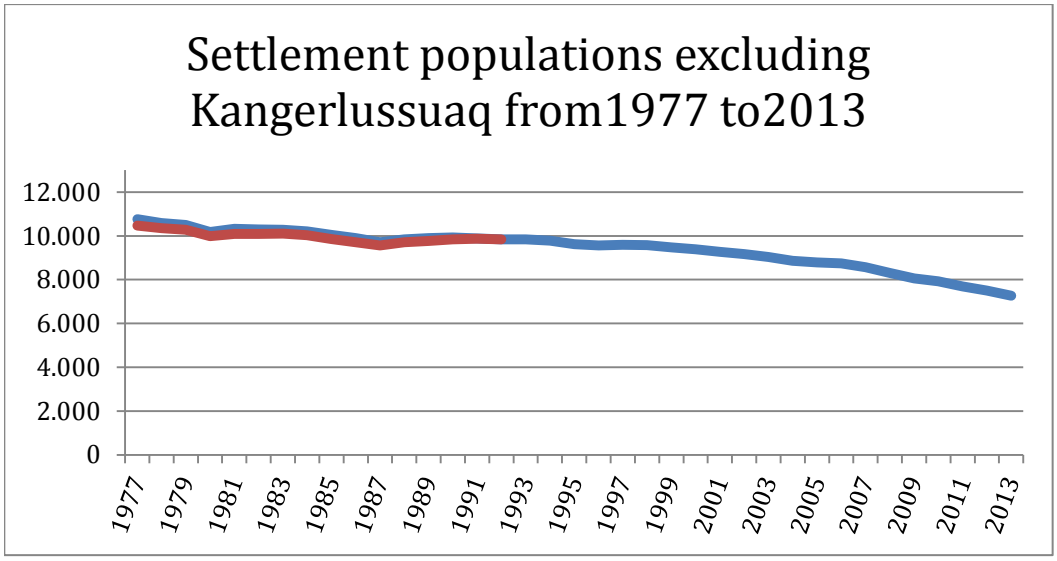

*Figure 4: Comparison between the individual municipalities' tax revenue and the Home Rule wages per. inhabitant of the old municipalities (2008) (Hendriksen 2013) (Based on Statistics Greenland)*

As shown, Greenland's economy is by no means sustainable, and although there is an emphasis on mining, there is nothing to suggest that the economy will change significantly within the coming decades. (The Committee for Socio beneficial exploitation of Greenland's natural resources 2014)

In the debate in Greenland's, as elsewhere, there is a tendency to perceive urbanization and thus the centralization of the population in fewer but larger settlements as a 'natural development', but to date a clear correlation is evident between, for example the population of settlements and a number of political and administrative decisions - or lack thereof. As shown in Figure 5, settlement population was stable during the first years of the Home Rulefrom 1979, when investments were made in e.g. purchase and storage plants. Around 1990 the cod disappeared, and initially, purchasing was shut down in the settlements. In 1994, uniform prices in the retail area were repealed and subsidization of Pilersuisoq was gradually phased out, and the population began to decline. In 2005, the uniform pricing of electricity and water was abolished, and electricity and water prices generally rose significantly in the smaller towns and villages, and migration rates increased. And in 2008, the Home Rule introduced a mobility enhancing payment for settlement residents who wanted to move to a bigger city (Home Rule 2008), continuing the downward trend. A quite similar graph can be displayed for the 13 out of 17 current cities that have lost their status as municipal centers.

*The village Nuussuaq in Upernavik 2009. Photo Kåre Hendriksen*

If it was because the people from settlements and small towns moved to jobs and a better life the need to discuss the urbanization trend and why it occurs would be modest and would mostly assume an academic nature, but it is far from clear that people move to a better life and work. At this stage, the major cities can neither accumulate or secure meaningful employment for the people of the towns and settlements that have lost their existesial and economic basis. The Greenlandic paradox is that the micro-state's modest population today is too big for the income base that the huge country can generate, and the question is whether this changes through urbanization and thus centralization of the population on fewer but larger settlements? *Figure 5: Evolution of settlement population 1977-2013 excluding Kangerlussuaq airport, which has received town status. The red line is the total population without lead and zinc mine*



*Maarmorilik, which closed in 1990.*In an urbanization perspective one of the paradoxes and thus one of the challenges that exist is that today there is neither any clear or economically rational argument for the ongoing urbanization trend of gradual centralization of the population in a few major cities. Due to the development of the resource base - mainly living marine resources - but just as much because of the decisions of localization of purchase and storage plants, a number of towns and settlements have lost their original existential and commercial basis. Meanwhile, a number of cities have lost the industrial base that was attached to being an administrative center of a municipality, and thus their raison d'être. Some of these towns and villages have potentials that are currently unused, but exploiting them will require conscious political and administrative decisions.

*The purchase and processing plant in the village Innaarsuit in Updrnavik 2009. Photo Kåre Hendriksen*

This raises the question of whether local resources are to be exploited by the local population or whether they should be seen as a national resource.
Halibut in Upernavik district is another example of this, as the district contributes around one-sixth of the total export income from halibut, making the population among the most income generating. Upernavik district is Greenland's most decentralized with just over 60% of its 2,800 inhabitants in nine smaller settlements, while the last 40% live in Upernavik city. The primary livelihood of the settlements is hunting for marine mammals, while their primary industry basis or registrable livelihoods are fishing for halibut and to a lesser extent the processing at the purchase and processing plants. The vast majority of the approx. 400 fishermen/hunters only sell quite modest amounts of halibut because their primary employment and identity is linked to the catch, but as an economic supplement to the family's household, they are completely dependent on being able to sell halibut when bills arrive or a need for investment arises. The combination of hunting and fishing for halibut has in recent decades made Upernavik the best performing remote district with a steadily increasing population in the settlements, and the district's population has largely had the halibut for themselves. However, to accommodate fishermen with bigger boats from the cities, half of the district's quota from 2012 was awarded to cutters coming from up to 800 miles south of Upernavik, and at the same time, restrictions were put on the fishermen with dinghies in the Upernavik district. This is an administrative decision that has pulled the economic foundation out from under the local population, and for a number of periods they have become dependent on welfare, and this inevitably raises the question of "why stay so far north"?

## Model for settlements' development dynamics

In connection with an analysis of the Greenlandic settlements' development dynamics the following model, which also can be used advantageously in the cities, has been developed.

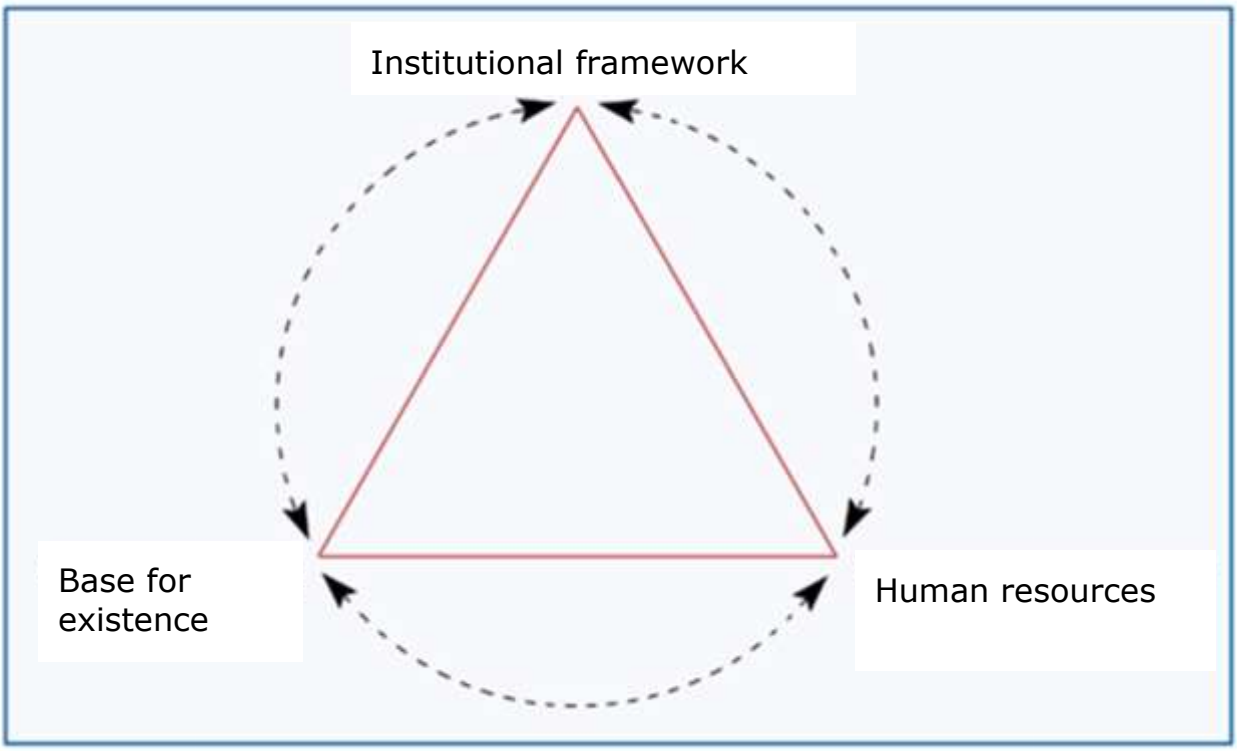



*Figure 6: (Hendriksen 2013)*

The baseline represents the background for setting up a settlement. There are - or has been - some natural resources at the site, and as is usually the case in Greenland these are living marine resources, and there have been some human resources that managed to benefit from this livelihood and therefore have settled on the site. If the resource disappeared, an attempt was made either to exploit other resources, they moved, or they starved to death. Since then, through first the Danish colonization and in particular through modernization a number of institutional framework have been built, such as a purchase and processing plant, school, health care, and social care, which act as support for the settlement. But the institutional framework will also guide the settlement's development dynamics. If better purchasing plants with more processors are established, and there is the necessary natural resource base, the settlement grows because there are better business and revenue opportunities. Similarly, if the institutional conditions are affected by the closing of plants or the awarding of purchasing allowances to others, the prices of basic goods will rise excessively, and the service level of health, education, etc. deteriorates, and this then creates a negative development dynamic that often leads to gradual depopulation.

The institutional framework is increasingly crucial for the individual settlement's development dynamics, and thus we see that the bigger cities of Greenland are growing, even though their livelihoods does not justify this, but because they in different ways are allocated a larger share of the subsidy from Denmark and/or the export earnings from fish and shellfish. Similarly, there are both towns and settlements that end up in a negative development dynamics because their

*Fishing halibut from sea-ice, Kullorsuaq in Upernavik April 2011. Photo Kåre Hendriksen*

institutional conditions deteriorate, even though they locally have a reasonably good resource base. As catcher Themotheus from Kullorsuaq in northern Upernavik said when we talked about the serious consequences of climate change for the local population, because the period of winter sea ice has been reduced significantly, so that the inhabitants are forced to hunt and fish in open boats in the dark period in waters filled with brash ice, ice floes and icebergs: "Climate change - it's something we have to adapt to - the threat to our way of life comes from Nuuk."

## 8. **Conclusions**

There is an apparent difference in the consequences of the factors that facilitate or drive urbanization in on the one side Denmark and the other Nordic countries and on the other side Greenland. Where changes in business and economic structures that are highly dependent on globalization and market dynamics play an important role in the Nordic countries, the institutional framework seems far more essential as a driving force for Greenlandic urbanization. If it was the actual and potential opportunities for a sustainable basis for exploiting local resources that guided the evolution of the Greenland commercial structures, urbanization and human settlement development would likely have a different character.

Hereby, urbanization is more a consequence of political and administrative decisions and priorities - or a lack hereof. Here it is worthwhile to look at the extent to which the current trend is a consequence of the fact that the Greenlandic decision making is based on tools and models derived from a different frame of reference and context, and not sufficiently adapted to the Greenlandic micro-state and island operation characteristics. Overall, research should be carried out in order to shine a light on the whole complex of problems surrounding Greenlandic urbanization and the development of commercial and settlement patterns.

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*Ten years back there was sea-ice in Upernavik from November to June but the last years the period had decrease dramatic. We ware the first to take the trip from Upernavik to the nearby settlement Aappilatoq Marchs 28 2011. Photo Kåre Hendriksen*

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# Scenarios for urbanization, infrastructure and employment

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## Abstract

Discussions about development in Greenland closely link the transfer from traditional hunting to fisher yand new forms of industrial activities to urbanization and centralization as the main models and imperatives for change. These changes in the Greenland society are set in perspective through visions of modernization and economic efficiency based on large-scale operations, though these visions tend to have little emphasis on the localized character of natural mineral and biological resources. In the perspective of sustainable utilization of natural resources, alternative visions and traditional knowledge frames and experiences become relevant for further development and the related policies and economization strategies.

The paper will present four scenarios that build the linkages between the processes of urbanization, infrastructure development, employment patterns and related policies and economic strategies. These scenarios will illustrate the need for investigations of alternative policy strategies concerning urbanization and infrastructure development.

## 1. Introduction

In the recent published study 'To the benefit of Greenland,' written by a group of researchers under the auspices of Ilisimatusarfik and Copenhagen University (2014), the core analysis in concerned with the future prospects of basic choices, challenges and outcomes for the development in Greenland in relation to potential future mining activities. Only a few months earlier, another report entitled 'Future scenarios for Greenland' was published by a group of business and government stakeholders supervised by the Copenhagen Institute for Future Studies (2013) also using scenarios to open up for a discussion of the challenges facing the Inuit society in Greenland concerning future business opportunities.

The choice of scenarios as tool in the policy and planning process is not at all a coincidence. Rather, it reflects the

challenging nature of the open ended and vulnerable situation that the Inuit society is facing. While traditional modelling and planning tools tend to favour a centralised and top-down planning ps rocthey also are dependent on a centralised power structure that is able to apply the results of the planning. The contemporary situation in Greenland is not in line with this condition. This is not due to a lack of central government and administration with the necessary legal authority, but instead due to the uncertainties and dependencies built into the different futures in sight.

A broader engagement of stakeholders inside and outside Greenland must engage with the challenges to make the Inuit society capable to cope with the challenges.

A huge commitment to engage with the upcoming changes is necessary from the side of the local population and from global companies and others engaging in Greenland. Such local and global commitment – at least ideally – does ask for a negotiation of conditions and for a policy process, including elements of social learning.

## 2. **The scenario concept**

Scenarios are storylines that describe aspects of future developments and provide a rich depiction of the changes and influences to be part of that future. A scenario is typically covering a selected field of phenomena and changes that are relevant to the type of choice and interventions that frame and define the outset of the scenarios.

As such, scenarios are tools for negotiation and intervention and not descriptions of finite futures. Their contribution is to provide background for, and input to the involvement of stakeholders in a process of critical discussion and negotiation of basic choices, as well as providing a background for social learning concerning what should be included and excluded from these, basic political negotiations. Scenarios are not mere predictions of futures to come, though their content should be trustworthy, but rather are depictions of possible outcomes of choices that the involved actors can include in the political process and that can become explicit parts of the learning and negotiation process (Heijden, 2005).

An illustration of this is the energy scenarios that often presented as tools in the climate debate. They seem to present consistent predictions of developments and futures to come, consequences of already established patterns of energy technologies and use, though they imply a replication of vulnerable institutional and everyday life practices that may be changing alongside with the consequences unfolding. The predictive value is building on anticipations of non-changing patterns of behaviour. Their practical policy value lies in their constitution of a possible future to come, not in their predictive quality. Their contribution is their capacity to open for controversies and negotiations concerning not only the preferred future but also interdependencies and actions involved in creating it.

## 3. **Historic projections of futures**

Even though scenarios are most often implicitly involved as part of policy processes, policy documents do not necessarily highlight and present them in explicit terms. In theory-based approaches as, for example, in those drawing on stylized models of economic futures, a combination of behavioral theories and political economic concepts for change are included that resemble the characteristics of scenarios.

This has been evident in core reports and policy documents that have set the course for the modernization of Greenland. In the government commissions reports from the 1950s and 1960s on economic and social development this was evident in their emphasis on economic developments based on private business activities. After WWII, the traditional trade monopoly of the Royal Greenland Trading Company was cancelled, but its provision duties continued. The goal was to provide a ground for private businesses to make the Inuit society independent and self-sufficient concerning economic incomes and supply.

At first, fisheries and fish processing were identified as the new core industry in combination with increased utilization of the mineral resources in Greenland (Grønlands-kommissionen, 1950). The policy used lowered legal requirements, compared to those of Denmark, for private operators for implementation. There were no customs or import restrictions and government taxes were kept low (Boserup, 1963). Some new business activities started in this period, but their owners were primarily individuals from Denmark and they concentrated on supply activities taken over from colonial Royal Greenland.

Realizing that private business could not deliver the needed industrial development in Greenland, Danish government began in the late 1950s to stimulate this through massive investments in the fish processing industry. Despite the lack of private investments, the next phase of government policy continued the vision of private based growth and development in Greenland. Government investments supported the policy in strategic parts of the fishing industry in parallel to massive investments in public schools, education, public housing and health care, providing a huge influx of Danish subsidies to Greenland (Grønlands-udvalget 1964; Boserup 1963).

In the wake of these investments placing fishery as the core business activity, new policies centralized the population in larger cities with harbors and fish processing industries. But unfortunately, and partly due to changes in the climate, the mono-culture based on fishing activities did not continue to grow and private fish processing industries went bankrupt or were taken over by government, thus demonstrating that the privatized grow the strategy largely had failed. The only private economic actors surviving were those in goods supply and in the housing construction and infrastructure sector that was very dependent on public spending.

In these historic examples, an explicit use of scenarios might have been more effective at handling all the uncertainties involved in future developments, but political demands for clarity and advice may overshadow the actual uncertainties involved giving priority to simple advice – unfortunately tending to be 'heroic'. Though factors outside the economic system were crucial for the problems arising, the policy discussions did not adequately address the possible impacts of the centralization policies or the challenges related to building a private sector in an economic system so dependent on isolated island economies (Hendriksen, 2013). The result has been the poverty and social problems in the larger cities exist at the same scale as those in some small settlements.

## 4. **Trends as political projections**

Another phenomenon often used in public reports and scientific publications to characterize developments is using the concept of trends. This is the case in the Nordic Council report about Megatrends (Norden, 2011). In this report urbanisation in presented as an indisputable and continued trend as illustrated in the following citation:

*Urbanisation is a process where society is transformed from predominantly rural characteristics in terms of economy, culture and lifestyle, to one which can be characterised as urban.*

*It leads to a further concentration of the Arctic population on fewer and larger places – with increased diversification of the economy, social relations, and cultural activities.* (Norden, 2011, p.9)

The analysis continues with some rather important observations relevant to the challenges in Greenland:

*In many instances immigrants are hired to keep the fishing and agriculture industries alive. In their place many new economic initiatives are developed based on enclave arrangements, for instance in connection with the establishing of mining and other extractive activities, either with the population staying for a defined and finite period of time, or through on/off working arrangements, generally, two weeks on/ two weeks off. In these circumstances the old notion of "the rural" as culturally pure and nationally original quickly becomes obsolete.*

Urbanisation is most often the averaged result of several processes of change leading to the rather important question of what types of contradictions and conflicts are involved in urbanisation. In third world countries, urbanisation is often the result of combined land use conflicts and claims in the rural, of the access to money-based economics in the urban and at the same time poverty and growing squatter areas with incomplete infrastructures.

The lesson from the centralisation and urbanisation processes resulting partly from the centralisation processes of the 1960s, partly from people moving to the cities for education, facilities and jobs in Greenland has been that unemployment and poverty has been a socially challenging issue.

## 5. **Recent projections and scenarios**

Lately the government of Greenland has tended to enter into a similar 'trap' of providing rather 'heroic' depiction of the future especially in three cases that are crucial to future developments in Greenland. The first has been the continued restructuring and centralization of the fishing sector. The second has been the reshuffling of the structure of municipalities in Greenland concentrating local governance into four regions. The third relates to the visions promoted especially by the former, but seemingly also by the recent government, concerning the necessity and impacts of large-scale mining and industrial activities in Greenland.

While fish processing industries in Greenland have been declining especially in relation to the processing of cod and shrimps, halibut has been a growing business both for coastal fishers and for trawlers. Recent regulations by the self-government have prioritized the use of quota and set standards for the size of vessels. This has turned to be a serious drawback for coastal fishers in the Upernavik district (Hendriksen & Jørgensen, 2014). This illustrates the distances in policies and governance, particularly between the central government in Nuuk and its administrative arms and the local communities. The conflict raises issues of ownership, and sustainability as well as legal power in the Inuit population.

The second administrative reform was motivated as a way to rationalize and improve the quality of the administrative support at the municipal level. However, at the same time, it has made possible, to a larger extent, the prioritization of resources for housing and institutional investments. The impact of this reform still needs to analyze how rational it may seem to be from an efficiency point of view.

The third politically driven projection of the potential economically promising future of Greenland through large-scale industrial and mining activities illustrated by the Alcoa smelter and the London iron mining endeavor in the fjord of Nuuk have been pushed by the former government and not in the least by the central public administration in the Raw Materials Directorate. Established before the self-government came into power in 2009, the directorate has a long history. Its position was a result of the dual-governance period where Danish and Greenlandic governments had a say over the natural resources.

This history and the subsequent rush from the Inuit politicians to liberate Greenland from the Danish economic influence illustrated by the Danish subsidies of 3 billion Danish kroner per year has spurred the interest in finding new sources of income. Though mining activities have not shown too positive prospects for decades and did not pay off as part of the 1960s economic policies, this option in recent policies is pointed to as the rescue for Greenland. Not only were the mining options presented as promising, but also they had spillover effects on a renewed centralization policy as well as on diminishing interest in the fishing activities though they are still the backbone of exports from Greenland.

The discussions and controversies around the role of smaller settlements and the idea that a centralised population living in a few larger cities may best serve the economic development of Greenland is far from over. As part of the focus on large-scale industrial and mining activities, the dominant concept promoted has again been to work with centralisation of the population as a core policy. This has been shown in reports on work force mobility and on business opportunities where a combination of mining activities that has a workforce living in cities and working in concentrated periods in the mining areas and in the city based supply and infrastructure businesses (Råstofdirektoratet, 2009). Here, the

implicit scenario combines an urban life style with work practices known from off shore and mining industries in other parts of the world with long periods of concentrated working hours away from family and the urban social life.

## 6. **Four future scenarios**

In the studies presented in the introduction: 'To the benefit of Greenland' and the 'Future scenarios for Greenland,' scenarios are core and both studies operate from the outset with a sceptical approach to the potentials ascribed to mining and large scale industrial activities and quick shortcuts out of economic dependency and problems of Greenland.

The analysis in the university-based report 'To the benefit of Greenland' presents five scenarios that focus on: (1) Status quo, (2) Greenland becoming a natural resource exporter, (3) Resource value is optimised through a wealth fund, (4) Multi-pronged strategy, and (5) Independence – the Greenlandic dilemma. The focus on these scenarios are all relating to the mining issue and as such are limited in scope to the alternatives that are related to this option, which is motivated by the reports outset in the discussion of economic independence through a prioritisation of mining activities. The conclusion though, is that mining activities do not provide a fast route to independence. Rather they provide a dangerous route to new forms of dependence and a risky depletion of non-renewable resources. This leads to the fourth and fifth scenario that operate with a combination of difference sources of income and a much longer route to independence that even may – in periods – lead to increased dependence of things such as Danish subsidies.

The business based study 'Future scenarios for Greenland' operates with four scenarios entitled: (1) The raw materials sleeping pillow, (2) Greenland 2.0, (3) The death trap, and (4) The long, dogged haul. This study shows some of same moderation and scepticism toward a fast route to independence based on prioritisation of mining endeavours as the main economic source of income. In these scenarios, the Greenland self-government is criticised for having relied far too much on projections and hopes related to mining and for not having made the necessary political priorities. As expected, the scenarios are supported by neo-liberal ideas in the analysis of the social and developmental problems of Greenland, leading to a focus on economic policy issues.

There is an obvious need to focus on more detailed and rich scenarios that take into consideration both the social, economic, institutional, and natural resource challenges that face the Inuit society. The size of the population, the island characteristics of the economy, and the dependence on infrastructure are also socio-material elements that define the possible development of Greenland. In this respect, one-dimensional projections and trends do not reflect the situation.

The path to urbanisation includes the question of where natural resources are located and what types on new usage becomes relevant. Some activities may be located adjacent to the larger cities, but e.g. farming, be it on land or at sea, are obviously located in specific, naturally defined places. Mining and industrial activities are also dependent of location of either raw materials or energy sources. On the other end of the spectrum, social costs related to settlement strategies and continued centralisation must be taken into account if a balanced development is to be achieved.

The basic condition of a set of rather isolated and specialised economies reduces the potential of classic market based approaches as local regulation and infrastructures become crucial input factors for the competitive conditions. The relationship between economic measures, infrastructure strategies and regulatory interventions are therefore crucial for the actualisation of business potentials (Hendriksen, 2013). This is evident in the cases of large-scale activities where infrastructure has to be included as part yet

it cannot be handled in the same way for small scale activities.

This leads to the formation of a number of scenarios that can highlight and open these contradiction and options for political discussion and scholarly debate. A suggestion for such structure of scenarios is:

1. Further centralisation and the building of a divide between industrial work and everyday urban life.
2. Flexible localisation strategies based on the local context around the utilisation of natural biological and mineral resources.
3. Marginalisation of the Inuit society due to a lack of new industrial investments.
4. Strategic dependency on Danish subsidies to cope with growing economic challenges to maintain social standards.

These scenarios will be detailed and elaborated in the presentation and improved version of the paper.

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# New arctic typologies in Ilulissat

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## Abstract

This article presents the involvement with changes of climatic conditions in Greenland and the related possibilities of a new urban development, using Ilulissat as an example. The influences of extreme climatic conditions under traditional and cultural aspects in architectural and landscape typologies will be presented. With a growing population, settlement of regions in extreme climates is becoming an urgent necessity. Greenland needs sustainable concepts for prospective urbanization. The ideas of new building typologies, based on the logic of climate context and developed with regard to their behavior to extremes of wind and sunlight, show possible urban developments for Ilulissat.

## 1. Introduction

In many ways, Greenland lies in the focus of the global climate change. It is the most concerned country, because it is where the most severe climate shifts will occur. The climate change leads to the development of new economies that will change the country from ground up. As ice draws back, it gives access to resources such as oil coal, gold and gemstone.

Many opportunities also lie in the melting water which can be used to produce cheap energy. Around 40% of Greenland's energy is produced by three hydropower plants. Two new plants are being planned in cooperation with the company Alcoa, mainly for aluminium production which will make Greenland the biggest player on the aluminium market. In addition, agricultural structures will change and evolve, as climate shifts will soon be possible to grow vegetables like potatoes (DMI Technical Report, 2013).

Facing these changes, how will Greenland's cities cope with the rapidly changing conditions?

## 2. Existing urban structures

With 4,600 inhabitants, Ilulissat is the third largest city in Greenland and is located near the most productive glacier. The ice fjord was announced as a UNESCO world heritage in 2004. A lot of scientific research concerning the climate change has taken place and will continue to increase the interests of scientists, politicians and media in the future. For these reasons, a new visitor and information centre is planned by the architect Peter Zumthor (Government of Greeenland) Ilulissat's population, tourism and economy will grow steadily in

*Figure 1: Typical house in Ilulissat (Jerzy Sawluk / pixelio.de)*

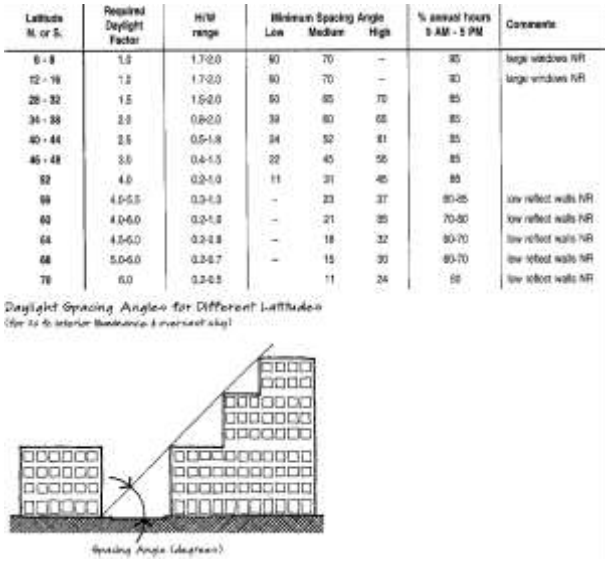
the near future. As such it offers a wealth of possibilities for urban development as the question of urban typologies for Ilulissat is yet to be answered.

As of now housing buildings as illustrated in Figure 1, are small constructions mainly built with wood on a base. These small houses are typically scattered around the city. Besides that, there are some bigger housing blocks as well as small groups of buildings. Sharing living space in the same building is not common in Greenland. Buildings are not oriented in any geographic direction, though some of the constructions are built on a northwestern hillside, as depicted in Figure 2. Single houses lie scattered, while some multifamily residences can be seen. Scattering is presumably owed to the low standing sun where space between buildings assures that neighbouring houses do not lie in total shade (Figure 3).

## 3. Urbanization in arctic climate in the past

Ralph Erskine, an architect from England working in Schweden, is considered the pioneer for architecture in cold climate. As early as the mid-fifties Ralph Erskine already sketched his vision for an ideal town in the Arctic. Figure 4 shows the fundamental characteristics of his artic town. In the drawing from 1958 "Study for an Arctic Town," we see a settlement which is placed on a southern slope and is enclosed by a contiguous building in the north, east and west. With few external windows it looks like a wall of a medieval town, but this wall will protect the community members from arctic winds and snow storms.

*Figure 2: Site plan of Ilulissat*



| Latitude N. or S. | Required Daylight Factor | H/W range | Minimum Spacing Angle Low | Medium | High | % annual hours 9 AM - 5 PM | Comments |
|---|---|---|---|---|---|---|---|
| 8 - 9 | 1.0 | 1.7-2.0 | 60 | 70 | – | 85 | large windows NR |
| 12 - 16 | 1.0 | 1.7-2.0 | 60 | 70 | – | 80 | large windows NR |
| 28 - 32 | 1.5 | 1.5-2.0 | 50 | 65 | 70 | 85 | |
| 34 - 38 | 2.0 | 0.8-2.0 | 39 | 60 | 65 | 85 | |
| 40 - 44 | 2.5 | 0.5-1.8 | 34 | 52 | 61 | 85 | |
| 46 - 48 | 3.0 | 0.4-1.5 | 22 | 45 | 56 | 85 | |
| 52 | 4.0 | 0.2-1.0 | 11 | 31 | 45 | 85 | |
| 58 | 4.0-5.5 | 0.3-1.3 | – | 23 | 37 | 80-85 | low reflect walls NR |
| 62 | 4.0-6.0 | 0.2-1.0 | – | 21 | 35 | 70-80 | low reflect walls NR |
| 64 | 4.5-6.0 | 0.2-0.8 | – | 18 | 32 | 60-70 | low reflect walls NR |
| 66 | 5.0-6.0 | 0.2-0.7 | – | 15 | 30 | 60-70 | low reflect walls NR |
| 70 | 6.0 | 0.2-0.5 | | 11 | 24 | 50 | low reflect walls NR |

Daylight Spacing Angles for Different Latitudes



*Figure 3 Sun spacing angle (SUN, WIND & LIGHT Architectural Design Strategies)*

Within these walls, the isolated houses and administrations are set up and oriented towards the sun. Erskine explains that "cities in the north ought, because of their isolation, to be made more attractive and pronounced than their counterparts in southern parts. They ought to be gathered in a cluster to create a human environment in the [arctic] desert" (Collymore and Erskine, 1994).

**Arctic Studies by Erskine**

In 1959, Erskine presented his designs at the Congrès Internationaux d`Architecture Moderne (CIAM) to show his ideas of

*Figure 4 Study for an Arctic town from 1958, (Collymore and Erskine, 1994, p.30)*

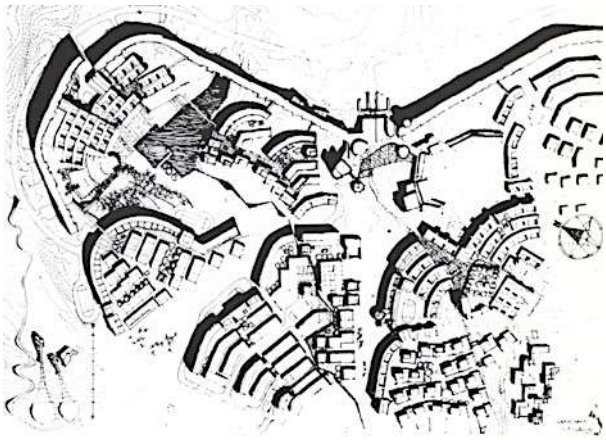


*Figure 8: Early sketch for Svappavaara (Collymore and Erskine, 1994, p.99)*

sustainable building in the Arctic and sub-Arctic areas. His studies show how settlement areas above the Arctic Circle in Swedish Kiruna and Savappavaara have been planned. The idea of "Study for an Arctic town" (1958) was a precursor to one of the projects of 1964 in Svappavaara.

Erskine won the contract in a competition for the city of Kiruna. But the association of iron mines which commissioned the construction was influenced by economic fluctuations and therefore, only parts of Erskine's ideas were realized. In the center along the wall-building a long pedestrian gallery was planned which would have been accessible from any other part of the building. This internal road was thought of as an exposed passage with further connections to other facilities. But this idea was never realized in the sense of Erskine.

Another project built on the studies of a town in the Arctic, is the city of Resolute Bay in Canada (1973-77). The settlement was planned for workers of the nearby weather station and the airport as well as for the Eskimos living there since 1953, with a distance of approximately 6 km to the airport.

Erskine's plans, as shown in Figure 6 intended to mitigate the climate, provide wind protection for open spaces, reduce snow drift and finally give a sense of identity and community. The building should have had an aerodynamic design and be formed in a very compact structure. A space under the building is supposed to prevent the melting of permafrost soil. The low sun should be reflected via reflectors from the roof into the house. Double entrances prevent that the entrances are covered by snow. Because of political and economic circumstances, this project was not finished.

At the CIAM meeting in 1959 Erskine devised "A grammar for high latitudes". The basic points in this grammar are: (a) The cold, (b) the warmer period, (c) snow, (d) ground frost, (e) light, (f) wind, (g) air drainage, (h) sun heat / radiation, (i) fauna, (j) vegetation, (k) micro-climate and as final point (l) isolation (Collymore and Erskine, 1994)

In his manual Erskine also writes about the idea of a town in the Arctic by other architects who imagined designs with a massive dome or membrane roof. However, the material costs were too high and it also causes difficulties in the social and psychological aspects. From his point of view "[...] instead of the science fiction city under a dome, other, more subtle, building forms [...]" should be devised (Collymore and Erskine, 1994).

Characteristics of such a city are: protected outdoor walkways coupled with a closed heated way, a third circulation system of roads and if possible parking areas are covered in the basement and a green belt for buildings with trees and shrubs as a wind catcher.

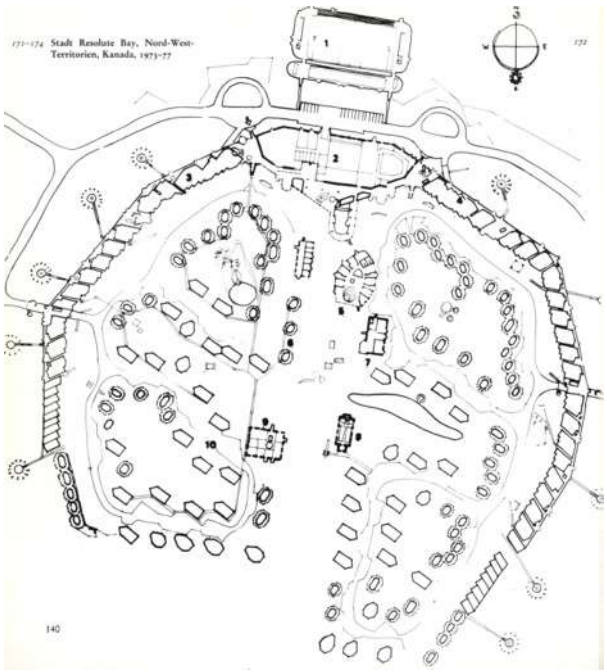



*Figure 9: Initial site plan (Collymore and Erskine, 1994, p.134)*

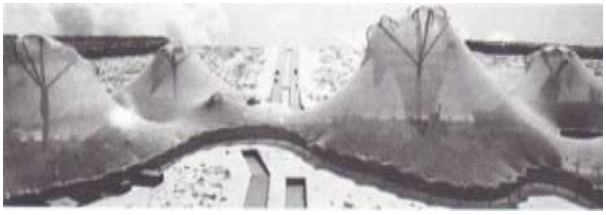


*Figure 10: Several tents strung together (Fullerton, 1984)*

**Arctic Climate Architecture by Arni Fullerton**

The design study of Arni Fullerton "58th North / Canada" of 1980-81 shows what Erskine would have considered a "science-fiction city". The plan was to delineate an area for workers employed by one of the largest oil sands deposits found in the sub-Arctic climate. In this study two basic concepts were developed.

The first consisted of a dome with a rope mesh as well as a transparent membrane, so that an air protected hall with 114,000 m² arises. The other approach had no dome, but instead relied on single tents from cable networks with partial transparent areas.

On the other hand no dome was created but several tents strung together with a single size of 5000 m². Both designs allow the residential building heat under the cover and are located on the border areas between the shell and the external air (Fullerton, 1984). The outer shells protect the climate in the interior of the city, so there is a temperature range from -3 °C to +10 °C in winter at -40 °C. In the tent solution solar energy is trapped best. Owing to its specific form, steep inclines could be orientated to the south.

*Figure 8: Dome with transparent membrane*

## 4. Solutions for Sustainable Urbanization

The examples of Ralph Erskine and the utopias of Arni Fullerton are two very different solutions for urban life in the Arctic. Still, these designs have one thing in common: they are both compact. Density is, in fact, an issue which is not to be found in the Arctic cities, although it subserves social identity, a major factor in urban planning.

I will deal with a similar approach in my work, in which I try to draw an urban development concept for the town of) Ilulissat, relating to its climatic situation.

**Climate as a chance for sustainable urban planning.**

The project of Atelier 5, a settlement in Switzerland, is an example in which high density of buildings can be observed. The town consists of 79 units logically linked to one another. As can be seen in the system interface the short distances to the neighboring building is possible by being built on a slope. In spite of the short distances between them, each building gets enough sunlight.

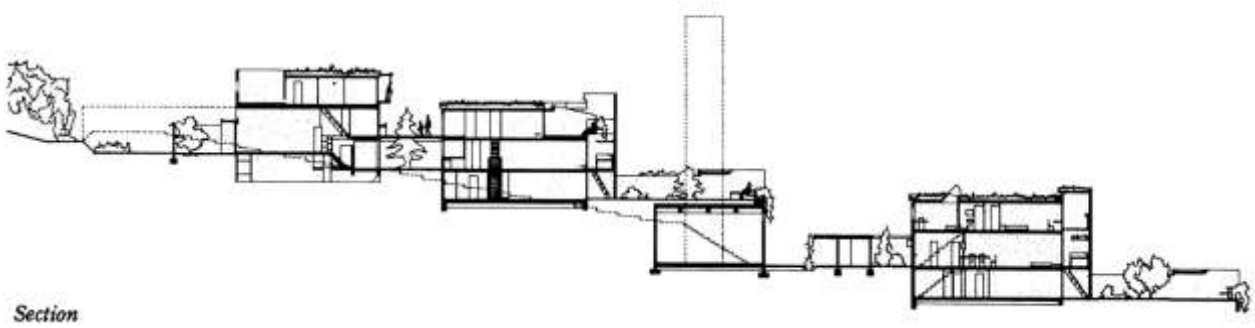



*Figure 9 Section. See p25 in (Achleiter, 2000)*

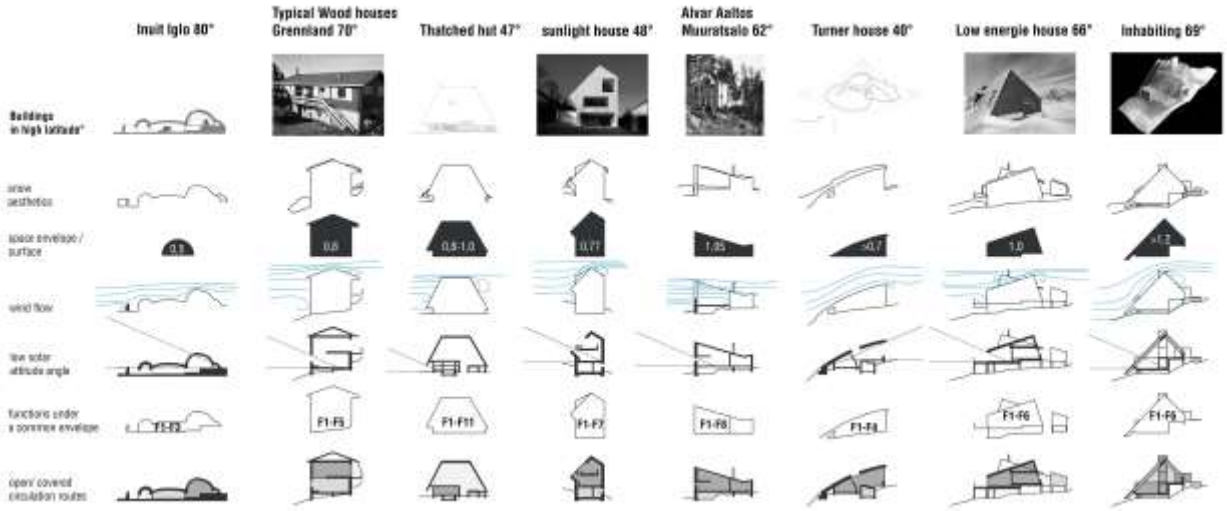



*Figure 11: building shapes in high latitude proved by Erskine's grammar*

The buildings were designed to be as simple and organic as possible, yet with exceptional attention for privacy guaranteeing visual protection. This settlement is like a small town, but there are no roads for cars. Apart from the economic focus, community facilities must also be included, as all residents are a part of the community. This settlement is "an economical interaction with the site, a rigorously organized, nearly urban complex, no cars in the facility, the simplest of housing units, a clear separation between public and private spheres, generous facilities for the community as a whole [...]" (Achleiter, 2000).

## 5. Study of arctic design

My research of building shapes and constructions from the past shows that the arctic designs based on Erskine's "Grammar" utilizes simplified shapes. The various conditions, such as wind or snow, are displayed graphically with the building examples. How these existing building shapes are impacted is also shown. In the graphic study above, seen in Figure 10, the different shapes in regions with cold to very cold climates are compiled and compared. They propose areas for consideration when planning an arctic design. This simple graphic portrays the typical arctic shapes. The following are compared: 1) aesthetics, 2) minimum space envelope/surface, 3) Wind and protection elements, 4) low solar altitude angle, 5) functions under a common envelope, and 6) open/covered circulation routes.

As has been found in the study of arctic examples, a recurring building form can be seen in different permutations. The classic gable roof form in the examples has typically been the foundation for housing typologies. Ilulissat consists of small houses with gabled roofs. If this form of houses should be adapted to the arctic and developed, then Erskine's approach could be a blueprint for adaptation to urban designs.

For a new urban development in Ilulissat the traditions of the old structures should be at the foundation of the designs. These

*Figure 11 Sun path and wind rose at winter start, Graphic: Jennifer Fiebig (climate data from suncalc.net 2009 and DMI Technical Report 13-16)*

old structures can, with the inclusion of solar radiation and wind, lead to a form adapted to the local climate. The thesis relies on the structures of Erskine.

This should help to develop a new form of housing density for the Arctic area. It is important to consider how density in the Arctic is to be defined, and how the extremely dense housing example of Atelier 5 can be compared. Based on the fast-growing population, the issue of density within the context of the climate will always be of paramount influence. The low solar altitudinal angle is to be improved by adaptation of the roof-form for urban solar spaces. At the site of Ilulissat, according to Erskine, the building may be oriented to the south or southeast in order to capture the sun's rays even in the early morning.

The roof-forms in the above table (Figure 12) are calculated for 72°N to determine the ridge height and if the building should orient at 45° to the harbor of Ilulissat and to the angle of daily sun. In Figure 13, the typical houses from Greenland are transformed according to orientation, solar radiation and wind based on Erskine forms. Erskine's shapes in the example of Resolute Bay are all broken down into polygons and even developing these polygons to round building forms. Also found repeatedly in his buildings are rounded corners. This choice of form should compact the buildings' positioning for better, grid-based urban development. The living-quarters are

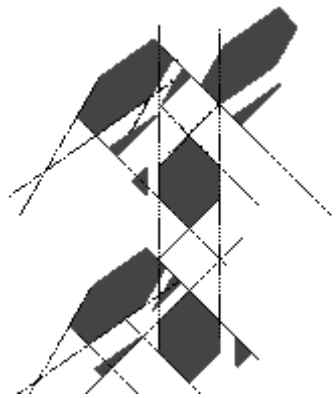


Figure 13: Cluster of Housing, Jennifer Fiebig

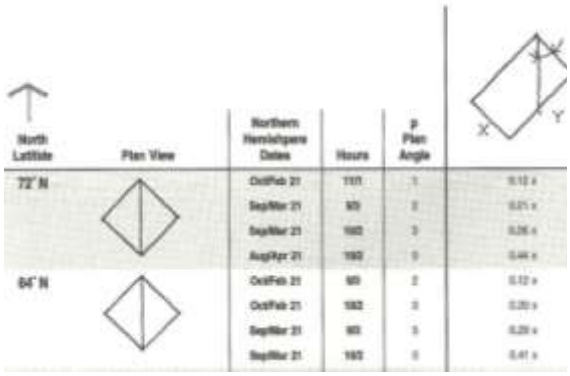



*Figure 12: Ridge Heights of Solar Envelopes (SUN, WIND & LIGHT Architectural Design Strategies)*

aligned with the axes of the facades. If two axes encounter each other and the minimum distance is kept, there will be no shading to the neighboring building as seen in Figure 14.

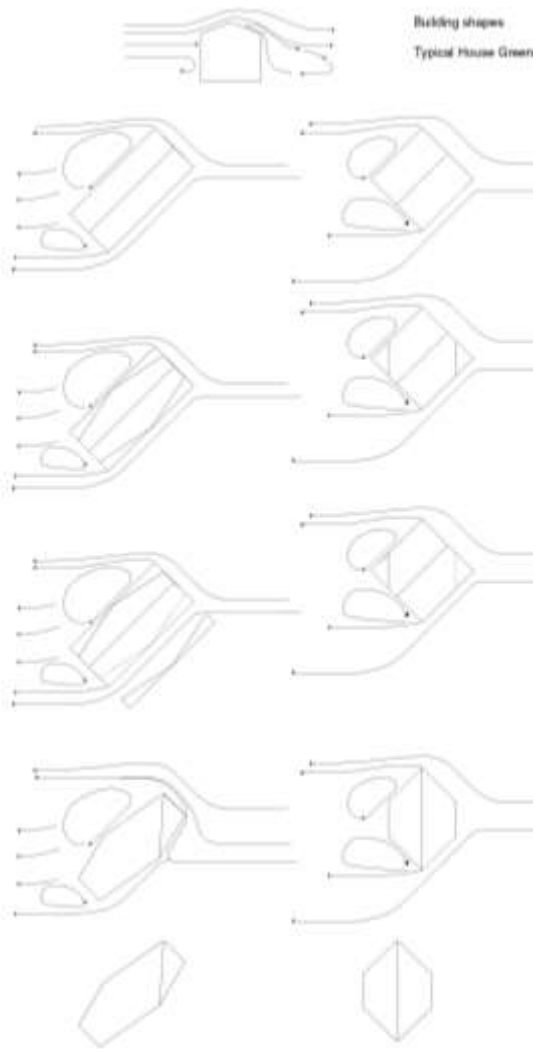



Figure 13: Transformed typical houses in Greenland, Graphic: Jennifer Fiebig


*Figure 14: From North to South Slope (Panorama of Illulissat, February 2006, Lucas Cullen, revised by Jennifer Fiebig)*

## 6. Site selection according to climatic conditions and social aspects

Ilulissat is home to the largest fish processing factory, Royal Greenland, where a third of the local inhabitants work. This port is the core of town, which offers a new potential for a subsequent port-of-culture. Prospectively, this could be a center with cafes and intercultural interactions fostered by the emergence of tourism. Up until now, the city has developed on the northern slope along the harbor. If one follows the studies of Erskine, arctic towns should be located on a southern slope where cold air cannot flow down to the hill. The opposite shore offers an appropriate place that is connected by a bridge, which follows a street up to the airport of Illulissat.

In site-selection, not only are the cultural social aspects are important for a sustainable urbanization but also the climate aspects. Further, the climatic influences define how towns will look. The main wind direction in Ilulissat is from the east in winter as shown in Figure 11. At the beginning of winter in October the solar altitude is already extremely low. Therefore, it is all the more important to align buildings with a southern-slope if possible.

The opposite shore of the port is not only on the southern-slope but also gives a view over the whole town and the icebergs which pass the coast in summertime. According to Erskine, arctic cities should use the wind and snow as a characteristic element for urban development.

In the located site, the south slope, which is opposite of the port, a new urban development to the existing main street was built, to the north on the site plan (Figure 16). The city develops according to Erskine's theory: the cluster of houses are

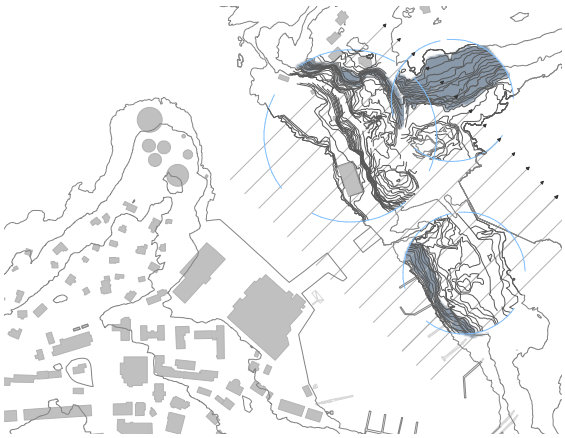


*Figure 15: Southern surfaces in the topography, Graphic: Jennifer Fiebig*

arranged so that they can develop in the future along the southern-slope.

## 7. Conclusions

The Arctic city is influenced by landscape

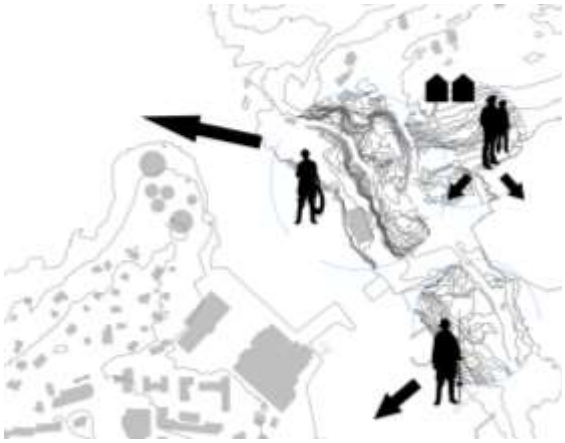


*Figure 16 Three Cluster built on the south solpe, Graphic: Jennifer Fiebig*

and climatic conditions. Wind and snow form aesthetic patterns. The presented historical- and climate-related ideas should give an indication for the transformation for new typologies. Aerodynamic building designs utilize rounded corners to address flow problems. The site was found according to climatic conditions and social aspects, three new centers could be built on the south slope near the port in Illulissat. Cluster One could be a settlement with harbor culture, the second could be an area for only workers of the export harbor, and the third cluster, located near the sea, is for private living. (Figure 18)

Each residential complex uses a main street and access routes in order to minimize energy and costs. The main road could be shared with additional residences and could be combined into a settlement. The cluster of arctic housing designs suggested by my study, are shown on the site plan in Figure 19. Different circulation routes (Erskine) offer public and private spaces. The architecture fits into the landscape, is protected from east wind and is orientated to the south.

The previously arranged structure was studied in a wind simulation Software Autodesk Vasari. These digital values are

*Figure 17: Urban analysis, Graphic: Jennifer Fiebig*

not an exact realistic representation, but it can investigate where the wind moves and at which points wind protection zones arise. In Figure 20 the blue areas are windless zones, and here should be built. The wind

*Figure 18: Site map of Cluster, Graphic: Jennifer Fiebig*

enters, slowed by the buildings in the quarter, and routing should develop. Snow-free roads are caused by wind movement. (Erskine) Squares and streets are formed only by windless or wind movement.
In winter, urban patterns were built with streets and wind-protected space, as well as interiors with open and covered circulation routes based on Erskine's theory.

The historical derivations by "Erskine Grammar" served as the foundation for the researched strategies in cold climates. The technical components, such as the calculation of roof shapes for optimal sun areas in the urban space, and the wind and solar analysis for the space and routing, are all based on the historical background of Erskine's theories. The main categories were taken from the Grammar for High Latitudes are summarized. Dealing with the topic of climate in Greenland is divided according to these theories.

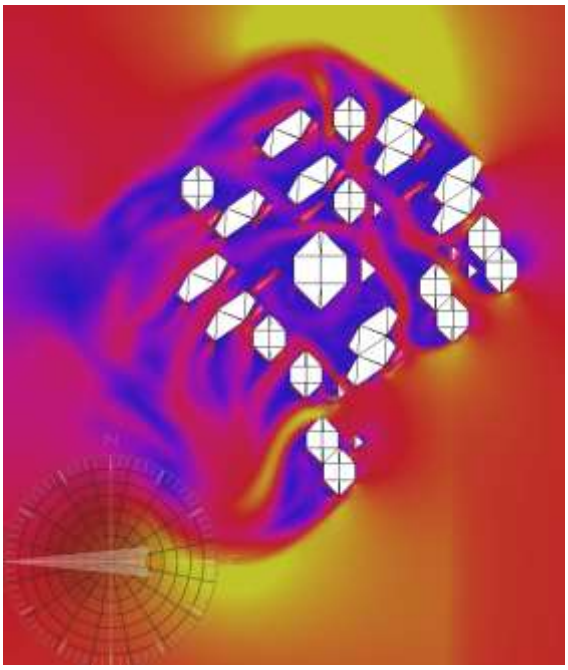


*Figure 19: Wind simulation of Cluster 3, October, Autodesk® Vasari*

In the design, each of the parameters were considered and applied as a grammar for the development of the building in climate-extreme Greenland. In my preliminary research I have proposed the thesis that in the future the strong population growth in Greenland must be addressed with increased residential buildings, which can be a sustainable solution to urban density. Erskine's theories should help to develop strategies through new typologies for the town ofnIllulissat and to condense them without large losses in solar radiation or being exposed to the cold arctic wind. The strategies and building references found that a kind of density that we know in temperate zone cities cannot be applied in arctic regions. The dark winter and long summer nights are large factors for the city structure. The arctic structures in urbanization are coming to exhibit low city

heights in order to provide solar space. The composition of the building should progress toward further development of still another level of housing density. By densely-arranging in the east, the wind should be slowed down from the east. In the summer the wind coming from the north should be able to flow through wider roads, built for this purpose.

The climatic and traditional strategies show the "grammar" for the city on the 69° latitude.


## Acknowledgements

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# ~~Winter Cit~~The Winter City: creating urban spaces for winter use

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**Abstract**

The project ~~Winter City~~'Winter City' aims to test, challenge and develop the use and design of urban spaces for the winter season. During the last few decades in Denmark, there has been a lot of focus on developing urban spaces that support a vibrant urban life. However, there is less focus on how these spaces support urban life during the winter. Statistics show that urban spaces in Copenhagen are less vibrant during the cold and dark months. The municipality of Copenhagen has it as an aim in their Urban Life Account 2012 to create urban spaces that make people spend more time outdoors. Since 2012, ~~Open Air Neighborhood~~Open Air Neighborhood has collaborated with a series of partners on developing elements that - when integrated in an urban space - can improve the usability of that space during the winter. Through a series of projects, the elements have been tested in different shapes and settings. This paper will highlight the results and explain how the elements have been utilised in the effort to create urban spaces that function as frames for urban life in wintertime.

## 1. Introduction

~~Winter City~~'Winter City' is an ongoing project by the urban design and innovation office ~~Open Air Neighborhood~~Open Air Neighborhood. The project was initiated in 2012 ~~and~~ based on ~~a~~ curiosity as to why the lack of urban life during the winter season in Copenhagen is rarely discussed in urban planning. In Copenhagen, there is a clear aim from the municipality to create a more vibrant urban life. In the Urban Life Account 2012 it says:

*We have three goals for urban life until 2015: More urban life for all, more people ~~to walk~~walking, more and more people to stay outdoor longer (*Urban Life Account, 2013).

It is clear from statistics that there is less outdoor life during winter, as shown in Figure 1.

Statistics show that there is room for improvement during the winter season. The winter season could be a good place to focus on in order to reach the stated goal. ~~Still~~ However you still have to look far to see anyone proposing that urban planners should consider the winter climate when planning urban spaces. ~~Statistically~~ This can, for instance be seen by the lack of Danish research into the area of urban planning in relation to the winter season. Also, looking at architectural renderings for new projects in Copenhagen almost all of them show sunny warm weather. This is inspite of the fact that winters in Denmark sometimes span more than half of the year.

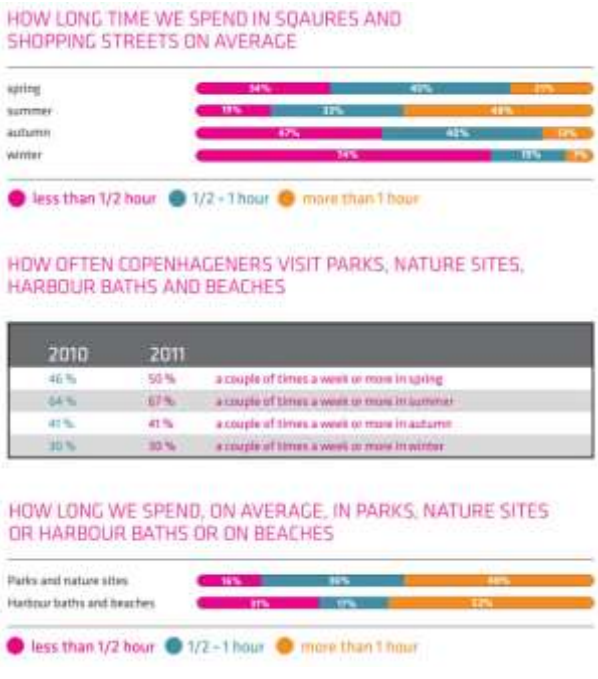


*Figure 1: Statistics from the Urban Life Account 2012.*

~~Open Air Neighborhoo~~Open Air Neighborhood has developed a ~~group~~ set of elements that have been tested in different settings. When placed in an urban space these elements will make a space more usable in winter. The elements ~~are~~ address heat, light, materiality and movement.

**Heat** – having a source of heat you can go to when you get cold will allow you to stay outdoor for a longer period of time. Heat sources also serve as social meeting points.

**Light** – in Denmark, the winters are very dark. Therefore it is interesting to work with light in different ways.

**Materiality** – is understood as the materials the urban spaces are made of.

**Movement** – moving your body creates heat enabling, you to keep warm in cold weather.

These elements have continuously developed throughout the duration of ~~Winter City~~'Winter City'. They are not to be seen as a final solution that will make an urban space vibrant with life, but are expected to change and develop as new findings are made.

At Artek Event 201,4 ~~Open Air Neighborhood~~Open Air Neighborhood will present the findings from ~~Winter City~~'Winter City'. The findings will contribute to the topic "Urban planning that facilitates social equality, positive intercultural interactions, sustainable living, and recreational activities while supporting public involvement".

## 2. Focus and context

This section explains the focus of ~~Winter City~~'Winter City' and~~,~~ the context it is developed in.

~~Winter City~~'Winter City' focuses its work within two fields: events and their physical setting, and urban design

At an outdoor event, the city functions as a backdrop for something special. An event poses the opportunity to test an idea in a short time with a critical mass of users. The collaboration with Frost Festival, a music festival, which normally takes place at indoor venues every February, on an outdoor concert in February is an example of this.

The field of urban design focuses on the spaces individuals pass daily on their way to work. The project Winter Light (Tåsinge Plads) is an example from this field. Findings from the events feed into the work with urban design, which are typically projects that last longer, as it takes a longer time to measure the effect of an urban space.

~~Winter City~~'Winter City' is presented and communicated through a Facebook page and a website. Part of the communication strategy is also ~~making~~ to make short films and interviews with people sharing their thoughts about urban life during winter. The purpose of the films is to exhibit good examples of how the winter's qualities can be used positively.


*Figure 2: Caption from a short film about a winter bather in Copenhagen.*

The ~~Winter City~~'Winter City' network is a multidisciplinary group consisting of municipalities, urban planners and architects, universities, housing organisations, street furniture manufacturers and cultural institutions. The team functions as discussions partners for Open Air Neighborhood and also as partners on specific projects.

## 3. Projects

To give an understanding of how the elements have come to be this paragraph presents three projects where the elements have been tested, as the elements have developed over time. The project Tåsinge Plads took place before the four elements had been formulated. Thereby the findings from that project were the base from which two of the elements were developed. For Innosite – Toftegårds Plads two other elements had been formulated and were tested. Remiseparken was the first project where all four elements were tested.

### 3.1 Tåsinge Plads

**Site:** Tåsinge Plads, Østerbro, Copenhagen

**Date:** December 2012 – April 2013

**Collaborators:** Municipality of Copenhagen, Philips Lighting, local businesses and citizens.

**Background and project description:** Tåsinge Square (Tåsinge Plads) was to be ~~renovated~~refurbished. While the plans were being made for the renovation, the municipality had initiated a row of activities that engaged the citizens around the square in different activities such as gardening or flea markets. The activities took place during the summer of 2012. The purpose of the activities was to create ownership amongst the citizens and get feedback as to how the square should develop. However, the activities stopped when fall started. This made some citizens who had been involved in the activities during the summer and had enjoyed meeting their neighbours through them, ask for similar activities during winter. The local planning office had heard about the project ~~Winter City~~'Winter City' and contacted Open Air Neighborhood to discuss the possibilities of collaboration. The collaboration started with Open Air Neighborhood being commissioned to do two winter events ~~on~~ at Tåsinge Square.

Open Air Neighborhood took part in a Christmas market on Tåsinge Plads. People were invited to sit in an outdoor living room and share their thoughts on winter in Copenhagen. The conversations were recorded and taped. What the conversations found that it was difficult for people to imagine what could make them spend more time outdoors in wintertime. Things that were most often mentioned as good about winter were Christmas decorations, Christmas shopping and ice skating. When asked about what could be done to make urban spaces more interesting during the winter season lighting was the thing most often mentioned.

This led to the idea of celebrating winter solstice on Tåsinge Plads. On December 21st 2012 Open Air Neighborhood invited the local community to celebrate winter solstice. A large balloon with light inside it was put in the swuare and there was live music. The evening was beautiful and despite of the freezing weather about 100 people attending the celebration.

*Figure 3: Photo of the outdoor living room at the Christmas market in Tåsinge Plads.*

A reporter from the local TV station covered the event. The square was furnished with benches and braziers and warm drinks were served. People gathered around the fires to keep warm. The event lasted two hours.

*Figure 4: Photo from Winter Solstice on Tåsinge Plads.*

These two events led to the project Winter Light that was a collaboration between Philips Lighting and Open Air Neighborhood.

Citizens, the municipality and local businesses were invited to participate in a workshop focusing on using lighting to make Tåsinge Plads more interesting during winter. Open Air Neighborhood and a light designer from Philips facilitated the workshop. Participants worked in groups discussing their ideas for the square. After the workshop, Philips and Open Air Neighborhood gathered the result from the workshop and designed a prototype light setting and installed it on Tåsinge Square. It consisted of a lamp post integrated into a seating arrangement, two spots that shined upwards illuminating the trees and coloured spots on three ventilation pipes.

*Figure 5: Photo from workshop about light on Tåsinge Plads.*

The light installation was officially opened with a speech and a warm meal. About 40 people participated. The installation was there for a month during which time participants in the project and others e-mailed their feedback to Open Air Neighborhood. The results of the workshop and the feedback on the temporary light installation was handed over to the municipality who used it as recommendations for the further development of Tåsinge Plads.

**Elements used for Tåsinge Plads:** Heat and light were the elements that were used for the projects on Tåsinge Plads.

The events that were held on Tåsinge Plads showed that a heat source would enable people to stay outdoors longer in the cold. Using braziers as heat sources also created a place where people could meet while they got warm.

Light is an obvious element to work with during the winter in Copenhagen. It is dark a lot of the time therefore even a small light pointed in an interesting direction can have quite an effect on a space. The project on Tåsinge Plads also showed that the light setting on the square did create more life.

*Figure 6: Photo of prototype light setting on Tåsinge Plads.*

### 3.2 Innosite – Toftegårds Plads

**Site:** Toftegårds Plads, Valby, København

**Date:** November 2013 – February 2014.

**Collaborators:** Innosite, FROST Festival.

**Background and project description:** During the summer Copenhagen's cultural calendar is packed with outdoor events but there are very few outdoor events in wintertime. One of those few events that took place outdoors was an outdoor concert on an ice skating rink in Copenhagen hosted by FROST Festival. Open Air Neighborhood found the project interesting because it placed a concert on an ice skating rink, representing a very interesting idea. Instead of having the audience stand still listening to music while freezing, the ice skating rink invited them to skate and thereby keep themselves warm while listening. FROST Festival was interested in further developing the concept so a similar event was planned for in February 2014. Open Air Neighborhood was to design the urban setting for the concert. It was decided to use www.innosite.dk, which is an online innovation platform, to ask the public for ideas on creating:

*the framework for an outdoor event during winter and make the urban space more exciting in the cold and dark months. Darkness and coldness should be incorporated and considered as elements, which can potentially assist in creating a unique experience and inspire more, like-minded projects in urban spaces during the winter.*

Designers, architects, engineers and others submitted 114 ideas to the Innosite platform. Three winners were chosen. The first and second price ideas were used as inspiration for an installation that was built on Toftegårds Plads for the FROST Festival concert. Two hundred straw bales were wrapped in plastic bags and used as building blocks and for seating. Straw is warmer to sit on than a regular bench and the building blocks encouraged movement, which helps you keep warm. The 400 people who attended the concert immediately took the installation into use. Most of those were adults and young people. They used the bales to sit on while talking with their friends and listening to music. Some kids did climb around on the bales and build with them.

*Figure 7: Photo of straw bales on Toftegårds Plads.*

**Aim:** The aim of the project was to involve a large number of people in coming up with ideas for creating a setting for outdoor events during winter.

**Elements used for Toftegårds Plads:** The elements included materiality and movement. A bench made of concrete or even wood can be quite cold to sit on. Straw is warmer to sit on. The event took place on a warm winter day so it is not possible to conclude ~~that~~ whether the bales allowed for people to stay out longer

because they sat on something warm or if it was due to ~~because~~ the weather ~~was~~ being quite warm. They were fully used throughout the two hours the event lasted. The straw bales were intended to be moved around and climbed on but mostly they were just used to sit on. Some kids did climb on and build with the bales. This implies that moving the bales around is an activity that appeals to kids.

### 3.3 Remiseparken

**Site:** Remiseparken, Urbanplanen, København

**Date:** 18:00 – 20:00, Tuesday 24th of February and 17:30 – 20:00, Saturday 1st of March 2014.

**Collaborators:** Municipality of Copenhagen, 3B , Amager Partnerskabs Tryghedsplan

**Background and project description:** The social housing organisation 3B heard of the ~~Winter City~~'Winter City' project and saw it as a possible way to work with creating a greater sense of safety in Remiseparken in Urbanplanen. Urbanplanen is a public housing area in Copenhagen. Many areas in Urbanplanen are experienced as unsafe by the ~~residence~~ residents who live there. Amager Partnerskab has been initiated to amongst other things find ways to enhance the feeling of safety in the area. Research shows that the presence of urban life can enhance the feeling of safety (Center for Boligsocial Udvikling, ~~(~~2012~~): Tryghed i udsatte boligområder).~~ ).Remiseparken is experienced as unsafe to walk through after dark by a high percentage of the ~~residence~~ residents in the area. The park is very dark and only the main path through the park is lit.

Open Air Neighborhood was commissioned to engaged the local public in a discussion on safety in the area and suggest initiatives that Amager Partnerskab could focus on to enhance the feeling of safety amongst the public in the area.

~~Open Air Neighborhood~~'Open Air Neighborhood' held two events - WinterTalk and WinterGames.

WinterTalk invited the local residents to an evening in the park after the sun had set. Rather than talking about whether it is safe or not to walk through the park the event focused on how we can create life in the park. By having the event outdoors it already created more life and the participants experienced being in the park at a time of year and day where they would normally not have been there. Installations were placed in the park to give an idea of and test what can be done to support urban life during winter and also to give the participants something specific to try and to give feedback on. There were three installations. Straw bales wrapped in plastic were used by kids to play in and to sit on. Four braziers offered a heat source, and coloured lights lit up four trees along the main path through the park. Soup, coffee and tea were served to the participants.

Thirty people participated in the event. Before the event even started the straw bales were a huge success amongst the children. They were building with them, jumping on them and it looked like they were having fun. Later in the evening the bales were used to sit on around the braziers. The small fires in the braziers were attractive to sit around. They created a calm and cozy atmosphere and became the centre of the event. Participants said it was nice to sit by the fire and meet their neighbours. Some said they would like to do that more often. The coloured lights on the trees along the path were great for marking the spot where the event took place. People who had not heard about the event came by because they saw the lights from a distance. People also mentioned that it was great to have some colour in the park.

Where WinterTalk was aimed at adults WinterGames was aimed at children and had bigger and more installations and activities while it also took up a bigger space in the park. The event started half an hour earlier than WinterTalk and thereby

the sunset and the change from day to night was part of the event. The installations and the effect of them are explained below.

The event had over 150 participants most of which were kids from five to fifteen years old.

**Aim:** The project had multiple aims. One was to see if the installations in the park could create activity. Another aim was to give the residence a special experience where the qualities of winter, that are often perceived as negative, were utilised to produce a positive and beautiful experience.

**Elements used for WinterGames in Remiseparken:** At WinterGames all the elements (movement, heat, light, materiality) were put into play in different ways.

*Figure 8: Diagram showing the placement of the installation in Remiseparken.*

**Florescent coloured tubes and lanterns**

*Figure 9: Florescent tube light lit up four trees along the path in Remiseparken.*

The florescent tubes were attached to four trees along the path running through the park. The tubes marked a point along the path indicating that something was going on. In another place, lanterns were hung from a tree. The coloured lights attracted a lot of positive reactions. Many pointed out that it was nice to have some colour in the park. Some people who had not heard about the event saw the lights and came over to see what was going on.

**Elements:** The florescent tubes make use of the element light. Coloured light is good for attracting attention. This might be because most lights in the area are not coloured.

**Portable work lights**

*Figure 10: Kids playing with light in Remiseparken.*

Five portable work lights each with a 30 meter long cord were placed on the ground of the event area inviting people to move them around and place and direct them in the manner they wanted. The park is normally very dark, so the light from the lamps made a big impact and created space where before there was just darkness. Some kids immediately understood the purpose without any instruction. They shined the light into the bushes where they then started playing. Some also directed the light on each other simulating a

spotlight on a stage. This made the kids act and ~~sign~~ sing as though they were on a stage.

**Elements:** The portable work lights made use of the element of light. Mobile lamps can encourage interaction with the physical surroundings which allowed the kids to play in new areas of the park that were not normally used because they were not lit. The mobile lamps allowed people to create a small space made by light within the big open park.

**Straw bales**

*Figure 11: Kids playing on straw bales.*

One hundred straw bales (35 x 45 x 75 cm) were wrapped in plastic bags and closed with tape. The bales functioned as building blocks and seating objects. The participants were invited to build with them and sit on them around the fireplaces. The bales were taken into use before the event even started. The kids began building with them, playing catch on them, throwing them around and having fun while doing so. One group of kids built a wrestling ring and fought each other in it. Others started doing parcour on them and another group wrote their names with them. The bales were further used to sit on around the fire. Here they offered a warm seat.

**Elements:** The bales make use of two of the elements: movement and materiality. The bales gave the kids a good excuse to move and thereby keep themselves warm. The straw bales encouraged play and the kids interacted with the physical surroundings by building it as they wanted and needed for their play. The bales offered a warm and comfortable seat in the cold weather.

**Braziers and food**

*Figure 12: Kids sitting around a brazier.*

There were five braziers placed close to each other in one end of the event area. At the beginning of the event dough and sticks were handed out so those who wanted would make stick bread by the fire. There were also sausages and marshmallows.

**Elements:** The braziers are heat sources. If there is a heat source to go to when it gets cold it becomes possible to stay outdoors longer. At the event the braziers also became the place where people sat down quietly to talk and had the chance to meet people they did not already know.

**Light relay**

*Figure 13: The light relay in the dark.*

A group of local kids who are part of a culture club organised a light relay. They used glow sticks to mark the route in the park and invited other kids to take part in the relay. The baton was a glow stick. Around 40 kids took part in the race.

**Elements:** The light relay made use of two of the elements – movement and light. The activity encouraged movement, which enabled the kids to keep warm. Marking the route with glow sticks is a great example of the potential light has in the city. By placing lights to mark a route the kids were able to transform the function of an area in the park to fit their needs.

**Draw with light**

*Figure 14: People drawing with light in Remiseparken.*

A member from a local photography group organised a post where you could draw with light. He took pictures with a slow shutter speed showing the movement of the light on the photo.

**Elements:** The activity made use of the element of light. In doing so it showed a positive way to utilise the dark and thereby put focus on how one characteristic of winter can be used in a positive and playful way.

## 4. Conclusions

This paragraph concludes what effect the elements can have on urban life in winter when used in an urban space.

Heat

- If there is a heat source to go to when it gets cold it becomes possible to stay outdoors for a longer time.
- A heat source often becomes a social place where people can gather.

Movement

- Having something that encourages movement will allow people to use their bodies actively and thereby keep warm.

Light

- Coloured light is good for attracting attention to a specific place.
- During winter it is dark a lot of the time. Therefore light is an obvious element to work with. Mobile and flexible light allows the public to shape the urban space based on their needs.

Materiality

- Materiality does have an influence on how a space can be used. Using materials that help people keep warm can enable people to be outdoors for a longer time.

**Acknowledgements**

We would like to express our gratitude to the members of the ~~Winter City~~'Winter City' network for their contribution to the project.

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# Quantitative and creative design tools for urban design in cold and windy climates

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**Abstract**
In cold and windy climates, the quality of the urban spaces is severely challenged. A design process with a very high level of information regarding wind, sun, daylight and water from the earliest of the design process will help create the most optimized design. For the last couple of years, the Technical University of Denmark has had an initiative to combine the University's existing knowledge, relevant for large scale physical planning, in new ways. Technical-scientific knowledge about traffic and transportation, water-management, snow drift, wind engineering, sun and daylight have prospered in academic 'silos' where little attention has been made in regards to architectural design processes. Simulation tools were developed that can render a larger amount of information available in a short time and thus can keep pace with an ongoing design process in an architectural studio. Bridging the gap between the design processes and the academic knowledge available is a focus area. The effects of climate change and a general higher demand for quantitative assessment of urban planning proposals in hard climatic locations have created a demand for research based design advice. The paper will present these 'design tools' and how they can inform an ongoing design process from the earliest of design phases and afterwards.

## 1. Introduction

The demand for documented sustainability and safeguarding, in respect to the effects of climate change, have raised the interest for a range of technical – scientific disciplines in the urban and landscape area. Simulation tools, developed to perform analysis of already existing systems and documentation, are now in demand from the earliest stages of the design processes. The researchers receive requests for advice from various actors in the planning sector that have not previously shown interest in simulation tools or quantitative evaluation of design proposals. Due to this new demand, a mapping of the research based tools available was initiated. Design methods for integrating results from simulations have a long record in building design and it is natural to profit from this pool of experience when addressing urban and landscape design. In this paper an outline of the major fields of interest for Arctic conditions and the related research based design tools are presented.

## 2. Architectural Wind Engineering

### 2.1 Windtunnels as a design tool

Wind tunnel tests have existed since the 1930's (Addis, 2007). At the Technical University of Denmark (DTU) large facilities for detailed testing are available through a collaboration with Force Technology, a private company associated with DTU. The testing is financially demanding and though Force Technology has actually experienced an increase in inquiries from architectural offices and urban planners, urban design is not their main business area.

At the Department of Civil Engineering, a smaller wind tunnel has been an efficient and popular design tool from the earliest conceptual design phases and onwards in the design process.

*Figure 1: Large windtunnel at Force Technology.*

In initial design phases, small mock-ups of city-shapes, made of cardboard or polystyrene foam in 1:500 – 1:50, are placed in the wind tunnel.

*Figure 2: Shaping the models for the tunnels in foam by means of a hot-wire cutter.*

Then, a powder is distributed evenly on the card board model which will erode according to the applied wind speed. Urban spaces with lee and areas with too much wind become immediately visible. The cardboard models can easily be modified to search for solutions to improve the local urban wind climate and hence, the resulting human comfort. Façade design of tall buildings or the effect of hills and mountains near urban settlements can in a similar way be altered to reduce the effect

*Figure 3: Wind test on foam model.*

of 'down wash' – the wind turbulence created by large height differences. For more advanced investigations laser light can expose the actual air movements down a mountain in detail.

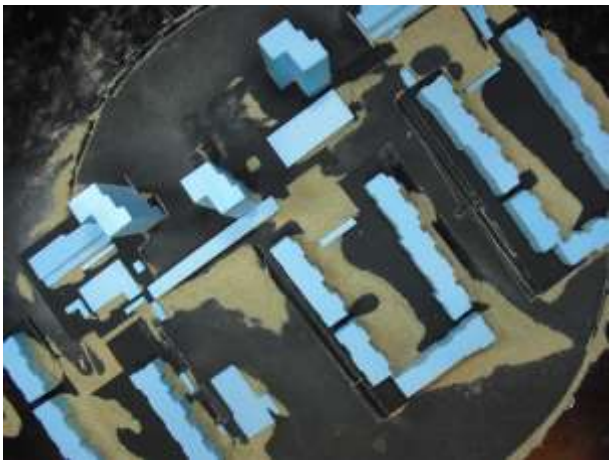

*Figure 4: Wind tunnel test of the Brøndby Strand Settlement.*

*Figure 5: Brøndby Strand at street level.*

*Figure 6: The international operating Danish architecture firm Bjarke Ingels Group (BIG) designed a new gallery in Greenland. The new building for modern Greenlandic art will be located on a steep hillside near the old colonial harbour close to the sea. The building forms a circle around an inner sculpture garden and follows with a nearly constant elevation height the contour of the rugged landscape (picture: BIG architects, available at: <http://big.dk/press/nuuk_146>).*

Another use of the wind tunnel is to predict snow drift. A study of snow drift and accumulation on the planned new National Gallery in Nuuk, Greenland has recently been performed. The approach chosen for this study concentrates on the surface transport process of powdery and granular material scaled to match reference observations from full-scale. Prior to the study of snow accumulation around the new national gallery building, a series of tests with different easily available materials was performed to identify those materials and test conditions that would exhibit the largest similarity to nature. Material transport and accumulation were tested for wind conditions comparable to during and after snowy weather.

The tests clearly revealed different scenarios of possible snow drift and accumulation. The build-up of snow can be influenced through spoilers and significantly reduced near the garden facade. These measures can be further developed for subsequent installation on the building if experience in the future will show major problems with respect to snow accumulation. Apart from the direct results on the National Gallery building, the project demonstrated the potential for investigating snow drift and accumulation issues in a wind tunnel experiment. Further tests will be conducted to refine the simulation technique and to expand the calibration and verification with more systematic observations and measurements in nature.

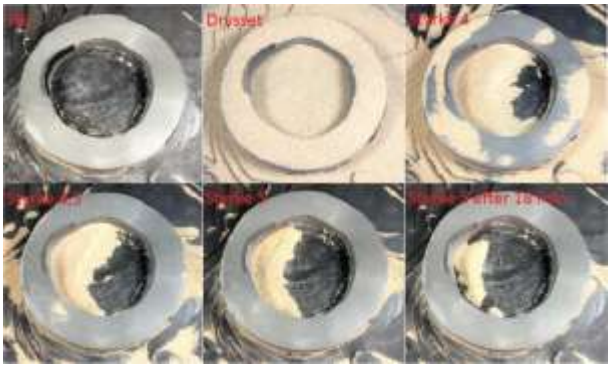

*Figure 7: The progression of different phases of a snow drift test (flow approaching from the left) with a wind screen on top of the building. The snow layer starts drifting from the downwind side of the sculpture garden and accumulates over a larger area on the upwind side of the garden.*

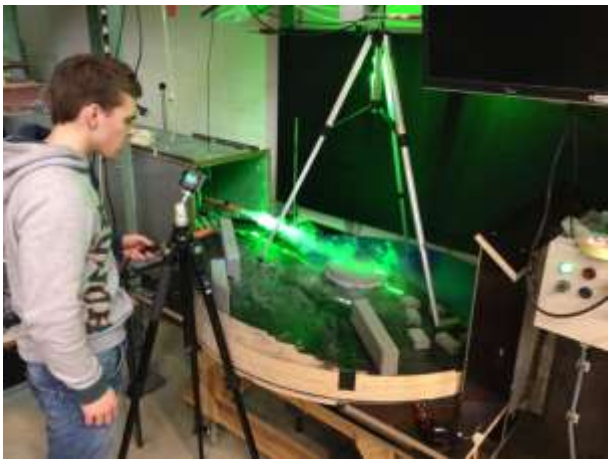

*Figure 8: Experimental setup for visualisation of wind flow around the new National Gallery building in the closed-*

*circuit wind tunnel at DTU Civil Engineering Department.*

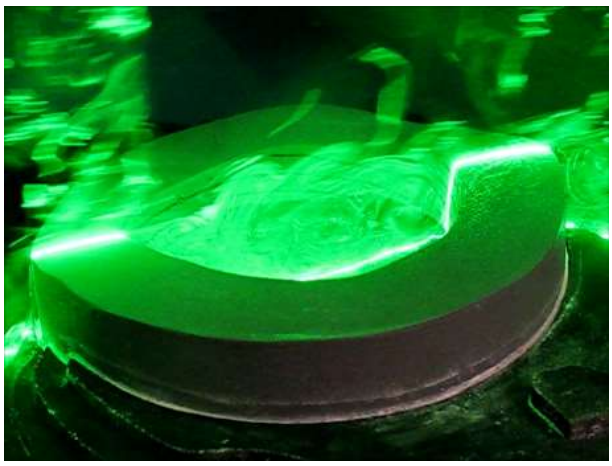

*Figure 9: Visualisation of the wind flow over the building of the new National Gallery (flow from left to right) to study the circulating airflow inside the sculpture garden. The visualisation helps understanding the snow drift mechanism and the function of spoilers and wind screens to alter the flow to influence the snow accumulation.*

In general, wind tunnel experimentation can be used as an efficient design tool to feed quantitative information into an ongoing design process. Design proposals are fast and easily evaluated and the results are visual and comprehensible to non-specialists in the field of atmospheric flow simulation. Speed, accuracy and visual communication are key words.

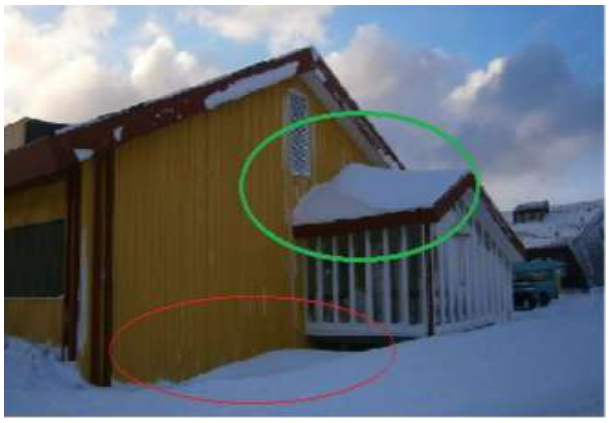

*Figure 10: Reference test case to calibrate the snow accumulation simulation on real life observations from Greenland.*


*Figure 11: Model of the snow accumulation in Greenland referring to real life observations. Airspeed and material are adjusted to reflect the snow drift mechanism at reduced model scale in the wind tunnel study.*

**2.2 Digital wind simulation**

Digital simulation of wind/air movement is developing rapidly in these years based on the principles of computational fluid dynamics. The method of computational fluid dynamics (CFD) was developed in the 1990s (Addis). An array of uses was developed including simulation of wind. The benefit of this method is that the accuracy can be very high and the effect of small details in the design can be evaluated using a CFD simulation. Ansys FLUENT is one of the relevant programmes which can also import CAD files (.dwg), which is a main program used for building rendering and modelling.

The CFD simulations using Ansys take a long time to perform- up to several days- and in that respect fail to inform an ongoing design process, where changes in the design take place from hour to hour. The reason for the long simulation time is that the simulation, apart from CFD, is built on finite element methods which calculate the impact on minuscule cells in a mesh. This accounts for the accuracy and the ability to calculate turbulence.

Recently, new digital tools for the early conceptual design phases have been developed, such as Project Vasari Autodesk.

It is also based on CFD but has a low accuracy compared to Ansys. However it allows for digital simulation and evaluation of a design idea within minutes. Wind simulations in Project Vasari are based on an average wind speed which is 'blown' on the digital model. However, it cannot account for elements like turbulence.

In the process, first a digital drawing, made in SketchUp software, is imported in the Vasari programme. Next, coordinates of longitude and latitude are placed. The software will then automatically draw information concerning prevailing wind conditions from the nearest weather station via Google Maps features. The shadow and sun exposure can also be simulated in Vasari.

As mentioned, the accuracy is much lower than when using the wind tunnel, but the speed and direct linkage to computer aided drawing programmes is an advantage.

The wind comfort in urban spaces is decisive for achieving liveable urban developments in the arctic than can enhance social interaction and urban qualities in general.

A conceptual design of landscape based on the analysis described above can help document and secure the outcome in respect to wind. By this the wind load can be predicted, and storm damages or problems with snow drifting can be reduced.

This holds a great potential for design of urban spaces with good thermal comfort in the Arctic region.

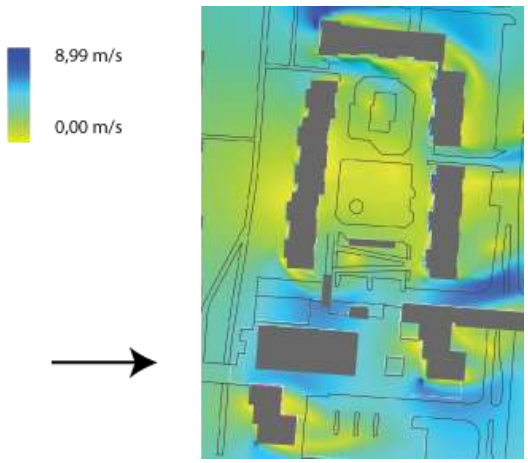


*Figure 12: Depiction of Project Vasari from simulation of Brøndby Strand.*

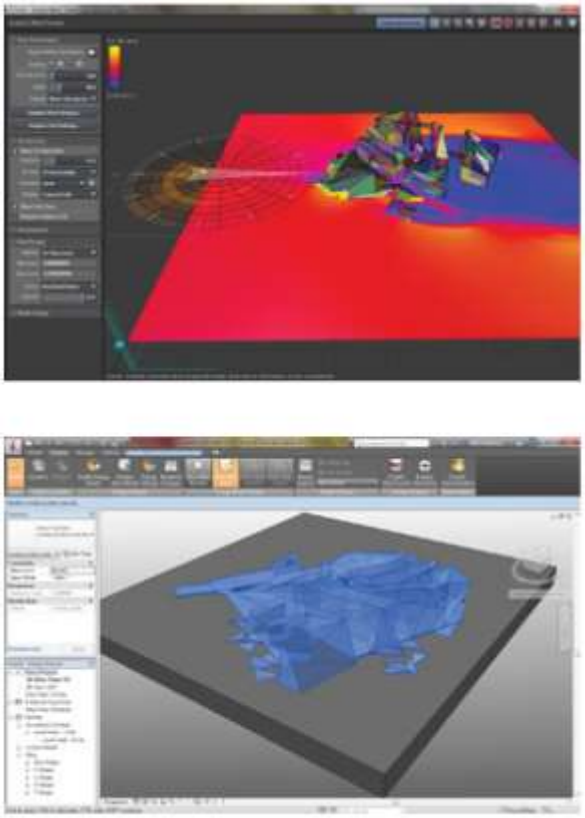

*Figure 13: Project Vasari illustrating different variables of a model.*

## 3. Simulation of sun, shade and daylight in urban design

The simulation of a building's exposure to sun and daylight have been thoroughly developed and tested for approximately two decades. Focus on the building's performance in regards to energy demand and indoor climate was important in the development. The aim was to use the information given by the simulations to design buildings with a small energy demand for operating the indoor climate systems: ventilation, lighting, heating, and cooling. The facades' exposure to direct sunlight can reduce energy consumption for heating, due to passive solar heating. On the other hand, the risk of overheating and thus a demand for cooling might arise. The windows in the façade also allows for daylight which is needed in order to reduce the energy demand for electric lighting.

However, the risk of also allowing for direct sunlight and overheating co-exists with a good intake of daylight. To handle these dilemmas accurately, fast and visually simulation tools have become widely available (Jensen et al., 2013).
Research of how to use these tools in a design process have had another parallel development. Urban planning could also draw from this pool of design methodological knowledge.

The innovative part is to use these simulations tools in urban design with the same methodology. In cold climates, the quality of urban spaces is determined not only by wind conditions, but also by the amount of sunlight they achieve. Areas which are not shadowed by objects like adjacent buildings and receive a maximum of sunlight are more used. The general amount of sunlight in an urban space can be estimated in hours of sun per year.

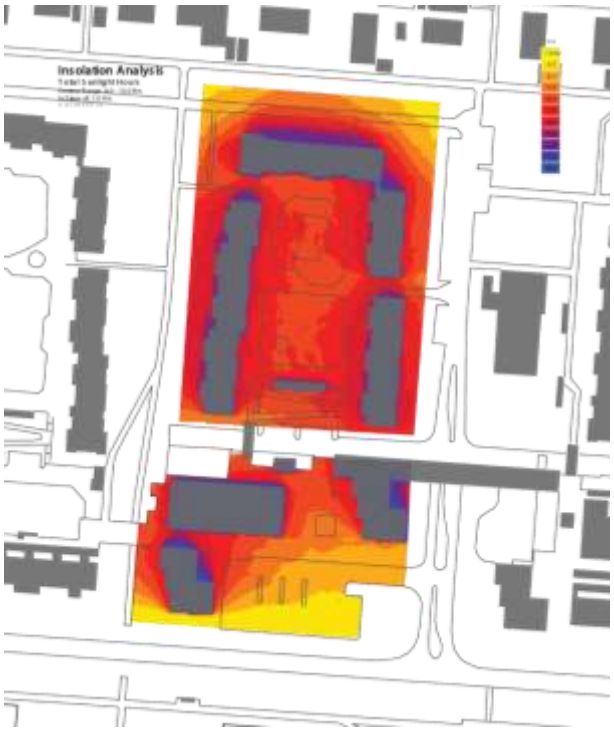


*Figure 14: Simulation of average sun hours per year at Brøndby Strand.*

Solar mapping is a term that signifies the mapping of external surfaces' exposure to direct sunlight. It is useful in urban design for several reasons. First of all, it maps the surfaces with the greatest potential for energy production, both in terms of electricity (photo voltaics) and hot water (solar heating).

Solar mapping can also be a tool for designing urban spaces with the greatest possible climatic comfort in cold regions. Spaces with quantified and documented sun and lee can be created.

The geometric layout of building volumes is a determining feature of any urban design. It is from these primary decisions that the quality of the interior spaces of buildings, and the exterior urban spaces, are determined. Research shows that the energy consumption in buildings is also predetermined by the urban layout.

Deciding on the geometry of building volumes and the density of the urban fabric is where the simulation tools of sun and daylight has a large role to play. A high urban density is wanted to create lee and social interaction etc. However, buildings cast shadow and a non-informed design risks creating interior spaces with too little daylight and cold, shadowed outdoor spaces (Strømann-Andersen & Jakob, 2012).

The interaction between the energy consumption for operating buildings and the urban layout is extremely complex, but can be systematically controlled in an ongoing design process. The simulation tools regarding energy and indoor climate – and with this also sun and daylight exposure - are amongst the best developed simulations tools in the industry. Due to this, a Heliodon is rarely used. The knowledge of how to use them in a design process is as mentioned also well researched.

Autodesk Ecotect Analysis is an advanced program which can handle solar radiation, daylight, shadows, reflections and thermal qualities. Additionally, it gives easy to read graphical results, which is very important in the design process (Jørgensen et al., 2011). An even faster assessment of a design proposal, but with less parameters, is to simulate shadows in SketchUp, a drawing program, where shadows in an urban space can be simulated quite accurately, according to location and time of year.

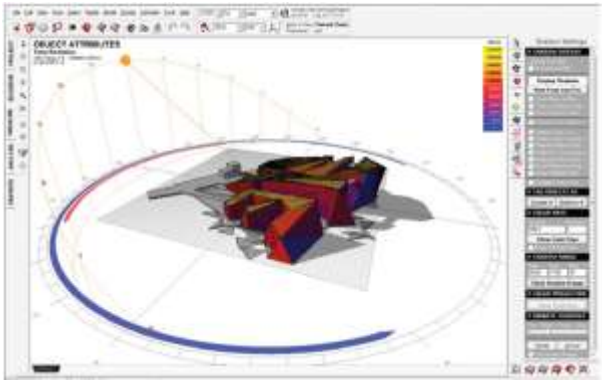

*Figure 15: Sun light according to Ecotect.*

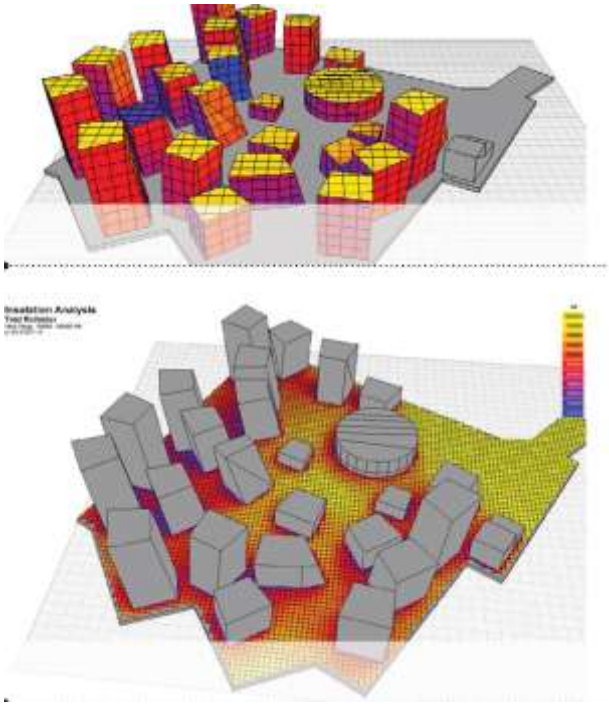

*Figure 16: Sunlight on buildings and the street, according to Ecotect.*

## 4. Simulation of flooding in an ongoing design process

Extreme rainfall, periodical effects of melted snow and changes in sea and riverbed level causes flooding that future urban design in the Arctic should take precautions against. At the same time, rain is a resource and urban planning regulations ask for reuse of rainwater for flushing toilets and for clothes washing in the design proposals.

The digital simulation of the effects of rainfall, or melted snow in a location is complex. Information regarding sewage systems, topology and the ability of the terrain to absorb water are parameters. MikeURBANflood is a simulation tool that accurately can simulate the effect of rainfall on a location. However, the program cannot import drawings and the build-up of the digital model is complex and time consuming. This makes MikeURBANflood more an analytical tool or a tool for documentation of finished design proposals.

Miljø-GIS is a Danish software that can take information from an overall GIS map. However, it can only simulate water flows in the existing – and thus GIS mapped –urban fabric. In other words, it cannot asses design ideas for future landscapes and urban spaces.

Rules of thumbs and a careful study of topological maps of the landscape can take the design process a long way in the right direction. Combined with simple algorithms, the flooding of a digital topological model of a landscape, have proved to be a relevant design tool. Such a model can help asses urban and landscape design in terms of flooding and thus, designs that allows for the water to periodical flood certain areas and have a natural flow through the landscape without causing problems.

Another option is the Rhino – Grasshopper combination. Rhino is a digital drawing /modelling programme that can link to Grashopper, where algorithms for volume, area and soil quality (percolation) can be set up.

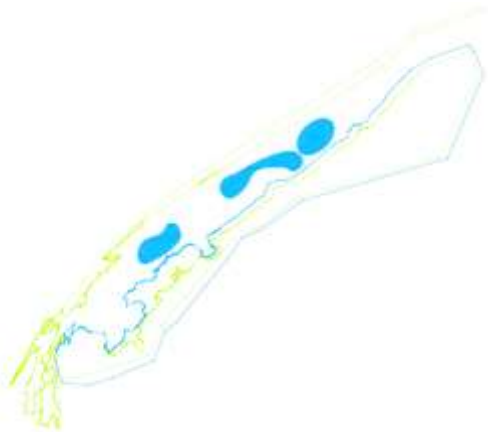

*Figure 17: Digital map of the Nørrebro area.*

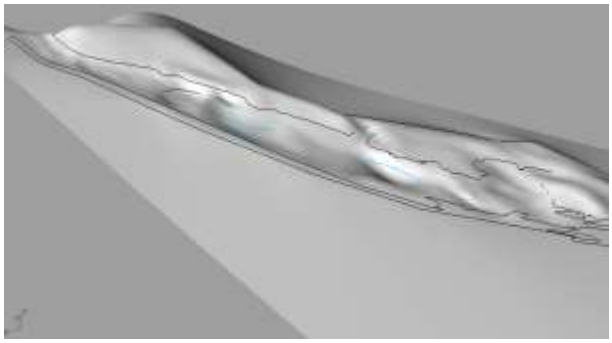

*Figure 18: Rhino model of the Nørrebro area.*

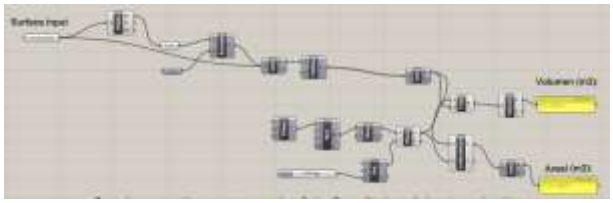

*Figure 19: Grasshopper model of the Nørrebro area.*

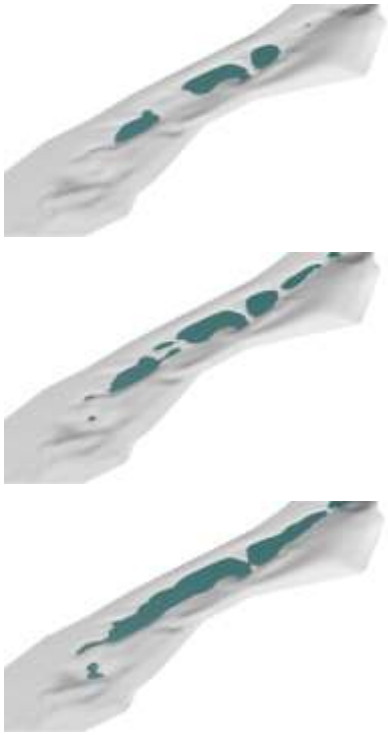

*Figure 20: Simulation of flooding in the Nørrebro area, using the Rhino-Grasshopper combination.*

The fast process of importing maps into Rhino and adding 'rules' (volume, area, percolation) by means of the Grasshopper program allows for the assessment of different design proposals. Since Rhino is a drawing/modelling program new landscape and urban designs can by tested quickly and quite accurately concerning the effect of water on the design: rainfall, melted snow, changes in sea and river bed levels.

## 5. Simulation of traffic

Transport modelling has developed since the 1950s from the need to predict the demand for new infrastructure links in large scale environments and networks. It is maybe not highly relevant for the Arctic but should be presented as it belongs to the set of tools available for informing urban and landscape design.

Features of the urban spaces have often provided inputs to the estimation of the demand for travel by mode without spatially explicit treatment of design and design decisions at the urban district level. With improvements in spatial data qualities, transport models are becoming increasingly detailed towards including local networks and paths, including e.g. qualities of cycling networks - which may then be evaluated for their effects.

Within urban districts and especially in critical locations, such as intersections, computational fluid dynamics and social forces also provide the basis for traffic simulation tools such as VISSIM. However, the traffic simulation programs are much faster than software simulating airflow.

A digital model of a road layout is made in the software and then exposed to traffic of a certain intensity, moving at a defined pace. Observation of the forming of events like traffic jam is visually perceivable. Design alterations can be easily transferred to model and a new simulation can be performed.

The optimal traffic simulation would link simulation to demand modelling for an assessment of transport by mode and spatial performance in combination.

Urban design's effects travel demand by car, public transport or non-motorized modes through networks, walking distances, connectivity, transit and parking provisions within the district. These features are increasingly explicitly treated in urban development projects but weakly linked to simulation capacities and options. Qualifying the links between the design decisions within urban districts, travel demand and spatial behaviours should be an area for further works in sustainable urban design.

## 6. Sustainability assessment of urban areas

For decades, buildings have been assessed and certified according to sustainability assessment systems. Deutche Gesellschaft für Nachhaltiges Bauen (DGNB) is a sustainability certification system with a special version addressing the sustainability certification of urban spaces. There are 55 criteria which each have a detailed description of how the criteria should be evaluated. In some of the criteria, the evaluation can be a simulation. Simulations are ranked higher and give a higher score for the specific criteria than other evaluation methods.

DGNB urban districts have the potential for becoming a documentation required by regulation authorities in the near future. Using simulations as assessment of design solutions will then become an integrated part of any design process.

## 7. Conclusions

Wind, sun, daylight, rain and traffic are phenomenon that all urban designers handle in their design proposals. Simulation tools that condense technical-scientific knowledge into a fast yet accurate and visual feature will not revolutionize urban design, but it will allow for more precise decisions and avoidance of severe failures in the design in extreme climates.

In the Arctic areas, growing urbanization is a trend and the focus is on social qualities in the city. The quality of urban spaces is closely linked to climatic comfort. The climatic comfort in the urban spaces can be addressed in a precise manner by means of quantitative evaluation of early design proposals by means of simulation tools. This could lead to new arctic urban spaces tailored for the specific conditions of the location.

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# Qeqqata Municipality as a sustainable community in 2020.

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**Abstract**

Sustainability 2020 in Qeqqata Municipality is a project ~~that develops~~developing over the coming years and ~~becomes~~ becomingga process with a wide~~ly~~ grid of collaboration on all levels of the society.
The Qeqqata Municipality has, in 2012 and 2013, developed 32 subprojects and two lighthouse projects within the frame of a sustainable Arctic society by 2020. The projects are divided into three main groups: educational, social and environmental, that all inspire and inform each other and have a joint focus on connecting the projects to Tech College Greenland and the University of Greenland. Important partners are also the Self Government and private business partners. The main goal is to set a focus on sustainability in all activities in the Qeqqata Municipality. This paper will outline a presentation of the whole project and focus on the project's that influence urban planning activities and the involvement of citizens and partners.

## 1. Introduction

The Qeqqata Municipality has a vision of becoming a sustainable Arctic community in 2020. This requires a holistic and radical transformation of the society in collaboration with key stakeholders. Sustainability is often considered as a static situation, a project outcome. However, sustainability includes processes and a way of handling projects, a way of cooperating, which keep ~~thinking of~~reinventing how to achieve the best possible results on the road to sustainability.
In relation to the Qeqqata Municipality, the sustainability project also becomes an organizational development project – the Qeqqata Municipality learns to think holistically, and involve the whole community in ways of thinking about sustainability. Ideally, we are well on the way to eliminate narrow minded thinking in the organization of the Qeqqata Municipality and have started thinking about activities holistically, with a focus on sustainability. In all projects there shall be a focus on social, educational and environmental aspects.

The sustainable project is a collaborative project, in which there is a focus on how to develop in a sustainable direction, with

*Figure 1: A location of the Qeqqata*


*Municipality, within Greenland* universities, businesses and citizens working for the development embedded
throughout Qeqqata Municipality. We are working to provide experience and results

to the rest of Greenland and the other Arctic countries

## 2 Background

The Qeqqata Municipality is a new Greenlandic municipality formed by the merging of the Sisimiut and Maniitsoq Municipalities in the Greenlandic municipal merging in 2009. Each of the two former municipalities consisted of one main town and three villages, so the new municipality is now composed of two towns and six villages. The two towns and largest villages are all known for their industriousness and technical innovation

The Qeqqata Municipality is a thriving society with a robust business community organized in the Qeqqata Business Council. The municipality's largest city Sisimiut is the center of Greenland technical education, which started with shipwright training and a technical school with a focus on training and courses in craft trades.

In the new millennium, the technical programs, expanded significantly, and now includes Tech College Greenland (formerly Building and Construction School) with Technical High School (HTX), Gymnasium (GU) and the Mining School. In addition there is cooperation between Tech College Greenland and the Technical University of Denmark (DTU) on the Arctic Technology Centre (ARTEK) and Nutaaliorfik - Greenland Innovation Centre of construction, energy, environment and natural resources.
The municipality, the business community and the education system all contribute and form part of the project.

These three stakeholders have worked together to focus on technology development, resulting in a large number of successful collaborative projects. The Sustainability project is based on the continuation of close cooperation between the parties. It has now expanded towards cooperation in a more sustainable direction and not only to act on the technological and environmental issues but also on educational and social services.

## 3. Sustainability 2020 project

The idea of the sustainability project stems from the successful collaboration between ARTEK at DTU and the Qeqqata Municipality. The collaboration has focused on technological and environmental sustainability, but has gradually developed more and more to incorporate the social structures, particularly education.

The sustainability 2020 project is conceptually rooted in the Brundtland Report and the Rio Declaration. Compared to previous primarily sectored technical approaches to sustainability, the project focuses on a holistic approach. In the Arctic, it becomes a special focus on three areas: education, society and environment, while IT, interdisciplinary and citizen involvement are also essential themes.

The Sustainability 2020 project proposes to develop cooperation between ARTEK and the municipality further, as applied research provides the framework for a cooperation agreement between the parties. The founding ~~is used~~ for the purpose is used for ~~by the~~ appoint~~ment of~~ing four new professors in Arctic sustainability. At the same time ARTEK builds up to a greater presence in Sisimiut, in Greenland and the Arctic countries.

Similarly, ~~there is started~~a cooperation started in the educational and social fields, between Ilisimatusarfik / University of Greenland and the Qeqqata Municipality. Initially, the funding allows for the recruitment of two professors. And if cooperation successfully evolves, these positions may be increased during the project.

It is an innovation in the Arctic, that a municipality, through funds, finances applied research. A prerequisite for success is good interaction between student projects, post-doctoral research, professor guided ~~application~~ applied research ~~of~~ in joint pilot projects ~~in~~ with the municipality to finally

end up in the subsequent construction and operation of municipalities. A number of cooperation agreements with ~~the~~ a wide range of organizations, institutions and enterprises in Greenland will contribute to a successful implementation and dissemination of the projects to the rest of the Arctic.

The Qeqqata Municipality has, in accordance, with the industrial councils and with Artek developed 32 sub-projects and two transverse lighthouse projects to be realized by 2020. The 32 sub-projects are grouped within the three areas of social, educational and environmental focus, each with its own mission and underlying purpose.

Initially, the environmental subprojects are primarily based on the successful collaboration between ARTEK and the municipality. In the long term, it is expected that the interaction between Ilisimatusarfik and the municipality will influence the educational and social subprojects. In one area, cooperation with Ilisimatusarfik ~~however,~~ already is in progress, namely in the 'iPads project' ~~where everyone is agreed that the positive experience of southern climes will be even more positive in the Arctic~~which will have even more effect in an arctic climate where digital learning and services can solve more problems.


*Figure 2: How to see the sustainability concept*

## 4. Sustainability 2020 - A holistic sustainability project in the Arctic

The goal of the project "The Qeqqata Municipality as Arctic Sustainable Society 2020" is to create a sustainable society. It focuses on three key areas: education, social and environmental sustainability. Generally it addresses the sustainability of the whole society, and therefore involves many different parties, including citizens in the project.

If the Qeqqata Kommunias vision, which is to undergo sustainable development by 2020, is to succeed, and set an example for the rest of the Arctic countries, the cooperation must include all of the new municipality as well as all settlements. The sustainability project will also increasingly work with citizen involvement.
If successful this sustainability project will be different from previous Arctic sustainability initiatives because it has:

- A holistic sustainable approach
- A structure for cooperation with academia
- A long-term schedule
- A comprehensive plan for an entire Municipality / Region
- Local ownership with a focus on citizen involvement
- An understanding of education as a prerequisite for the transition process

It should be emphasized that this sustainable approach / work process is not carried out in an instant. Rather it should be seen as an integral part of the project to gradually develop and implement these systems, and to document and evaluate the decision-making process through the project on the basis of measurable sustainability indicators in an Arctic context. Cooperation with ARTEK / DTU and Ilisimatusarfik is set up specifically to include and ensure this systematic development and follow-up.


*Figure 3: Vision and missions.* Within the educational mission, it is especially the sub-projects around the establishment of an inclusive and cohesive school, and building bridges between the different stages of study, that is in focus. Within the social mission, it is in particular the development of an inclusive labor market ~~and~~ in order to avoid wasted life that ~~are~~ is important. Within the environmental mission it is especially waste and wastewater management, reduction of CO2 on the basis of environmentally friendly energy production and sustainable infrastructure that provides the setting for Artek's and the municipal pilot projects.

The two lighthouse projects of best practice will use this state-of-the-art sustainability in all three missions, and benefit from the best of the 32 sub-projects. The two ~~transverse~~ cross-cutting lighthouse projects are physical buildings where people, students, professionals, politicians, public servants, researchers, tourists and others can sense and feel the sustainable project. The two lighthouse projects must shine for all and become the epitome of sustainability of the project.


*Figure 3: The grouping of 32 projects.*

The first lighthouse project is a public swimming pool ~~swimming hall~~ in the mountains, which is expected to be constructed from 2014 to 2017. That itself is a breakthrough in Greenland to build in the mountains. The second lighthouse project is the ARTEK house, which is expected to be constructed from 2018 to 2021. It will contain Artek's research, education, etc. in Sisimiut, and thus help to realize ARTEK / DTU's 'vision 125 plan' to become more deeply rooted in Greenland and the Arctic.

A crucial cross-cutting theme is citizen involvement, which was evident in the pilot project. New ways and efforts to involve citizens ~~efforts~~ by including a continuation of the citizen-oriented sustainability pool. All the partners and sub-projects are to be assembled and will help spreading knowledge to the rest of the Arctic through annual sustainability events.

The sustainability of the project is visible when Qeqqata Municipality, vision of a sustainable Arctic society in 2020, ~~can be~~is implemented for the benefit of Greenland and the rest of the Arctic.

## 5. The current focus ~~of city building~~on building a city

Our focus on sustainability has been developed over many years, but appears for the first time in a strategic plan for the municipality of Qeqqata in 2010. This plan contains political goals for all activities in the municipality, which we have opportunity to change~~, and~~. S~~s~~o far, it marks the first step

towards the holistic approach of developing the Qeqqata Municipality.

In relation to sustainability and urban development we have for many years been focusing on creating a better utilization of the technical infrastructure of the towns in the municipality by densifying the cities, a condensation of urban structures which challenges construction projects. In Greenland, experience is needed from countries where cities are built in mountainous terrain.

The focus has also been to create a basis for integrating the students at Tech College Greenland in Sisimiut, and create the opportunity for them to feel at home. ~~since a~~ A lot of the city's leisure and recreational activities ~~are integrated~~take place around the college and the surrounding neighbourhoods. These recreational Aativities ~~we still develop~~are still being developed and they are very important because it is, ~~and~~ where the students ~~merge~~ interact with young people from the city.

The sustainability elements also include a focus on creating pedestrian connections that supports ~~travels on foot~~pedestrian and bicycle transportation~~s~~, instead of using motorized transport. In most cases, this also means that children are well ~~cared for~~protected on their way to school and ~~it~~ physically disabled people find it easier to use the city despite the challenging landscape.

The municipality has also worked to ensure inspiration for a more sustainable urban development through a "Vision Report" for primarily Maniitsoq , but also with examples in Sisimiut and Kangerlussuaq , compiled by a Norwegian architectural company: 70° N, from Tromsø.

One of our challenges in the future will be to ensure that the urban development supports this holistic approach. For example~~, to~~ by taking ~~e~~ social responsibility, and both developing and maintaining a coherent education system.

One of the sub-projects is a ~~quarter lift~~urban renewal project in Paamaap Kuua neighbourhood in Sisimiut, which will support the above mentioned holistic thinking, but we hope to be able to develop new tools.

This will be the starting point for the concept to be applied elsewhere in the municipality, as we develop the well-known concept, in a Greenlandic context.

In our development of, for example, Sisimiut, we put emphasis ~~to~~ on the ~~condensate~~ densification of the urban structure and at the same time to maintain the city's scale.~~,~~ It is the intention to maintain a number of basic structures that support that the city is understandable, inviting and helping the citizens to meet eachother.
The key structures, includes equipping Aqqusinersuaq, the main commercial street ~~trade street~~ with seating opportunities along the street.~~,~~ T~~t~~he green activity connection through Tech College Greenland and the central lake area with the many leisure activity opportunities in front of Taseralik (Culture house) is another example~~.~~

Our focus is also to treat our garbage and wastewater in a proper manner and to use renewable energy as much as possible.


*Figure 4: Description of a subproject about wastewater treatment.*

It is one of our sub-goals to use Kangerlussuaq as a project area where we test different environmental solutions, to then create an example fo~~create an example of our~~ of our sustainability concept.

With the "Sustainability 2020 project", we focus on~~,~~ how to provide and use clean technology in the A~~a~~rctic and how we can maintain the clean environment of the A~~a~~rctic countries. In the Arctic countries there is a lot of space, but the environment is also very sensitive and if we don't take care, we easily make environmental footprints that last for an extremely long time.

## 6. Conclusions

Sustainablility 2020 in Qeqqata is a new project which we expect to develop through the coming years.

It is therefore very important that the discussions with other planners and people who focus on a ~~how the~~ holistic sustainability concept, will make~~make a~~ diff~~fff~~erence in urban planning. We ~~nead~~ need metods that support~~s~~ the integration of non-technical elements from the social and educational fields.

Should any of the participants therefore wish to help with inspiration we will ~~be the~~ welcome the ~~happ~~the ~~y~~ dialogue ~~partners,~~ with the goal of ~~better~~ expanding and developing our sustainability vision further.

## 7. Acknowledgements

At this place it is important to acknowledge Professor emeritus Arne Villumsen, ~~who through his,~~ and the work of many ~~a lot of~~ teachers and students ~~work with~~who developed sustainable elements in the environment of Sisimiut and Western Greenland. They~~,~~ have inspired the whole sustainability project as it is formed today.

Also the politicians of our municipality must be acknowledged for ~~their~~ giving priority ~~of~~ to the sustainability project, and their courage to reach ~~for at~~for being a community on the forefront of sustainability.

The ~~big engagement~~commitment from the side of the administration ~~so far~~ have to be mentioned. ~~,~~ W~~w~~ithout this, the project ~~never would be possible.~~ would not have been possible

At last the Villum Found must be mentioned. Without their economic support and critical approach it would not have been possible to create our sustainability project in Qeqqata Municipality

Happy Youth from Sisimiut – one of the important goals..

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