NORDIC KNOW-HOW 2022

BEST PRACTICES OF
SUSTAINABLE HEALTHCARE
IN THE NORDICS

REPORT SERIES BY
NORDIC CENTER FOR SUSTAINABLE HEALTHCARE

#7 COOLING SYSTEMS

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NORDIC KNOW-HOW #7 COOLING SYSTEMS
REPORT BY
NORDIC CENTER FOR SUSTAINABLE HEALTHCARE/BELOK
2022

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INTRODUCTION

The **Nordic Know-How** report series shares best practices and technologies from the Nordics, aiming to improve the sustainability performance of hospitals and other healthcare facilities. The series greets an international audience, especially those working with hospital management and design, healthcare procurement, or looking for practical green solutions.

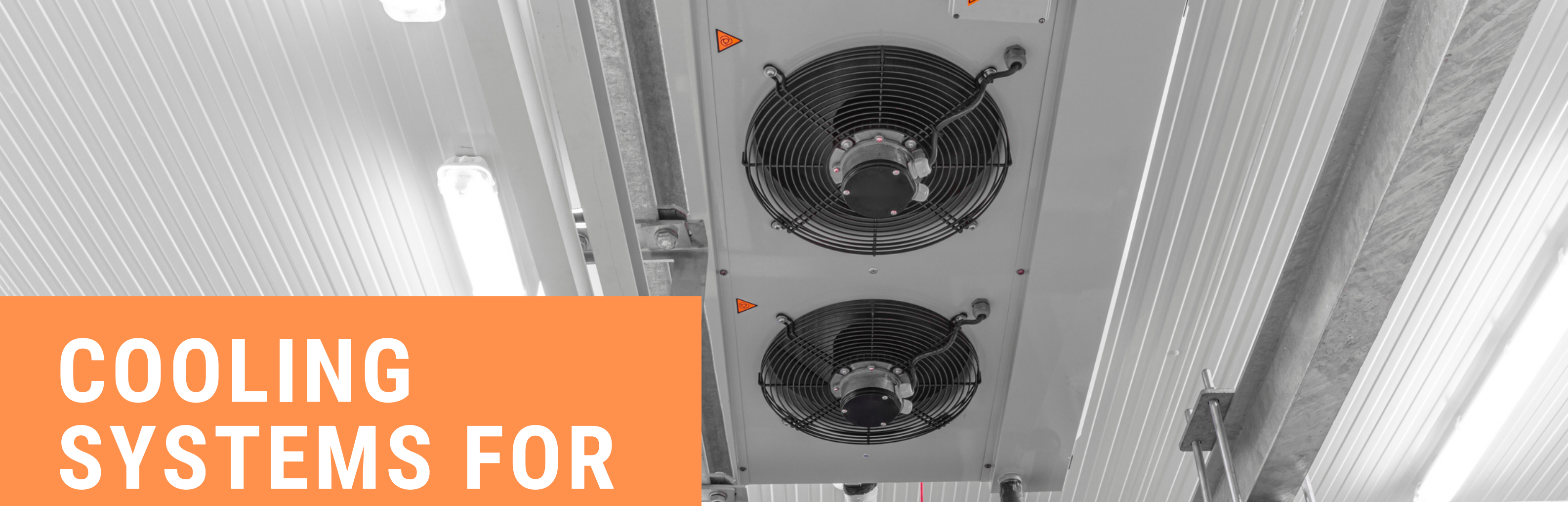
This seventh report addresses the topic of cooling systems for healthcare facilities. The topic represents a strategic challenge, as comfortable indoor temperatures are vital for the comfort of personnel and patients, including patients' mental health and healing processes. Temperature is further key for maintaining medical equipment and proper preservation of pharmaceutical products and clinical samples.

At the same time, cooling systems contribute to the environmental impact of the healthcare sector. 4.4% of all global CO_2 emissions derive from the healthcare sector, cooling included. For hospitals, this implies about 465 Mt annually (Hovland, 2018), including CO_2 emissions and other greenhouse gases (GHG).

There is accordingly a need to increase collaboration between healthcare actors to promote sustainable cooling systems. Collaboration will involve ensuring proper temperature conditions for strategic installations and diminishing environmental impacts.

Such efforts can improve the sustainability performance of hospitals and at the same time facilitate the implementation of the European Green Deal, along with international frameworks like the Paris Agreement (avoiding GHG and achieving carbon mitigation) and the Kigali Amendment (phasing out hydrofluorocarbon (HFC) by replacing conventional cooling systems) (IEA, 2018).

With this objective, the **Nordic Know-How #7** includes the most updated and relevant solutions installed and evaluated at Nordic hospitals. The report provides decision-makers with overarching knowledge of the systems' significance, the technologies on the market and practical lessons from the Nordics.



COOLING SYSTEMS FOR HEALTHCARE FACILITIES

Today's climate crisis has accelerated phenomena such as heatwaves and increased global temperatures. Adapting public and private infrastructure is a necessary and pressing task, giving special attention to cooling installations.

According to the IEA, conventional cooling produces more than 7% of the world's GHG emissions. Climate change is likely to initiate the use of more cooling, with emissions expected to double or triple by 2050 (IEA, 2020).

An urgency to the situation has been recognized by the international community. Within COP26, a partnership with 120 organisations led by United Nations Environment Programme has been established: the Cool Coalition. The coalition emphasizes the growing environmental impact of cooling systems, including systems in healthcare facilities.

The importance of the topic is major. Hospitals and other healthcare facilities are strategic infrastructures on which ones wellbeing and sustainable development depend. This requires an effective and reliable functioning of all the systems that integrate it, cooling systems included.

Cooling systems are present across healthcare installations, playing a fundamental role in the health of the patients, staff and lifespan of equipments, pharmaceuticals and organs.

The diverse use and forms of cooling reflects on the diversity of technologies, methods and approaches that can be applied in a healthcare facility.

In order to show the importance and state-of-the-art in this topic, the process of writing the **Nordic Know-How #7** has included a dialogue with hospitals across Sweden. A survey has been carried out with answers from 15 different counties, to collect opinions and experiences about cooling systems in healthcare facilities.

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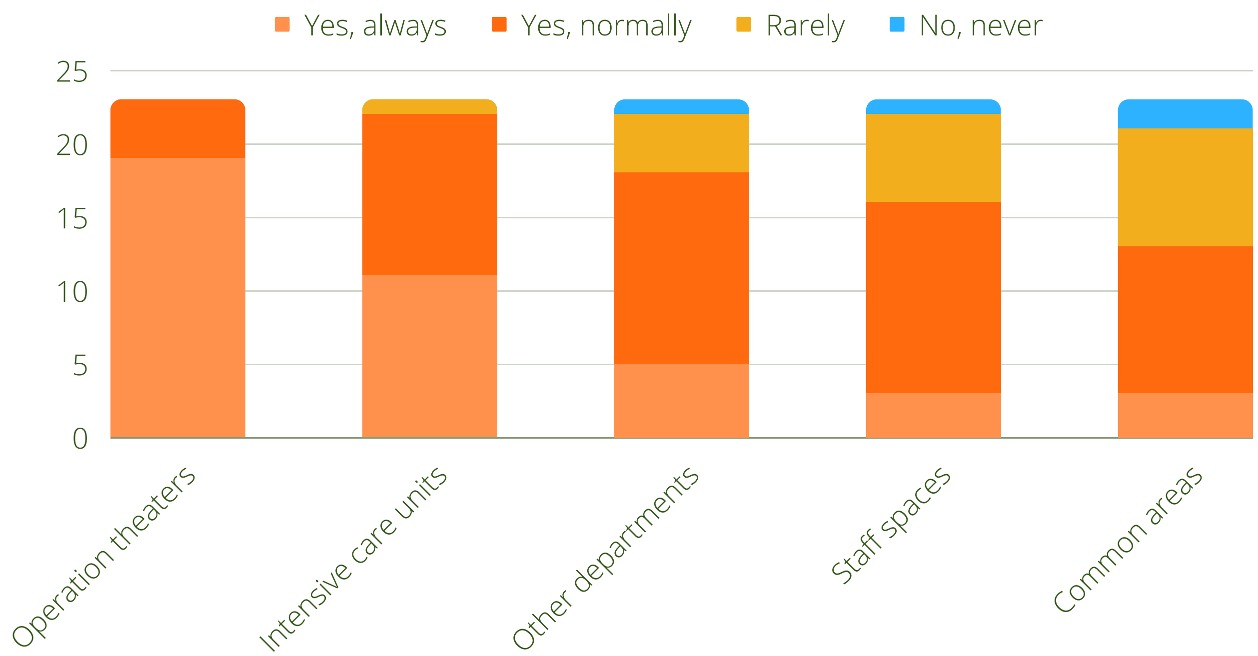
The survey was shared via email to actors that had previously participated in Belok's focus area "Energy-efficient care facilities". Responses were received from 23 people representing 17 different counties (Figure 2). All of the respondents work with emergency hospitals. Most of the respondents are also employed at health centres, regional hospitals and/or specialist hospitals.

The responses show that cooling is fundamental for healthcare, being most common in operating theatres where over 85% responded that cooling is always used. Cooling is further common in intensive care units and other healthcare departments, as shown in Figure 1.

The survey answers illustrate that cooling systems are used widely across all areas in the facilities. Everyone who answered the survey offered some form of cooling process to the health service.

This sample shows the importance of cooling systems for areas like operation theaters and intensive care units. The type of cooling system used varies depending on specific contexts, availability and other variables, as is shown under the title *Experiences from Swedish hospitals* below.

Figure 1. Do you use cooling in the following spaces?



COOLING TECHNOLOGIES

How to define a cooling system for healthcare facilities is subject to the energy source used to produce the cooling effect.

For the purposes of this report, "cooling system" has been identified as passive cooling, free cooling, mechanical cooling and district cooling. These are the main systems through which it is possible to identify and combine different sources and types of cooling techniques.

PASSIVE COOLING

Passive cooling is a method employing design and technology for reducing the amount of heat which the system needs to take care of. Strategies include climate-appropriate building orientation, construction materials as well as design: windows, shading and natural ventilation (BTH, 2020).

The Nordic countries have a strong tradition of construction codes that can deliver thermally efficient buildings. For example: Sweden Green Building Council uses 16 different indicators for the use of energy and types of construction materials. This is done to ensure that buildings have positive standards for people and the environment. One of the indicators points to the need to limit solar heat gain.

FREE COOLING

Free cooling uses ambient external air temperatures in the natural environment to lower the temperature of stored water or indoor air. The cooled water can at times completely replace the chiller in a cooling system, considerably decreasing electricity consumption. Examples of free cooling is cold groundwater or night air. Free cooling in combination with modern heat pumps can ensure both heating and cooling in a building.

GROUNDWATER COOLING

This system directly employs groundwater for cooling in the warmer seasons. During the winter, pumping systems' flow direction is reversed to take in heat from the groundwater reservoir.

Groundwater cooling is one of the most sustainable cooling solutions and is installed at an increasing rate in the Nordics.

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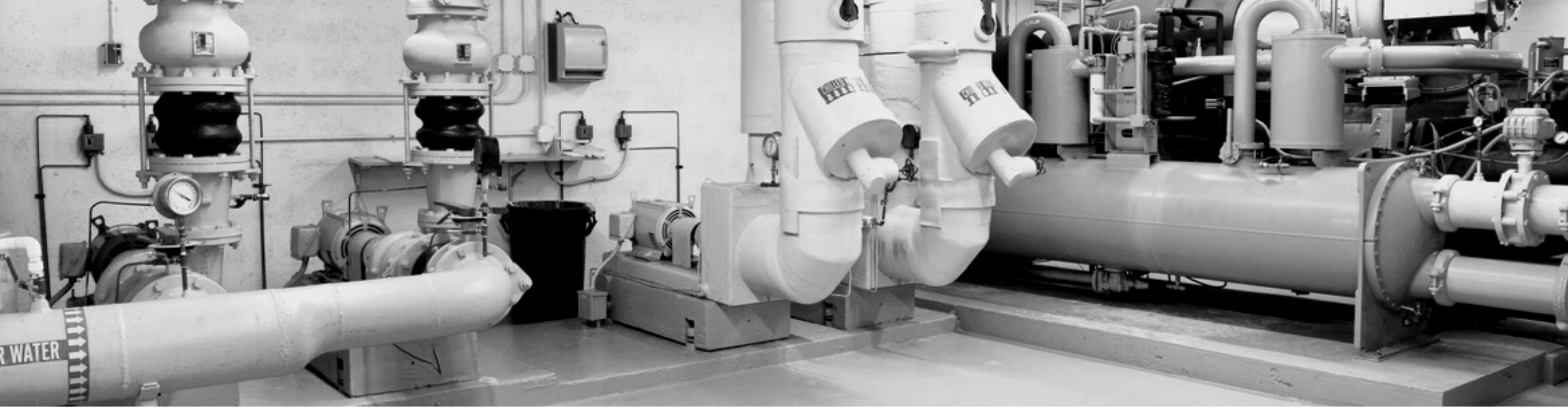


GEOTHERMAL COOLING

Geothermal cooling operates through a rock's temperature. Thereafter, the ground is heated and the heat is passively conducted away to the surroundings. This cooling can occur with and without a cooling machine.

EVAPORATIVE COOLING

In an evaporative cooling system, the air is cooled through the evaporation of water. By adding water to dry air, the water will evaporate. The energy required for evaporation causes a decrease of the air temperature. This can be implemented in the supply air stream. However, to avoid high indoor-air humidity, it is often better to implement it in the exhaust air and use a heat exchanger to cool the supply air.

SORPTIVE COOLING

Sorptive cooling is a development of evaporative cooling. By first drying the air, evaporation cools the air to a much greater extent. The entire cooling system is powered by district heating or a local heat source and can – with a few adjustments – be connected and used by anyone who has district heating installed and the space for it (this cooling method is rather space-consuming).

MECHANICAL COOLING

Mechanical cooling refers to the electricity-driven vapour compression cycle, where the use of a compressor makes it possible to transfer heat from a lower to a higher temperature. The same process is used in heat pumps and household refrigerators. In addition to requiring electricity, mechanical cooling also requires the use of refrigerants: A collective name for the medium inside a closed-circuit process, from which useful cooling or heat is delivered.

Refrigerants are employed in air conditioning systems, refrigerators, freezers, heat pumps and more. Considering that the most common refrigerant is a nearly 2 000 times more potent GHG than CO_2, it is urgent to find systems that combine passive and active cooling – to either use the energy more efficiently or for more sustainable refrigerants (IEA, 2018).

Refrigerants

- The Montreal Protocol (1987) phased out the use of CFC and replaced it with HCFC. The Kigali Amendment (2016) then presented the progressive replacement with HFC (non-ozone depletes, yet with high GHG emissions).
- The F-gas regulation from EU will phase out refrigerants with high environmental impact.

DISTRICT COOLING

District cooling refers to the infrastructure connecting central cooling plants or local sources with cooling demands – usually providing chilled water for indoor cooling through a closed-loop pipe network. Functionally and technically, this works parallel to district heating. The cold water employed in a district cooling system can come from natural sources such as seas and lakes. It can also be produced by electric chillers or from waste heat through absorption cooling.

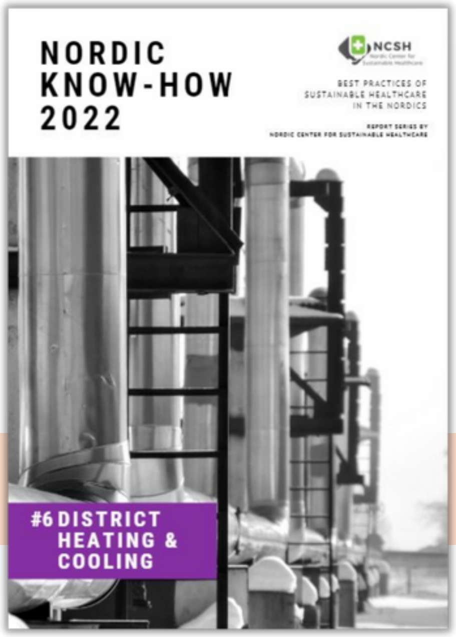
On a larger scale, applications underground and snow storage are alternatives. In an underground storage, cold winter temperatures are exchanged from the air and loaded into either the bedrock or an aquifer by bore holes. A snow storage works instead to store frozen water: To utilize the cold, melted water is pumped to the cool object – directly in a district cooling system or indirectly by a heat exchanger. Snow cooling works as a single cold source yet can additionally be used for peak cooling, as no relevant cooling limit exists (see the Sundsvall hospital case below for further analysis).

Not all district cooling systems are the same and there can be different approaches depending on the local source of cooling, the density of the interconnected system and the available technology.

In a traditional district cooling system, water is distributed between the plant in which it is chilled and the connected buildings where it absorbs heat. However, there are other approaches. One existing system uses intelligent controls to ensure that excess heating or cooling capacity in one part of the network gets used elsewhere. This technology improves efficiency and cuts energy consumption. Further efficiency is said to come from balancing cold and hot water flows. Each linked building in the closed system grid has heat pumps and cooling units to finetune indoor temperatures, reducing the need for energy to heat or cool the balancing unit. The system can act as giant thermal battery, storing excess energy when available and powering down to reduce load when demand is high.

A district cooling system can be more efficient than a traditional cooling system. These systems are scalable, serving anything from a few buildings to an entire city. They can also be powered with renewable energy, where available, to reduce emissions.

FOR MORE INFORMATION, CHECK OUT THE NORDIC KNOW-HOW #6: DISTRICT HEATING & COOLING



District heating and cooling systems are efficient (as shown in Nordic Know-How #6). These networks can pair heating and cooling services to increase the net efficiency and flexibility of the entire system and use free cooling technologies.

ABSORPTION COOLING

Absorption cooling is produced from district heating or other heat sources: solar energy, a fossil-fuelled flame, waste heat from factories, and so-called heat-driven cooling. This is a technology which makes use of the heat in a district heating network to drive the refrigerating machine producing district cooling or cooling for individual buildings.

In the refrigerating machine, water is exposed to strong negative pressure. The negative pressure causes water to boil and evaporate at a temperature of around 3 degrees Celsius. This water is subsequently allowed to cool the water used in the district cooling network.

For absorption cooling to be economically viable, accessibility to excess heat at a low price is necessary. Such accessibility can be enabled through waste heat from an industry or waste incineration in the summer, when heat might otherwise simply be cooled away. There is no extra production of heat for the purpose of producing cooling, meaning climate emissions from district cooling are minimum.

SOLAR COOLING

This is an emerging technology which involves the direct use of solar panels through heat pumps, air conditioning units, or solar thermal collectors connected to a heat driven absorption chiller device.

COMPLEMENTARY TECHNOLOGIES

Complementary technologies involve the digitalisation of buildings and operative systems that can improve cooling systems. An example being smart thermostats that strengthen the energy-efficiency of a system. This directly raises the energy-efficiency of air conditioning units and other cooling equipments.

Apart from these complementary technologies, the role of user adaptations and behavioural changes should be noted as important factors for cooling efficiency. Additionally, the fundamental importance of good operations and maintenance should be considered.

Cooling is addressed in many ways. An integrated whole-system approach can foster collaboration, reduce the risk of negative effects and increase benefits as well as efficiency in the entire system.

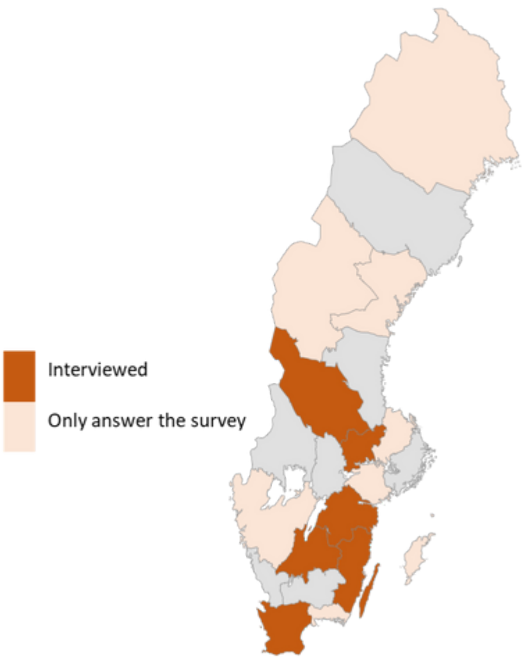
EXPERIENCES FROM SWEDISH HOSPITALS

The Nordic countries are at the forefront in many sustainability aspects of healthcare. In Sweden, there is a combination of innovative and holistic approaches, as well as the existence of innovative companies and cross-sectorial collaboration including local governments and research institutions.

This ecosystem reflects on the best practices and knowledge that could contribute to decisions about which cooling system to use most effectively for a particular healthcare facility.

As previously stated, this **Nordic Know-How #7** has included a dialogue with actors representing hospitals within 17 different counties and a collection of their experiences (Figure 2).

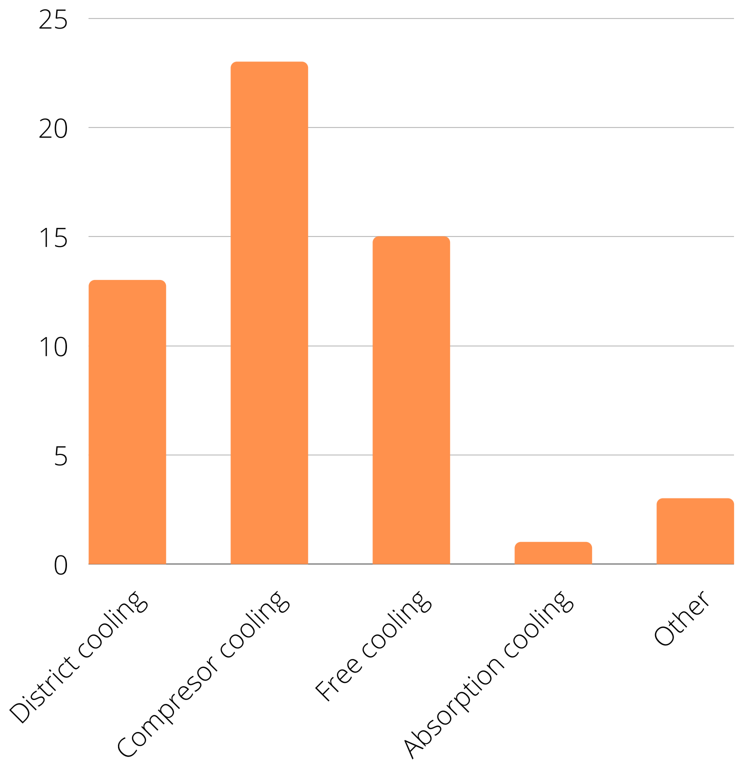
Figure 2. Sample of consulted hospitals



The information obtained in surveys and interviews shows that cooling systems are present all over the healthcare system. The results indicate that mechanical cooling is the most common way of producing cooling for healthcare facilities, followed by free cooling and district cooling. Only one county point to the use of absorption cooling. The respondent answering "other" offered the explaination that the county uses pumps to generate free cooling from boreholes, which by other counties is defined as free cooling.

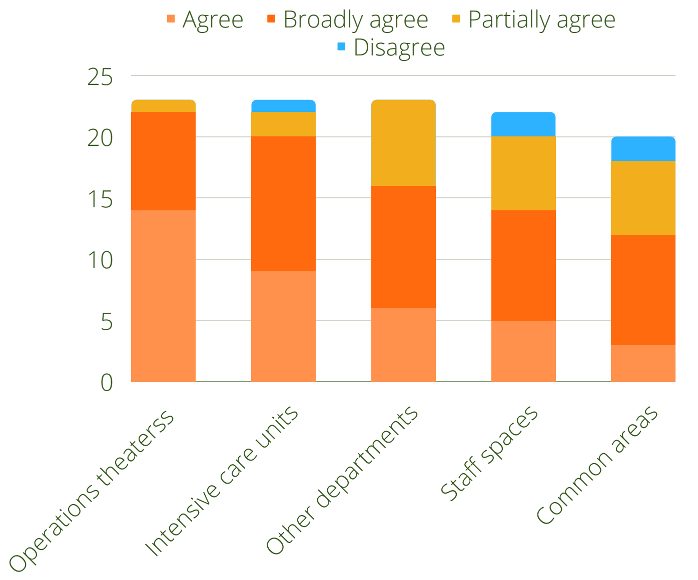
Compressor cooling is the most common way of producing cooling, illustrated in Figure 3.

Figure 3. How is cooling produced?



Most of the respondents believe that their cooling systems work well in operating theatres. In other premises, such as intensive care units and public areas, the answers vary (shown in Figure 4).

Figure 4. The cooling systems normally work well in:



Still, the type of cooling system used in operating theatres differs between central cooling systems and local units. Airborne cooling appears more common than chilled beams. The type of cooling system also varies for other premises within hospital areas, yet central systems seem most common.

Everyone who answered the survey pointed to some type of process cooling to the health service. This differs between process cooling connected to the central system or produced via separate units. Determining factors are the comfort cooling system design, the need for the equipment, and the temperature levels.

In order to further evaluate the use of cooling in Swedish hospital, some of the respondents were contacted for an interview. The distribution between survey answers and interviews is presented in Figure 2.

The interviews highlighted an increasing demand for cooling in Swedish healthcare facilities. Temperature levels are explained as more difficult to maintain due to heatwaves linked to global warming and hightened demands on indoor climate. There are also higher cooling requirements when it comes to machines.

Regarding energy-efficiency in healthcare facilities, it is important to optimise in existing premises without risking the patients' safety.

Some respondents mentioned that they work in collaborative groups to exchange experiences in, for example, energy issues. Collaboration was considered to be of great benefit, offering insights and triggering individuals as well as ideas against each other in order to improve.

INTERVIEW HIGHLIGHTS

Production

The interviews concluded that cooling in today's hospitals is mainly produced by district cooling or local mechanical cooling. Many highlight the advantages of district cooling, as the system often is easy to install and requires less maintenance. However, it works best if there is already a fairly centralised cooling system at the hospital. The disadvantage of district cooling is a dependency on suppliers.

Some interviewees had clear strategies outlining which cooling systems to install, while others said that they decide on a case-by-case basis and adapt to local conditions – for instance by trying to avoid using electricity for cooling due to problems with capacity levels of electricity, having mechanical cooling only as a back-up alternative.

Due to the F-gas regulation and the goal of reducing climate impacts, refrigerants and absorption chillers are now being investigated by respondents.

Efficient distribution and robust systems

The Swedish Civil Contingencies Agency (MSB) requires Swedish hospitals to have high resilience, representing a challenge for cooling systems. More proactive actors are looking for flexible solutions and ways of supplying in different ways. Some mentioned advantages of centralized systems are a simplicity of recovering heat and requiring less maintenance. However, this demands an ability for cooling to be shunted as needed in different buildings, in order to limit overcooling. Local back-ups like smaller units are often required for sensitive processes.

Most interviewees prefer airborne cooling, but this is more energy-intensive.

A limitation of cooling capacity is the wish to reduce air flows to achieve other comfort aspects, along with energy. Chilled beams (especially older models) can be difficult to clean and come with problems like condensation during hot and humid periods. On the other hand, there are contexts in which chilled beams are a good alternative: in draft-sensitive environments where air flows are low.

Respondents recommend a separation of systems for process cooling and comfort cooling where possible. The reasoning is that the need for process cooling tends to be twenty-four hours a day, seven days a week – while cooling in general is more seasonal.

INTERVIEW HIGHLIGHTS

Minimising the need

Many of the respondents' organisations focus on energy-efficiency during building construction. In some cases, goals are set to achieve certain levels within environmental certification systems. Another example is the use of solar shading to reduce the need for cooling.

It is important to choose flexible technologies. For instance, it could be wise to divide sun shading into several zones to avoid the risk of blocking views when the shading is not needed. Manual control is further valuable to meet different patients' varying needs and preferences, where the amount of sunlight through windows is one of many examples.

There are several other ways to minimise cooling needs in existing buildings: selection of windows (g-value), planting trees that contribute to solar shading and so on.

Rather than adapting the climate system to the building, you can adapt the building to the climate system. Building design can be based on how much heat and cold that can be produced with existing/intended systems, reducing heating and cooling needs. This can involve smaller window sizes and reviewing the orientation of the building, with more heat-sensitive activities located in the north (in the Nordics).

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BEST PRACTICES

REGION JÖNKÖPING
USING SUPPLY AIR AT ROOM TEMPERATURE

On the county's main hospital site (Ryhov), a new building of 35 000 m2 has been constructed. Within the building, a range of different activities exists, associated with varying needs for cooling.

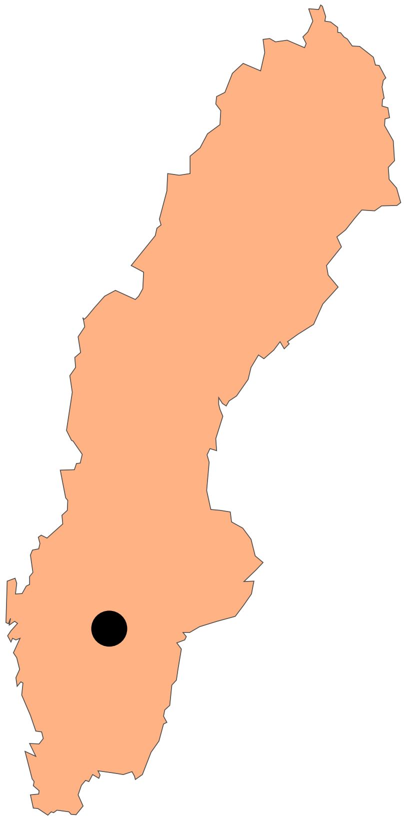
A distribution system with air cooling was preferred at Ryhov. This implied a will to work with low temperatures for heating and high temperatures for comfort cooling, to reduce the energy demand of both cooling and heating.

The chosen system design uses supply air at the temperature specified by PTS (Program for Technical Standards) in each room, rather than the more common slightly chilled or heated air. Any dehumidification need is handled by the main cooling machine. Such needs occur during the warmest days of summer, and the energy demand will be covered by new solar panels. Extra heating is supplied via a heating panel instead of traditional radiators. The same applies to cooling, where additional cooling is provided by the same panel over using chilled beams.

Panels' advantages include the ability to fully integrate them in walls or ceilings. This type of system solution places extra high demands on the selection of air diffusers. Those in charge therefore carried out several tests with different suppliers before they found the right solution.

By integrating cooling/heating panels into the ceiling, higher hygiene requirements can be obtained as they have a completely smooth surface. Without a radiator, the room will also be easy to furnish. Another advantage of the system design is the central dehumidification, reducing the risk of having to switch off cooling due to panel condensation.

One notable success factor is that the future need for cooling was taken into account early on, already at the building design stage. Thereafter, the project worked to minimize the need for cooling. The project results are currently being analysed and there are plans for further installations at the hospital site in Värnamo.



BEST PRACTICES

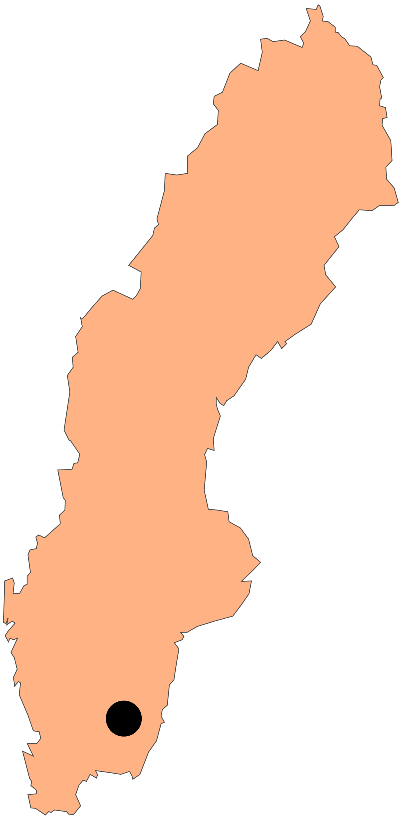
REGION KALMAR COUNTY
ACHIEVING SUSTAINABLE COOLING WHILE MEETING AN INCREASING DEMAND

Region Kalmar County has commited to making comfort cooling available in all workplaces throughout the region in the phase of constructing new buildings and renovating existing ones (including the region's hospitals). This implies hightened requirements for produced cooling. To achieve sustainable cooling, the county works primarily according to a two-track approach: intelligent systems that optimise the need and the testing of more climate-friendly production techniques.

For production, there is a switch towards using larger mechanical cooling units and a central distribution system, suppling the majority of buildings within the hospital site. The system design also enables heat to be recovered for hot water production and so forth.

Primarily, distribution via airborne cooling is selected. By cooling the air in central units within buildings and by using intelligent regulation of air flows in every room, the flows will be high enough to meet the desired cooling effect. The basis for the regulation is presence and temperature at room level. CO_2 is not used for control within the care facilities. The county also works actively with solar shading and building design to reduce the need for cooling.

In order to achieve a more sustainable production, Region Kalmar County is attempting to find alternatives to conventional cooling machines. At the writing of this report, an installation of an 800kW cooling machine with CO_2 as refrigerant is taking place. CO_2 as a refrigerant is quite unusual for comfort cooling at hospitals today. The region also has a geothermal cooling unit at one of its hospitals.



BEST PRACTICES

SUNDSVALL'S HOSPITAL
SNOW AS A COOLING SOLUTION

At Sundsvall County Hospital in Sweden, Västernorrland County Council has solved three problems with a smart-energy solution. The County Council is taking advantage of snow being transported away from public areas. Next to the hospital, a pool has been built with a capacity to accommodate up to 70 000 m3 of snow. With the help of a heat exchanger, pumps and a pipeline system, cold meltwater is used to cool the hospital during hot days. When additional snow is needed or snow is melting, snow cannons and an insulating layer of wood chips are employed. The hospital can further collect pollutants accompanying the snow.

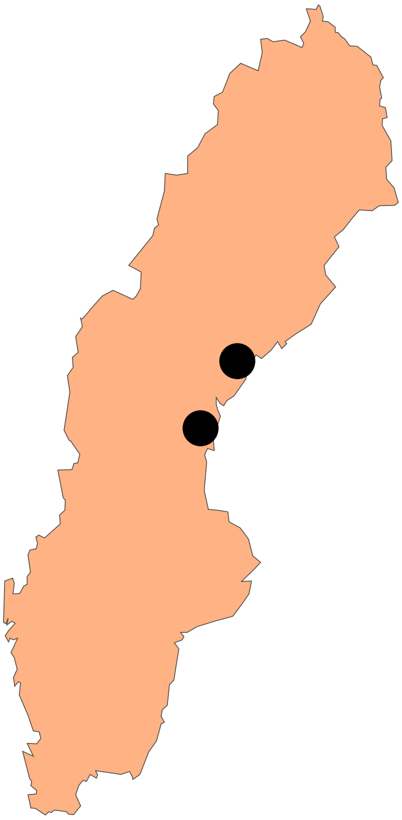
This solution has greatly reduced the need for mechanical cooling at the hospital. Other benefits include a decreased electricity consumption by over 90% and a reduced risk of hazardous leakages while phasing out refrigerants. Emissions of the GHG HFC-134a have decreased by approximately 70 tons of CO_2 equivalents per year. Other CO_2 emissions have been reduced by 290 tonnes per year, along with noise.

The technology is already used at several facilities in Japan and at Gardermoen Airport outside Oslo in Norway.

NORRLAND'S HOSPITAL

Norrland University Hospital, based in Umeå (Sweden), has managed to save 600 tonnes of CO_2 while diminishing operational cost with 438 000 EUR per year. Behind these savings is a new geothermal energy solution, combined with a heating and cooling centre with ground storage of energy.

"Previously, we paid for energy three times when we bought district heating, district cooling and electricity at the same time. Now, we only buy electricity for the heat pumps and can use all the energy in the building in the right way" says Jesper Burlin, technical coordinator at the hospital.

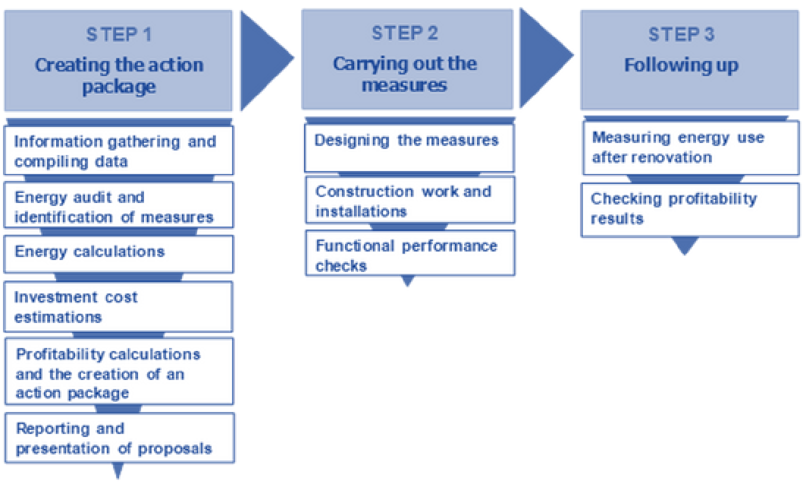


THE TOTAL CONCEPT: A WAY FORWARD

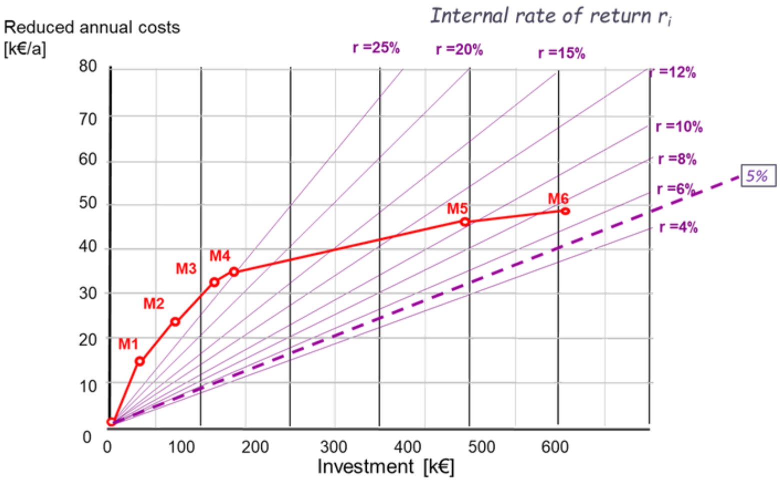
As stated earlier in the report, the demand for cooling will be increasing. There is therefore a need to improve energy-efficiency at existing hospitals – not only focus on smart buildings when constructing new facilities and systems. The Total Concept ("Totalmetodiken" in Swedish) is a method and financial tool designed to improve the energy performance of existing non-residential buildings. The aim is to ensure maximum energy savings and simultaneously fulfil company demands for profitability.

Many building owners face the dilemma of improving their buildings' energy-efficiency while simultaneously living up to their different financial goals. The Total Concept applies a comprehensive approach to work with energy issues in a building. It does this by identifying and carrying out a package of measures that fulfil building owners' demands of profitability over applying individual measures.

The method has been developed by a network of non-residential real-estate owners, both commercial and public, in Sweden – and has been tested in Estonia, Finland, Denmark and Norway through the EU project "Total Concept". It consists of the following steps:



In Step 1, an action package is developed from a careful analysis of the building. A broad range of different energy measures should be identified and evaluated. For instance: When improving a cooling system, you need to overhaul the heating system, insulation, window status, regulation systems and so on. The evaluation includes calculating the saving potential and life cycle costs. Life cycle costs for the energy measures are then weighed using the internal rate of return, followed by visualising the package of measures in a diagram.



If a building manager is required to improve the cooling systems, the Total Concept can be used to identify other measures that would be profitable to carry out simultaneously. The method has been used on hospital buildings and care centres in Sweden with good results. An example is at Akademiska Sjukhuset in Uppsala: The Total Concept was used in a project to reduce CO_2 emissions by improving energy-efficiency.

To learn more, visit the Total Concept webpage, where information is available in Swedish, English, Danish, Finnish, Estonian and Norwegian:
www.belok.se
http://totalconcept.se

CONCLUSIONS

FOR COOLING SYSTEMS WITHIN HEALTHCARE

- It is necessary to develop and implement a comprehensive national policy on cooling. This includes putting forward and enhancing regulatory measures, as well as improving the information available (especially about new techniques, technologies and their practical use).

- Building design can minimize the use of air conditioning units and need for cooling.

- District cooling is one of the most efficient, climate friendly, secure and economically beneficial ways of providing cooling systems for public installations (including hospitals and other healthcare facilities).

- There is a challenge in responding to the increasing demand of cooling, without negative impacts and further global warming. To navigate this, it is necessary to deliver the required amount of cooling with the most energy-efficient model, along with cutting emissions and fostering a sustainable transformation of the healthcare sector.

- Holistic energy plans are recommended. These can embody the role of healthcare systems within energy infrastructure and land use planning. A cooling policy strategy needs to account for multiple factors: local circumstances, the current state of the market, the outlook for cooling demand and energy use, economic drivers, social and cultural considerations, as well as traditions surrounding policy making.

FOR MORE INFORMATION ABOUT HOW TO TRANSFORM SUSTAINABILITY CHALLENGES INTO INNOVATIVE SOLUTIONS FOR THE HEALTHCARE SECTOR, PLEASE CONTACT NCSH:

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