Building Strategies in Greenland

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Abstract
Greenland has an Arctic climate and very few resources; furthermore, it is island operated. In combination these circumstances means that there are high demands on buildings to maintain acceptable indoor climate and all resources must imported and transported by either ship or plane. Overall, this makes buildings in Greenland costly. The paper describes the setting, including climate and access to building materials, and current building strategies and new trends.

Greenlandic setting
Greenland is the largest Island in the world (2,600 km from north to south, and 1,050 from east to west); however, most of it is covered with ice, and the people live along the coast. Most of the 56,000 inhabitants live on the south part of the west coast, approximately 3,000 people live on the east coast. The capital Nuuk is by far the biggest city with 18,000 inhabitants, the second largest city Sisimiut has 5,600 inhabitants. Greenland is a self-governing part of Denmark. Thule Airbase, a US military airbase with about 800 people, including 600 civilians is situated in the northwest. The buildings in this area differ considerably from the buildings in the rest of Greenland, as they are built according to US standards and traditions.

Island operations
With very few people scattered over a large area, mobility becomes a problem, especially because in Greenland there are no roads between the cities or settlements. Everything must be transported by ship or plane. Therefore, Greenland is an island-operated community, which implies:

- Inflexible work force as it is impossible to commute between cities
- High transportation costs
- Highly vulnerable time schedules as replacements for missing or broken parts are difficult to quickly obtain. This problem is aggravated in a climate where the building season is short.

Climate
The Greenlandic climate varies; High Arctic in the North, Low Arctic in the middle and southern parts, whereas the deep fjords of the south have Sub Arctic climate. In terms of Building Regulations, energy demands are divided in two zones, north and south of the Polar Circle, as illustrated in Figure 1.

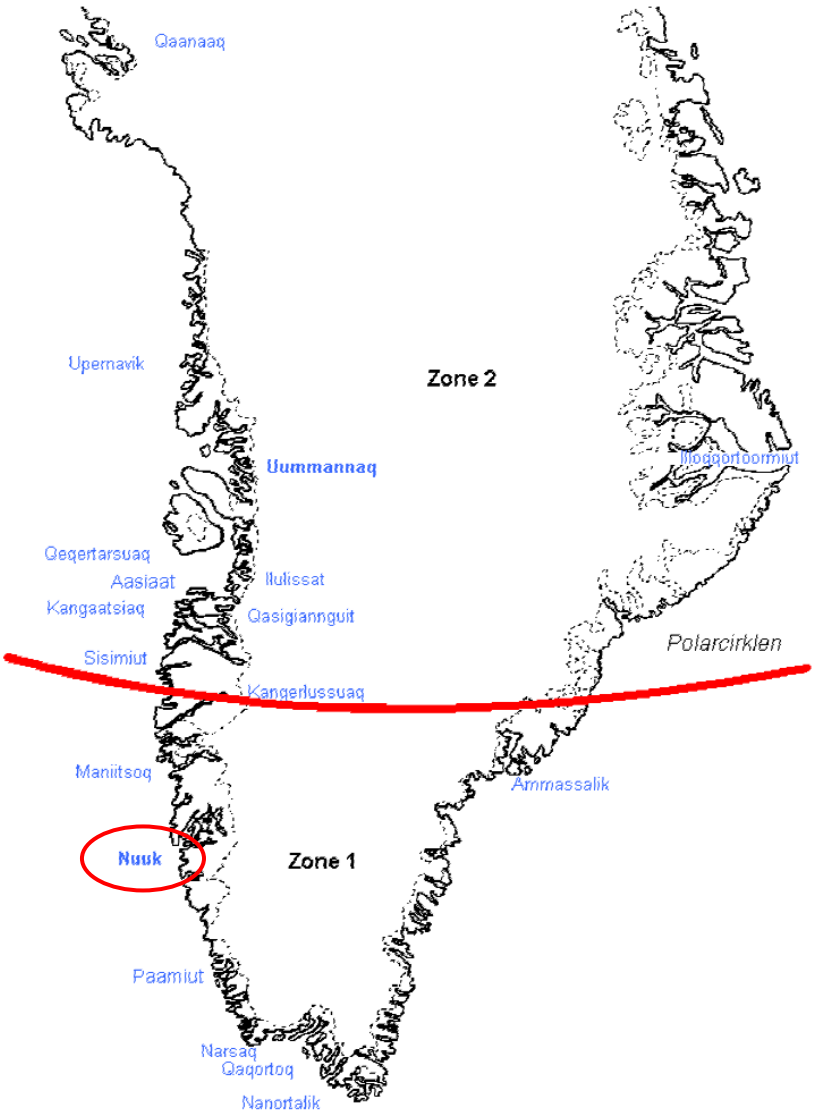

Figure 1. Map of Greenland, showing the two climate zones, divided by the polar circle (red line). The capital Nuuk is marked by a red oval. Thule Airbase is situated relatively close to Qaanaaq in the North West.

Table 1 lists temperatures measured in 2018 in six different places. In general; as one travels North, the weather becomes colder, dryer, and less windy. Because different ocean currents (the warm Gulf stream and a cold polar current) meet in the sea between Greenland and Iceland, there are large differences in the accessibility of the coast line. The East coast contains much more ice than does the warmer West coast, making transportation by ship possible in the West most of the year, in contrast to the East coast.

The average wind speed may not be high, and short but strong storms occasionally occur.

Table 1: Monthly Average maximum temperatures, average temperatures and average minimum temperatures in six different Greenlandic cities in 2018. All temperatures in °C.

	Qaanaaq (Thule)			Ilulissat			Kangerlussuaq			Nuuk			Narsarsuaq			Tasiilaq		
	North			North			West			West			South			East		
	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.
January	-3.6	-21.3	-30.3	0.0	-12.9	-22.5	-0.7	-21.2	-33.3	4.4	-8.8	-15.3	6.6	-6.2	-19.6	3.1	-4.2	-14.7
February	-4.4	-21.9	-32.4	-3.2	-17.9	-26.8	-3.0	-25.0	-38.7	0.7	-13.5	-20.7	8.3	-12.7	-22.8	2.8	-5.1	-15.5
March	-3.3	-24.9	-34.5	6.3	-13.5	-27.4	6.9	-16.2	-34.7	9.6	-5.6	-16.7	9.4	-4.3	-14.7	3.6	-4.9	-13.9
April	-0.5	-14.9	-28.2	5.1	-6.7	-18.3	5.0	-6.0	-15.7	7.0	-1.9	-7.6	13.2	1.6	-7.4	6.3	-2.1	-12.4
May	3.7	-6.2	-19.8	12.1	-2.0	-15.4	11.9	-0.1	-13.7	6.5	-1.6	-9.5	11.9	2.0	-9.4	4.9	0.4	-7.9
June	15.1	2.7	-4.7	19.1	3.7	-1.6	21.4	8.9	0.1	19.3	4.1	-1.4	17.7	7.7	2.4	7.1	3.7	-2.3
July	12.0	5.0	0.1	14.0	5.4	0.0	21.0	10.3	1.7	17.2	7.0	0.3	19.2	9.2	2.5	16.7	7.4	1.2
August	12.9	5.1	-0.7	15.9	6.4	-0.6	20.7	8.8	-1.4	15.5	7.1	1.7	17.0	8.8	2.4	14.2	7.1	2.2
September	5.5	-0.7	-8.4	11.1	1.7	-5.0	14.5	3.3	-6.0	10.9	4.0	-0.1	13.1	4.6	-2.3	9.0	4.4	-0.8
October	1.0	-9.5	-19.7	5.6	-5.8	-16.1	7.2	-7.1	-21.0	10.0	-2.9	-8.3	10.3	-1.3	-9.9	4.6	-0.8	-8.4
November	0.9	-17.0	-25.0	8.3	-7.8	-17.8	10.3	-13.1	-26.4	8.0	-4.1	-9.7	9.7	-2.6	-13.0	5.4	-1.5	-9.2
December	-7.5	-20.1	-31.7	-1.1	-8.3	-15.6	5.3	-12.7	-27.6	3.6	-3.3	-9.7	9.1	-3.1	-11.1	5.6	-3.6	-12.9

Strong winds make it impossible use lightweight interim construction to protect buildings against precipitation during the building process. Instead, materials that are resilient to moisture must be used, in combination with heaters and dehumidifiers. Moreover, because the building season is short, it is important to close buildings fast.

Energy supply

About 20 % of the Greenlandic energy supply comes from hydropower plants, which are situated in the five largest cities. The rest of the energy supply is based on fossil fuels.

Natural resources for building materials

Greenland has several rare minerals and metals, however, so far mining has not paid off. Because average monthly temperatures rarely exceed 10 °C, there are very few trees. Stone could be used as building material, but costs for cutting and transportation over land are too high. Consequently, all building materials must be imported. Yet, concrete is seen as a somewhat more “domestic” than other building materials, since cement is the only ingredient that must be imported; water, sand and gravel fit for use are abundant. This is one of the reasons why concrete construction has become popular.

Before the Europeans rediscovered Greenland in the beginning of the 18th century, buildings were either not permanent or build in stone and/or peat in combination with driftwood.

Building design

Most buildings in Greenland were built after the Second World War, less than 5% are older. The few older buildings are almost entirely used as cultural buildings, and will therefore not be considered in this paper. The building style has changed several times; the oldest houses, mostly single-family houses, are built in a traditional Norwegian way, later Danish methods, mainly concrete construction, were adopted. Today the building industry is dominated by Danes who have settled in Greenland and a few Greenlanders who have received their education in Denmark. Inspiration from Iceland is increasing. The craftsmen are either Danes or Greenlanders.

There is currently a building boom in Nuuk and several cities on the West Coast, while there is unemployment in the South. Consequently, the building costs on the West coast are very high. Especially because there is very little competition; there are a few established contractors in the different cities; and because of the high transportation costs, companies do not bid on projects where they are not already represented. Consequently, unless the client has specific demands, there is very little innovation in the building industry.

Although privately owned houses and homes do exist, the government or municipalities own most houses. Consequently, either the government or the five municipalities have financed most building activity, and has been able to control the development of the building design by making specific demands. Demand for new housing could be higher than that prescribed in the building regulations, which traditionally have been heavily influenced by Danish Building Regulations, and which are more than 10 years old due to the lack of resources for writing Greenlandic building regulations. Recently, a new trend has started; developers build dwellings that are rented out to housing associations owned by the government or municipalities. However, even with this current situation, it is not possible to demand higher standards than given in the building regulations, even though these might be outdated.

It has been claimed that traditional Greenlandic cooking, which involves lengthy time boiling of meat, contributes excess moisture in the building that would be higher than the humidity classes described in the ISO Standard 13788. However, indoor climate measurements show that the humidity classes for maritime climates apply equally to both Greenland and Denmark. Therefore, higher ventilation rates do not seem to be necessary.

Single-family houses

Single-family houses built before the Second Word War were generally unhealthy and had a short service life. In 1950, the Danish government established a central

organization, the GTO (Greenlandic Technical Organization), which over the years has planned several standardized types of wooden single-family houses, of which 10 specific types were mass produced. These were insulated with 3-10 cm of mineral wool. Many of the characteristic colorful houses origininate from this time.

The houses were shipped from Denmark as assembly kits. Very few were privately owned houses and maintenance was secured by a yearly inspection, after which users were told what to fix. In the 70s, this system was abandoned and since that time, maintenance has declined substantially.

Modern single-family houses are also standard wooden houses, but currently, more of these are of individual designs and privately owned.

Multi storey houses
In the 60s, multi-storey houses were erected in the larger cities; these were built after Danish principles for precast structures with sandwich elements. The elements were either shipped from Denmark, or produced locally in primitive concrete factories. Today these buildings need renovation and —as in many other parts of the world— have become ghettos with social problems I addition to building related problems.

Building with concrete has continued, although precast elements are less common. For many years, there has been no factory to produce concrete elements in Greenland and if precast is being used, it is as floor structures, some as semi precast, some have been shipped from Denmark. In contrast to wall elements, floor elements can be packed on flat racks, which reduces the transport costs.

In-situ concrete structures are common in modern multi storey houses; floors, load-bearing separating walls and gables are made of concrete, while facades are made of timber frames with 200 mm thermal insulation. The roof construction is timber with a ventilated attic and roofing with plywood with roofing felt. The ceiling is insulated with approximately 300 mm mineral wool. The amount of thermal insulation seems to be low compared to the thicknesses used in Denmark, where the climate is much milder, however, the building regulations are less strict in Greenland and energy prices are lower. Figures 2 to 4 show details of how the building envelope in a typical multi-storey house of today is constructed.

Multi-storey houses of the past were three to four storeys high, and relatively long with five to eight staircases per building. In the past 5 years, multi-storey houses have become more compact with one staircase but up to seven storeys. This choice has been made to reduce the routes for installations.

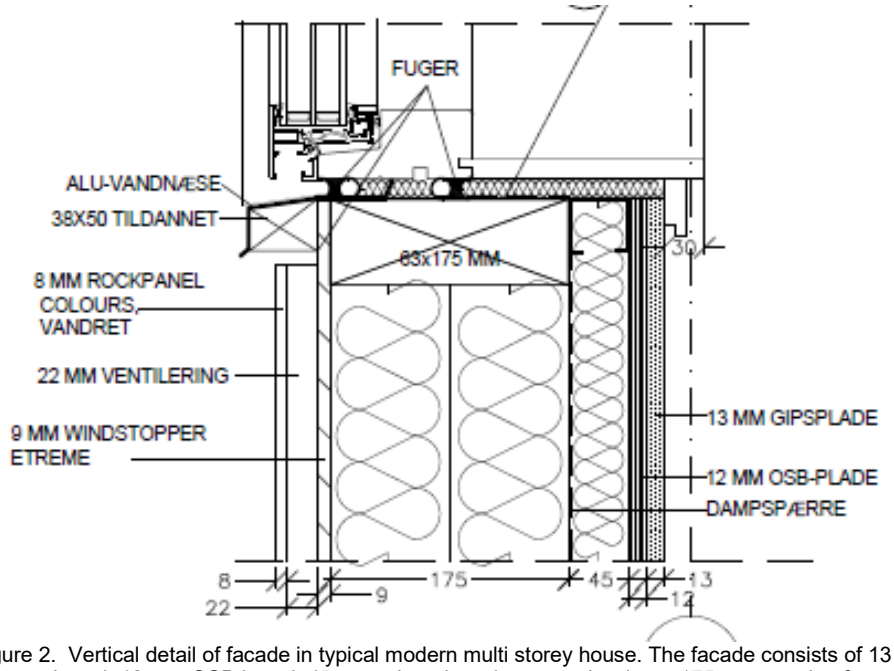

Figure 2. Vertical detail of facade in typical modern multi storey house. The facade consists of 13 mm gypsum board, 12 mm OSB board, 45 mm mineral wool, a vapor barrier, a 175 mm wooden frame filled with mineral wool. On the outside a sealed fibre cement based wind stopper, a ventilated gap and a cladding of compressed mineral wool boards.

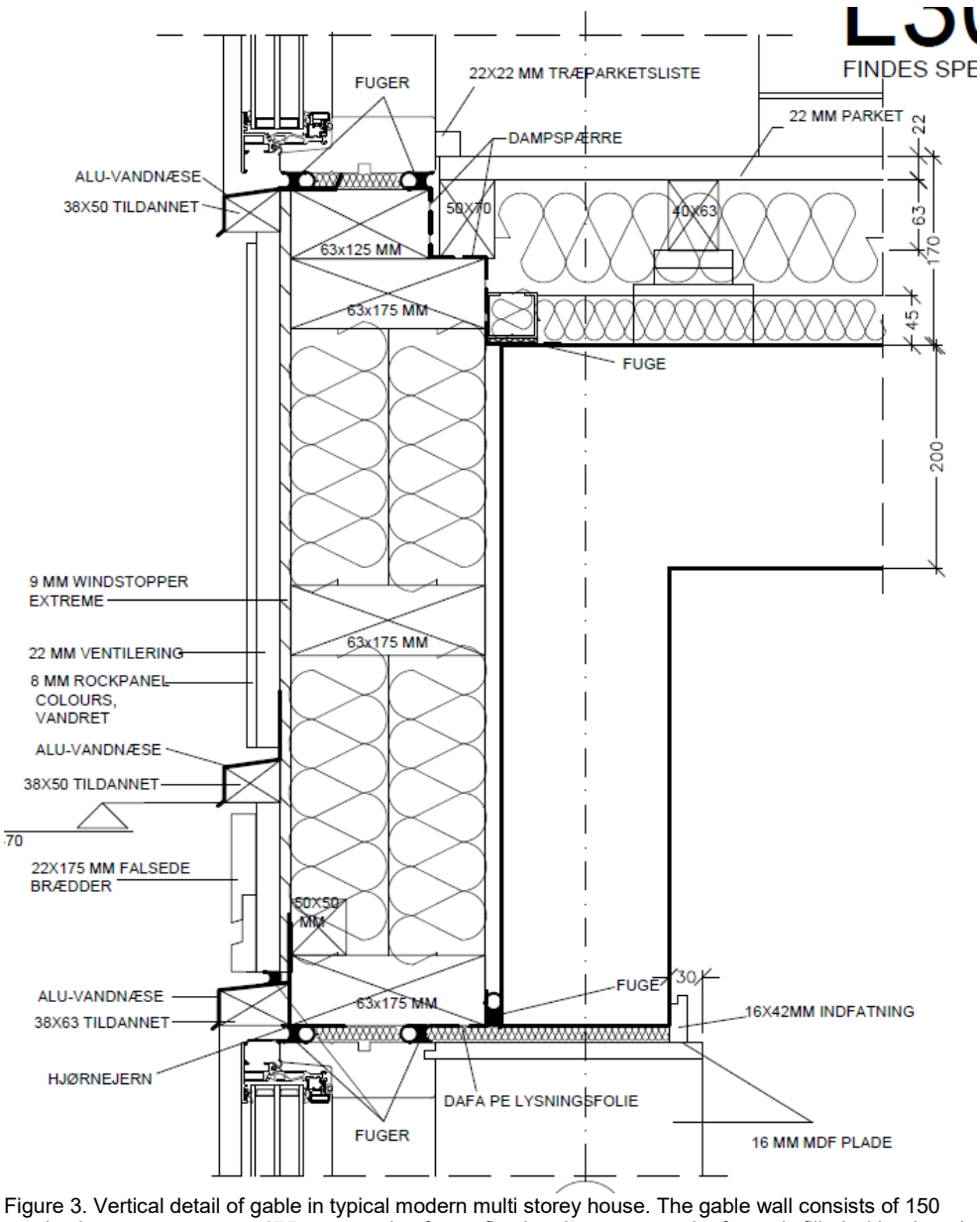

Figure 3. Vertical detail of gable in typical modern multi storey house. The gable wall consists of 150 mm in situ cast concrete, a 175 mm wooden frame fixed to the concrete, the frame is filled with mineral wool. On the outside a sealed fibre cement based wind stopper, a ventilated gap and a cladding of compressed mineral wool boards.

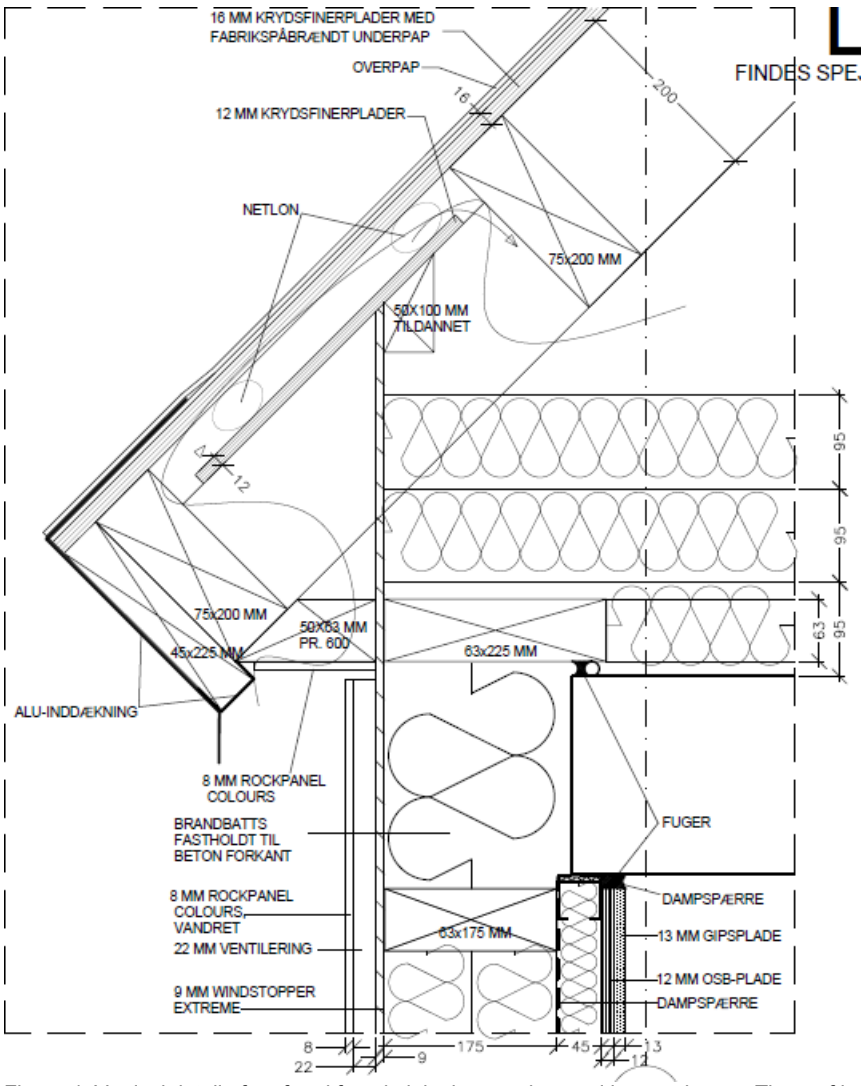

Figure 4. Vertical detail of roof and façade joint in a modern multi storey house. The roof is ventilated trough openings in the horizontal boards at the eaves. The roof is insulated with 285 mm mineral wool.

New trends – motives and solutions

There are different reasons why the authorities and parts of the Greenland building industry are interested in new building technologies:

- *Mold* is a big problem in Greenland. Many buildings have been shut down because of mold-related indoor climate problems. To avoid this in new buildings, the authorities try to promote building technologies without any organic materials, i.e., without wooden elements. Unfortunately, this has in some cases been done at the expense of buildability. The introduction of new materials or new methods always involves the risk of incorrect installation. Furthermore, avoiding organic materials may not be enough, as mold can thrive on a dirty substrate so mold growth can also occur on concrete.

- *Maintenance* has been neglected for a long time. The tradition is to keep maintenance at a very low level and demolish instead of renovating. Maintenance can be difficult in many cases, either because skilled craftsmen are rare, or the climate and accessibility makes it difficult to perform maintenance work. As wood need regular maintenance, the authorities hope that the strategy of avoiding wood will not only prevent mold growth but also reduce the need for maintenance.
- *Long building period and high costs* should be avoided. The authorities and some contractors try to cut down the costs and building time by using prefabricated construction components. However, concrete components are difficult to transport in an island-operated community. At this writing, one contractor in Nuuk is building a factory for fabricating concrete wall components. However, transporting elements from Nuuk to other cities will be costly and possibly difficult because of the lack of machinery to transport elements at their destination. On the other hand, lightweight elements for single-family houses may be a solution for that specific marked.
- *Sustainability* is also an issue in Greenland. Some consider concrete to be the most sustainable building material, as only the cement has to be imported, contrary to other building materials. Others see wood as the most sustainable choice because it is renewable. There is no commonly accepted way to evaluate sustainability criteria in Greenland, as some of the parameters, which are used by different certifications, do not apply in Greenland. However, at least one contractor, who is also a developer, is using cross laminated timber (CLT) components. This goes against the official philosophy of not using wood; ths contractor therefore concentrates on the private market.

Most contractors in Greenland have very little motivation to try new methods, as there is currently very little competition in the building industry. Consequently, the driver has to be the client. In most cases, the client is the government and municipalities, whomust demand specific building technologies. When these demands are met with scepticism from consultants and contractors, locations like Iceland are given as examples where new materials and technologies hae succeeded. However, Iceland differs from Greenland in that it has a road system and very cheap energy. In at least one case, an Icelandic systems that is currently being used in Greenland had to be modified because it was planned for an insulation thickness of 100 mm, while 200 mm was needed in Greenland. The contractor needed to either extend the mounting or make cut-outs in the insulation layer for each mounting; he chose the latter, which included the risk of introducing thermal bridges in the whole facade.

The American Way

As described earlier, the building style at Thule Airbase is different from the rest of Greenland as it is governed by the American military. Thule buildings are erected over steel frames; the external façade is constructed of prefabricated steel-clad insulated components installed over a ventilated gap. The authors have not studied the buildings at Thule airbase and do therefore not know how they work. However, a similar system has been used at a prestigious building in Nuuk; a 10-storey building that houses, among other things, government administration offices. Unfortunately, the building has experienced many problems in maintaining water tightness during storms; 2 years after the building was finished, mold growth was discovered. However, the system might work in lower buildings situated in areas with less precipitation.

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