ENERGI

THERMAL ENERGY SYSTEMS RESILIENCE IN COLD/ARCTIC CLIMATES
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Specifics of construction in Arctic climate

Experience from Greenland, Quaanaaq

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Introduction

75% of Greenland is covered by permanent ice sheet. Almost the whole population of about 60,000 live in 20 towns ranging from 20,000 in the capital Nuuk to 300 in the smallest.

The public utility of Greenland, Nukissiorfiit, is responsible for all supply energy.
Each of the towns has their own power production, operating in island mode, as there is no interconnected power grid.

Most of the largest towns have established district heating, which supplies most of the central urban area.

The power to the largest town Nuuk and four smaller towns are supplied from a hydropower plant; the remaining are supplied from oil-fired engines fueled by arctic oil.

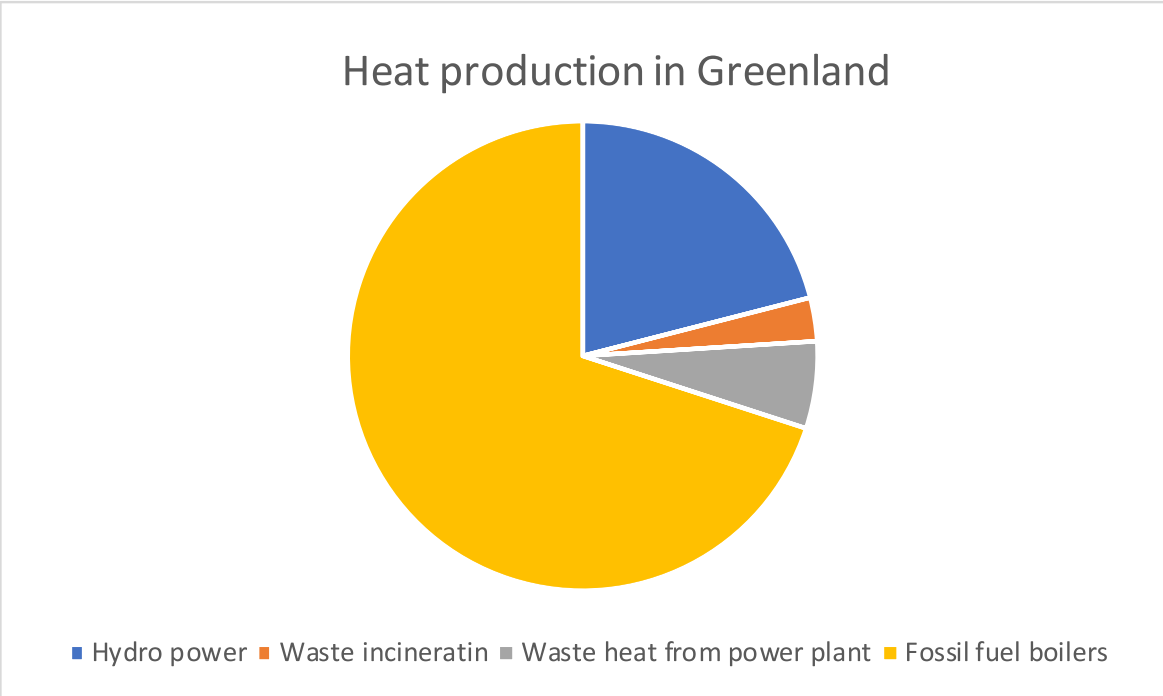
Surplus hydropower, which can be interrupted, and waste heat from the power production is used for district heating.

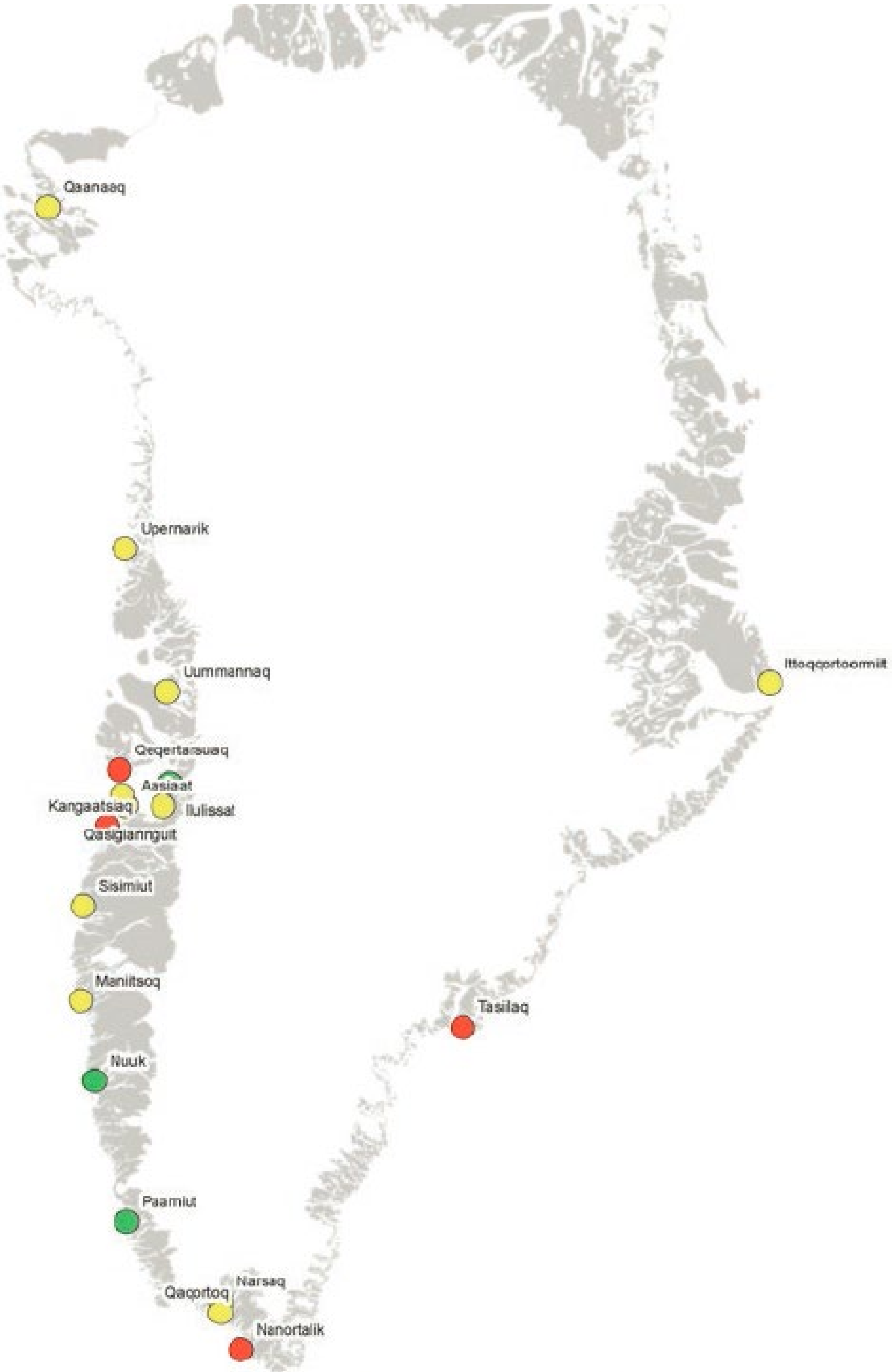
Waste is incinerated in five local waste incineration plants from which waste heat can be used.

The average daily temperature of Nuuk varies from −5.1 to 9.9 °C (23 to 50 °F).

Surplus heat form power generation and from processing the waste can be used from the plants at no cost and at no additional CO_2 emission compared to the base line, whereas oil is expensive.

Heat supply in Greenland





Green:	Excellent sources for surplus heat
Yellow:	Some sources for surplus heat
Red:	Little source for surplus heat

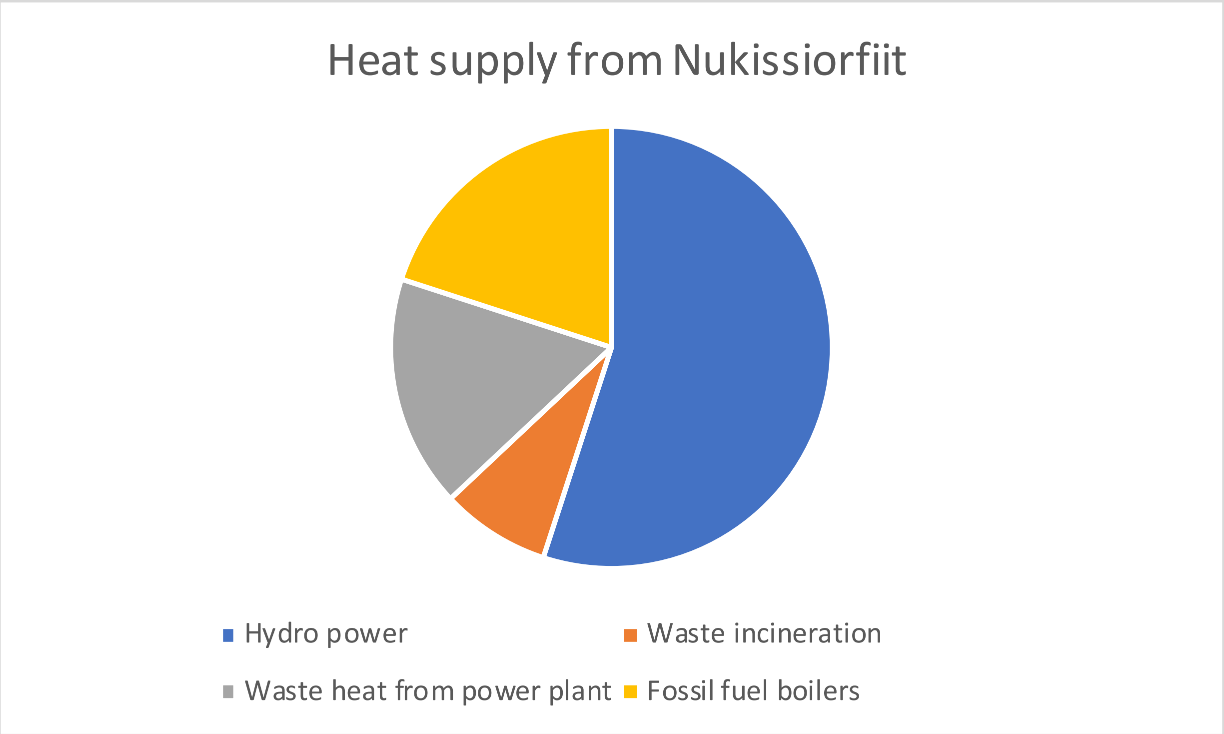
District heating

The district heating systems that have been developed in Greenland are hot water systems with a supply temperature typically below 100 °C, powered by surplus heat from power generation using waste incineration and hydropower. The systems can be interrupted since the district heating systems have backup from boilers.

An exemption is the Thule Airbase, in which there is installed a steam system.

The buildings in Greenland are in general insulated to an optimal level. Heat is distributed in low temperature hot water systems. Direct electric heating is an option in towns with hydropower.

All district heating is delivered by Nukissiorfiit. Most district heating is sourced from hydropower, most of which can be interrupted.



The construction of the district heating systems must consider the arctic climate and frozen soil. (See the northern town Quaanaaq case, described below.)

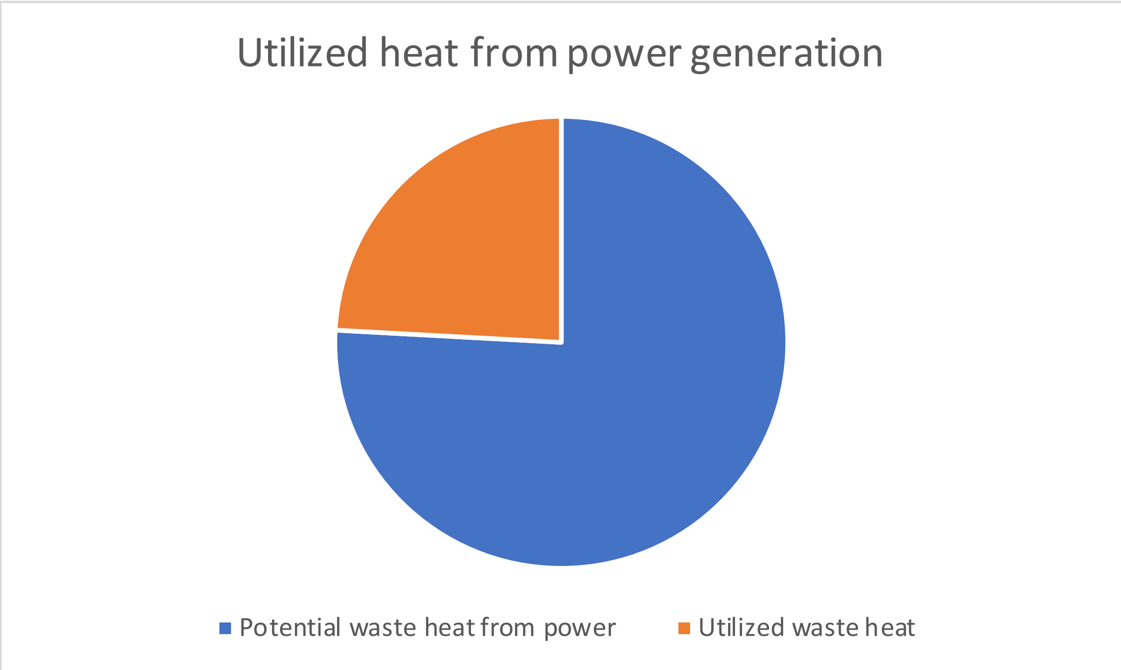
It is local government policy to further develop district heating to replace individual oil boilers and to increase the use of renewable energy and waste heat.

Hydropower

There are five hydropower plants with a total capacity of 91 MW, of which the largest plant (Buksefjordsværket), located near the largest town, Nuuk, has a capacity of 45 MW.

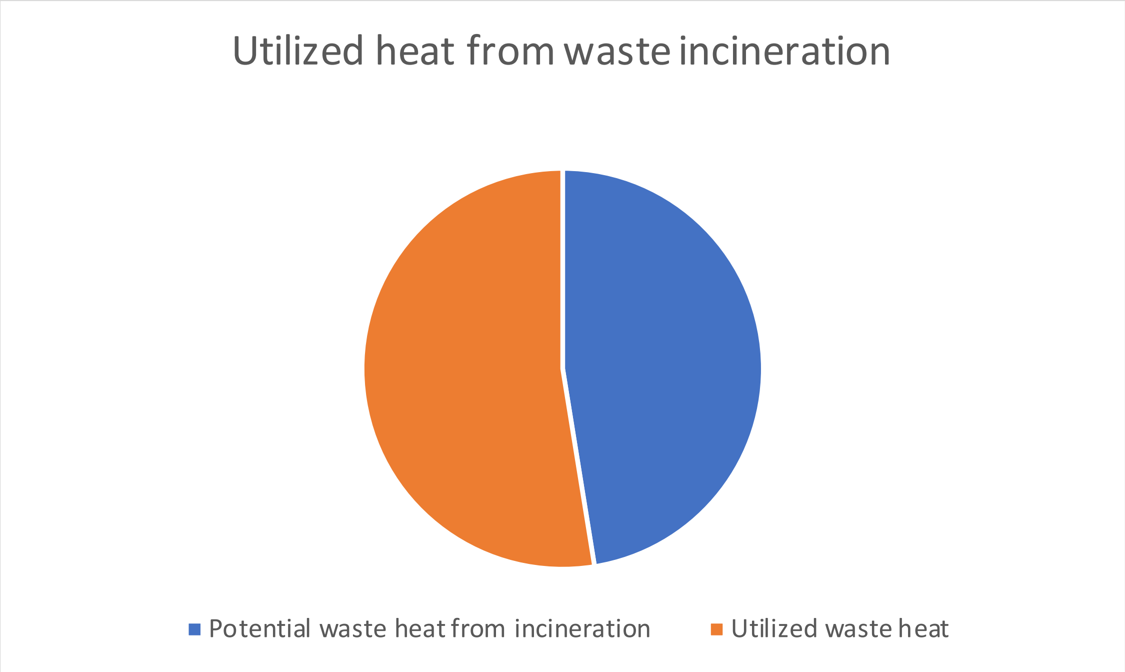
Waste heat from power generation

All the power plants, except the hydropower plants, use diesel engines. All excess heat can, in principle, be used for heating. Today around 25% of the potential is used for heat to the district heating systems. Some of the untapped potential cannot be used because the power plant is located too long distance from the heat demand, and some because it is in competition with waste heat from waste incinerators.



Waste Incineration

Nuuk and five of the largest towns have installed waste incineration plants, which process the municipal waste and deliver waste heat to the district heating.



Allmost all waste is incinerated in six waste incinerators, which deliver heat to the district heating systems. In total 50% of all thermal energy is used, and the rest is cooled by sea water.

Waste incinerator	Municipal waste (tonn/a)	Heat potential (GWh)	Utilized heat (GWh)	Utilized heat %
020 Qaqortoq	2.129	5,9	5,0	84%
060 Nuuk	10.470	27,5	12,5	45%
070 Maniitsoq	2.004	3,8	2,7	71%
080 Sisimiut	3.603	7,7	3,2	42%
100 Aasiaat	2.193	5,4	4,3	79%
120 Ilulissat	2.957	8,5	1,6	19%
Total	**23.356**	**59**	**29**	**50%**

Case: District Heating in Quaanaaq

In remote arctic regions far from the electric grid, the challenge of resilient solutions and efficient use of resources and opportunities is paramount.

When practically no local resources are near, the aim is to minimize the import of Arctic Grade Oil for the diesel motor powered generator and the heating of buildings in the most cost-effective way. If some local resources could be viable, it is a challenge how to use them.

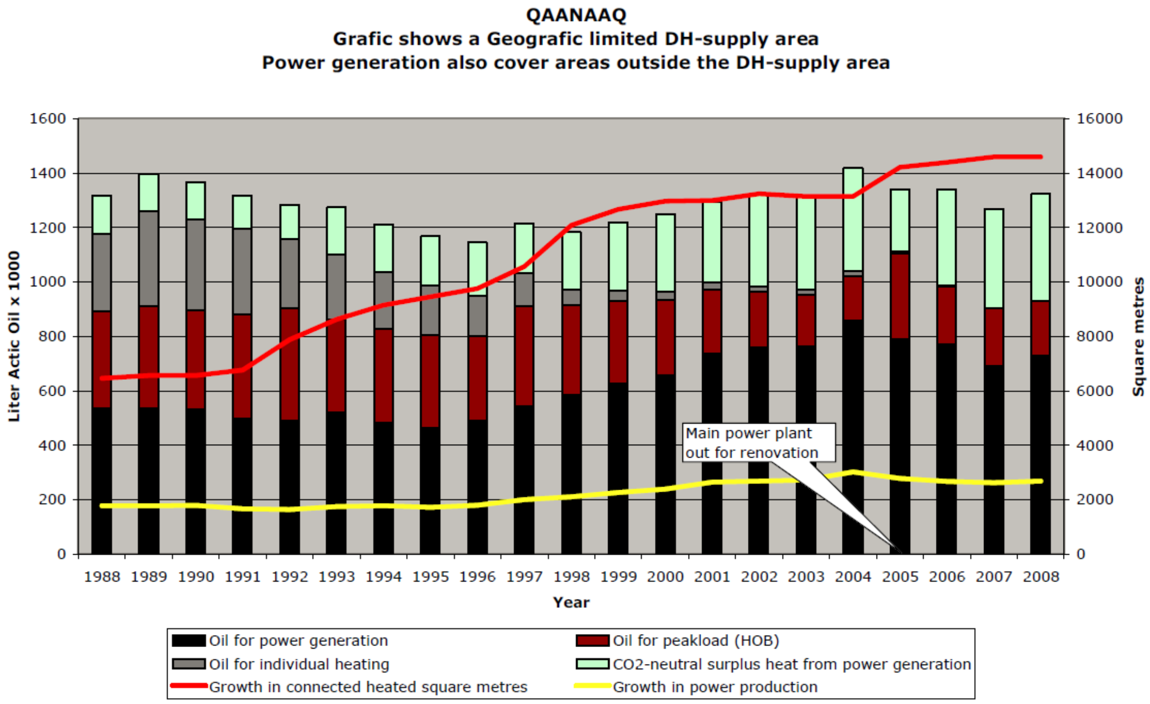
The establishment of QAANAAQ close to the north pole took place back in 1952-53 to host the native population of the Uummannaq area, which in 1951 became the Thule Air Base.

As the settlement was planned as a green field project, it was possible to establish an infrastructure tht was both energy efficient for the time then and resilient for the population.

As a result, after some modifications tht ere made through the 1990s, the system in Qaanaaq can show a remarkably high energy efficiency today, which provides a striking example for any other local and isolated community.

The district heating infrastructure which is the key to this high efficiency is owned by Nukissiorfiit, Greenland's national supply company. Ramboll provides consulting services.

The overall efficiency of the imported arctic fuel (light oil) for electricity and the heating measured at end-user level was up to year 2010 around **80-85%** based on the LCV (lower calorific value), as a fully developed district heating network distributes all the surplus heat from the diesel engines. In fact, this surplus energy, which else would otherwise wasted, covered around 70% of the total heat production. Where individual oil boilers are used instead of district heating, the total efficiency of all electricity and heating would not have been 80-85%, but only **55%** (40% for the electricity only and 80% for small oil boilers).



It is remarkable that an overall efficiency of 80-85% is possible without a thermal storage, which could be installed if necessary. Moreover, if the network were supplemented by thermal storage, it will be ready for efficient integration of renewable energy like wind and solar PV. These renewables would supplement the diesel engines and boilers, and the renewable energy would be used by an electric boiler, stored in a tank and used for heating in accordance with the demand.

Additionally, the district heating system is fueled by local waste, which is the case in several larger settlements in the arctic. Potential options for the entir country include, in the short term, hydropower alone, and in mid- to longer term, hydrogen and carbon capture synthetic generated E-fuels.

An important precondition for these future success is that the heating density be sufficient and that the costs of the district heating pipes be modest, as they are placed in ducts above ground together with other infrastructure, such as wastewater pipes and fresh water pipes, which must be protected against frost; the systems work together as low heat losses of the district heating pipes contributes to keep the other pipes warm. Moreover, all the heat losses are generated by heat from the diesel engines, which else would otherwise be ejected to the ambient air.

Qaanaaq:
Inhabitants: 656 people in 2018

Below figures are from 2010

District heating Heated floor area: 14,600 sqm
Annual heat demand (DH) an net: 5,227 MWh
Annual electricity demand: 2,752 MWh

Combined heat and power plant:

2 newly (2015) renovated B&W-man MBDH diesel engines type 5T23LH from 1984, 550 rpm. Rating each 518 kW power, plus
1 Scania diesel engine type DI 16 44, 1500 rpm rating 400 kW power.

All units are cooled by DH return water, from turbocharger, lubrication, piston and cylinders to the exhaust gas systems which are attached to exhaust boilers for optimal use of energy almost to condensation level.

Cooling fans on the roof is now only for emergency.

Additionally, 2 Scania diesel engines each with generators of 600 kW power serving as emergency units.

CHP Power/heat capacities:
Total generator capacity 1436 kW power. Steady performance 918 kW power. Surplus heat from 3 temperature levels ranges 2.5 MW thermal.

Boiler Heat capacity:
3 Peak load boilers Danstoker type VBN can operate in parallel and seriel with the CHP plant.

The Peak load boiler plant was renovated in 2000-2004. New boiler capacity 1.5 MW thermal.

Efficiency rate 93-95% at fluegas temperature of 110-120°C.

Description of a Technical Highlight

The picture below shows the infrastructure interconnect the buildings in this arctic climate. All the infrastructure is located above ground as the arctic permafrost makes it very difficult to build under ground.

This construction has several advantages:

- The district heating pipes keeps the other infrastructure warm and prevents break down due to frost.
- The pipes can easily be repaired in case of leaks, which seldom occur.
- The top of the construction can be used by pedestrians.

Sources:
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- https://stateofgreen.com/en/partners/ramboll/solutions/low-carbon-arctic-community-qaanaaq-in-greenland/
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