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Development of a Greenlandic sustainable index for residential buildings

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Abstract. Globally, there has been a rising focus on improving the sustainability of buildings. Reaching zero net greenhouse gas emissions or producing excess renewable energy throughout the entire lifetime of a building is now clearly possible and certainly worth aiming for. However, in remote Nordic regions like Greenland, current building practices are so far away from these targets that setting intermediary goals is the only option for moving forward in the construction industry. Besides, remote Nordic regions are facing different challenges that are not considered into current building certification schemes, making some practices that can be highly sustainable in some regions inapplicable or even detrimental there. It would be highly desirable to have a certification scheme more accessible for improving current building practices in remote Nordic regions. For a sustainability index to be widely adopted in such a context, it should be relatively simple and straightforward to implement. This contribution presents the Greenlandic Sustainable Index (GSI) for residential buildings, which was developed with the goal to be simple to implement while being ambitious in terms of level of performance. This index is composed of three main categories: Economical, Social and Environmental sustainability.

1. Introduction

There are currently over 50 different building certification programs all around the word. Some are regional while others have been implemented in more than 50 countries. They can vary greatly regarding their energy and sustainability goals, with some focusing on one main parameter (e.g. simulated energy consumption) and others encompassing a wide range of topics. Reaching zero net greenhouse gas emissions or producing excess renewable energy throughout the entire lifetime of a building is now clearly possible and certainly worth aiming for if one wants to alleviate environmental impacts of the construction industry. However, in remote Nordic regions like Greenland or Northern Canada, current building practices are so far away from these targets that setting intermediary goals is the only option for moving forward in the construction industry.

While some indicators of the sustainability of buildings are universal (e.g. energy-efficiency), the sustainability of some practices is strongly dependent on the local climate, degree of urbanisation and culture. Remote Nordic regions are facing specific challenges that are not considered into current building certification schemes, making some practices that can be highly sustainable in some regions inapplicable or even detrimental there (e.g. proximity to public transport or white roofs).

While it is highly valuable to have some building certification programs that have a comprehensive agenda and consider various aspects related to sustainability like the DGNB program in Denmark [1], attaining this certification is currently too time consuming to be adopted in Greenland where construction costs are already high. With the current building codes that are far from stringent in terms of energy consumption in Greenland and Northern Canada, it would be highly desirable to have a certification scheme more accessible for improving current building practices in remote Nordic regions.

Considering the currently high demand for building energy consumption allowed in building codes in Greenland and Northern Canada, there is ample room for improvement.

This contribution presents the Greenlandic Sustainable Index (GSI) for residential buildings. This index was established with the goal to be simple to implement but ambitious in terms of level of performance. This index was developed as a part of a bachelor project in collaboration with a local Greenlandic industry partner.

2. Theoretical background

The Brundtland report defined sustainable development as*" (...) development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* [2]. Herein the interpretation that materials and resources should be used in such a way that the future generations will still have access to those. Another interpretation is also that one's culture should be preserved so that future generations can have the same access to it as the current generation does.

One may then define a sustainable building as a construction that is built in a way that it has low impacts on the environment while also providing a healthy living space for its residents that supports their daily activities. A sustainable building in the Arctic region should reflect the special needs associated with this geographical location, both in terms of climate and in culture.

Luis Suter and Robert Orttung wrote in 2016 a conference paper [3] which can be considered as a stepping stone for developing a sustainable building certification scheme for the Arctic. Herein they describe and present methods for assessing sustainability that have been implemented in other countries and cover merits and flaws of different approaches.

2.1. Scope

One import decision when developing a sustainability index is related to amount of data required for proving compliance. Here is it necessary to find a balance between exhaustiveness and user-friendliness. A complex, exhaustive index require fine, detailed data, which is available only once the design is nearly finished. This largely prevents using the index as a design tool. For this index, considering the lax current building regulations (e.g. the 2006 Greenlandic Building Code [4]), high construction costs and labour shortage in Greenland, it was decided to aim for a relatively simple index which can be used at the early/mid design phase for informing more sustainable design decision.

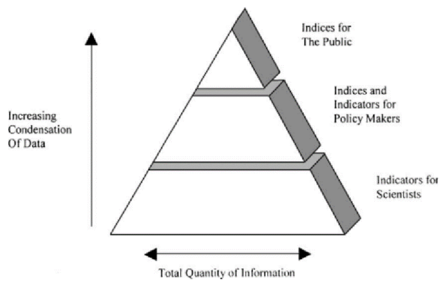

Figure 1. Pyramid illustrating the need for condensation of data for communicating with different target groups. Source: [3]

2.2. Indicators

In defining the number of indicators for an index, there is a clear trade-off between accuracy and accessibility. On one hand, the number of cities or institutions that adopt an index testify to its usefulness as a tool to compare global sustainable development policies. However, in order to make cities comparable, one also must aggregate the large number of indicators that comprise the breadth of the pillars of sustainability into a relatively few core indicators. This simplification reduces accuracy. The solution lies in selecting a set of indictors that can fulfil both the global comparative need while remaining locally relevant, which remains a pressing issue [3]. A successful index should be able to be deployed broadly across the target region, using the smallest possible number of indicators without sacrificing scientific accuracy.

3. The Greenlandic Residential Sustainable Index

Greenland is today still a part of Denmark. The culture and way of life in these two countries vary greatly even though there is a common history. Greenland today have self-government and their own building regulations.

This index is composed of three categories that encompass 13 indicators which are evaluated with 27 parameters. There are up to100 points that can be collected from the various parameters for each category. This section briefly describes the main indicators and parameters of the three categories and justify their relevance. An overview of all sustainability parameters and how they are calculated and weighted is then presented as a checklist in Table 2.

3.1. Economical sustainability

Within the economical sustainability category, the goal is to reduce expenses, both during the construction and the entire lifespan of the building, while keeping the value of a building. In Greenland the land is allocated by the municipality and therefore available at no cost. The cost of a building is therefore primarily dependent on land development, materials and workforce. A high building cost represents a scarcity of resources whether it be manpower or building materials. When this happens in the construction market it is said to be “overheating”. When the construction of a building is rushed due to labour shortages, the risk of mishaps and shoddy workmanship increases which can have a significant impact on the effectiveness of the building regarding energy consumption, function and durability.

This category also addresses issues related to the quality of foundations and permafrost, which are of high importance for the building structural integrity and thus its longevity and economical sustainability.

<u>Utilization</u>

Area utilization
When designing and/or constructing a residential building, utilizing as much of the construction area for the residence is ideal, as you then essentially get as much real estate as possible for the area available. In DGNB the procedure of calculating the area utilization is by defining what makes a useable area (UA) and dividing this by the gross area (GA). The GA is comprised of the entire land area while in DGNB the UA is excluding stairs and hallways that are outside the residences.

Since the weather can be rather harsh in Greenland, a residential building that provides shelter for people when they access their residence is clearly beneficial and promotes safety (e.g. by avoiding injuries caused by icy stairs). This index therefore includes protected stairs and hallways in the useable area.

Room height
The height of rooms in a building can play an important factor in an eventual building retrofit that affects the building performance or room usage. Having a higher room height increases the possibilities when altering room use, as the new changes will likely involve systems like new ventilation ducting or cable trays, where a higher room height can greatly facilitate the installation of these new systems without hindering occupants’ movements.

Nonbearing inner walls
During the lifetime of a residential building, room usage generally evolves over time following the needs of families. Often residents wish to expand, demolish and move room partitions in their building. If the inner walls are nonbearing, the structural integrity concerns involved when changing the placement of inner walls would be significantly less which would also reduce refurbishment costs.

Access to technical installations
The same concept is applied to the technical installations. Maintenance, repair and replacement of technical installations is easier if the installations are not cast in place or not readily accessible.

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Cost

Building cost
The complete construction cost of a building project (DKK/m^2), and not a complete LCC analysis, is used in this index to assess the quality of the project, rewarding low costs over higher ones. This is both due to the intent to keep the index simple, and to the fact that little to no data is to be found on building materials life span in Greenland. The goal with this indicator is not to hinder investment in energy efficiency or renewable energy but rather to control excessive costs related to the remote location of Greenland. After consultation with local experts [5], a categorization of the cost per built area was developed and is presented in the GSI checklist.

Maintenance

Estimated lifespan of building elements
Since no arctic building element index is available, this indicator is thus based on the building element index that is found in the Danish DGNB certification program [1]. With the significant differences between the Danish and Greenlandic climates, it would be desirable to adapt estimations of building material longevity to Greenlandic conditions in the future.

Placement

Foundation anchored to bedrock
Permafrost, which is ground that has been at or below 0° C for two or more consecutive years, is present in Greenland. Thawing of the permafrost affects the structural quality of soils and sediment. Rising of the permafrost can also generate significant damage, causing water expansion and rising ground. With climate change, it is risky to build on permafrost. The safest option is to simply avoid soils with permafrost. This is best done by anchoring the foundation on bedrock.

Sheltered entrance to building
Large amounts of snowfall can potentially cover the entrances due to wind and snow drifting [6]. The annoyance, work and resources required to keep entrances passable can be significantly lessened when the predominant wind directions are considered. This index thus rewards entrances that are designed based on local assessment of wind directions.

3.2. Social sustainability

As a typical "western" house has been the template for the fabricated houses of the north during the 20th century, the focus on adapting the building template to accommodate the cultural needs in Canada have received more focus in the past decade [7].

Accessibility

Presence of entrance stairs
For promoting accessibility to all, this index rewards buildings that not have any stairs between the building and its access road. If stairs are unavoidable, the presence of a ramp or elevator is then promoted.

Indoor Air Quality

Mechanical ventilation
A study of the Indoor Air Quality (IAQ) in 79 households in Greenland showed insufficient ventilation rates and poor IAQ in many buildings [8]. The use of mechanical ventilation is slowly being introduced in Greenland. While not required in BR06, it is more common for apartment buildings than for single family houses. This index promotes the installation of mechanical ventilation and rewards systems with efficient heat recovery, flow control and low noise levels in living area.

Fire safety

Fire alarm system
As a fire alarm system is not yet mandatory for single family houses in the Greenlandic building regulations, the GSI rewards smoke detectors for promoting the safety if occupants.

Fire engineering installations
Fire engineering installations such as sprinklers, water-filled hoses and fire extinguisher can save lives and are thus promoted in this index.

<u>Utility space</u>

Depository available
In Greenland, hunting, fishing, foraging, trekking and camping is an important part of the culture. The interior design of a building should be made in a way to promote such activities. These generate a demand for a butchering space and large freezers, as most of the animals, game and berries are stored in freezers. Access to a depot or storage room for storing seasonal equipment, tools and chest freezers can have a tremendous importance for building occupants in Greenland.

Scullery room
A scullery room would support traditional activities such as hunting and fishing by providing an appropriate place for butchering large animals at home.

<u>Common space</u>

Communal area
Celebrations are an important part of Greenlandic culture. When a person celebrates a birthday, wedding or catching ones first seal, reindeer or musk ox, an open house event known as “kaffillerneq” is held where everyone remotely associated to or known by the family can come and drink coffee or tea while eating cakes, pastries and/or some local delicacy. A communal building, banquet hall or area with access to kitchen and toilet facilities would support the tradition of hosting social gatherings.

Communal residence
Having access to bedrooms or dormitories would provide accommodation for the guests of the neighboring residents. Not having to build a guestroom in every household by instead having a temporary accommodation for guests is a more effective use of space and resources.

3.3. Environmental sustainability

<u>Energy consumption</u>

Building energy consumption
Greenland has its own energy framework which is described in the Greenlandic building regulations BR06 [4]. Greenland is split up into two zones where zone 1 is the region south of the polar circle and zone 2 is the region north of the polar circle. For a single floor family house, the maximum permissible energy consumption is equivalent to 194 kWh/m^2 pr. year and 231 kWh/m^2 pr. year for zone 1 and 2 respectfully. For the size of an average Greenlandic home, 66m^2 [9], the comparison of the energy framework in Greenland and Denmark is presented in Table 1 below.

Table 1. Energy frameworks for a single storey 66 m^2 home in Denmark and Greenland

	Energy framework, 66 m^2 single floor house
Denmark	45 kWh/m^2/year
Greenland, zone 1	194 kWh/m^2/year
Greenland, zone 2	231 kWh/m^2/year

Greenland’s energy framework for a 66 m^2 building is over four times higher the amount allowed in Denmark. Buildings with such a high energy consumption also pose concerns about thermal comfort and durability (risk of mold growth on cold surfaces). Therefore, this index will reward buildings with a simulated energy consumption of 60 kWh/m^2 per year and less, as calculated with BE18 [10], the national program for documenting code compliance in Denmark.

Renewable electricity production
Having access to a renewable electricity or heat source not only reduces environmental impacts but also increases the resiliency of a remote settlement. This index rewards local production of electricity where points are awarded depending on the percentage of the building heating needs covered.

Renewable heat production
Similarly, the local production of renewable heat is promoted within this index.

Water and waste management

Access to water infrastructure
The state of the water and waste infrastructure in the different settlements in Greenland differ greatly. Some places have waterworks that supply clean water to the whole community all year round, while some places still utilize water tanks or water station while some places, like Qaanaaq, must even resort to harvesting ice blocks during winter with the purpose of melting them to get water [11].

Access to wastewater infrastructure
Not every home has access to sewerage. Even in the largest cities in Greenland, some residences have septic tanks or even bucket toilets. Having bucket toilets implies material consumption for the plastic bags, creating higher environmental impacts than if it was connected to a sewer system. Same could be said for septic tanks, as they require trucks to come and empty them on a regular basis. Therefore, this index promotes buildings that are equipment with municipal wastewater infrastructure.

There is currently no wastewater treatment in Greenland. This is a serious issue that should be solved at the national or local political level. The rationale for promoting wastewater infrastructure in this context it that it is arguably easier to lead wastewater to a treatment plant when an existing sewer system is already in place.

Mold index

Highest simulated mold index
Mold has a damaging effect on building materials and human health. It is an agreed consensus that Greenland is having a significant problem with mold in its national housing stock. A statement from the Greenlandic ministry from September 2015 mentions, that out of, at that time, 399 residences that stood empty because of planned renovations, 300 of those had problems with mold [12].

A methodology for calculating the mold index of a material has been established [13] and implemented in building hygrothermal simulation software. With the Arctic being a place with high risk of mold growth, such programs are a good tool to help avoid mold problems at the design stage. The WUFI Pro [14] program and the addon named "WUFI® Mold Index VTT" developed by VTT Technical Research Centre of Finland LTD can be used for estimating the mold index associated with various building elements.

Materials

Use of local or national materials
If there is any chance of using local or national resources, this would not only be preferable due to the reduced GES emissions associated with shipping, but also for developing local industries and enable Greenland to be less dependent on imported goods.

Use of Eco-labelled materials
Today more environmentally friendly products or materials can usually be identified by an ecolabel. The ecolabels that can be used to document the sustainability of the building materials used in a project must be listed in the Ecolabel index [15], which currently include 463 labels.

Table 2. Greenlandic Sustainable Index Checklist

Indicators	Criteria				Points
ECONOMICAL				(0-100)	
Utilization				(0-30)	
Area utilization	> 0,8	If yes		5	
*Room height **	> 2.8 m	If yes		5	
Nonbearing inner walls	Y/N	If yes		10	
Access to technical installations	Y/N	If yes		10	
Cost				(0-25)	
*Building cost **	Select one:	> DKK 26.000/m^2		0	
		< DKK 26.000/m^2		5	
		< DKK 25.000/m^2		10	
		< DKK 24.000/m^2		15	
		< DKK 23.000/m^2		20	
		< DKK 22.000/m^2		25	
Maintenance				(0-25)	
*Estimated lifespan of building elements ** Facade					
Load-bearing structures	Select one:	< 40 years		0	
Foundation		40 < 80 years		2	
Roof		> 80 years		5	
Door and window					
Placement				(0-20)	
Foundation anchored to bedrock	Y/N	If yes		10	
Sheltered entrance to building	Y/N	If yes		10	
				Sum:	
SOCIAL				(0-100)	
Accessibility				(0-20)	
*Presence of entrance stairs **	Y/N	If no		20	
IF YES Ramp available	Y/N	If yes		10	
Elevator available	Y/N	If yes		10	
Indoor Air Quality				(0-25)	
Mechanical ventilation Presence of a mechanical ventilation system?	Y/N	If yes		5	
IF YES Including minimum flow control at 3 levels?	Y/N	If yes		5	
Including heat recovery?	Select one:	< 75 %		0	
		75 > 85 %		5	
		> 85 %		10	
Noise below 25 dB(A) in living areas?	Y/N	If yes		5	
Fire safety				(0-10)	
Fire alarm system Smoke detector?	Y/N	If yes		5	
Carbon monoxide detector?	Y/N	If yes		2	
Fire engineering installations	Y/N	If yes		3	
Utility space				(0-25)	
Depository available	Y/N	If yes		15	
Scullery room	Y/N	If yes		10	
Communal				(0-20)	
Communal area	Y/N	If yes		10	
Communal residence	Y/N	If yes		10	
				Sum:	
ENVIRONMENTAL				(0-100)	
Water and waste management				(0-10)	
Access to water infrastructure	Y/N	If yes		5	
Access to wastewater infrastructure	Y/N	If yes		5	
Energy consumption				(0-50)	
*Building energy consumption **	Select one:	> 60 kWh/m^2		0	
		60 < 40 kWh/m^2		20	
		40 < 20 kWh/m^2		25	
		< 20 kWh/m^2		30	
*Renewable energy used for power **	Y/N	If yes		10	
*Renewable energy used for heating **	Y/N	If yes		10	
Mold Index		Struct.	Int.	(0-20)	
Highest simulated mold index after 4 years	Select one:	MI = 0 < 1	MI=0<0.5	10	
		MI = 1 < 2	MI=0.5<0.8	8	
		MI = 2 < 3	MI=0.8<1	5	
		MI > 3	MI > 1	0	
Materials				(0-20)	
Use of local or national materials *	Y/N	If yes		10	
Use of Eco-labelled materials * Walls	Y/N	If yes		2	
Floors	Y/N	If yes		2	
Ceilings	Y/N	If yes		2	
Roof	Y/N	If yes		2	
Windows/doors	Y/N	If yes		2	
				Sum:	
* Interpolation of results, if possible, is encouraged.				**Total:**	

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4. Discussion and conclusion

A user manual with instructions for evaluating the different parameters is available at GSI User Manual. This index was tested on a case study that consists of an apartment building to be built in Nuuk, Greenland. This case study allowed to conclude that this index is easy to implement during the design phase, as intended. This first experience allowed to validate the usefulness of this tool for informing more sustainable design decisions in Greenland.

While more complex and exhaustive sustainable building certification programs exist, they are not implemented in Greenland because they represent a seemingly unreachable target compared with the current building practices based on the 2006 Greenlandic Building Code. With this contribution, the authors hope to start a dialogue with other actors interested in sustainability in the Arctic and look forward upon implementing this first version of the GSI in more case studies and its future refinement.

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